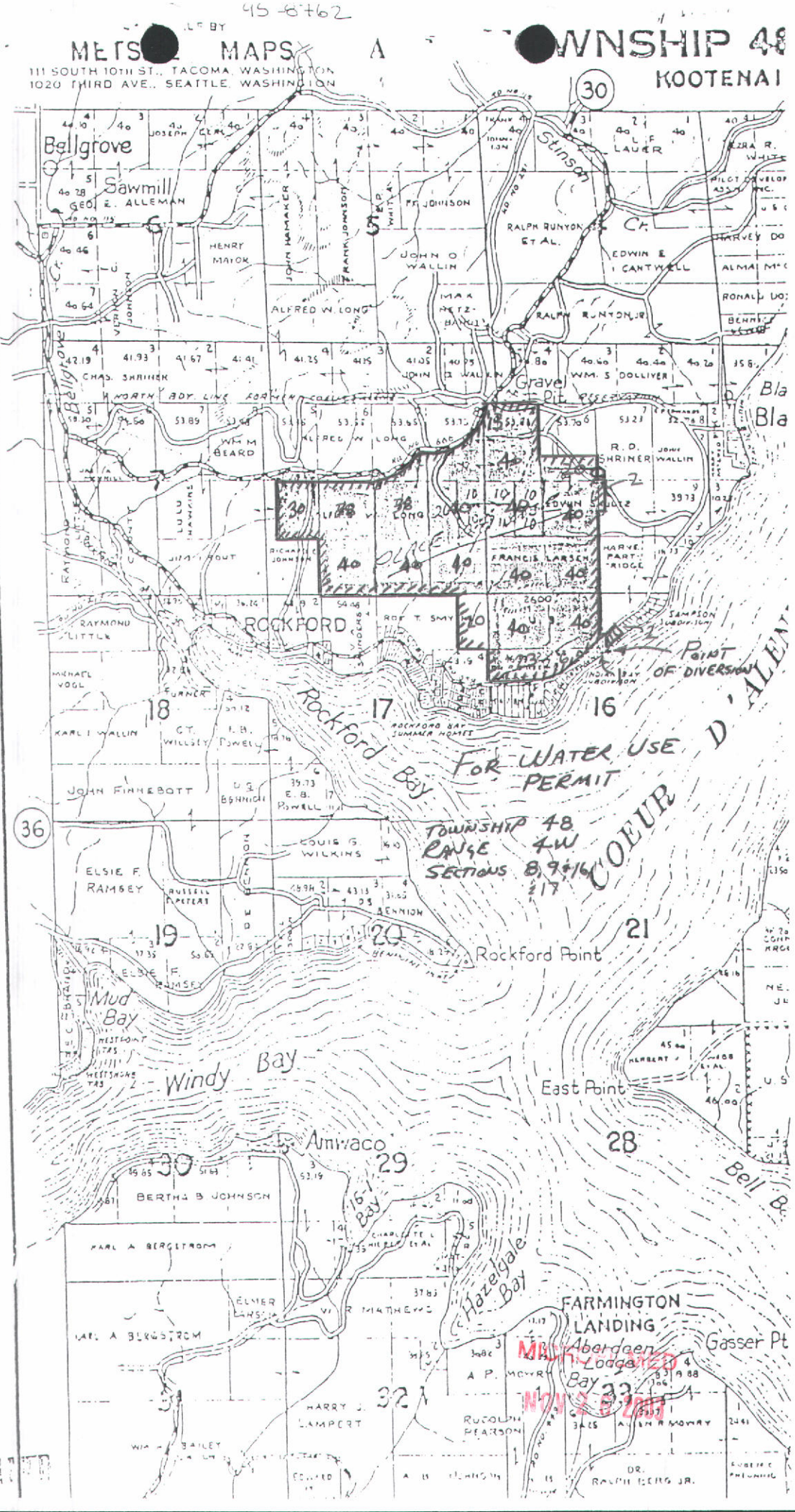
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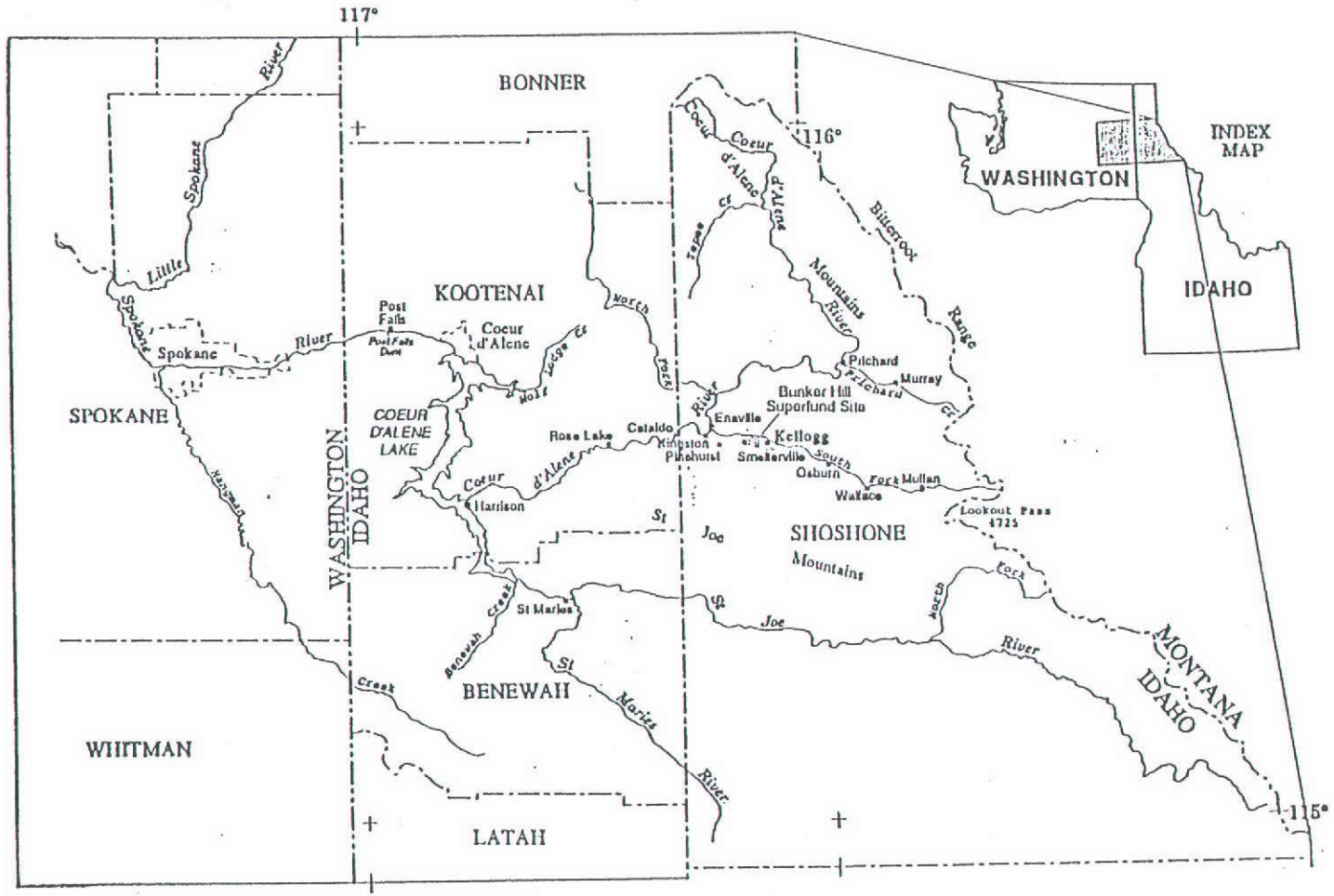


Figure 1.--Location of Coeur d'Alene Lake.

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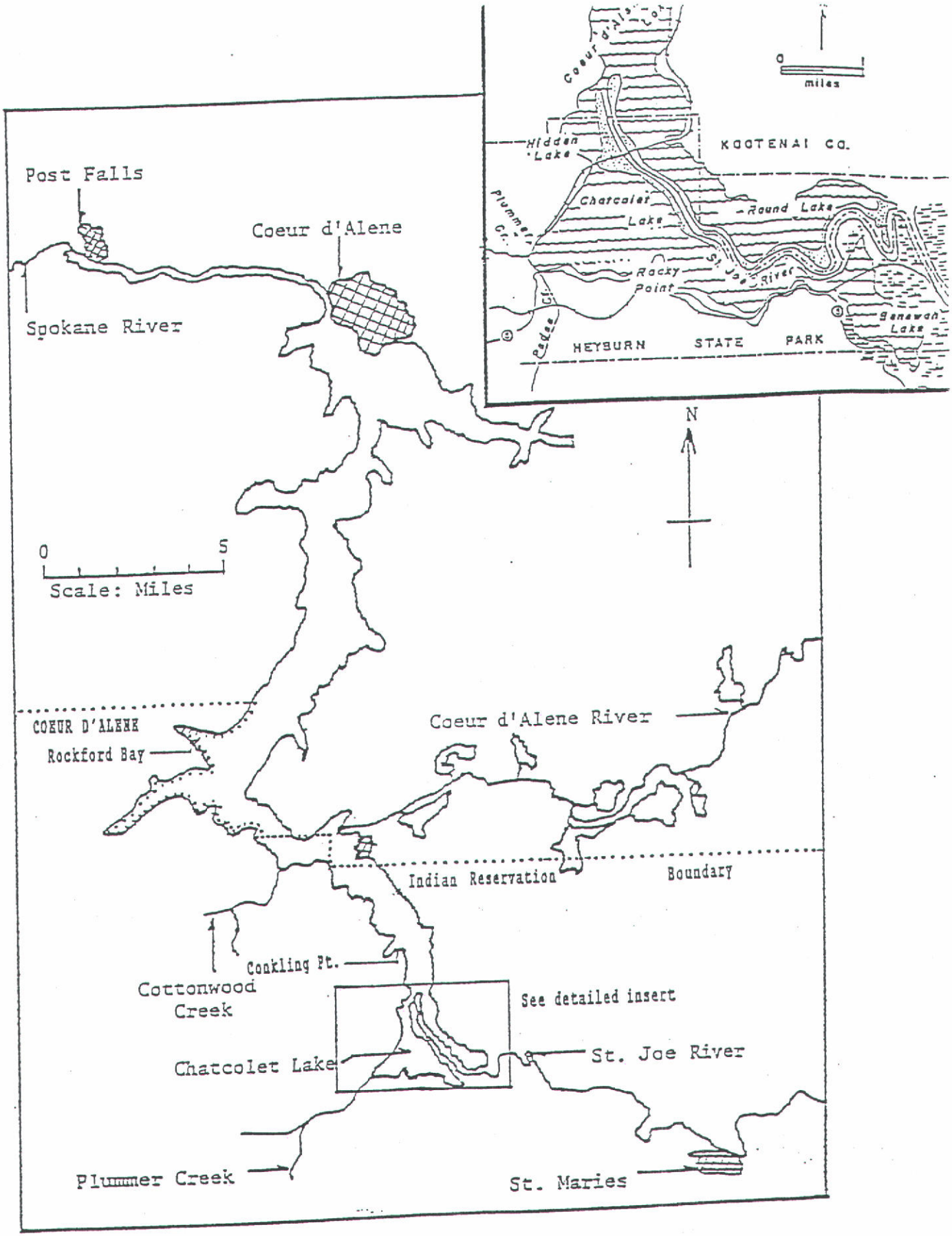
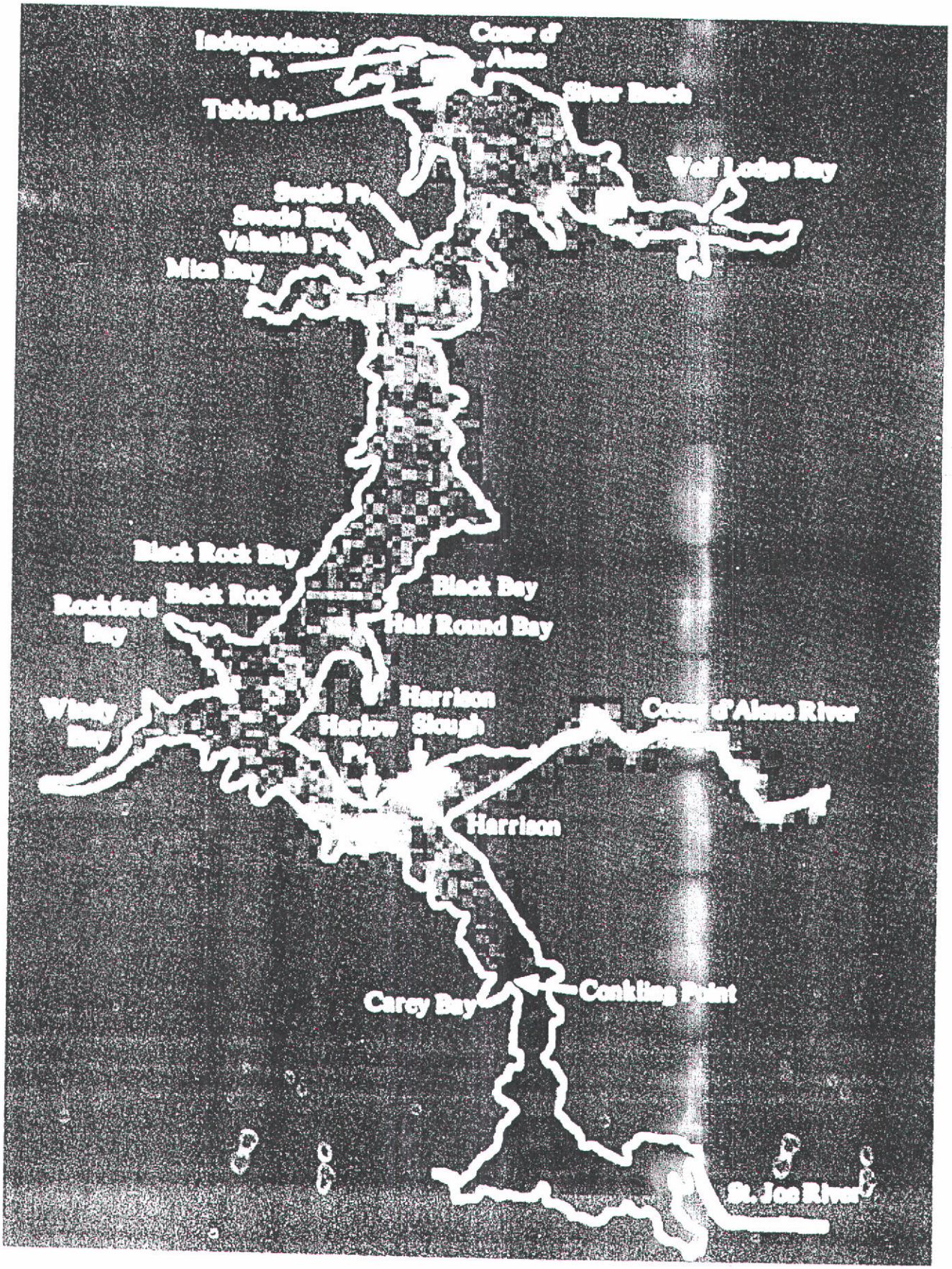


Figure 2.--Coeur d'Alene Lake

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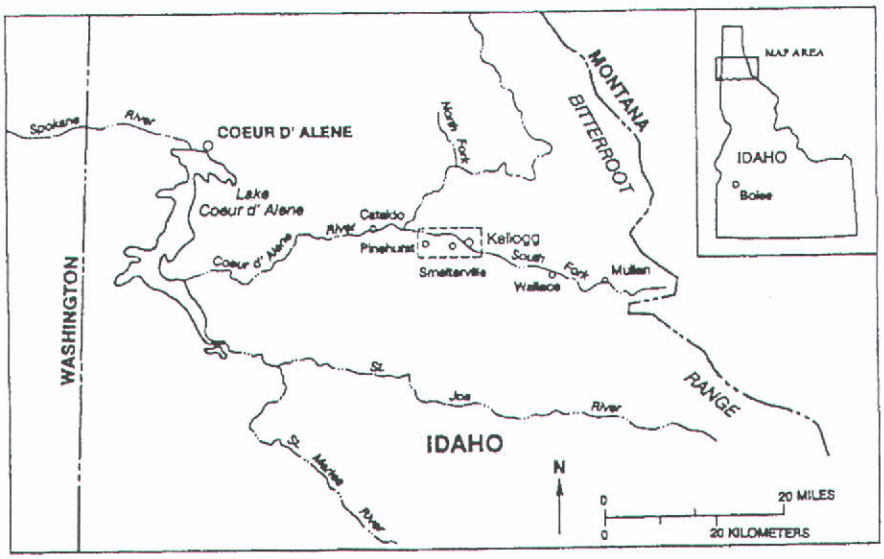


Figure 1. General location map of the South Fork of the Coeur d'Alene River, the St Joe River and Lake Coeur d'Alene. The dashed box outlines the location of the 54 km^2 US EPA Bunker Hill Superfund Site (after Bender, 1991)

(Meckel Engineering *et al.*, 1983; Bender, 1991). The main body of the lake is about 3·2 km wide by 40 km long; however, the southern part is composed of four smaller interconnected lakes that were formed in 1906 when the Post Falls Dam (10 miles downstream on the Spokane River) was completed (Meckel Engineering *et al.*, 1983) (Figure 1). The St Joe and CDA Rivers annually account for 94% ($\approx$ 4·73 Gm^2/yr) of the inflow to Lake CDA (Meckel Engineering *et al.*, 1983; Javorka, 1991). Major outflow from the lake occurs at the northern end through the Spokane River (Figure 1).

The South Fork of the CDA River, which flows into the CDA River, and thence into Lake CDA, drains a substantial part of the CDA mining district and the so-called 'Silver Valley'. The mining district has been in operation since the 1880s and was one of the major sources of Ag, Cu, Pb and Zn in the USA (e.g. Bender, 1991). Until 1968, when ponds were established to trap/retain tailings and limit sediment transport, most of the mining and ore processing wastes were discharged directly into the South Fork of the CDA River. These materials were highly enriched in Ag, As, Cd, Cu, Fe, Mn, Pb, Sb and Zn (Rabe and Bauer, 1977; Bender, 1991). It has been estimated that during the course of mining, processing and smelting operations in the area, about 115 million tonnes of mine tailings were produced and that 60% of this material probably entered the South Fork of the CDA and the CDA River system (Javorka, 1991).

In 1983, as a result of the increased trace element concentrations in the mining and processing wastes, the US Environmental Protection Agency (EPA) established the Bunker Hill Superfund Site that encompasses 54 km^2 in the Kellogg and Smeltervillie Flats area, about 50 km upstream of Lake CDA. (e.g. Bender, 1991; Figure 1). The Superfund site encompasses the Bunker Mine (Pb and Zn), a milling and concentrating plant, a Pb smelter, a Ag refinery, an electrolytic Zn plant, a phosphoric acid and phosphate fertilizer facility, a sulphuric acid plant, a Cd plant and a 0·65 km^2 mine tailings and waste water disposal area (Woodward-Clyde Consultants and TerraGraphics, 1986). Most of these facilities are no longer active and several have been dismantled.

Over the years environmental studies have indicated that large amounts of mining, milling and ore processing wastes, enriched in a variety of trace elements, have been deposited throughout the lower CDA River and Lake CDA, and have had a substantial effect on the sediment geochemistry, the water quality and the biota of the South Fork of the CDA River, the main stem of the CDA River, Lake CDA and the Spokane River (Ellis, 1940; Galbraith, 1971; Ellsworth, 1972; Funk *et al.*, 1973; 1975; Bauer, 1974; Maxfield *et al.* 1974a; 1974b; Norbeck, 1974; Sheppard and Funk, 1975; Johnson *et al.*,

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Similar procedures were used to evaluate the phase associations for the trace element-rich subsurface sediments. However, partial chemical extractions were omitted because there were indications during core thawing and sampling (e.g. the precipitation of reduced Fe as Fe oxide) that at least some of the original sediment–trace element phase associations were altered. As data were already available on the

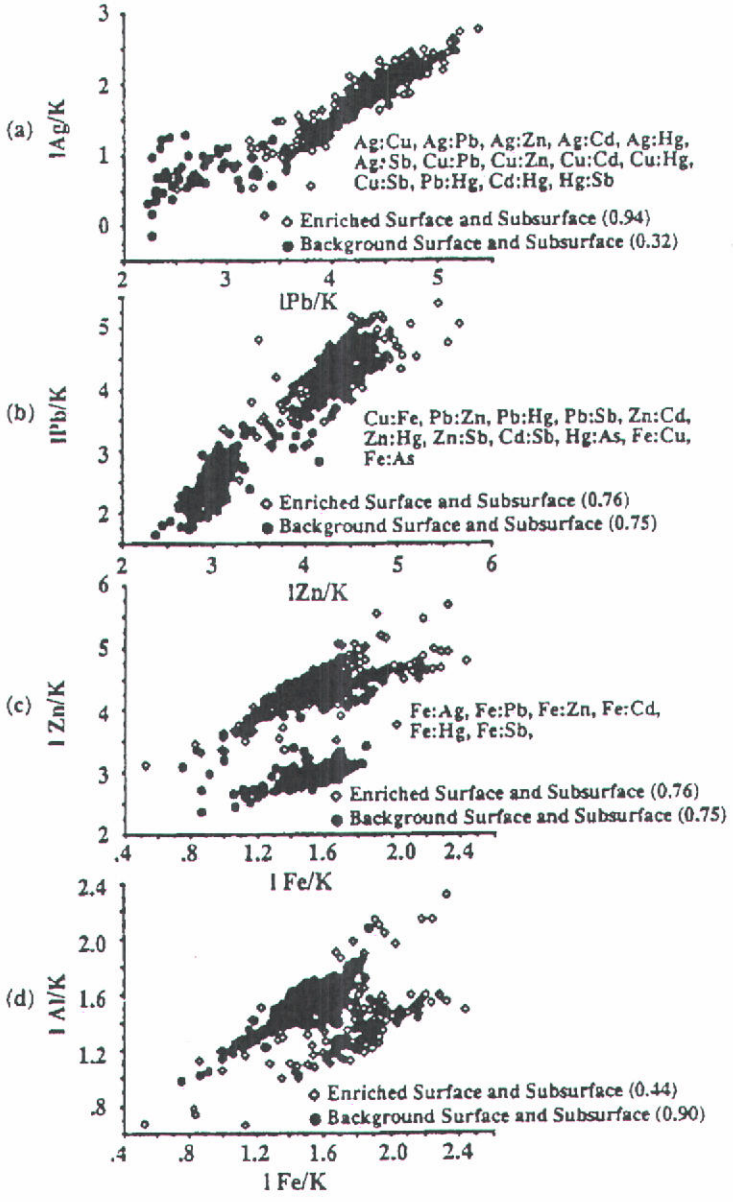


Figure 4. Selected plots of correlation coefficients comparing trace element-rich surface and subsurface samples with those for surface and subsurface background samples. The coefficients were calculated after normalization to Ti/TOC and log transformation (see Horowitz *et al.*, 1993). The element pairs listed adjacent to each graph display similar patterns to those shown in the graph: (a) strong correlation coefficients for the enriched sediments which do not occur for background sediments; (b) strong correlation coefficients for both enriched and background sediments where the slope for each set are different; (c) strong correlation coefficients for the enriched sediment-associated trace elements and Fe which differentiate them from background sediments; and (d) a graph of the correlation coefficients for Fe and Al which differentiates the trace element-rich surface and subsurface samples from those for surface and subsurface background samples

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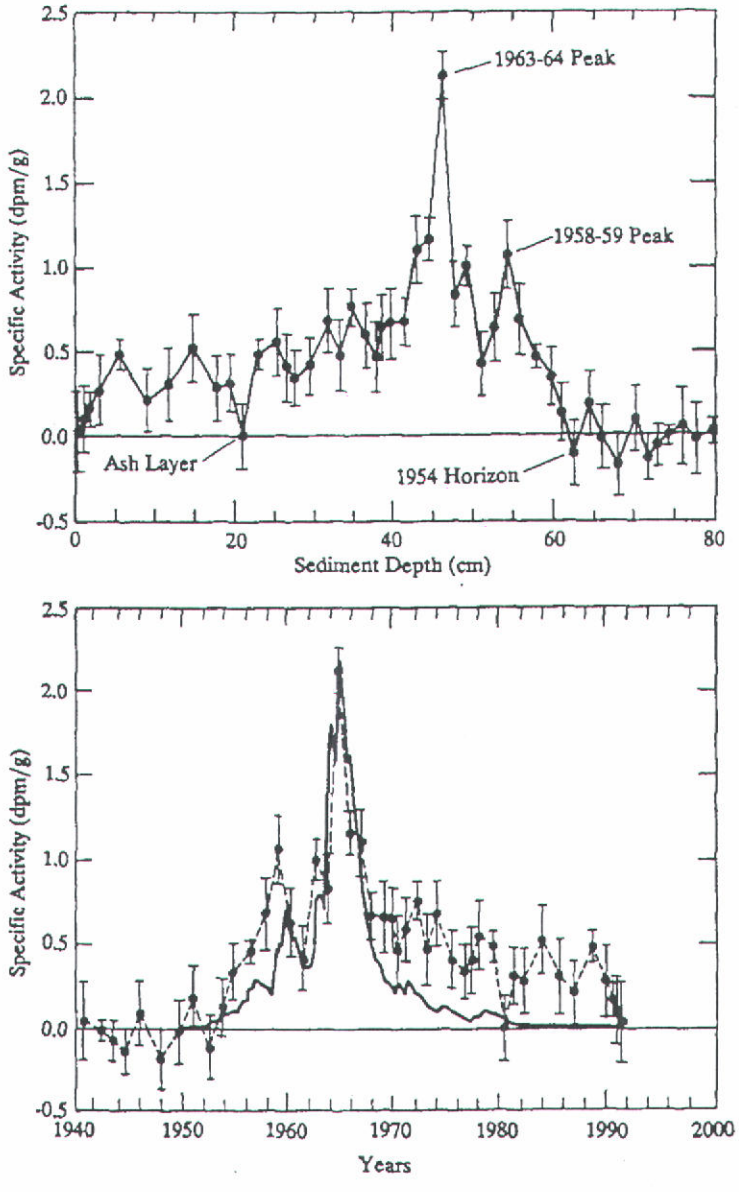


Figure 6. The upper panel is a plot of ^{137}Cs activity (dpm g^{-1}) against sediment depth (cm). The lower panel is a recast of the upper panel and displays ^{137}Cs activity (dpm g^{-1}) against age (broken line). The solid line is a plot of the well-developed loading function for the Great Lakes region (Robbins, 1985)

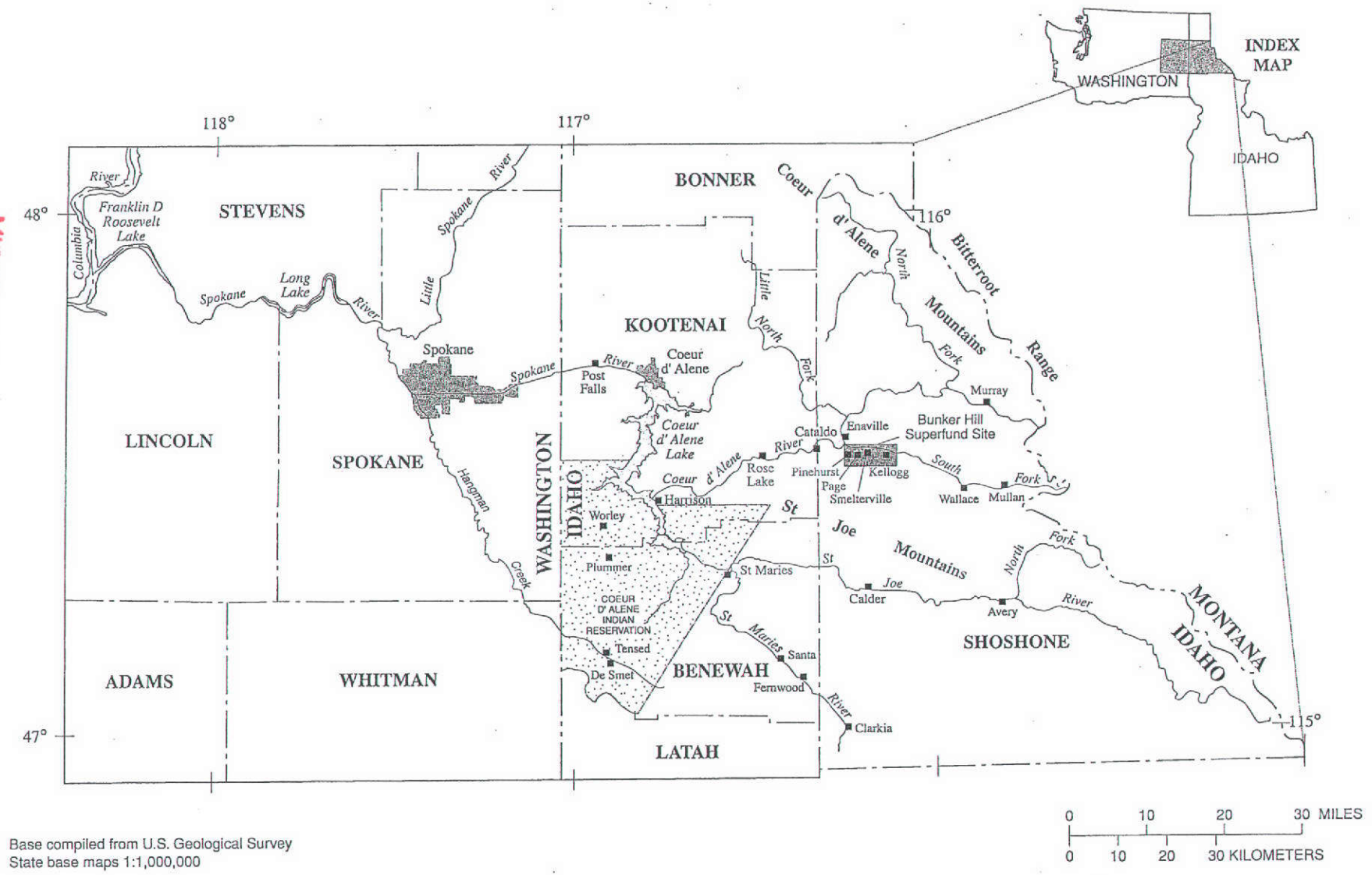
onset of trace element enrichment in the lake probably falls between 1895 and 1910. These dates are consistent with the onset of mining and ore processing in the CDA mining district, and these activities probably represent the major source of the extreme trace element enrichments in the sediments of Lake CDA.

REFERENCES

Bauer, S. 1974. 'Heavy metals in lakes of the Coeur d'Alene valley: Idaho', *Unpublished MS Thesis*, University of Idaho, Moscow, Idaho, 63pp.

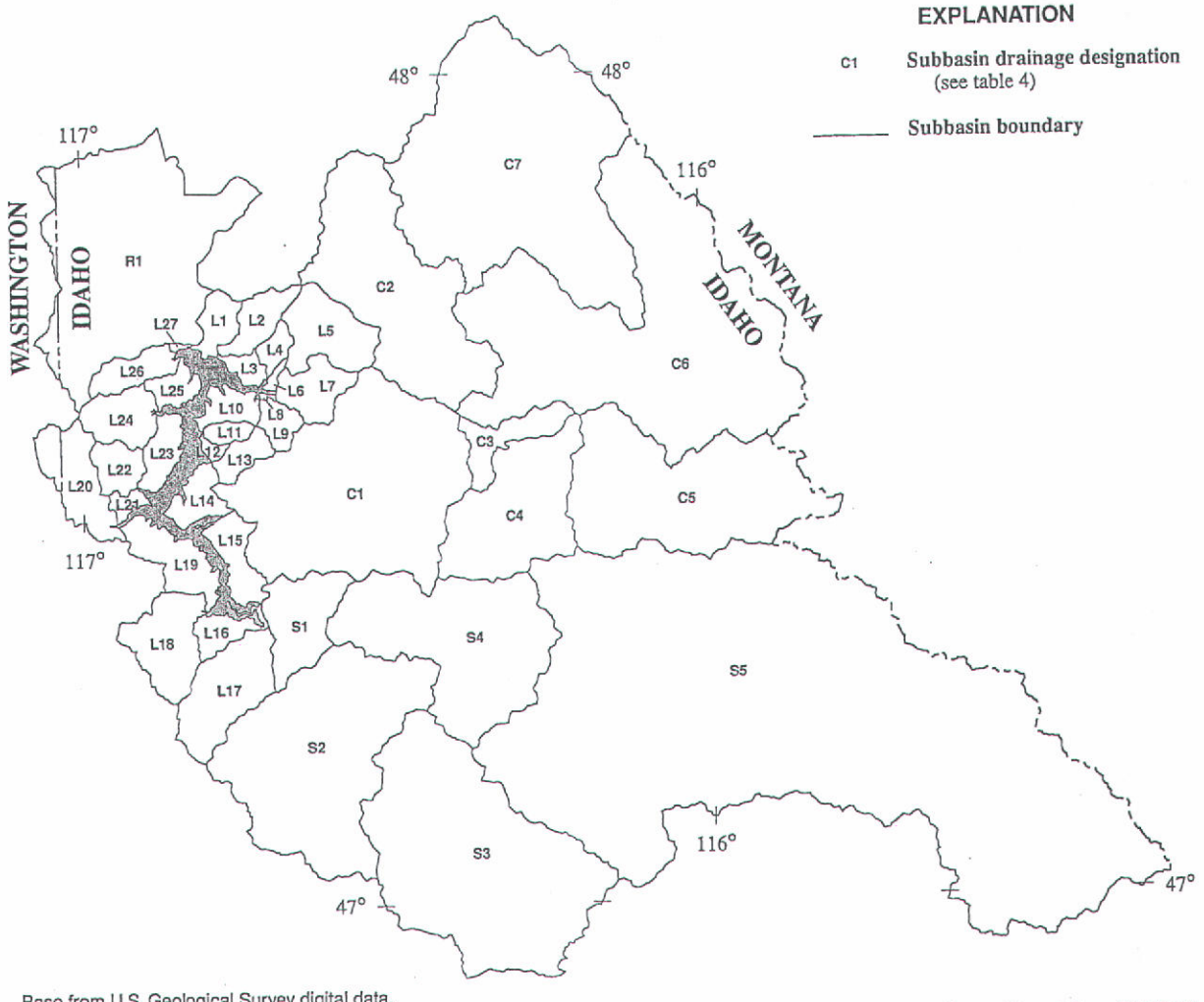
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Base compiled from U.S. Geological Survey
State base maps 1:1,000,000

Figure 1. Location of study area.



Base from U.S. Geological Survey digital data,
1:24,000 quadrangles, 1981
Universal Transverse Mercator
(UTM) projection, Zone 11

Figure 3. Locations of 40 subbasins within study area

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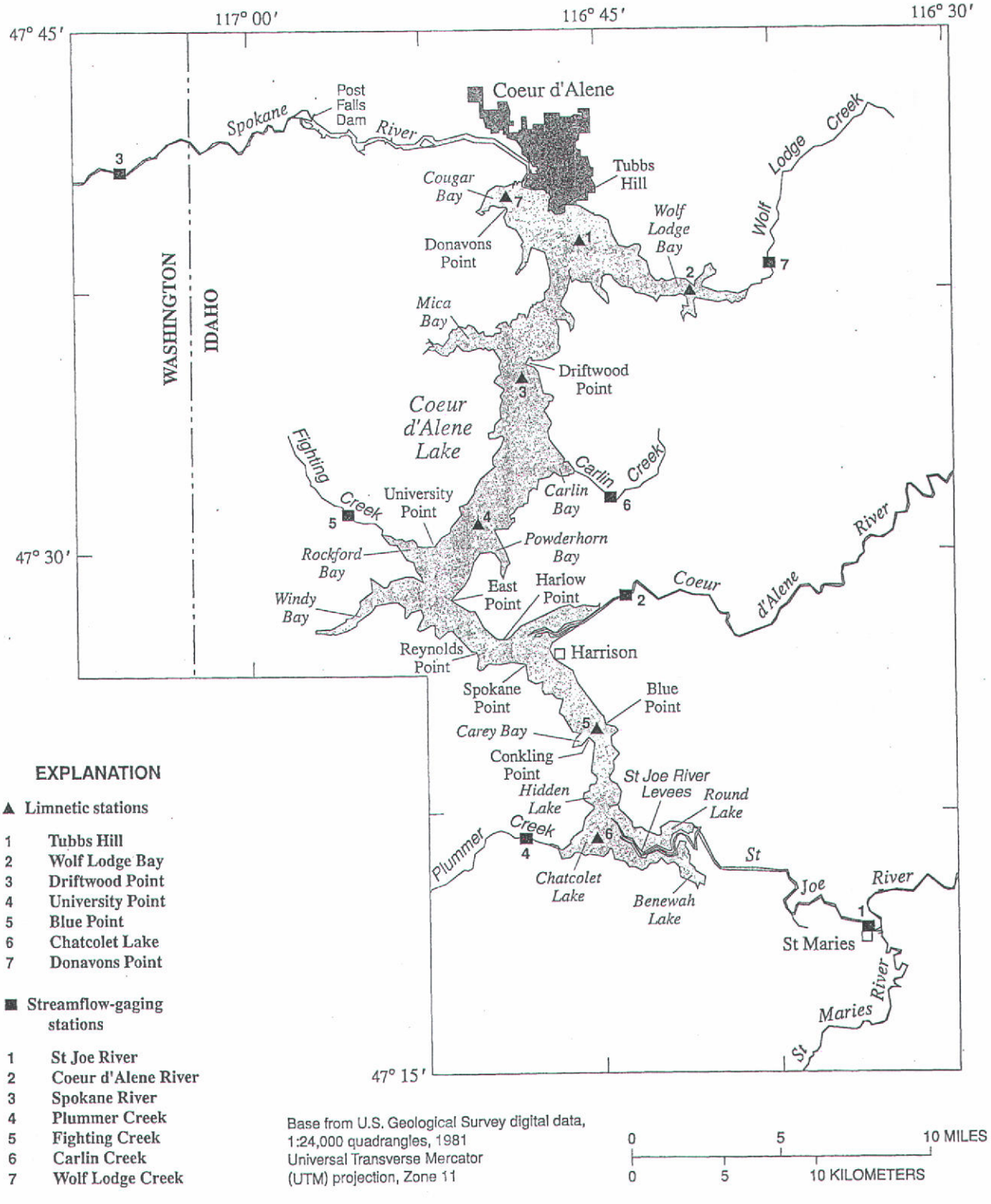


Figure 4. Locations of limnetic sampling and streamflow-gaging stations.

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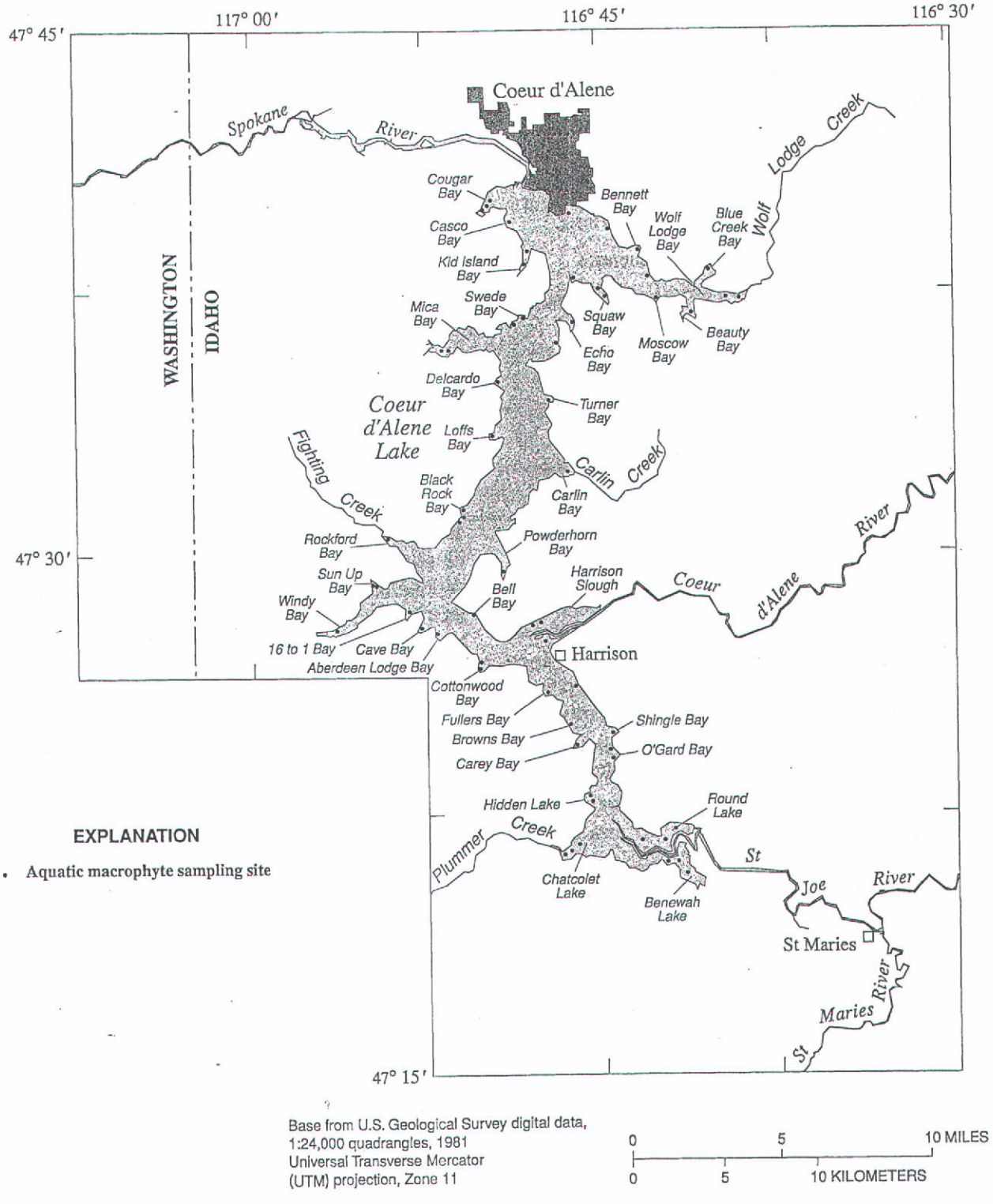


Figure 5. Locations of aquatic macrophyte sampling sites.

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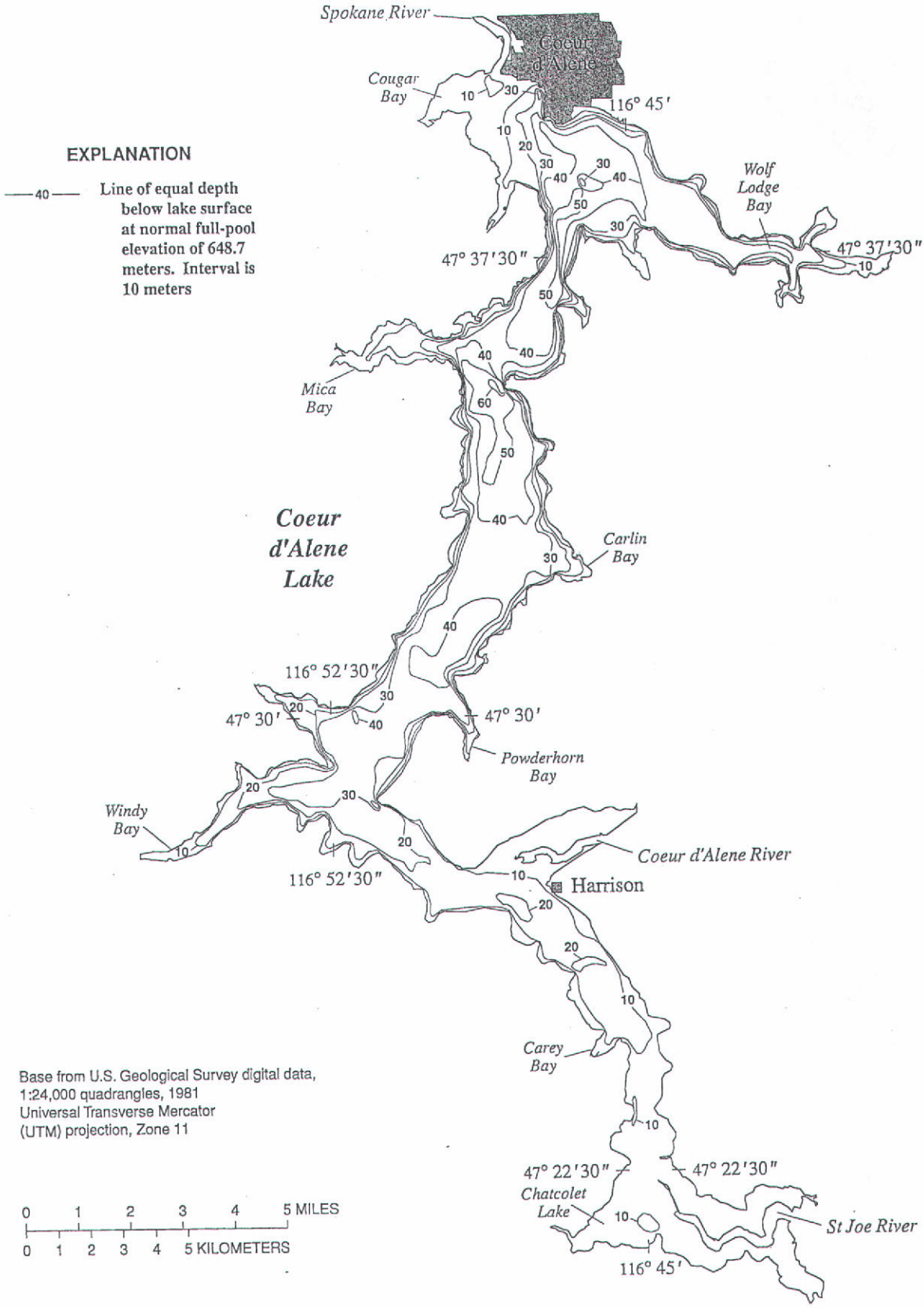


Figure 8. Bathymetric map of Coeur d'Alene Lake.

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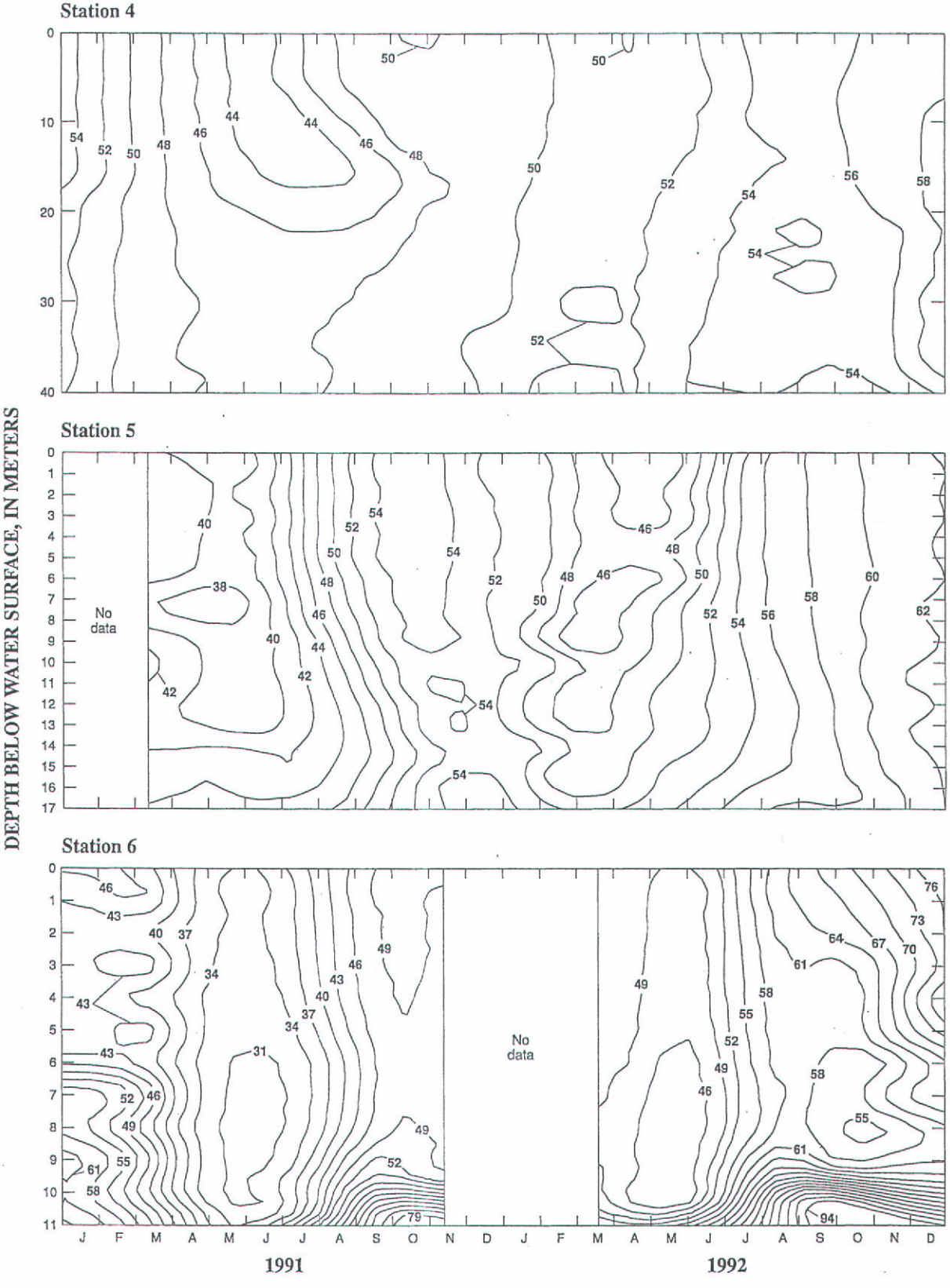


Figure 11. Lines of equal specific conductance, in microsiemens per centimeter, at stations 1–6 during 1991–92—Continued.

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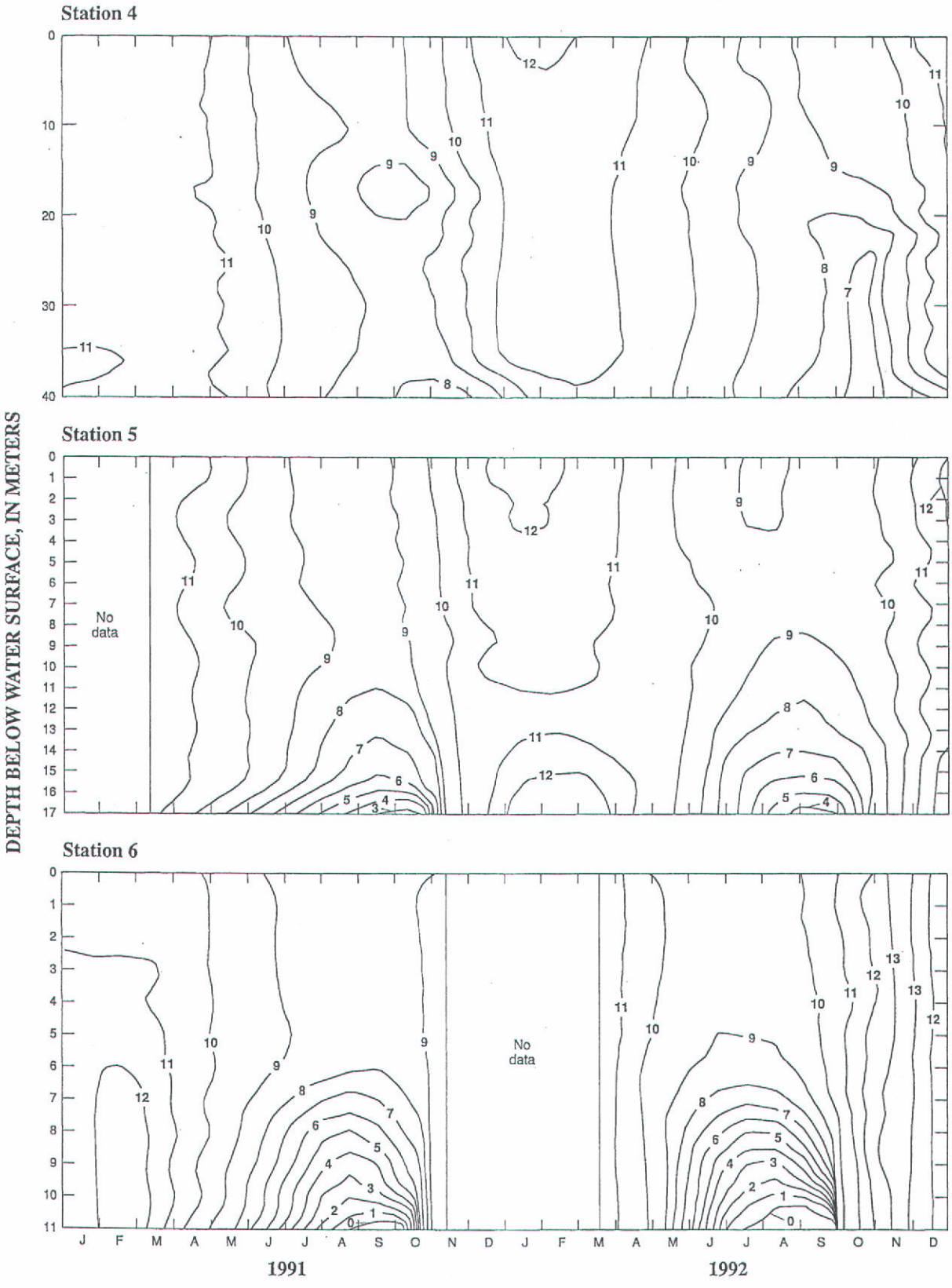


Figure 13. Lines of equal dissolved-oxygen concentration, in milligrams per liter, at stations 1–6 during 1991–92—Continued.

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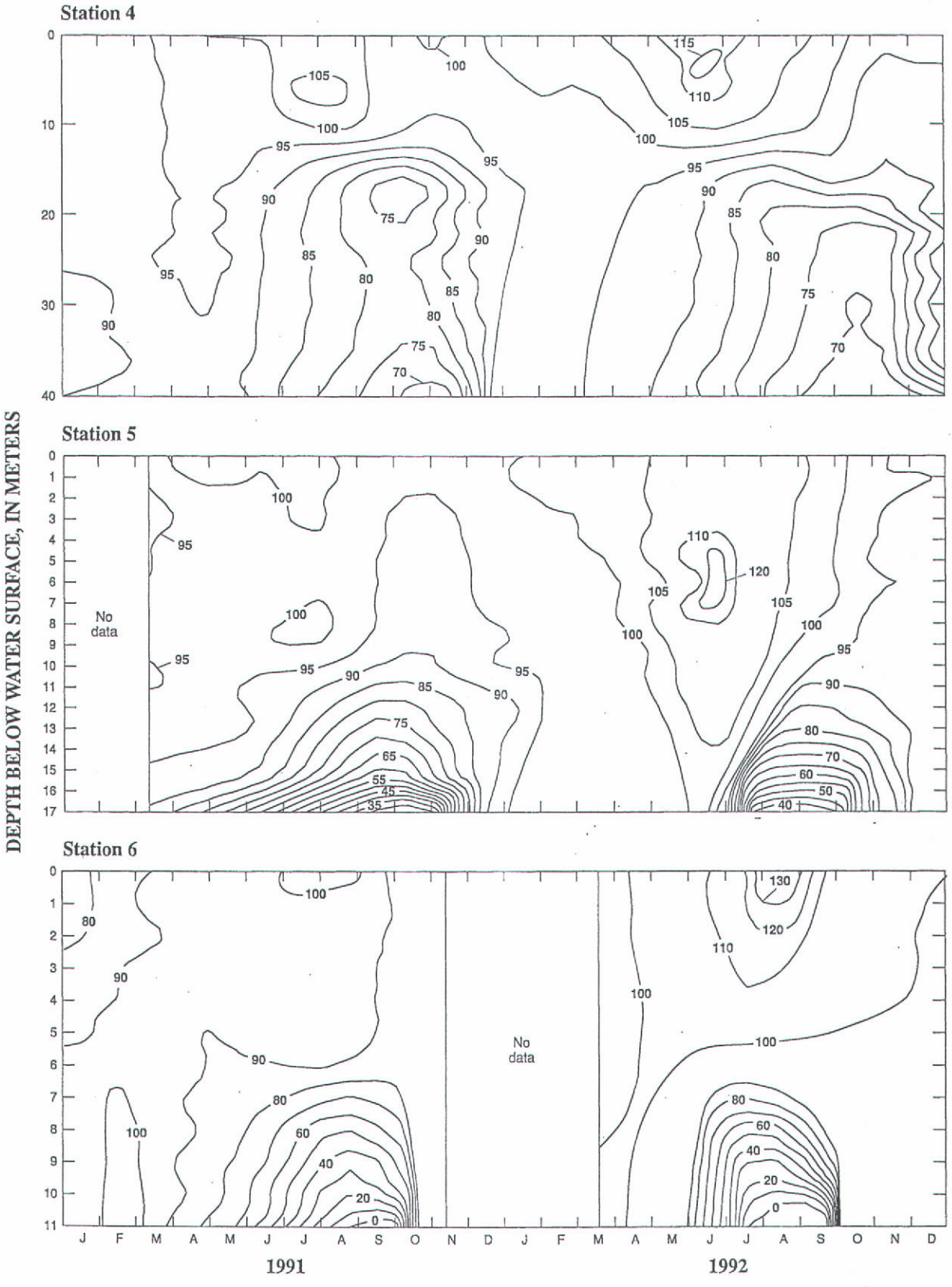


Figure 14. Lines of equal percent saturation of dissolved oxygen at stations 1–6 during 1991–92—Continued.

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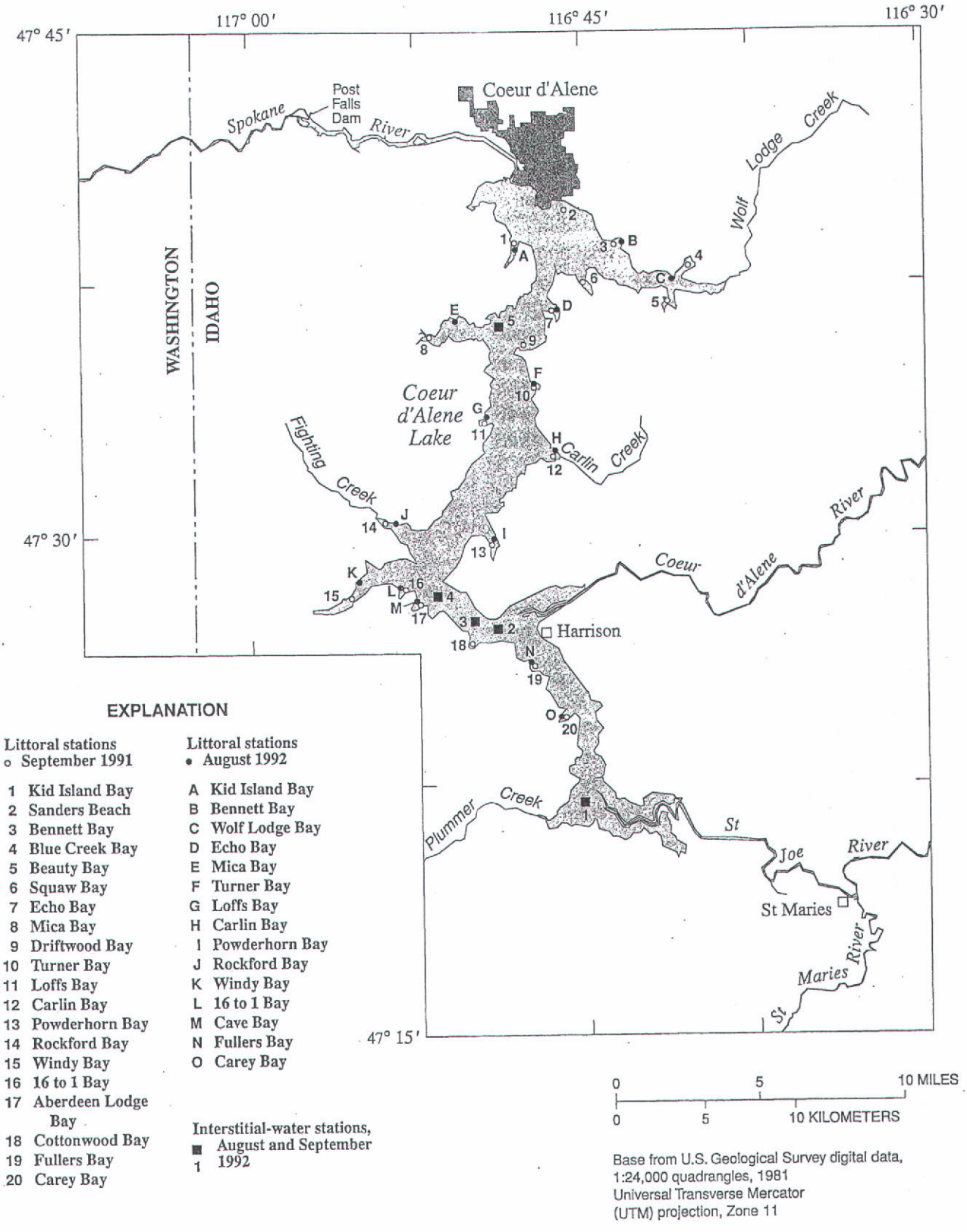


Figure 20. Locations of littoral sampling stations, September 1991 and August 1992, and interstitial-water sampling stations, August and September 1992.

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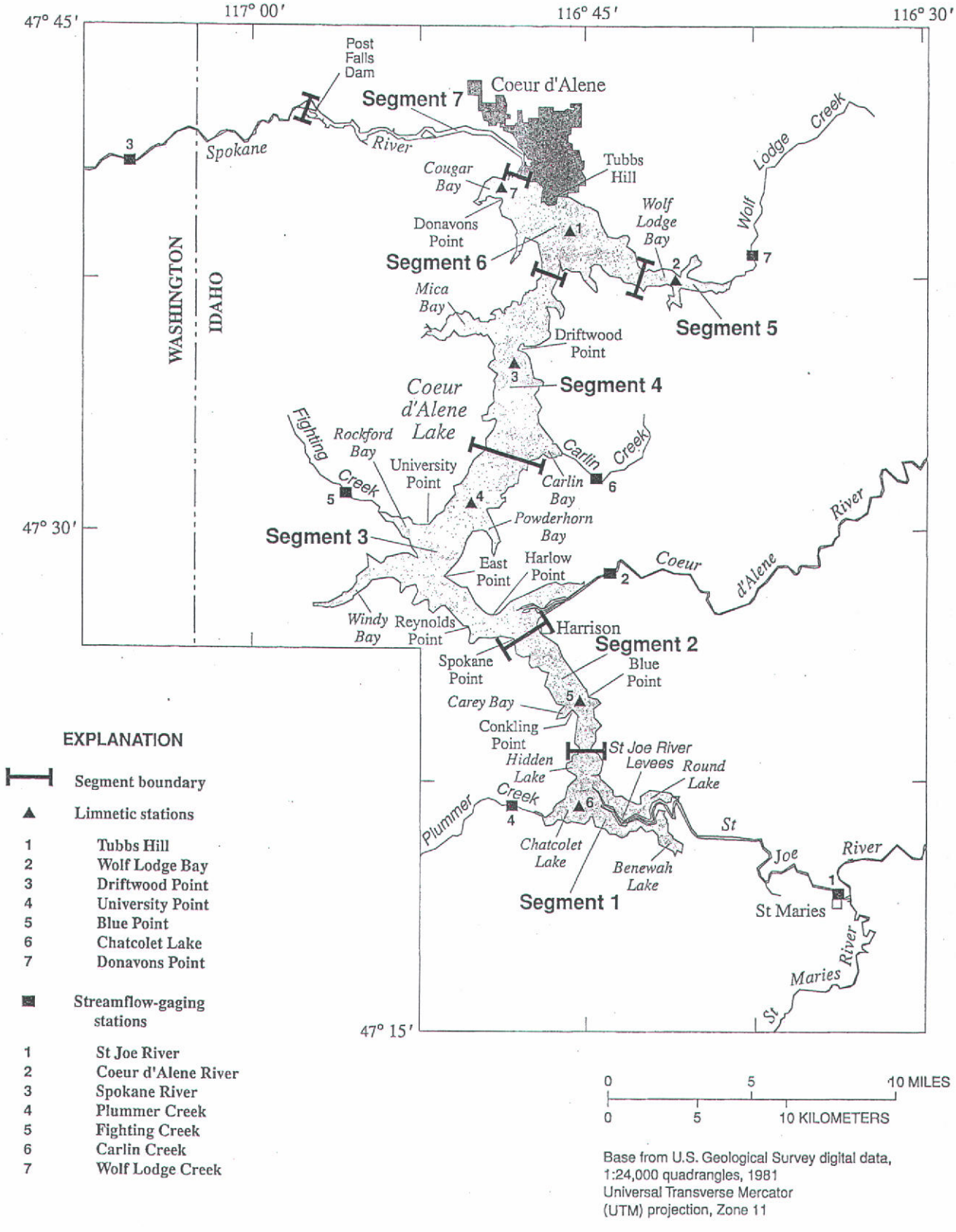


Figure 22. Segmentation of Coeur d'Alene Lake for nutrient load/lake response model.

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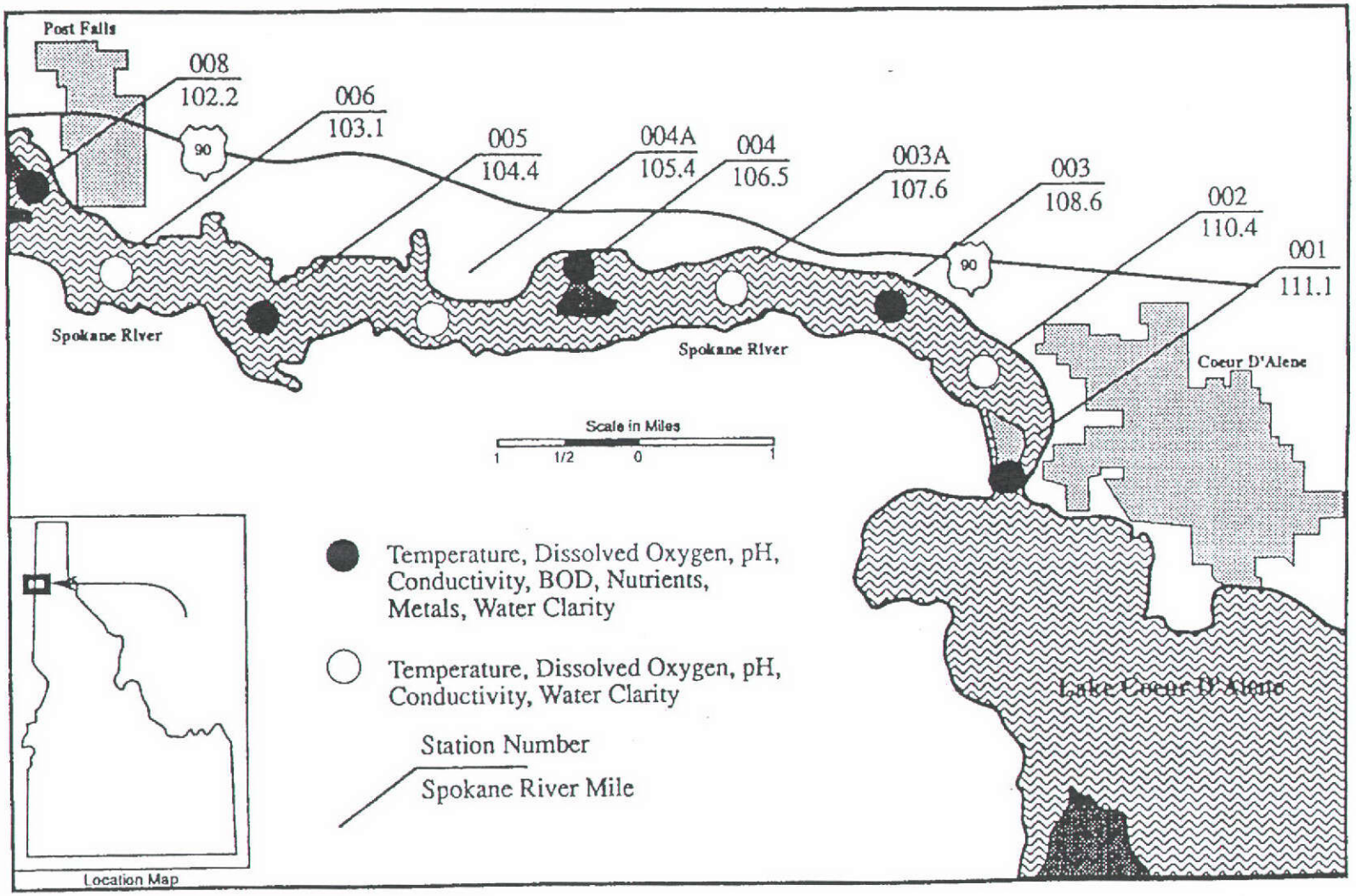
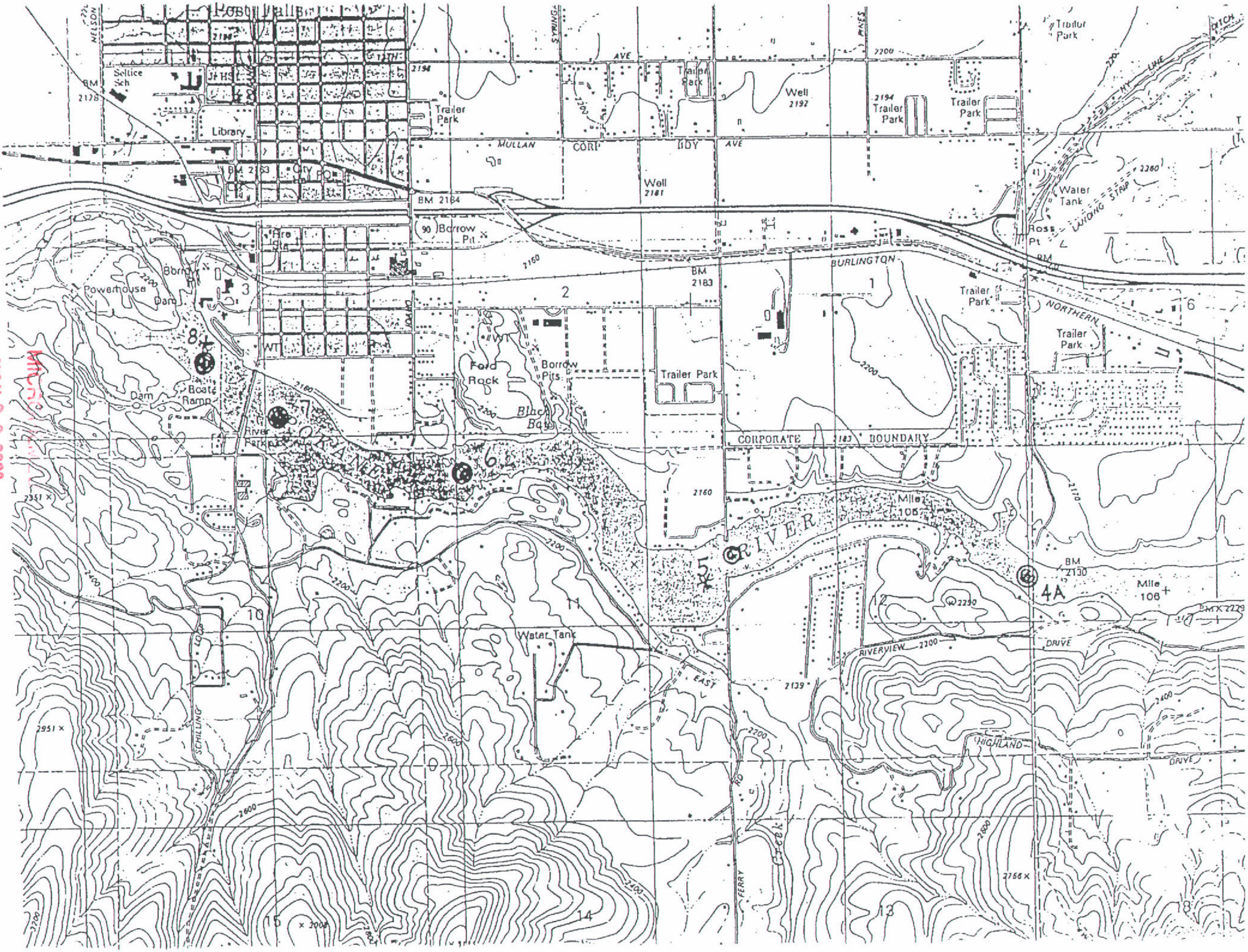


Figure 1. Location map for the field study of the Spokane River, August 16-18, 1988 showing water quality sampling stations

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Rest Area
Gravel Pit
Cem
OLD RAILROAD GRADE
BURLINGTON NORTHERN
Race Track
Huetter
Well
Atlas
Golf Course
Gravel Pits
Gravel Pit
Pumping Station
Harbor Island
Mile 107
Boat Ramp
SPOKANE RIVER
3A
Gravel Pit
Borrow Pit
Kootenai Mem Hospital
NORTHERN
Mile 110
Storage Bins
BLACKWELL
HIGHLAND DRIVE
RIVERVIEW DRIVE
JASPER RD
RUBY RD
Well
Borrow Pit
Blackwell Slough
Blackwell Island
Borrow Pit
Memorial Field
North Idaho College
City Park
Independence Point
COUGAR BAY
Light
Donevons Point
HERNE ROAD
CLEMENSON ROAD

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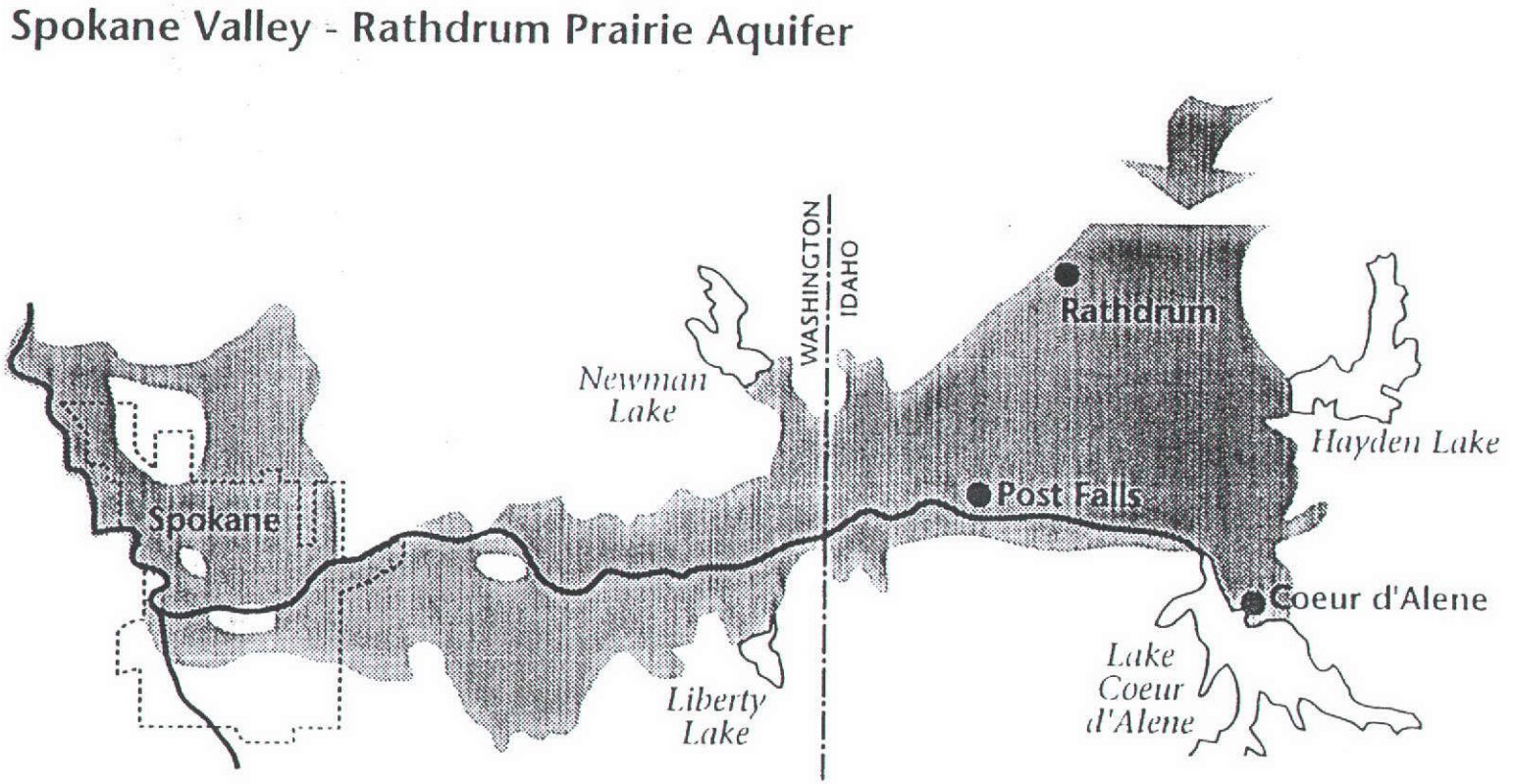
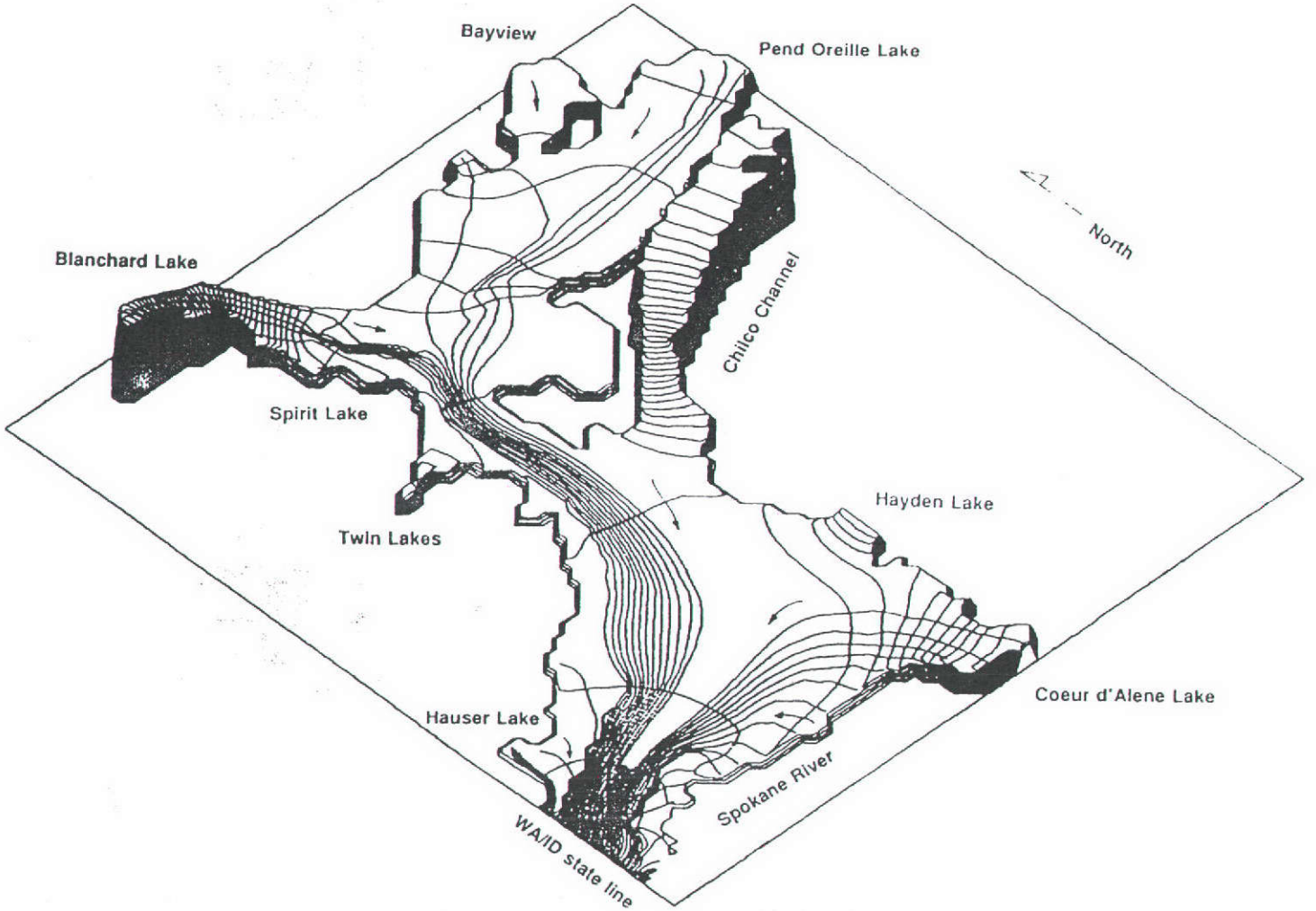


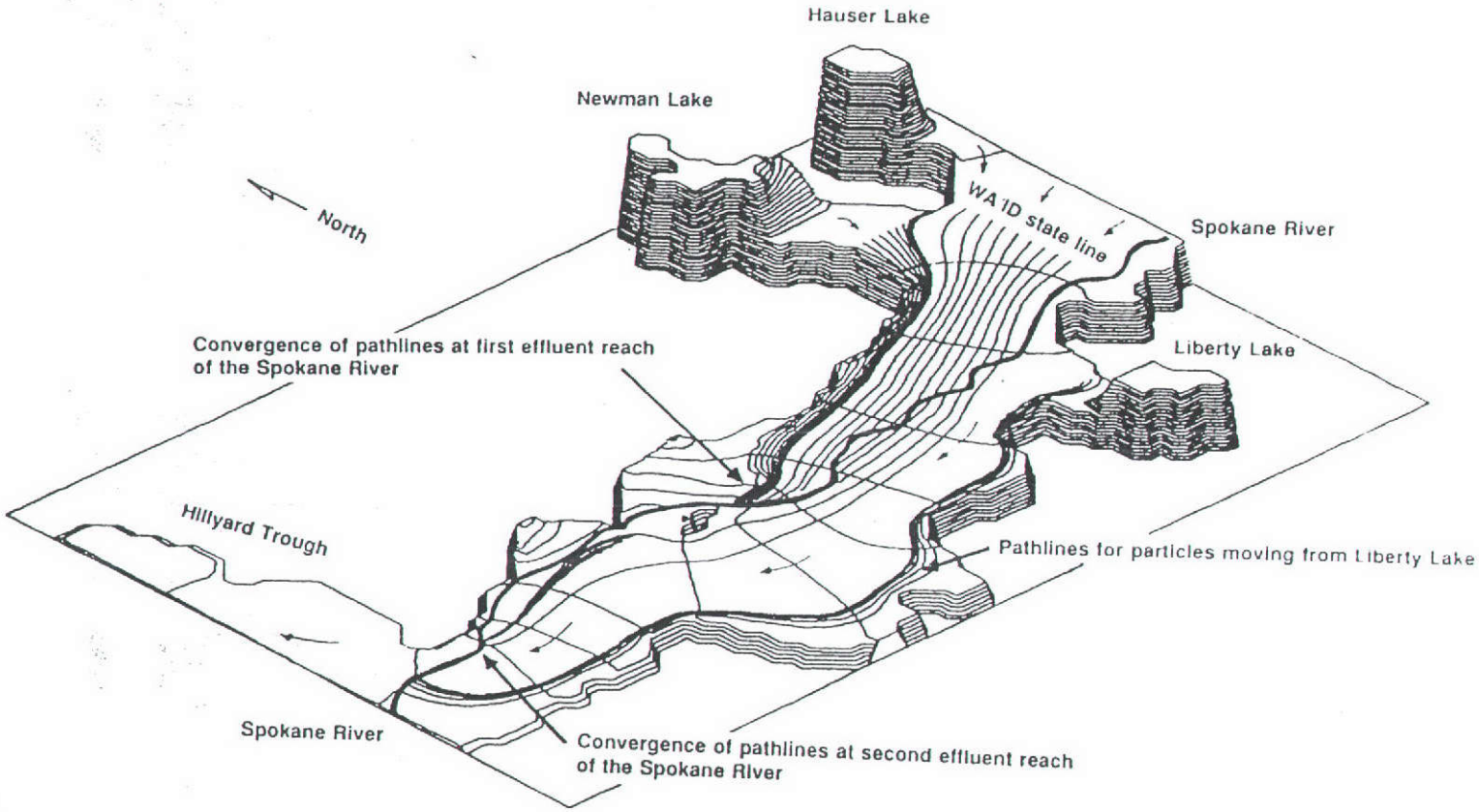
Figure 7. The Spokane Valley/Rathdrum Prairie Aquifer system.

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Figure 9. View to northeast (up-gradient) of the groundwater table map of the Rathdrum Prairie portion of the Spokane Valley /Rathdrum Prairie Aquifer system produced by computer simulation by utilizing MODFLOW (adapted by Buchanan from Painter, 1993, pers. comm.). Note the streamlines produced by back-tracking 50 particles placed at the state line toward their source. Arrows indicate direction of groundwater flow



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Figure 11. View to northeast (up-gradient) of the groundwater table map of the Spokane valley portion of the Spokane Valley/Rathdrum Prairie Aquifer system produced by computer simulation by utilizing MODFLOW (Buchanan and Olness, 1993). Note streamlines produced by forward-tracking 25 particles placed at the state line, Newman and Liberty Lakes, WA. Particles move toward effluent (gaining) reaches of the Spokane River, WA between Sullivan and Trent and just below Upriver Dam and Greene Street. Arrows indicate direction of groundwater flow.

Coeur d'Alene Tribe
Environmental Action Plan
(EAP) Project

EAP Assessment of Environmental Concerns on and near the Coeur d'Alene Reservation July 2000

Prepared by
The Coeur d'Alene Tribe,
the EAP Steering Committee
and
EAP Technical Workgroup

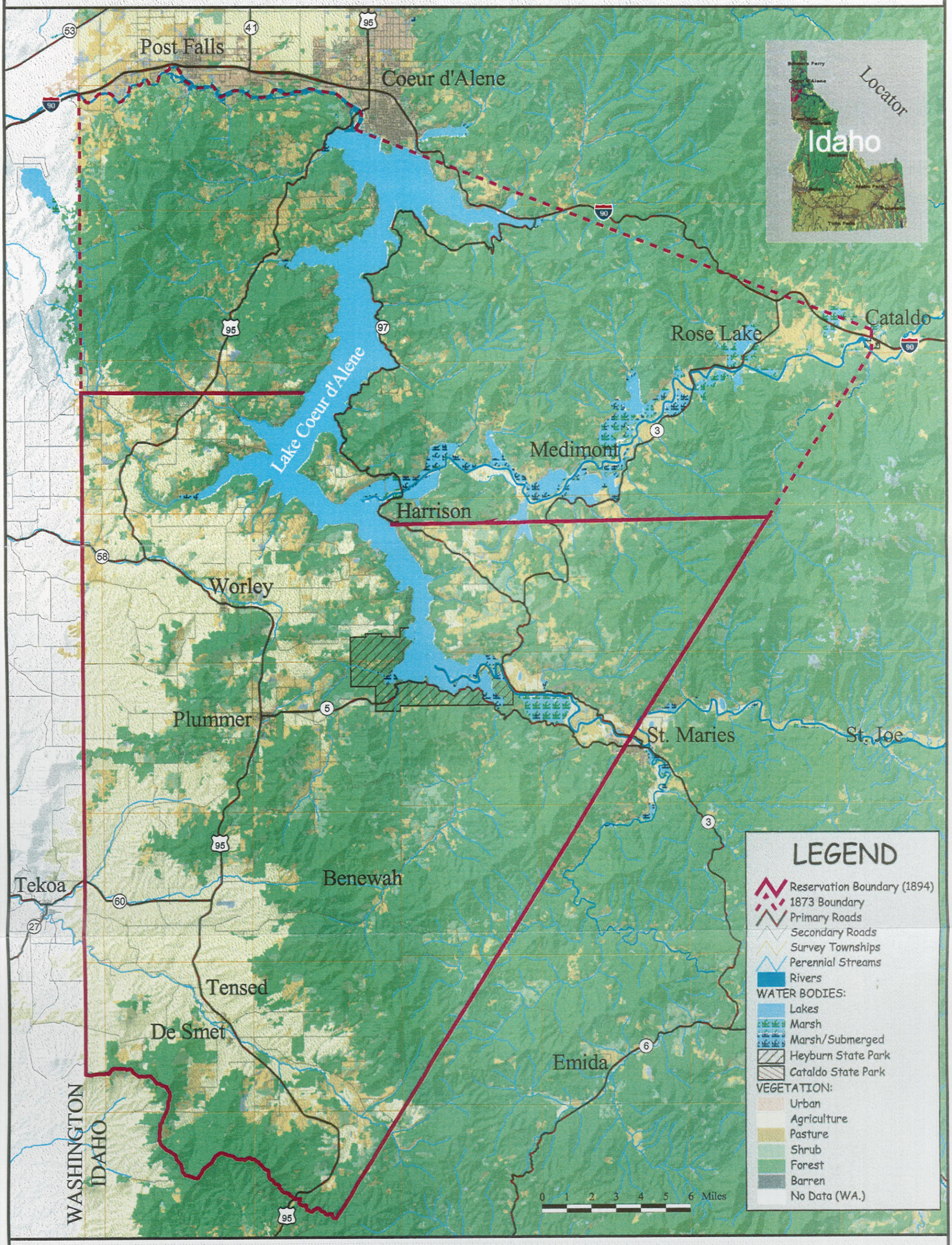
Funding Provided by United States Environmental Protection Agency



Executive Summary
Volume 1

MICROFILMED Entire Book
NOV 2 6 2003

Coeur d'Alene Reservation



Coeur d'Alene Tribe Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 5/31/99



Trails such as this are found in forests throughout the Coeur d'Alene Tribe's traditional territory. Scenes like this emphasize the importance of protecting the environment for all people.

Purpose of the Assessment of Environmental Concerns

The Coeur d'Alene Tribe's Natural Resource Department (NRD) began the Environmental Action Plan (EAP) Project in response to Tribal members' and Tribal Council's request for the NRD's goals. The Tribe's NRD was established and grew quickly between 1992 and 1996. Recognizing that an integrated or holistic approach to environmental management was needed due to the size and diversity of the Department, the NRD Director determined that a Reservation-wide environmental management plan was needed.

- The purpose of the Assessment or Phase I of the EAP Project is to collect and analyze existing information on a comprehensive set of potential environmental concerns on and near the Coeur d'Alene Reservation

The information contained in the Assessment report was used to rank the severity of the 25 broad environmental concerns that were identified. It will also be used to assist in developing goals for the Tribe's environmental management plan, Phase II of the EAP Project. Additional uses may include developing environmental education curricula for local schools, sharing it as a reference document to orient new employees of the Tribe's NRD and for general education.

What the Assessment of Environmental Concerns IS and IS NOT

The Tribe's Assessment of Environmental Concerns **IS**:

- an information tool
- a gathering of existing information on the Reservation's natural environment
- an analysis of existing information combined with "Best Professional and Community Judgment" to determine potential environmental concerns and rank the risks that they pose
- a beginning, a place to start in understanding the human-induced changes in the natural environment

The Tribe's Assessment of Environmental Concerns **IS NOT**:

- designed to set environmental management priorities by itself
- able to address the entirety of the Tribe's aboriginal territory and all Tribal resources due to time and funding constraints



Wheat fields after harvest. Agriculture on the Coeur d'Alene Reservation has many economic and environmental impacts.

Coeur d'Alene Tribe
Historical Atlas
Executive Summary

Introduction

The Coeur d'Alene Tribe Historical Atlas attempts to use historical information to produce maps showing changes that have occurred in the local environment over the past 150 years. A total of 13 maps were produced for the Historical Atlas. The benefit of looking to the past is that context can be gained for interpreting the conditions of the present. While it is not possible to go back to some correct "starting point" (since any snapshot in time is just one moment in a continual flow of change), by looking back as far as possible there can be some yardstick from which to measure change.

Methods

Historic maps, documents, survey records, soil reports and inventory data were acquired from various sources including Libraries, Archives, Government Agencies, collections of private individuals and the Coeur d'Alene Tribe. These materials were evaluated for their descriptive potential and entered into the Tribe's Geographical Information System (GIS). More than a dozen new GIS layers were created and over 500 aerial photographs from 1933 and 1946 were saved in digital format for future analysis. The project also produced a large inventory of historical documents and maps which have been indexed and catalogued for future use by the Tribe.

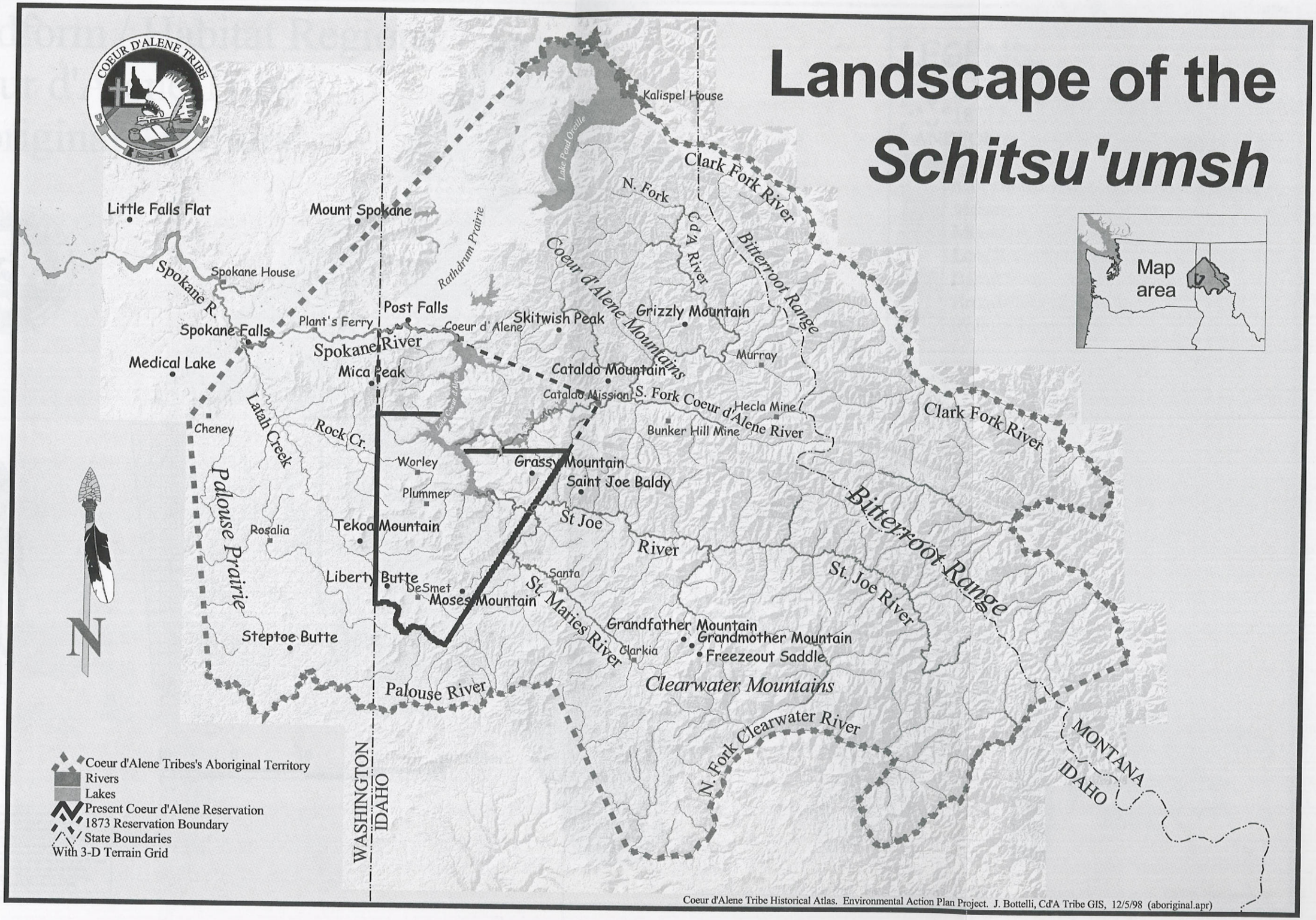
Description of Maps

Maps 1 & 2: Landscape of the *Schitsu'umsh*; Landform / Habitat Regions: Coeur d'Alene Tribe's Aboriginal Territory

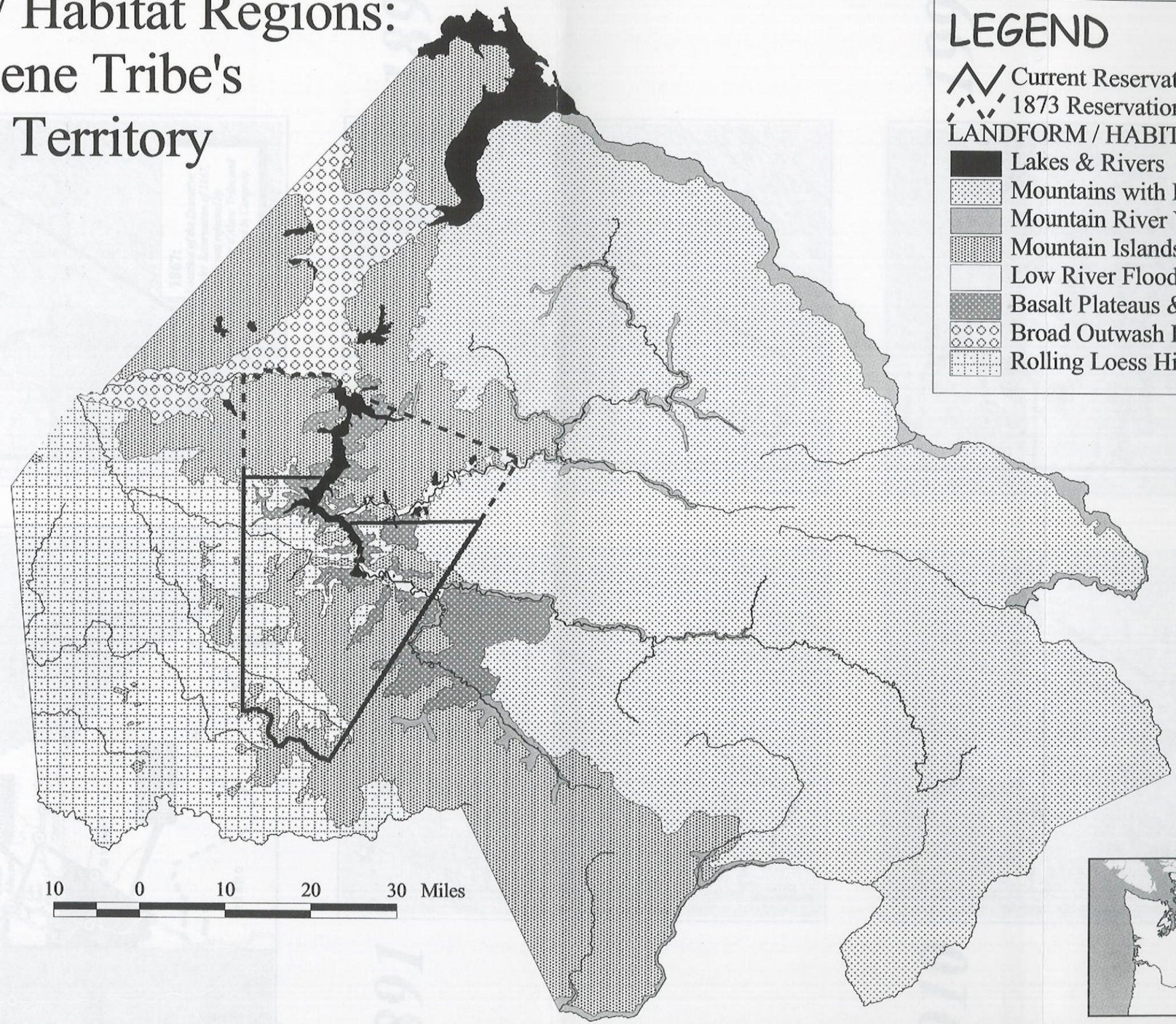
The first two maps in the Atlas show the area of the Tribe's Aboriginal Territory. The first presents the general layout of the landscape and the second is an interpretive map that speaks to the composition of the landscape, showing landforms and discussing their history and origins. The remaining maps in the Atlas demonstrate changes in the cultural and natural landscapes on the Coeur d'Alene Reservation.

Map 3: History of Reservation Boundaries

This map shows changes in land ownership over time which have influenced the patterns of land use affecting the Reservation environment. From the 1873 Reservation that was negotiated from an aboriginal territory that spanned millions of acres, Tribal land


Landscape of the
Schitsu'umsh
COEUR D'ALENE TRIBE
Kalispel House
Lake Pend Oreille
Clark Fork River
N. Fork
Little Falls Flat
Mount Spokane
Rathdrum Prairie
Coeur d'Alene Mountains
Cd'A River
Bitterroot Range
Spokane R.
Spokane House
Post Falls
Plant's Ferry
Coeur d' Alene
Skitwish Peak
Grizzly Mountain
Spokane Falls
Spokane River
Medical Lake
Mica Peak
Cataldo Mountain
Murray
Cataldo Mission
S. Fork Coeur d'Alene River
Hecla Mine
Bunker Hill Mine
Clark Fork River
Cheney
Latah Creek
Rock Cr.
Worley
Grassy Mountain
Saint Joe Baldy
Plummer
Palouse Prairie
Rosalia
Tekoa Mountain
St Joe
River
Bitterroot Range
Liberty Butte
DeSmet
Moses Mountain
Santa
St. Maries River
St. Joe River
Steptoe Butte
Grandfather Mountain
Grandmother Mountain
Clarkia
Freezeout Saddle
Clearwater Mountains
Palouse River
N. Fork Clearwater River
MONTANA
IDAHO
WASHINGTON
IDAHO
N
Map area
Coeur d'Alene Tribes's Aboriginal Territory
Rivers
Lakes
Present Coeur d'Alene Reservation
1873 Reservation Boundary
State Boundaries
With 3-D Terrain Grid
Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/5/98 (aboriginal.apr)

Landform / Habitat Regions: Coeur d'Alene Tribe's Aboriginal Territory

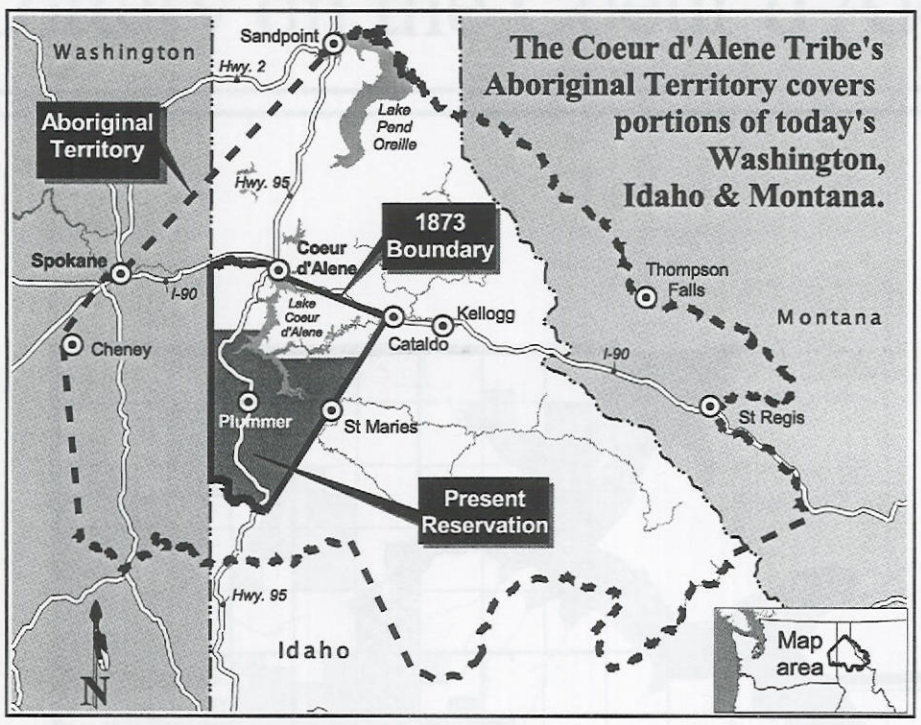


The information depicted on this map is the result of digital analyses performed on a database consisting of information from a variety of governmental and other credible sources. The accuracy of the information presented is limited to the collective accuracy of the database on the date of the analysis. The information is believed accurate and reasonable efforts have been made to ensure the accuracy of the map. However, the Coeur d'Alene Tribe expressly disclaims responsibility for damages or liability that may arise from use of this map. This product is the property of the Coeur d'Alene Tribe and its use is thereby restricted.

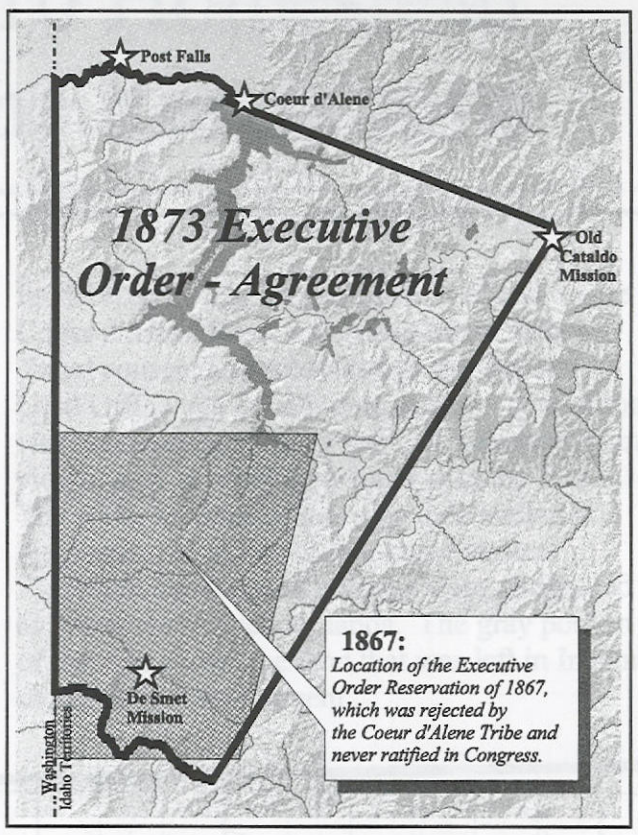
Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 1/24/99 (physmap.apr)

History of Reservation Boundaries

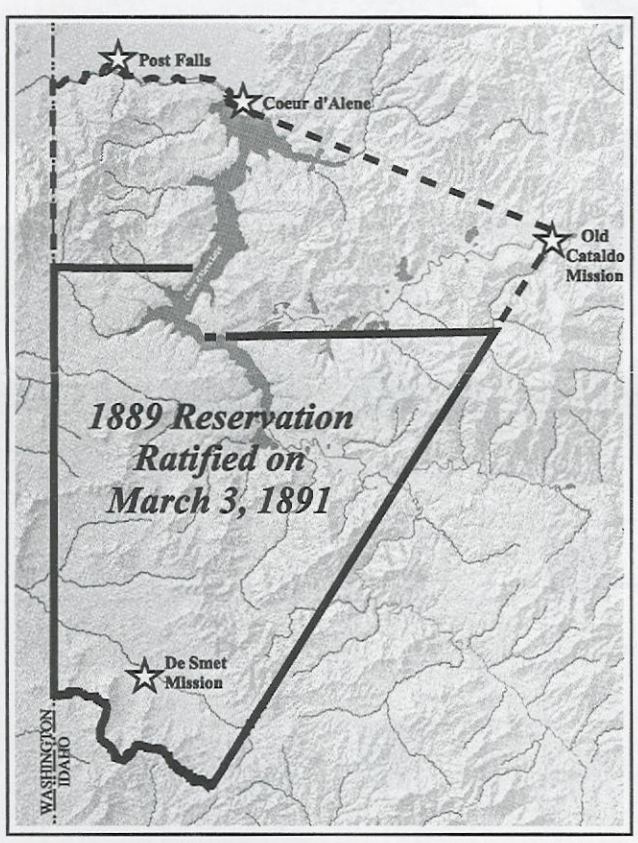
OVERVIEW



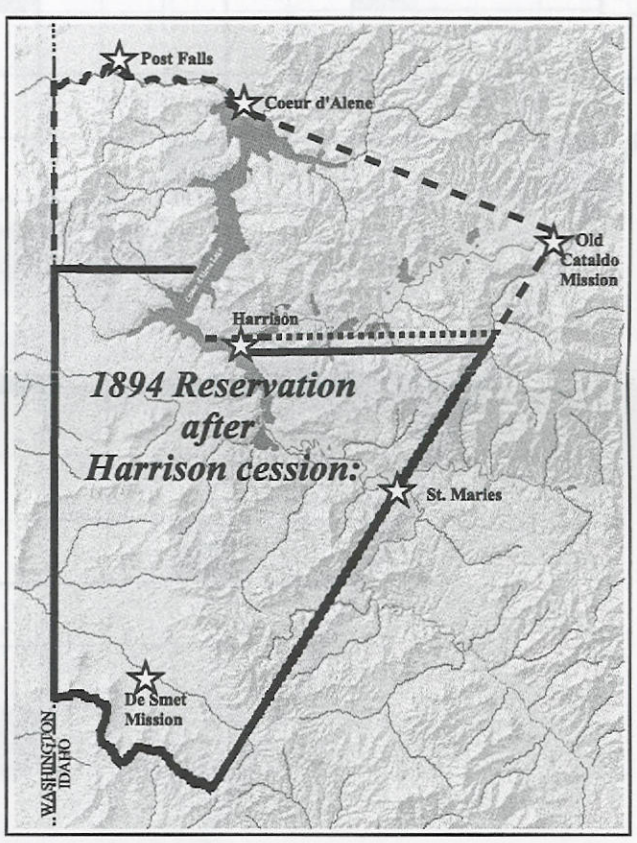
1873



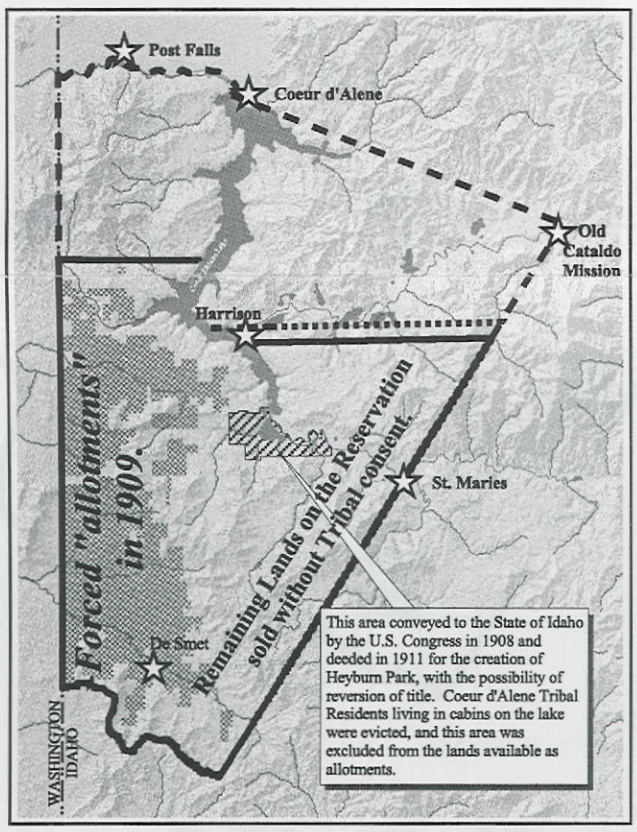
1891



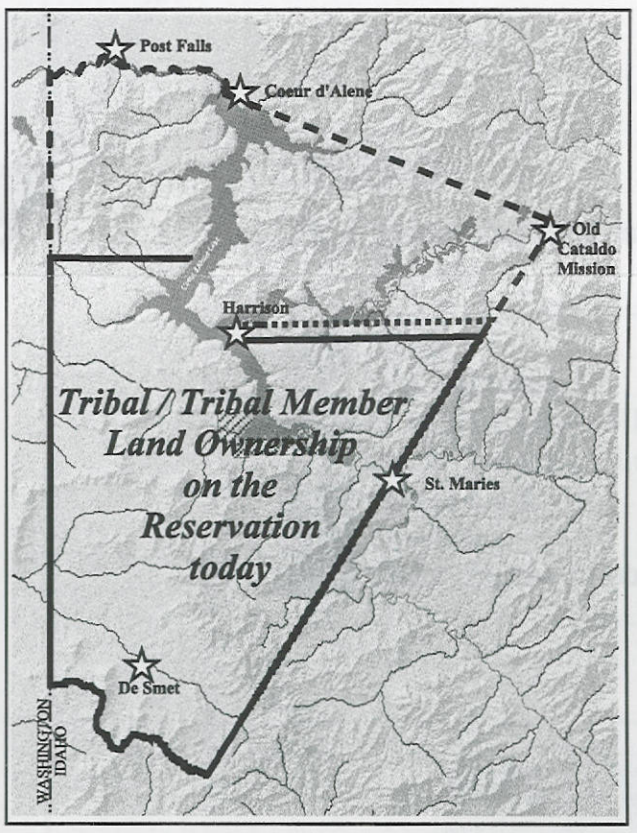
1894



1910

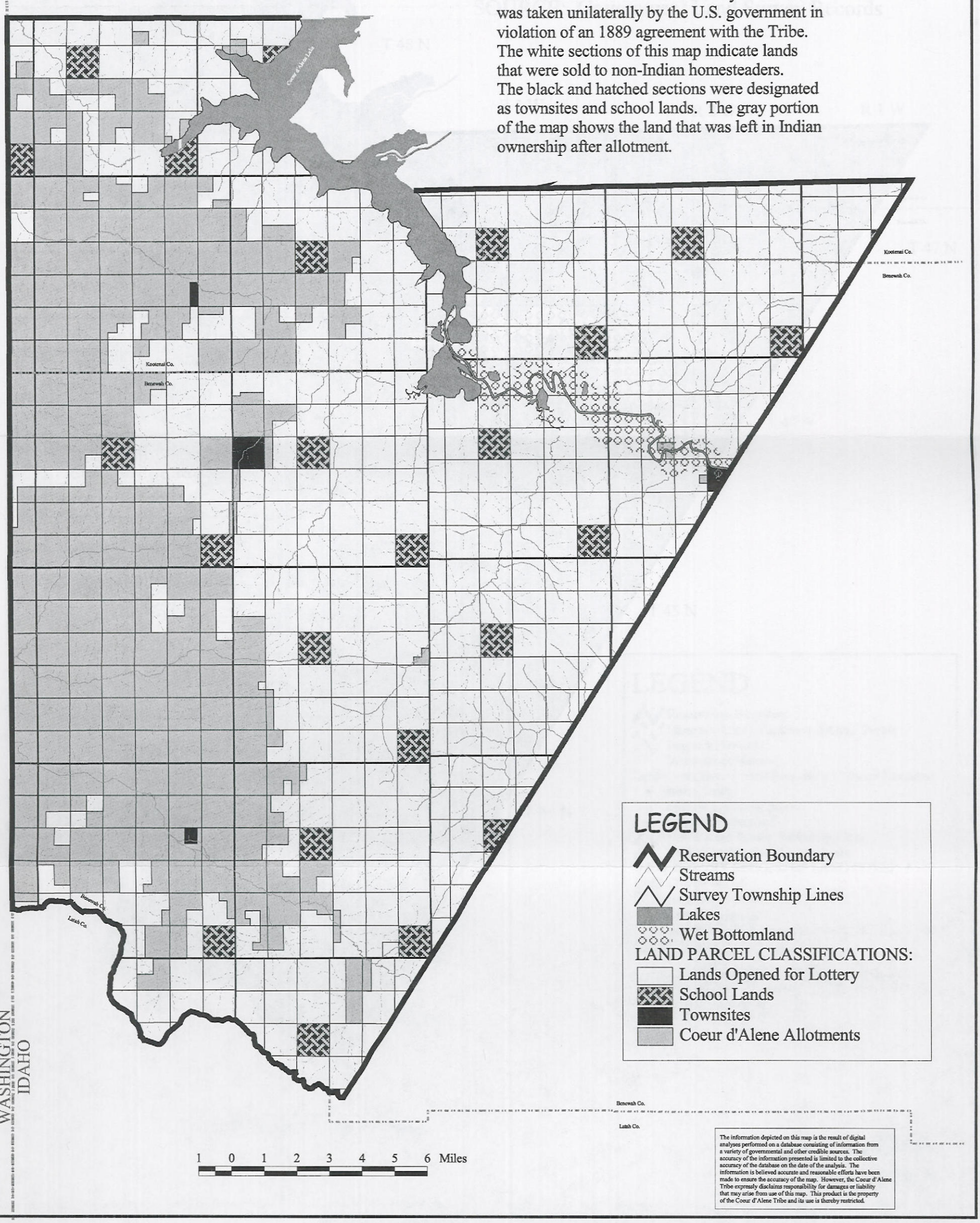


1999



Lands "Opened" for the 1910 Homestead Lottery on the Coeur d'Alene Reservation

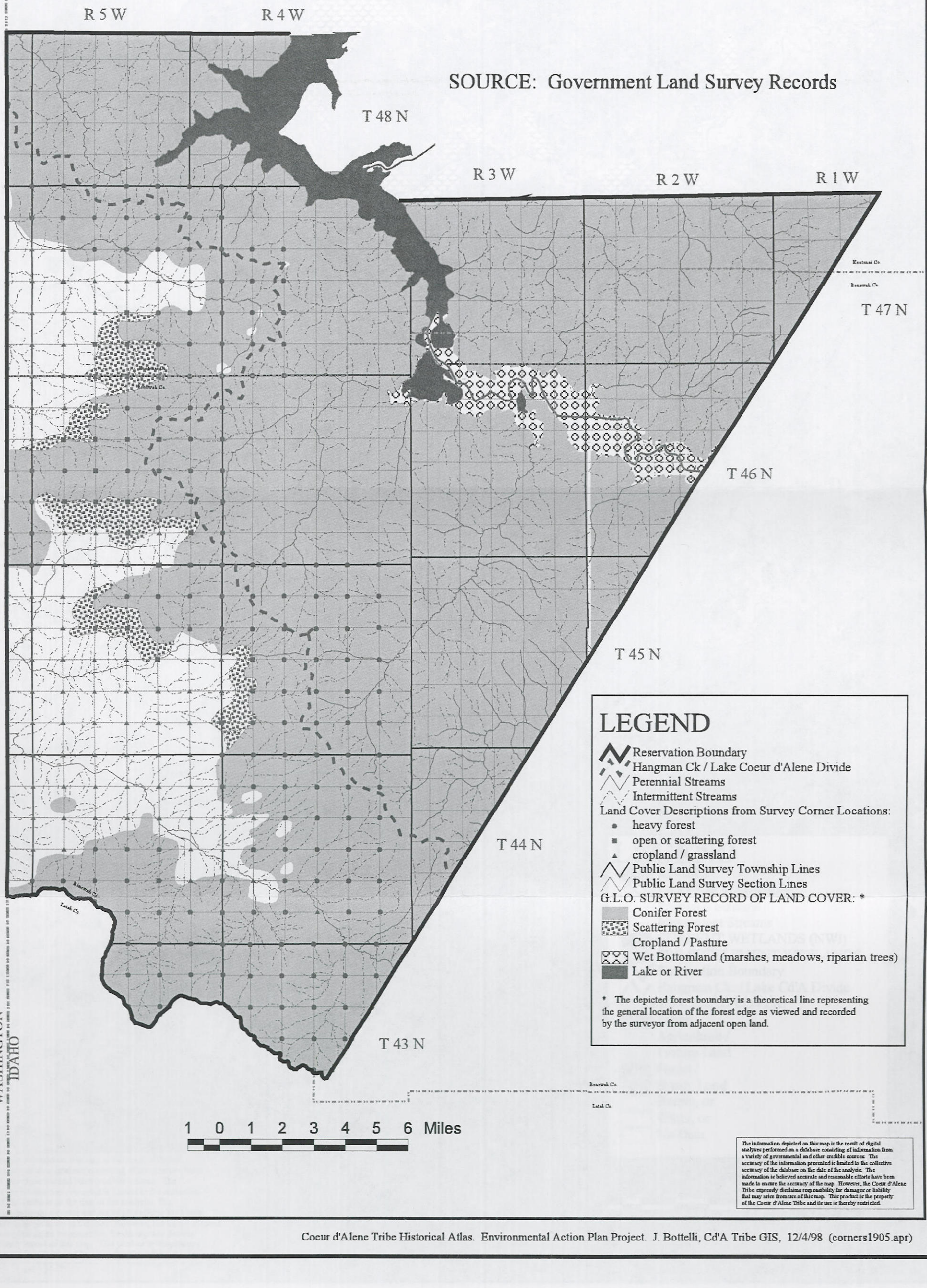
In 1910, more than two-thirds of the land on the Coeur d'Alene Reservation was taken without Tribal consent and sold through the General Land Office in a nation-wide lottery. This action was taken unilaterally by the U.S. government in violation of an 1889 agreement with the Tribe. The white sections of this map indicate lands that were sold to non-Indian homesteaders. The black and hatched sections were designated as townsites and school lands. The gray portion of the map shows the land that was left in Indian ownership after allotment.



The information depicted on this map is the result of digital analyses performed on a database consisting of information from a variety of governmental and other credible sources. The accuracy of the information presented is limited to the collective accuracy of the database on the date of the analysis. The information is believed accurate and reasonable efforts have been made to ensure the accuracy of the map. However, the Coeur d'Alene Tribe expressly disclaims responsibility for damages or liability that may arise from use of this map. This product is the property of the Coeur d'Alene Tribe and its use is thereby restricted.

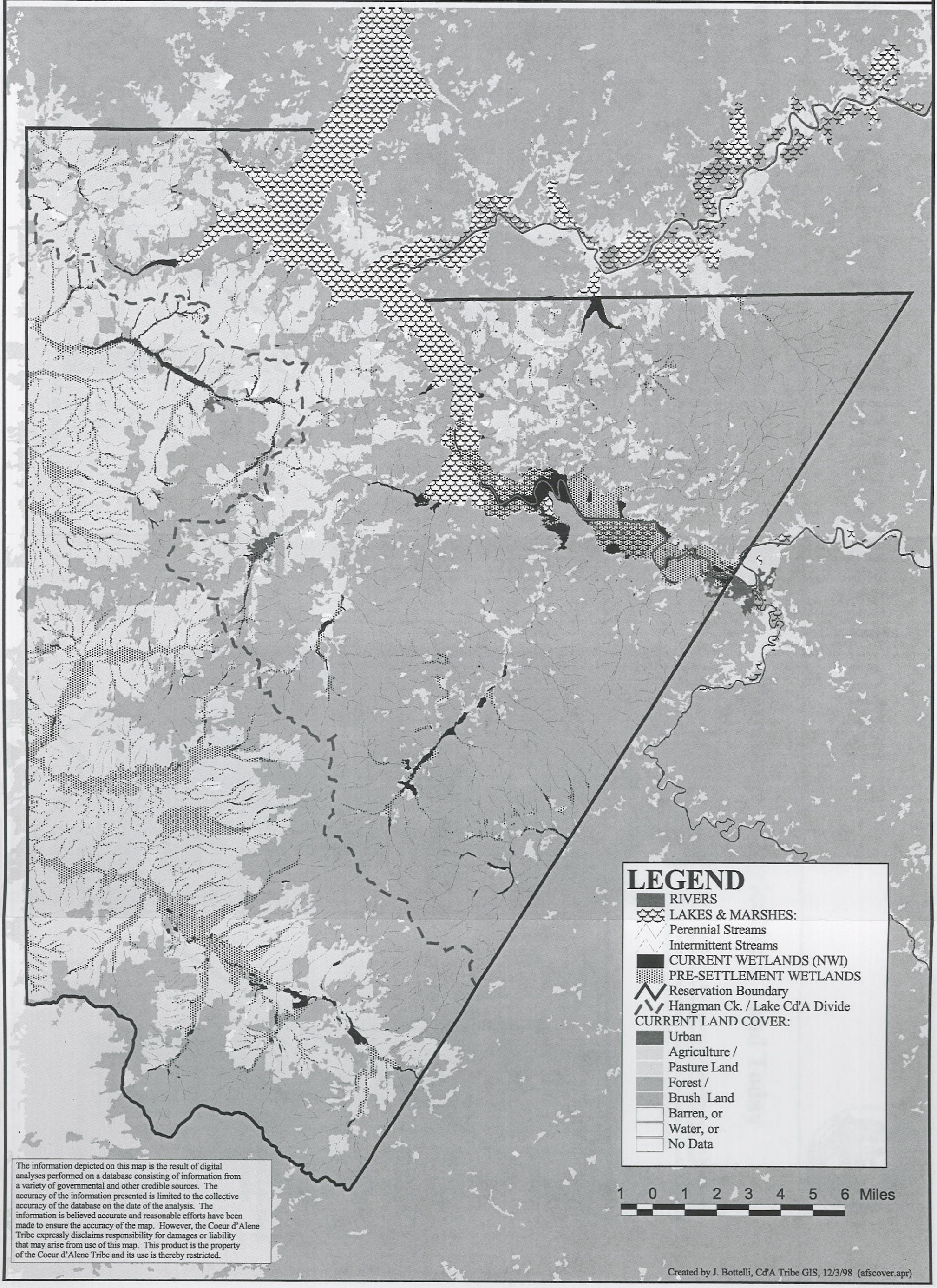
Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/4/98 (allotments.apr)

Locations of Forest Land and Agricultural/Grasslands in 1906



Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/4/98 (corners1905.apr)

Estimated Pre-Settlement Wetlands Compared with Current Land Cover

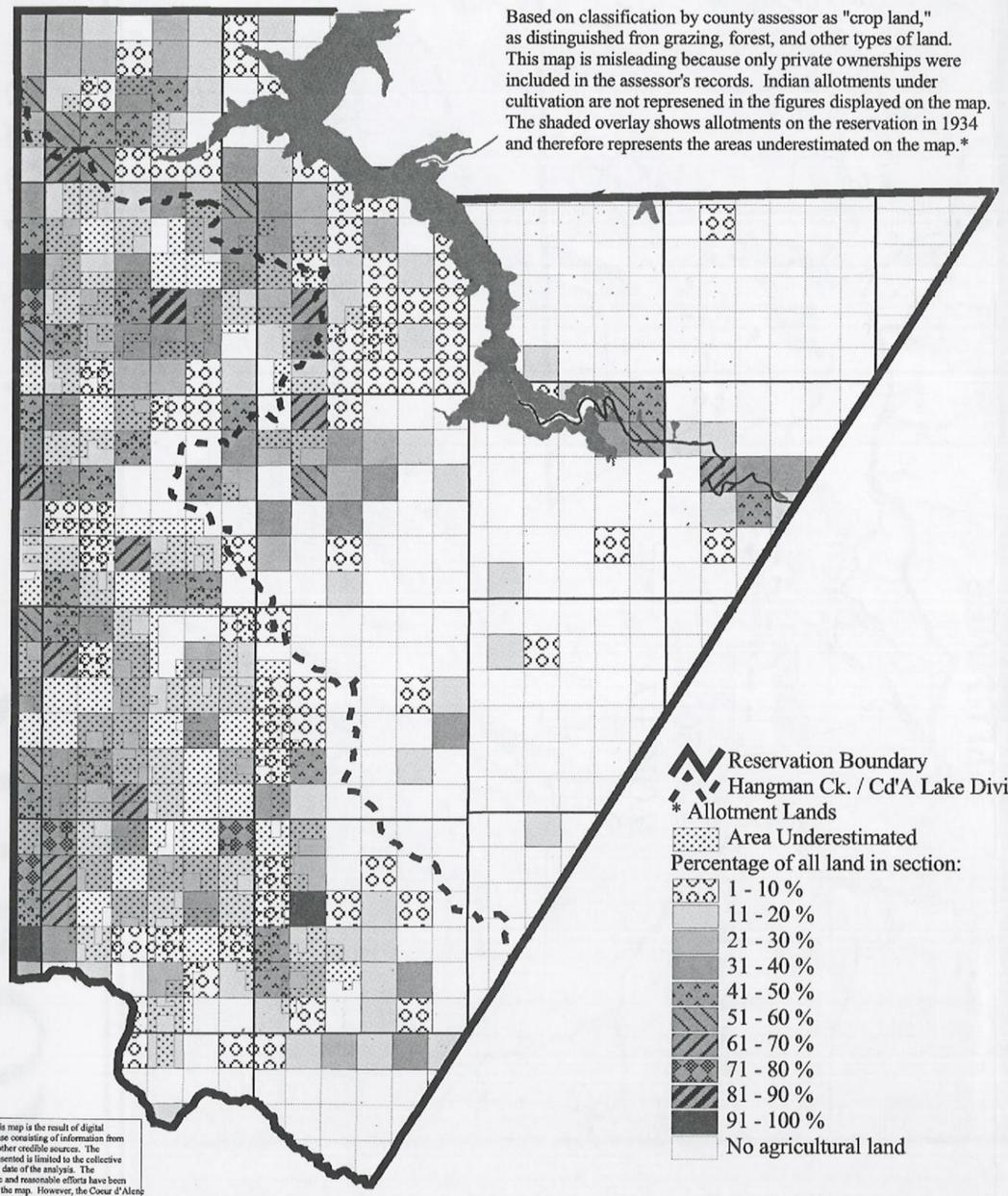


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Created by J. Bottelli, Cd'A Tribe GIS, 12/3/98 (afscover.apr)

Proportion of Cultivated Land

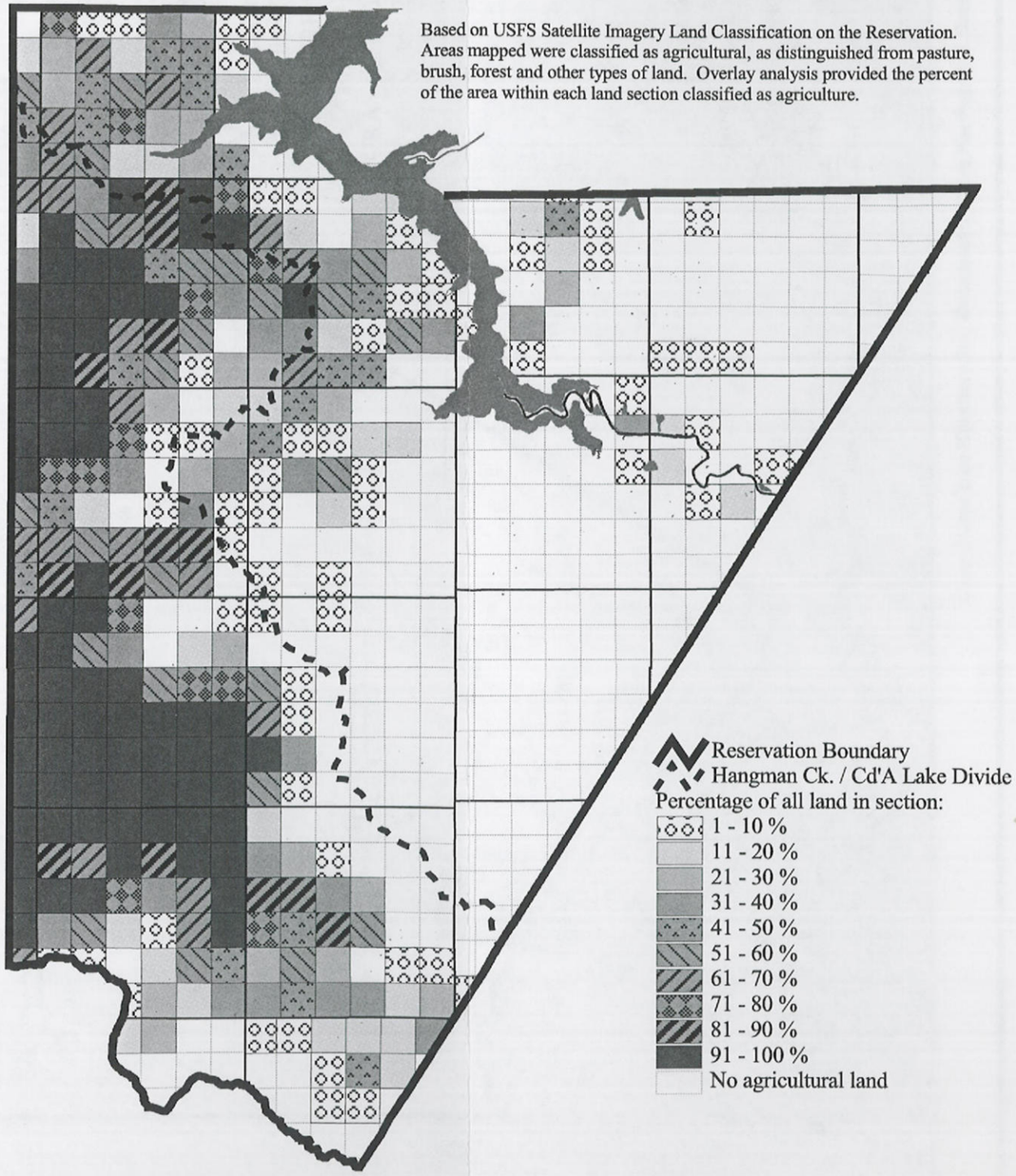
Percentage of land in Agriculture in 1933



Based on classification by county assessor as "crop land," as distinguished fron grazing, forest, and other types of land. This map is misleading because only private ownerships were included in the assessor's records. Indian allotments under cultivation are not represened in the figures displayed on the map. The shaded overlay shows allotments on the reservation in 1934 and therefore represents the areas underestimated on the map.*

The information depicted on this map is the result of digital analyses performed on a database consisting of information from a variety of governmental and other credible sources. The accuracy of the information presented is limited to the collective accuracy of the database on the date of the analysis. The information is believed accurate and reasonable efforts have been made to ensure the accuracy of the map. However, the Coeur d'Alene Tribe expressly disclaims responsibility for damages or liability that may arise from use of this map. This product is the property of the Coeur d'Alene Tribe and its use is thereby restricted.

Percentage of Agricultural Land Today



Based on USFS Satellite Imagery Land Classification on the Reservation. Areas mapped were classified as agricultural, as distinguished from pasture, brush, forest and other types of land. Overlay analysis provided the percent of the area within each land section classified as agriculture.

Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/4/98 (agstats.apr)

ROADS: Coeur d'Alene Reservation circa 1939

Approximate location of the Mullan Military Road, as first laid down in 1859 - 1860.

Coeur d'Alene Lake

Amwaco Line (Abandoned)

WORLEY (pop. 200)

O. W. R. & N.

C. M. St. P. & P.

Chicago, Milwaukee, St. Paul & Pacific Railroad

PLUMMER (pop. 300)

ST. MARIES

Oregon Washington Railroad & Navigation Co. Railroad

TENSED

DESMET

Mc Goldrick Lumber Railroad

LEGEND

- Reservation Boundary
- Mullan Road 1859-1860

HARD SURFACED ROADS
- Primary Highways

GRAVEL & DIRT ROADS
- Gravel Roads
- Dirt Roads (graded)
- 4WD (unimproved) Roads

ACTIVE RAILROADS
- C. M. St. P. & P. RR
- O. W. R. & N. Co. RR
- Lumber Railroad

ABANDONED RAILROADS
- Amwaco Line
- approximate locations of schools
- PLS Township Lines
- WASH./IDAHO Boundary

3-D terrain grid

1 0 1 2 3 4 5 6 Miles

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Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/5/98 (roads_old.apr)

ROADS: Coeur d'Alene Reservation Today

Approximate location of the Mullan Military Road, as first laid down in 1859 - 1860.

Coeur d'Alene Lake

WORLEY

PLUMMER

ST. MARIES

TENSED

DESMET

WASHINGTON

IDAHO

LEGEND

PAVED ROADS:
- Primary Highways
- Secondary Roads

NATIVE SURFACE ROADS:
- Gravel Roads
- Dirt & 4WD Roads
- Railroads
- Abandoned Railroads
- Reservation Boundary
- PLS Township Lines

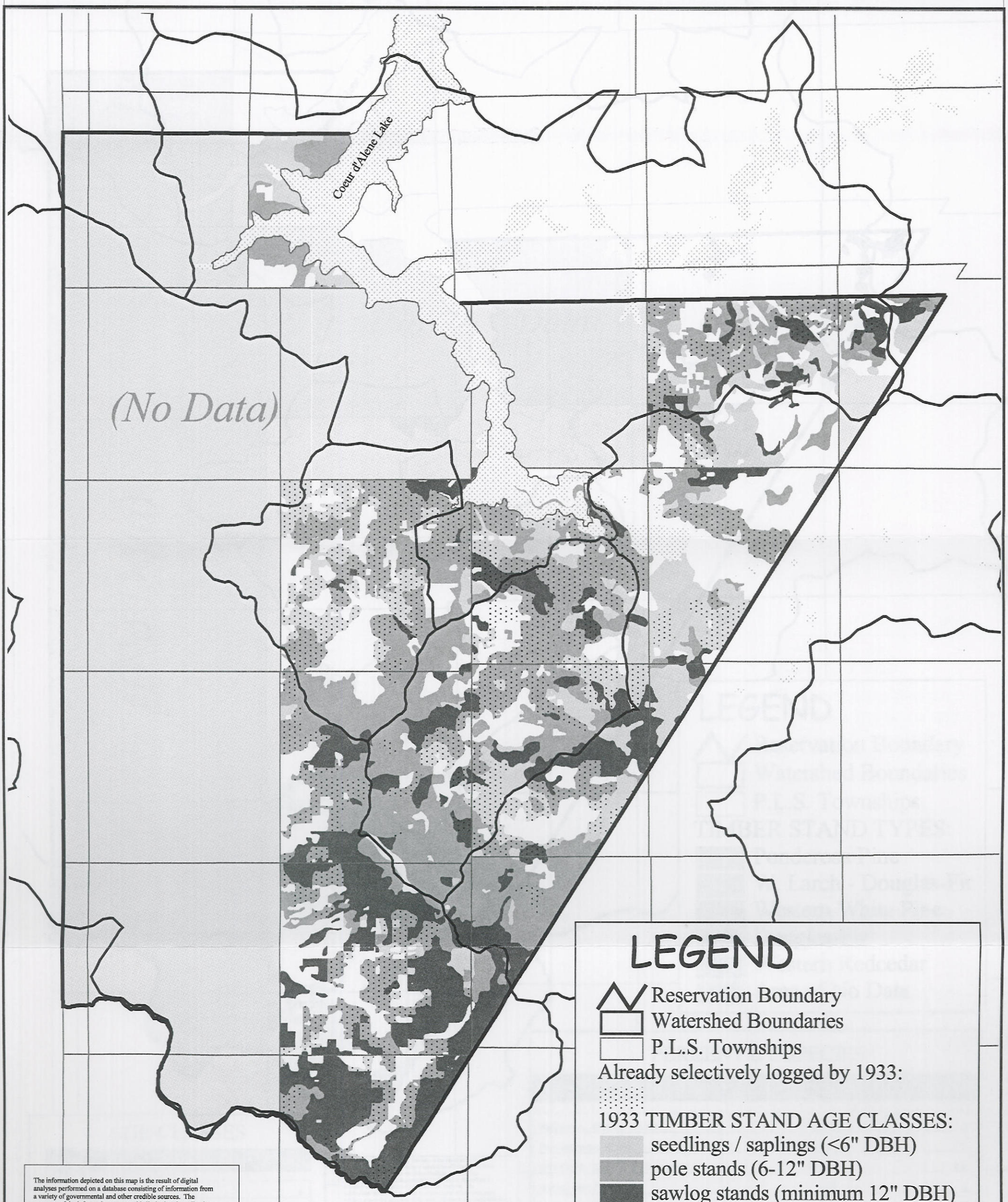
3-D terrain grid

1 0 1 2 3 4 5 6 Miles

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Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/5/98 (roads_old.apr)

1933 Forest Survey Data: Size Class of Timber Stands

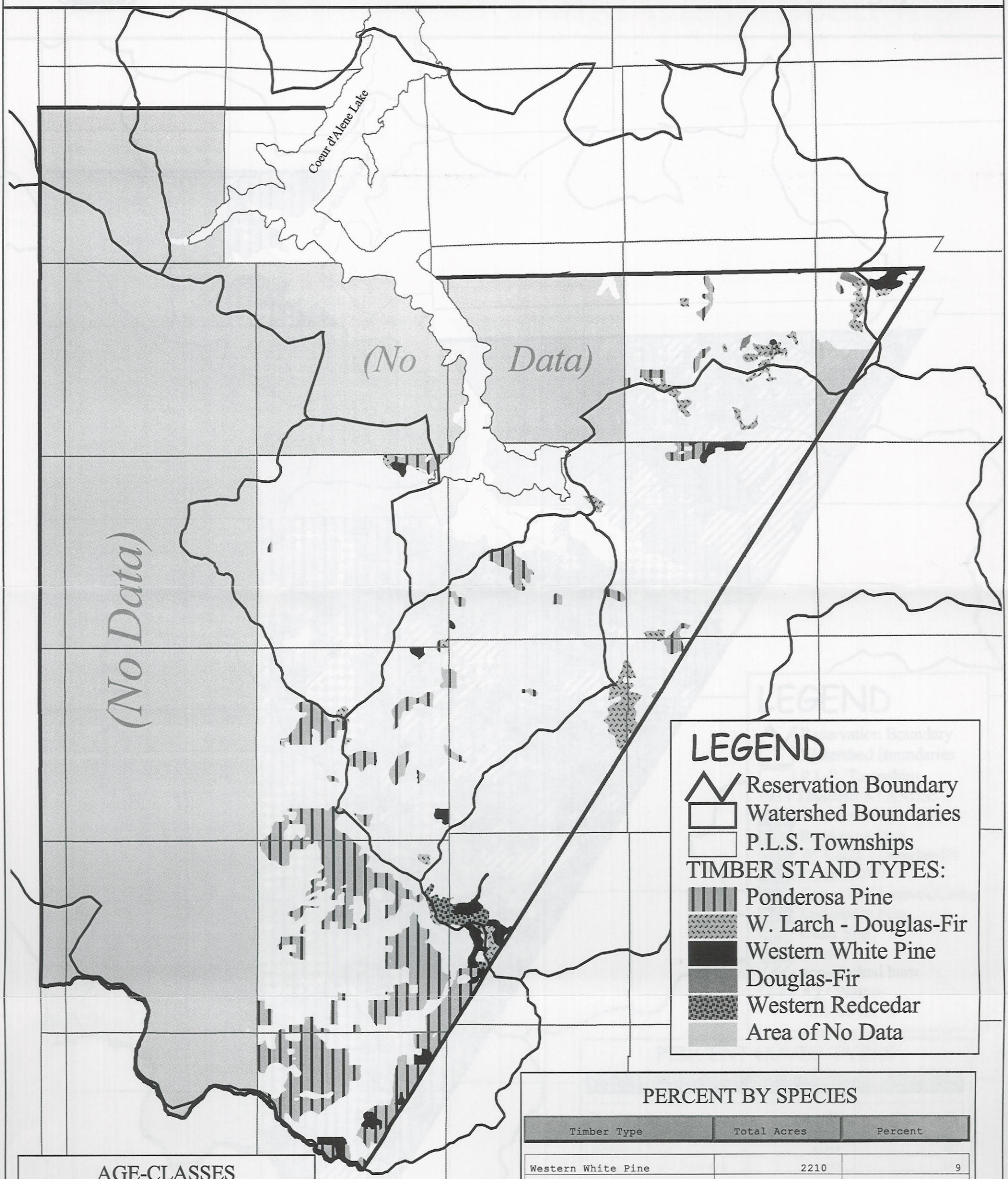


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Coeur d'Alene Tribe Historical Atlas. J. Bottelli, Cd'A Tribe GIS, 1/25/99 (forests33.apr)

1933 Forest Survey Data: Potential Old Growth Stands

* Unmanaged Pole and Sawlog Stands that were identified as 160-200 or 200+ years old in 1933.



LEGEND

- Reservation Boundary
- Watershed Boundaries
- P.L.S. Townships

TIMBER STAND TYPES:

- Ponderosa Pine
- W. Larch - Douglas-Fir
- Western White Pine
- Douglas-Fir
- Western Redcedar
- Area of No Data

AGE-CLASSES

Age	Total Acres	Percent
161-200	1848	8
200+	22602	92

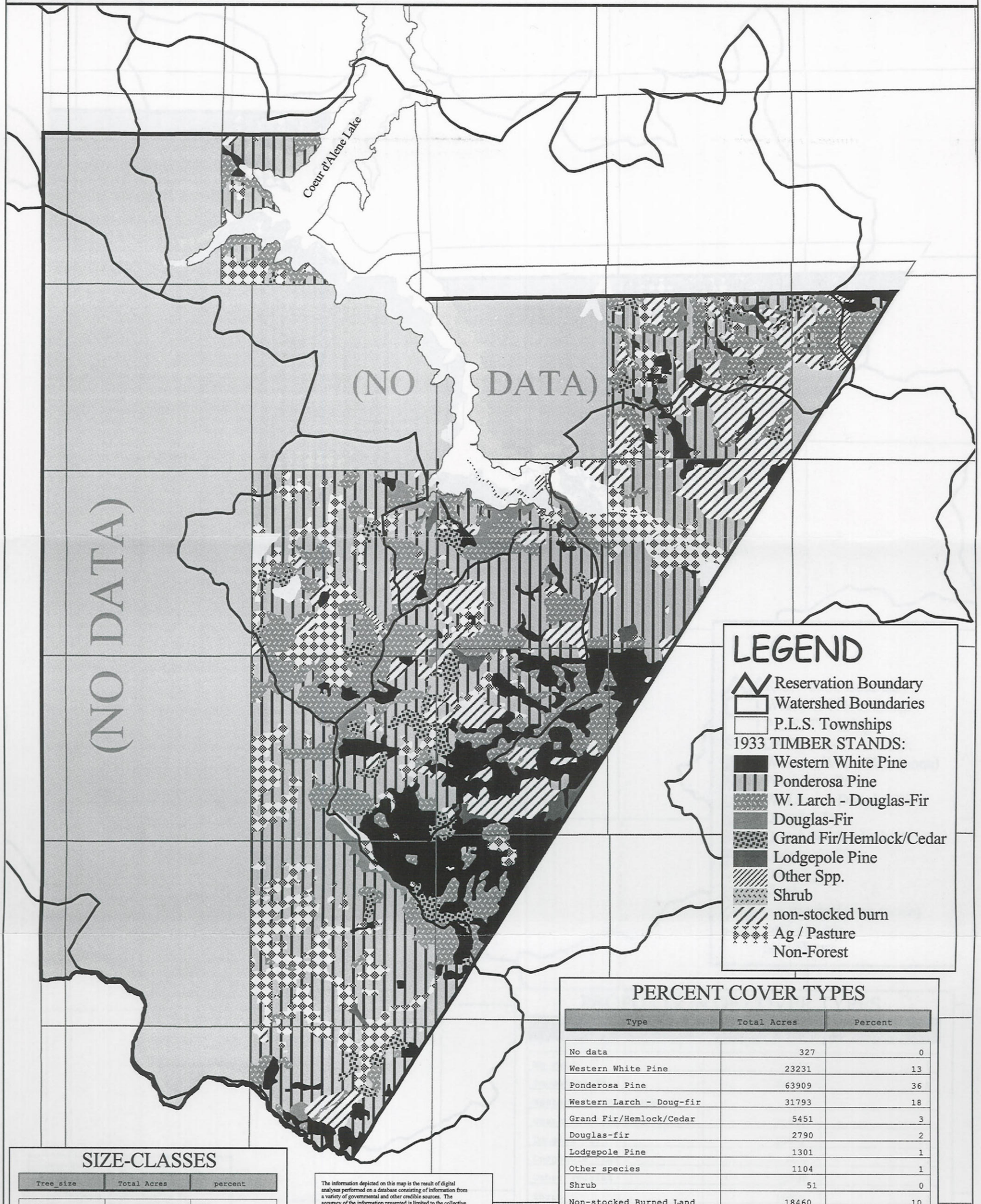
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PERCENT BY SPECIES

Timber Type	Total Acres	Percent
Western White Pine	2210	9
Ponderosa Pine	18282	75
Western Larch - Doug-fir	3058	13
Douglas-fir	143	1
Western Redcedar	755	3

Coeur d'Alene Tribe Historical Atlas. J. Bottelli, Cd'A Tribe GIS, 1/25/99 (forests33.apr)

1933 Forest Survey Data: Economic Timber Stand Types



SIZE-CLASSES

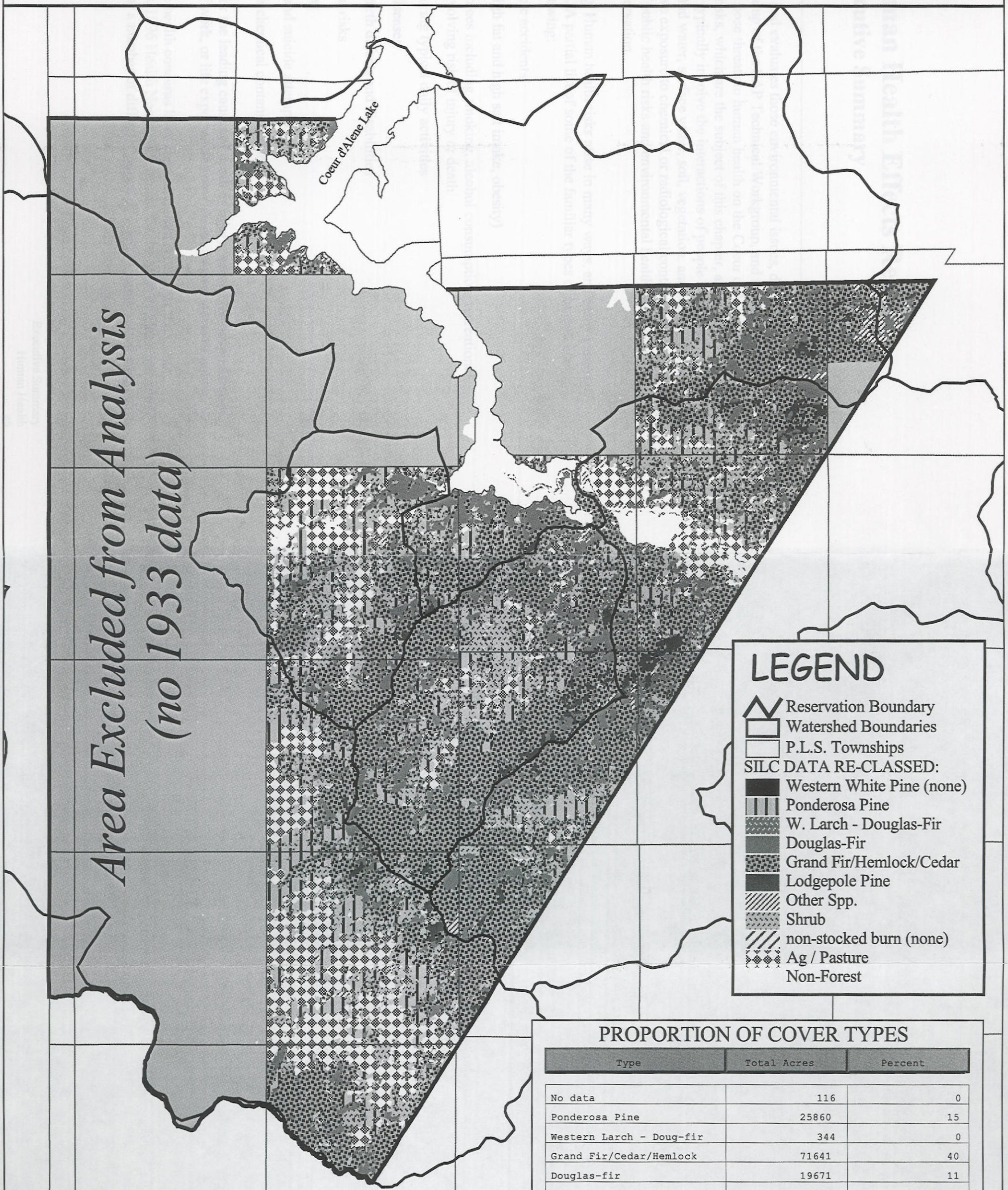
Tree_size	Total Acres	percent
Saplings	28856	25
Poles	55128	48
Sawlogs	31438	27

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PERCENT COVER TYPES

Type	Total Acres	Percent
No data	327	0
Western White Pine	23231	13
Ponderosa Pine	63909	36
Western Larch - Doug-fir	31793	18
Grand Fir/Hemlock/Cedar	5451	3
Douglas-fir	2790	2
Lodgepole Pine	1301	1
Other species	1104	1
Shrub	51	0
Non-stocked Burned Land	18460	10
Agriculture / Pasture	22937	13
Non-forest	5756	3

Current Satellite Land Cover Data: SILC Cover Types Grouped into 1933 Timber Stand Classifications



PROPORTION OF COVER TYPES

Type	Total Acres	Percent
No data	116	0
Ponderosa Pine	25860	15
Western Larch - Doug-fir	344	0
Grand Fir/Cedar/Hemlock	71641	40
Douglas-fir	19671	11
Lodgepole Pine	3507	2
Other species	1939	1
Shrub	16612	9
Agriculture / Pasture	32968	19
Non-forest	4452	3

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Coeur d'Alene Tribe Historical Atlas. J. Bottelli, Cd'A Tribe GIS, 1/25/99 (forests33.apr)



Lake Coeur d'Alene in winter. Both the snow and the lake are important components of the Reservation's water resources.

Hydrologic Change

Hydrologic change relates to changes in the quantity and timing of surface water runoff. Human health effects related to hydrologic change on the Reservation are most likely to be associated with increased peak flows and associated flooding, but may also be related to decreased base flows which may lessen the ability of surface waters to dilute pollutant discharges.

Key Findings

1. Sources of contamination associated with flooding on the Reservation are most likely to include bacterial contamination from overflowing sewage treatment plants, lagoons, or septic systems, and agricultural or industrial contaminants.
2. Other sources of physical injury may include swiftly flowing water or deep standing water, and damaged electrical systems, natural gas, or propane tanks.
3. Individuals may be exposed to contaminants in flood waters through ingestion, through skin contact, especially in cuts or open sores, and through inhalation of airborne bacteria, mold, or viruses.
4. Individuals living in frequently flooded areas are most likely to be affected, especially those living immediately downstream from pollutant sources where concentrations of contaminants may be the highest.
5. Although skin contact with water does not, by itself, pose a serious health risk, there is some risk of disease from eating or drinking anything contaminated with flood water. Inhalation of airborne bacteria, molds, or viruses may cause disease or trigger allergic reactions. There may also be health risks related to physical hazards like fires, explosions, or electrical hazards.
6. Outbreaks of infectious diseases that were not present in the community before the flood are not usually a problem. However, the rates of diseases that were present before the flood may increase because of decreased sanitation or overcrowding among displaced persons.



Plummer Butte rises over agricultural lands and forest. Such areas are rich in the many plant and animal species found on the Coeur d'Alene Reservation.

Ecology Report
Executive Summary

Introduction

The Ecology Chapter documents the results of one of several assessments conducted to characterize the environmental health of the Coeur d'Alene Reservation. The areas studied include human health, ecological health and quality of life. The Ecology Chapter documents existing information regarding the ecological health of the Coeur d'Alene Reservation. The primary objectives of the analysis used to develop the ecology chapter included:

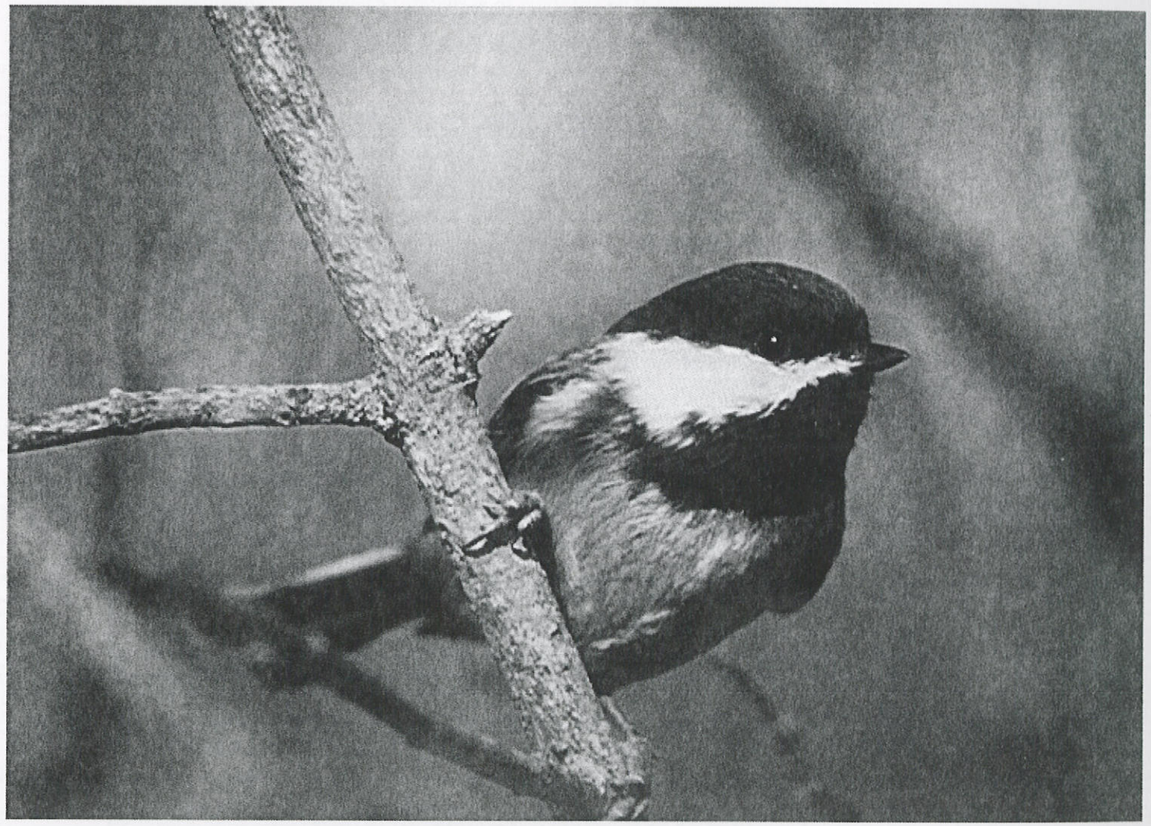
- Identify each major environmental stressor, for each of the environmental concerns identified through public input.
- Characterize the effects, or environmental risks, associated with each stressor.
- Describe the severity of the ecological impacts, in terms of the ecological health and evaluation criteria, identified through public involvement.

Methods Used to Develop the Ecological Assessment

Environmental concerns were identified during a series of public meetings by the EAP Steering Committee, EAP Technical Workgroup and Tribal Natural Resources staff. A total of 25 concerns were identified for detailed evaluation. Of these, 5 concerns were determined to be primarily human health or quality of life issues. Therefore, this chapter deals only with the 20 concerns involving ecological health which are listed below.

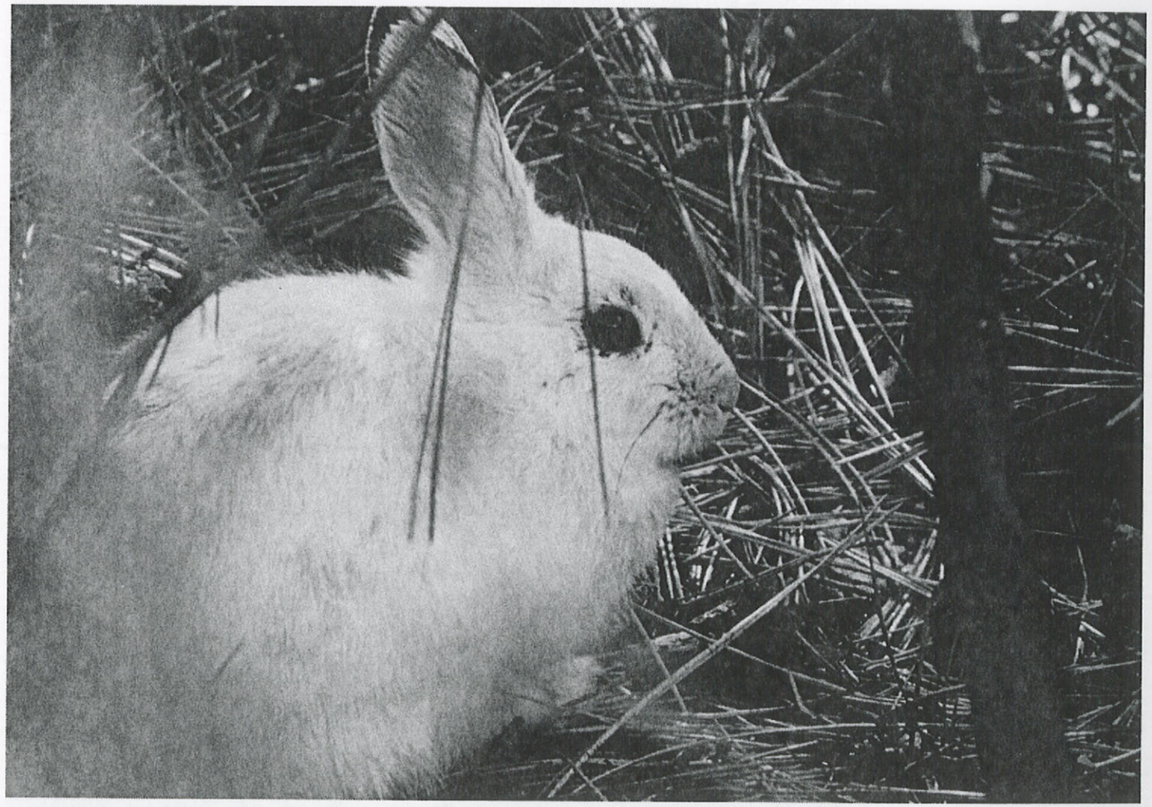
20 Environmental Concerns Addressed in the Ecology Chapter

1. Agricultural Chemicals
2. Energy Production and Consumption
3. Forest Health
4. Hazardous Waste
5. Human Population Growth and Development Patterns
6. Roads
7. Solid Waste Generation and Disposal
8. Outdoor Air Pollution
9. Localized Effects of Atmospheric Changes
10. Localized Effects of Hanford Nuclear Reservation
11. Ground Water Contamination
12. Hydrologic Changes
13. Non-Point Source Surface Water Pollution



Birds such as this Chestnut-sided Chickadee are typical of the diverse native wildlife found on the Coeur d'Alene Reservation.

Tribal Culturally Important Species Populations and Diversity	
Criteria	**Evaluation**
Changes Since Settlement	Human development has reduced the abundance of many known Tribal culturally important species.
Magnitude of Impacts	About 135,828 acres of forest, grassland, scrub shrub and wetland have been converted to other uses. Another 193,465 acres of forested lands have been impacted by uses which alter forest structure and function. Non-native species have invaded and out-competed native fish, wildlife and vegetation throughout the Reservation, and are found in all habitats, including lakes, rivers and streams, wetlands, riparian areas, agricultural lands and both dry and moist forest lands.
Severity of Impacts	Salmon and steelhead populations have been eliminated in the Hangman Creek watershed. Those species dependent on old growth, wetland, and native grassland habitat have been greatly reduced or eliminated, including sharp tail grouse, blue grouse, water potato and camas. It is possible that unnamed culturally important species have been lost entirely from the Reservation.
Reversibility of Impacts	Total eradication of all non-native species which impact culturally important species is not possible. Most species can be restored to the extent that sources of impact are eliminated and habitat restored.
Degree of Uncertainty	Complete inventories of culturally important species are not available. The cultural significance of many plants is known only to selected individuals.
Current Trends	Human development and associated impacts are continuing to have an effect on culturally important plants and animals. Although many stressors remain, improved management practices and other mitigation efforts are being implemented to improve fisheries habitat on the Reservation. Attempts are also being made to better inventory large game and other culturally important wildlife species on the Reservation.
Impact to Future Generations	Reduction or loss of important species will add to potential loss of knowledge of uses by Tribal members. Detrimental impacts are expected to continue to exist, although some improvements may occur as well.
Fairness/Equity of Impacts	The bulk of native species were probably lost in the western lowlands of the Reservation. Species dependent on aquatic, native grassland, wetland, and old growth habitat have been more affected.



Like most of the native species, the snowshoe hare has cultural significance to the Coeur d'Alene People.

Native Wildlife and Fisheries Habitat (element) Nearly all of the native wildlife and fisheries habitat on the Reservation has been altered by human development, land conversion, management activities and presence of non-native species. Approximately 135,828 acres, including all of the native bunchgrass prairie and 21,417 acres of Palustrine wetlands, were converted to agriculture or other human development. Forest types dominated by large, old growth ponderosa pine or white pine have been virtually eliminated by logging, fire, or disease (i.e. white pine blister rust). Fisheries habitat has been severely impacted by sediments, nutrients, stream channelization, and loss of stream side vegetation related to changes in vegetation cover and land management. Non-native plant, animal, and fish species are directly competing with their native counterparts. White pine blister rust has permanently altered forest structure and function on those sites where white pine was a dominant species, thus impacting wildlife associated with white pine forests. Exact evaluation of impacts cannot be assessed because pre-settlement wildlife and fisheries habitat conditions have not been quantified.

Native Wildlife and Fisheries Habitat	
Criteria	**Evaluation**
Changes Since Settlement	There have been dramatic changes in the landscape and watersheds of the Coeur d'Alene River Basin and ancestral lands of the Coeur d'Alene Tribe since European settlement. Forest lands, grasslands, and wetlands have been converted to other land uses or altered by human development. Erosion of the landscape has been widespread and excessive. Sediment has been delivered to stream channels. Livestock grazing occurs in most of the watersheds and along streams. Watersheds and channels have been de-stabilized. Water has been withdrawn for agricultural and domestic uses. Old growth forests have been virtually eliminated.
Magnitude of Impacts	Approximately 21,417 acres of Palustrine wetlands have been converted to other land uses. An estimated 114,411 acres of combined forest, grassland, and shrub types have also been converted, including all the native bunchgrass prairie community which is believed to have existed on the Reservation. Forest types once dominated by large, mature or old growth, ponderosa pine and white pine have been lost.
Severity of Impacts	Forest connectivity has been reduced along with actual acres of forest habitat. Loss of wetland habitat reduces its availability to waterfowl, fur bearers and other wildlife. Its loss also affects hydrologic response to storms, increasing potential degradation of fisheries habitat. Fisheries habitat has been severely impacted in all Reservation streams. Bull trout are listed as threatened and Cutthroat trout were proposed for listing under the Endangered Species Act, although the U.S. Fish and Wildlife Service has stated that listing is not warranted at this time.. Exotic species are impacting native plant communities. Blister rust has permanently altered forest structure and function on those sites where white pine was a dominant species.
Reversibility of Impacts	Native wildlife and fish habitat can be restored to the extent management practices are altered, and restoration takes place where needed.
Degree of Uncertainty	The pre-settlement wildlife and fisheries habitat conditions have not been quantified. This makes assessment of impacts less accurate.

Forest Health
Quality of Life Sub-Group

Spiritual/Moral
The health of the forest speaks to the health of the traditional Coeur d'Alene people spiritually.

Economic/Subsistence (Qualitative)
Healthy forests have been key to the local economy for 100 years. Healthy forests are key to some people as part of their community and places to gather important plants and animals.

Tribal Culture
It is essential and it needs to be considered very closely.

Personal Well-being
People like to enjoy healthy forests. When there is less diversity, it causes concern.

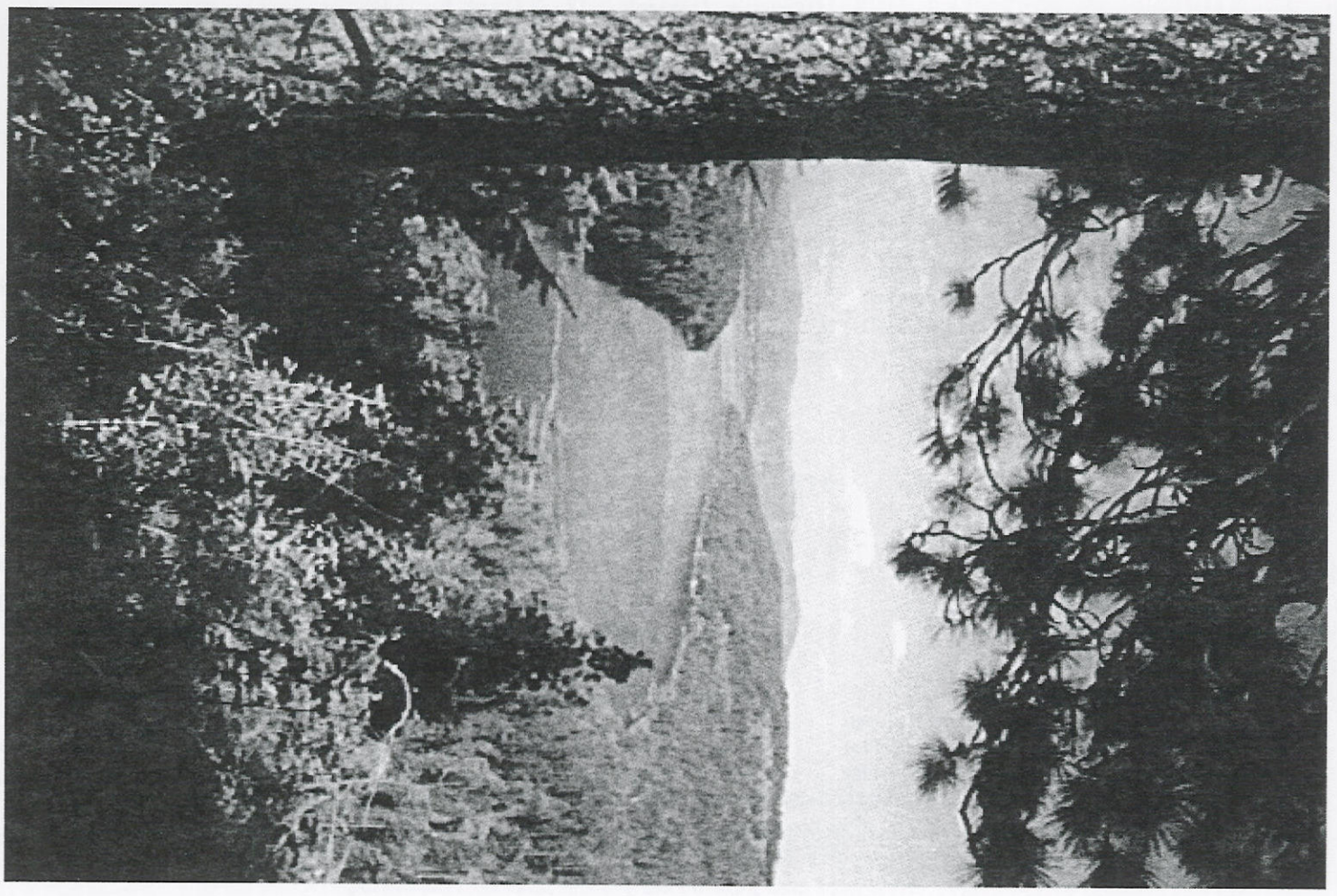
Aesthetics
There is a strong relationship as people don't like to look at mono-culture or clear-cut forests.

Community Well-being
For traditional communities, the health of the forest is vital because the forest is part of the community.

Degree of Uncertainty
Low degree of uncertainty. Pretty clear that forest health has much to do with all parts of our quality of life.

Fair and Equitable
Many impacts are distributed fairly and equitably across the community, but land owners and traditional Coeur d'Alene may feel greater impacts.

Trends, Seasonal Differences, and Future
Forests have to be sustainable in many different ways--how trees grow; species diversity; water quality; and quality of life.



Ponderosa pines like this one (with Lake Coeur d'Alene shown in the background) comprise much of the forest cover found on the Coeur d'Alene Tribe's native homeland.



The Pygmy Owl—a native species that shares the land with the Coeur d'Alene Tribe and adds to its rich diversity.

Native Plant and Animal Populations and Species Diversity
Quality of Life Sub-Group

Spiritual/Moral
There is a strong relationship, involving stewardship and a moral obligation to protect native plant and animal populations; you should relate to them spiritually and morally in the same manner you would relate to any family member.

Economic/Subsistence
Subsistence activities have a closer relationship with native plant and animal populations than economics.

Tribal Culture
Given Tribal relationships with native plants and animals, which value all species, the impacts are greater than for non-Tribal members, who may only value species that give a return to them.

Aesthetics
There is a strong relationship, though varied with individuals.

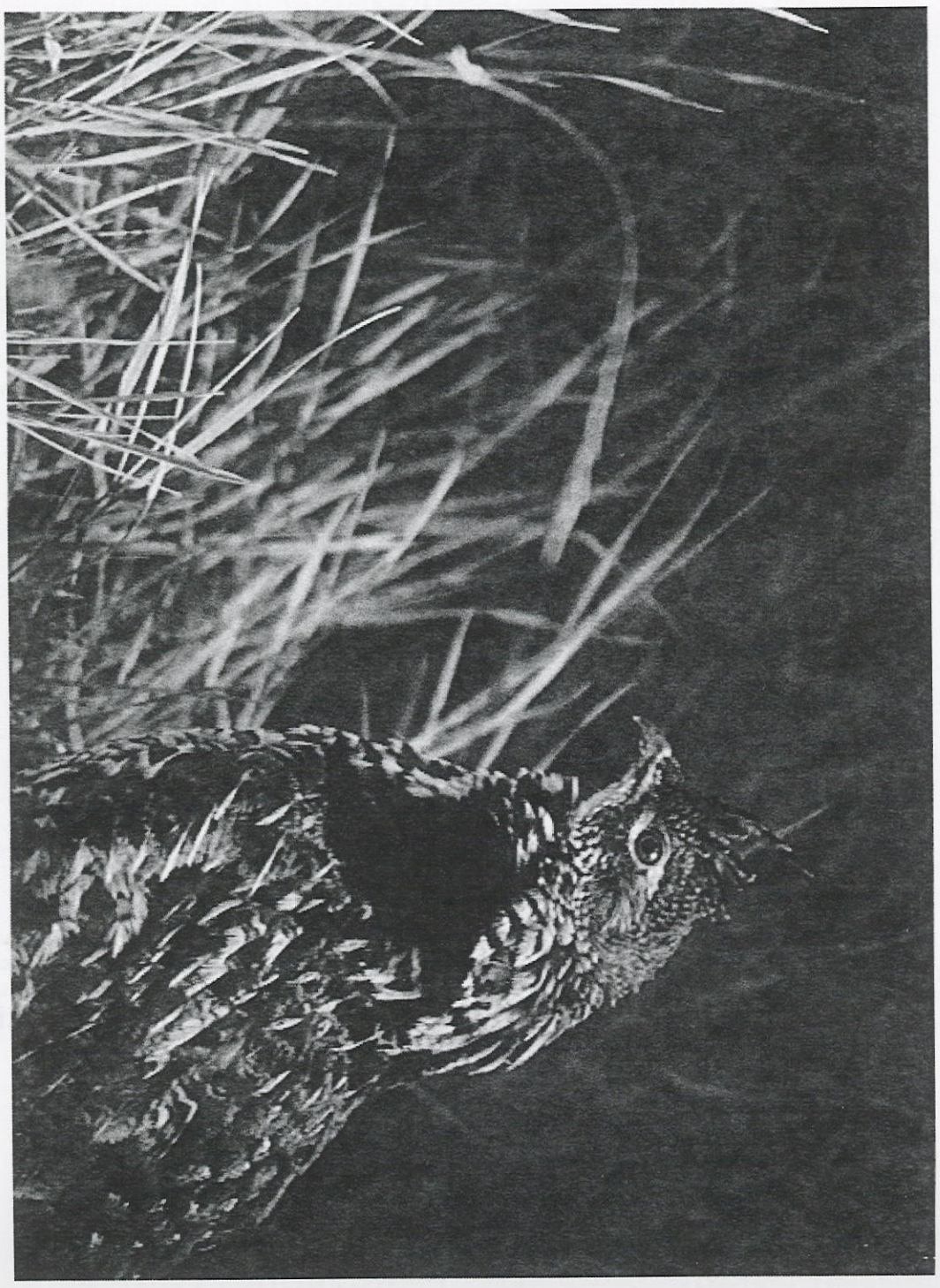
Personal Well-being
Varies with individual, depending on how outdoor oriented he or she is.

Community Well-being
There is an important and strong relationship, encompassing hunting, aesthetics, and economy. A good economy makes a community function.

Degree of Uncertainty
Both Tribal and non-Tribal members share the conviction in a low degree of uncertainty. But there is a lack of understanding of the implications of the impacts.

Fair and Equitable
Tribal culture is much more severely impacted, and thus there is not a fair and equitable distribution of the impacts.

Trends, Seasonal Differences and Future
The trend may be an increase in non-native species, and as native species decrease, the Tribal knowledge of how to use them also decreases. Seasonal changes are not a huge factor. One member felt we are going to be better off in the future than we are today.



The Ruffed Grouse is one of many species that are culturally important to the Coeur d'Alene Tribe.

Non-Native Plant and Animal Species
Quality of Life Sub-Group

Spiritual/Moral
Most agree a relationship exists but the definitions vary on an individual basis.

Economic/Subsistence
Strong and direct relationship both for intentionally introduced species like wheat, and unintentionally introduced species, like white pine blister rust.

Tribal Culture
Large impacts for obvious reasons, but impacts could depend on culture's adaptation.

Personal Well-being
Most of what we eat is non-native so this relationship is very large.

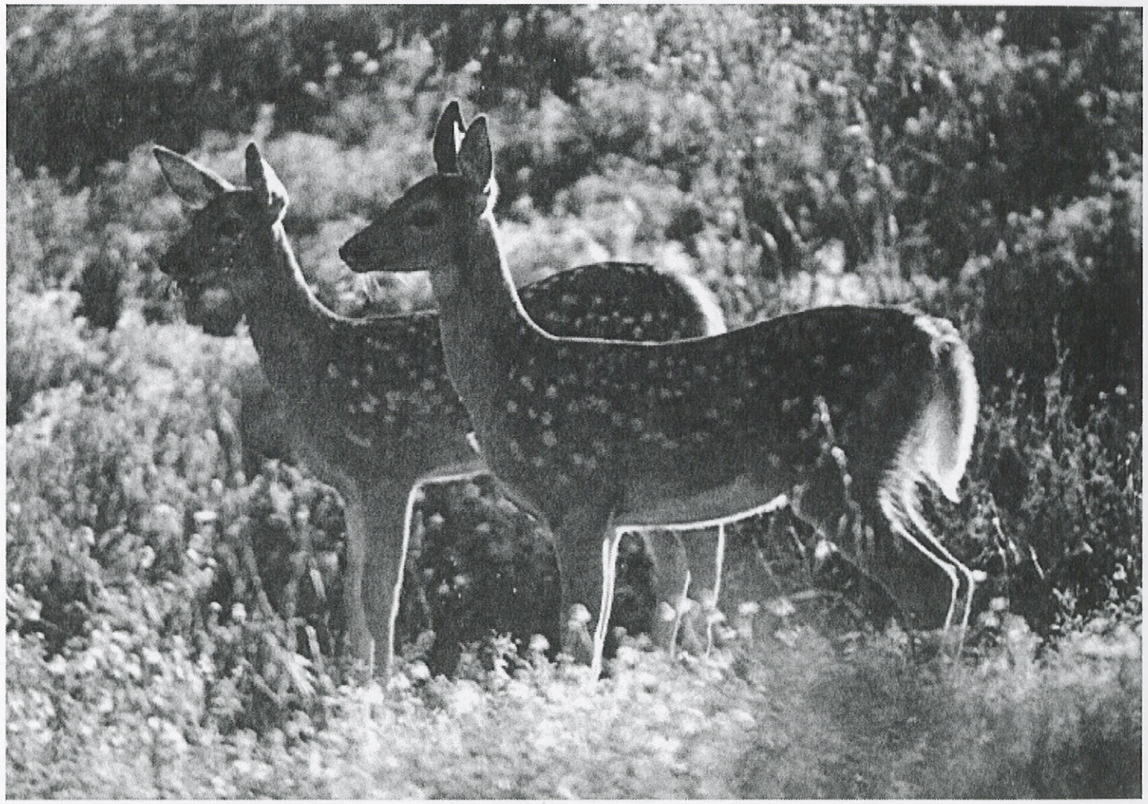
Aesthetics
Beauty is in the eye of the beholder.

Community Well-being
"Clear and direct" relationship with both negatives and positives.

Degree of Uncertainty
No degree of uncertainty; tied up with many other categories.

Fair and Equitable
A mixed response. Some believe the sheer amount of non-natives make them distributed equally. Others said it depended on circumstances and opinions about non-native species.

Trends, Seasonal Differences and Future
A trend of increasing numbers of non-native species. Control of non-natives are seasonal. In the future, decisions will have to be made regarding which non-natives can stay and which should go.



The deer people are an important part of the Coeur d'Alene Tribal family. These fawns remind us of the need to consider environmental impacts on future generations.

Summary of Interviews Supplemental to Focus Group Information

Prepared by Rodney Frey
12 March 1999

Purpose and Method

The following information is a selective summary of twelve interviews conducted between September 30, 1998 and November 12, 1998 among residents of the Coeur d'Alene Reservation community, including the city of St. Maries. The intention in conducting these interviews was to broaden the demographic representation of the Quality of Life assessment, expanding the scope of the information obtained from the Focus Group sessions. In selecting these interviewees, the members of the Focus Group developed a demographic profile of their own membership. Based upon non-representative and under-representative community segments, "holes" were determined. Using a "snowball" sampling method, i.e., who in the community is informed on this subject, members of the Focus Group were asked to identify additional community members who might represent these "holes" and be willing to be interviewed. Approximately fifty individuals were so identified. In conducting these additional interviews, it was not the intent to develop a statistically reliable and valid systematic random sample.

A simplified, shortened version of the questionnaire used in the Focus Group sessions was developed. It retained the five key categorical questions, i.e., What is the relationship between the economy or subsistence activity and the environment? What is the relationship between the spiritual and moral well-being and the environment? What is the relationship between recreational use or aesthetics or artistic appreciation and the environment? What is the relationship between the community's well-being and the environment? What is the relationship between the individual's well-being and the environment? The interviewees were then asked to rank according to their severity of importance the five categories and any particular issues he or she may have brought up during the interview.

Eleven interviews were conducted by undergraduate and graduate students from the Department of Anthropology at the University of Idaho, under the direction and coordination of Rodney Frey. A twelfth interview was conducted by a member of the Focus Group. At the time, all of the college students were enrolled in a Research Methodology course taught by Frey, and also participated in a morning "workshop" introducing the interview questionnaire, as well as the Coeur d'Alene Tribe's Environmental Action Plan project. It was planned that high school students from Lakeside High school would be paired and accompany the college students. The mentoring relationship would be mutually beneficial, as high school students would be provided a "role model" and learn something of conducting ethnographic interviewing, while the college students would learn something about the "local culture" and have a guide to the interviewee's residence. Because of logistical and scheduling considerations, in only a few instances did any "paired interviews" transpire.



Pheasants such as this rooster are one of many non-native species now found on the Coeur d'Alene Reservation.

Acronyms List

AIDS -	Acquired Immune Deficiency Syndrome
ANA -	Administration for Native Americans
ASCS -	agricultural stabilization and conservation service
BOD -	Biological Oxygen Demand
BMPs -	Best Management Practices
DBH -	diameter at breast height
DDT -	a banned agricultural chemical
DEQ -	Department of Environmental Quality
EAP -	Environmental Action Plan
EPA -	Environmental Protection Agency
ESA -	Endangered Species Act
FSA -	Farm Services Agency
GIS -	Geographic Information System
GUP -	General Use Pesticides
HEDR -	Hanford Environmental Dose Reconstruction
HCWMP-	Hangman Creek Watershed Management Plan
HHIN -	Hanford Health Information Network
HTDS -	Hanford Thyroid Disease Study
HUS -	Hemolytic Uremic Syndrome
IDWR -	Idaho Department of Water Resources
ICBEMP -	Interior Columbia Basin Ecosystem Management Project
IWRRI -	Idaho Water Resources Research Institute
KEC -	Kootenai Electric Cooperative
LUST -	Leaking Underground Storage Tanks
MBF -	1000 board feet (lumber measurement)
MCPA -	an agricultural chemical
NAAQS -	National Ambient Air Quality Standards
NOAA -	National Oceanographic and Atmospheric Administration.
NPDES -	National Pollution Discharge Elimination System
NRCS -	Natural Resources Conservation Service
NRD -	Natural Resources Department
NWI -	National Wetlands Inventory
PAHs -	polynuclear aromatic hydrocarbons
PM -	Particulate Matter
RC&D -	Resource Conservation and Development
RUP -	Restricted Use Pesticides
S&WCD -	Soil and Water Conservation District
SCS -	Soil Conservation Service
T&E -	threatened and endangered
TERO -	Tribal Employment Rights Office
TSS -	Total Suspended Settlement
USDA -	United States Department of Agriculture

State of Idaho
Department of Water Resources

Permit To Appropriate Water

NO. 95-09045

Priority: April 12, 2000 Maximum Diversion Rate: 3.50 CFS

This is to certify, that **CAG INVESTMENTS LLC**
PO BOX 3070
COEUR D ALENE ID 83816
has applied for a permit to appropriate water from:
COEUR D ALENE LAKE tributary of **SPOKANE RIVER**

and a permit is **APPROVED** for development of water as follows:

BENEFICIAL USE	PERIOD OF USE	RATE OF DIVERSION
IRRIGATION	03/15 to 11/15	2.50 CFS
DOMESTIC	01/01 to 12/31	1.00 CFS
	Totals	3.50 CFS

LOCATION OF POINT(S) OF DIVERSION: Lot 1(SWNE), Sec. 16, Township 48N, Range 04W
KOOTENAI County

PLACE OF USE: IRRIGATION

TWN	RGE	SEC		ACRES		ACRES		ACRES	TOTAL
48N	04W	8	SWNE	6.0	SENE	22.0	NESW	38.0	
			NWSW	30.0	SESW	40.0	NESE	40.0	
			NWSE	38.0	SWSE	40.0	SESE	40.0	294.0
		9	NENW	13.0	SWNW	40.0	SENW	26.0	
			NESW	40.0	NWSW	40.0	SWSW	40.0	
			SESW	40.0	SWSE	3.0			242.0
		16	NWNE	2.0	Lot 1(SWNE)	1.0	NENW	40.0	
			NWNW	40.0	SWNW	23.0	SENW	6.0	112.0
		17	NENE	20.0					20.0

Total number of acres irrigated: 668.0

PLACE OF USE: DOMESTIC

TWN	RGE	SEC						
48N	04W	8	SENE	NESW	SESW			
			NESE	NWSE	SWSE			
			SESE					
		9	NENW	SWNW	SENW			
			NESW	NWSW	SWSW			
			SESW	SWSE				
		16	NWNE	Lot 1(SWNE)	NENW			
			NWNW	SWNW	SENW			
		17	NENE					

Scan from this Point down. plus rest in pouch.

CONDITIONS OF APPROVAL AND REMARKS

1. Proof of application of water to beneficial use shall be submitted on or before **September 1, 2005.**

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State of Idaho
Department of Water Resources

Permit To Appropriate Water

NO. 95-09045

CONDITIONS OF APPROVAL AND REMARKS

2. Subject to all prior water rights.
3. Project construction shall commence within one year from the date of permit issuance and shall proceed diligently to completion unless it can be shown to the satisfaction of the Director of the Department of Water Resources that delays were due to circumstances over which permit holder had no control.
4. After specific notification by the department, the right holder shall install a suitable measuring device or shall enter into an agreement with the department to determine the amount of water diverted from power records and shall annually report the information to the department.
5. This right when combined with all other rights shall provide no more than 0.02 cfs per acre nor more than 3.0 afa per acre at the field headgate for irrigation of the lands above.
6. The applicant shall submit to the Department the final design of the water use facilities including waste water treatment and storm runoff facilities for the project for review and approval prior to construction.
7. The right holder shall install and maintain a fish screen with 1/4 inch or smaller mesh at the point of diversion.
8. The right holder shall design and construct the water use facilities to assure that the facilities are capable of complying with the water quality requirements of the Division of Environmental Quality. Within one year of this approval, the right holder shall provide evidence to the Department that the facility has been constructed to meet these compliance requirements. The Director can extend the time for demonstrating compliance upon written request of the applicant and a showing of good cause therefor.
9. Domestic use is for the equivalent of 350 residences and does not include water for lawn, garden, landscape, or other types of irrigation.
10. If the right holder develops the domestic use from groundwater, the domestic use authorized by this approval is rescinded and will be of no further force or effect.
11. This permit replaces Permit 95-08762 and is not additive to it.

This permit is issued pursuant to the provisions of Section 42-204, Idaho Code. Witness the signature of the Director, affixed at Boise, this

20th day of October, 2000.

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NOV 2 8 2000

for Karl J. Dreher, Director

BEFORE THE DEPARTMENT OF WATER RESOURCES

OF THE STATE OF IDAHO

IN THE MATTER OF APPLICATION FOR PERMIT NO. 95-09045 IN THE NAME OF CAG INVESTMENTS, LLC	))))	**PRELIMINARY ORDER**

This matter having come before the Idaho Department of Water Resources (the "Department") in the form of an application for permit and the Department having held a fact-hearing in the matter, the hearing officer enters the following Findings of Fact, Conclusions of Law and Preliminary Order:

FINDINGS OF FACT

1. On December 7, 1992, the Department issued Permit No. 95-08762 ("permit") to Rockford Bay Inc. authorizing the diversion of 3.5 cubic feet per second ("cfs") of water from Coeur d'Alene lake (the "lake") tributary to the Spokane River. Of the 3.5 cfs, 2.5 cfs is for irrigation purposes from March 15 to November 15 each year and 1.0 cfs is for year-round domestic use. Proof of beneficial use of water ("proof") was due on or before January 2, 1998. On January 14, 1998, the Department extended the proof due date to January 1, 2001 based on due diligence as authorized in Section 42-204(5), Idaho Code.

2. On March 16, 1998, Rockford Bay Inc. assigned ownership of the permit to CAG Investments, LLC ("applicant"). Even though the applicant has indicated that it can not complete the anticipated development by January 1, 2001, Section 42-204(5), Idaho Code, does not authorize the Department to grant an additional extension of time in which to submit the proof.

3. On April 12, 2000, the applicant submitted Application for Permit No. 95-09045 ("application") to the Department to replace Permit No. 95-08762. The application proposes the diversion of 3.5 cfs with 2.5 cfs of water to be used for irrigation purposes from March 15 to November 15 each year and 1.0 cfs to be used year-round for domestic purposes. The proposed point of diversion is located within Lot 1 (SWNE) Section 16, T48N, R4W, B.M. and is within the upper two-thirds of the lake. The proposed place of use is located within parts of Sections 8, 9, 16 and 17, T48N, R4W, B.M.

4. The Department published notice of the application, which was not timely protested. The Department did, however, receive a late protest from the Coeur d'Alene Tribe (the "Tribe"), and letters of concern from the Idaho Fish and Game Department ("Fish and Game") and the Kootenai Environmental Alliance.

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5. On August 21, 2000 the Department conducted a fact hearing in the matter. Marshall Chesrown and Joe Hassell appeared on behalf of the applicant. Howard Funke represented the Coeur d'Alene Tribe. Mike Mihelich appeared on behalf of the Kootenai County Alliance. Fish and Game did not attend the hearing.

6. On its approximate 650 acres, the applicant's plans include the construction of an 18-hole golf course and development of enough water for 350 single family residences. The projected buildout for the project is from 5 to 10 years with the golf course ready for play in 2002. Phase I of the project includes 292 home sites. On May 10, 2000, the Kootenai County Commissioners issued an Order of Decision approving the Planned Unit Development (PUD-037-99).

7. Even though the application seeks 1.0 cfs for domestic use, the applicant prefers to develop the community water system using groundwater for the domestic use, if the groundwater supply is adequate. Only irrigation water then would be provided from the lake.

8. The applicant has coordinated the project with the Division of Environmental Quality, PanHandle Health, the Worley Highway District, Kootenai County, the Corps of Engineers and the Idaho Transportation Department and has preliminary approvals to proceed with the project. Construction of the project has been ongoing for some time, including logging of trees on the land.

9. Applicant's planned irrigation system will be a sprinkler system including moisture probes and will cost in excess of a million dollars.

10. Information offered for the record by the Coeur d'Alene Tribe includes the following:

a. United States of America and Coeur d'AleneTribe v. State of Idaho, July 28, 1998 and a Ninth Circuit Court of Appeals opinion in the case

b. Letter dated May 24, 2000 to Robert G. Haynes from Ernest L. Stensgar together with 2 newspaper articles

c. Lake Water Quality Assessment – Coeur d'Alene Lake – January 1991

d. Surface Water Quality Data Compilation and Evaluation by Ridolfi Engineers, August 1995

e. Effect of Mining and Related Activities on the Sediment Trace Element Geochemistry of Lake Coeur d'Alene, Idaho, USA – Part I – Surface Sediments – USGS – 1992

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f. Effect of Mining and Related Activities on the Sediment Trace Element Geochemistry of Lake Coeur d'Alene, Idaho, USA – Part I I– Subsurface Sediments – USGS – 1993-94

g. Nutrient and Trace-Element Enrichment of Coeur d'Alene Lake, Idaho – USGS Water –Supply Paper 2485

h. Coeur d'Alene Lake Management Plan – Executive Summary

i. Draft Report titled Water Quality Studies of the Spokane River Between Coeur d'Alene, ID and Post Falls, Idaho – 1988

j. Comparison of Non-Point Source Phosphorous Loading to the Spokane River From Its Headwaters to Long Lake, WA with that used in the Spokane River Phosphorous Attenuation Model – July 1993

k. Map – Lead Contamination – Lower Coeur d'Alene River and Coeur d'Alene Lake

l. Cadmium, Lead, and Zinc in the Spokane River – Washington State Department of Ecology, September 1998

m. Case No. PUD-037-99, Findings of Fact, Comprehensive Plan Analysis, Conclusions of Law and Order of Decision

n. EAP Assessment of Environmental Concerns on and near the Coeur d'Alene Reservation – July 2000 – Executive Summary

11. The position of the Coeur d'Alene Tribe with respect to the application is as follows:

a. The Tribe should be considered a protestant, since the Department did not give the Tribe accurate information relative to the end of the protest period.

b. The Tribe believes it is entitled to a hearing as provided in Section 42-1701A (3), Idaho Code.

c. The Tribe believes there should be joint management of the water of Lake Coeur d'Alene between the state of Idaho and the Tribe. The Tribe believes that the applicant should file a water right application with the Tribe.

d. The Tribe believes that wastewater from the applicant's irrigation may be nutrient laden and if the water reaches the lake, it will cause heavy metals

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to be released from the lakebed.

e. The Tribe believes that compliance with best management practices by the applicant in connection with use of water is not sufficient.

f. The Tribe wants to review final design of the water use facilities including wastewater treatment and storm runoff facilities for the project to be sure there is no nutrient loading of the lake. The Tribe wants "assurance" that there will be no additional nutrient loading of the lake.

g. The Tribe believes the state of Idaho and the Tribe should enter into a "compact" for joint management of the water in the lake.

12. Avista Corporation (formerly Washington Water Power Company) has the right to use up to 5,000 cfs of water from the Spokane River for hydropower generation purposes downgradient from the applicant's proposed use. Avista has not sought to curtail diversion of water by junior priority water rights from the lake even though there are times when 5,000 cfs is not available for power generation purposes at Post Falls Dam.

ANALYSIS

Section 42-203A, Idaho Code, provides that protests against the approval of an application must be filed with the Department within 10 days of the last date of publication of the notice of the application. It is unfortunate if the Department, by error, gave the wrong date to the Tribe, but the applicant is entitled to rely on provisions of the code section. The code section also requires the Department to evaluate certain criteria whether an application is protested or not. Recognizing the Tribe's interest in the matter, the fact finding hearing held by the Department provided the opportunity for the Tribe to express its concerns to the Department even though the Tribe is not a party in the matter.

In connection with a compact suggested by the Tribe between the state of Idaho and the Tribe for the joint management of the water in Coeur d'Alene lake, the matter could be pursued in an appropriate forum, but not in connection with the pending application.

The water appropriation statutes of the state of Idaho provide the authority for the Department to require a water right application for the proposed project. The statutes do not authorize the Department to require the filing of a water right application with the Tribe.

Even though 5,000 cfs is not always available for use by Avista at its Post Falls power generation facility, there are times during the year when water in excess of Avista's rights is available for diversion and use under a new appropriation.

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CONCLUSIONS OF LAW

1. Section 42-203A, Idaho Code, provides in pertinent part as follows:

> In all applications whether protested or not protested where the proposed use is such (a) that it will reduce the quantity of water under existing water rights, or (b) that the water supply itself is insufficient for the purpose for which it is sought to be appropriated, or (c) where it appears to the satisfaction of the director that such application is not made in good faith, is made for delay or speculative purposes, or (d) that the applicant has not sufficient financial resources with which to complete the work involved therein, or (e) that it will conflict with the local public interest, where the local public interest is defined as the affairs of the people in the area directly affected by the proposed use, or (f) that it is contrary to conservation of water resources within the state of Idaho; the director of the department of water resources may reject such application and refuse issuance of a permit therefor... .

2. Use of water as proposed in the application will not injure existing water rights, since senior water rights can make a call on junior rights and water rights can be delivered in order of priority.

3. The water supply itself is sufficient for the purposes intended.

4. The application is made in good faith and not for delay or speculative purposes.

5. The applicant has sufficient financial resources with which to complete the project.

6. The application does not conflict with the local public interest.

7. The application is not contrary to the conservation of water resources within Idaho.

8. The Department should approve the application with certain conditions.

ORDER

IT IS THEREFORE, hereby ORDERED that application for Permit No. 95-09045 in the name of CAG Investments, LLC is **APPROVED** subject to the following conditions:

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1. Use of water under the permit is subject to all prior water rights including those of Avista for power generation purposes.

2. The permit holder shall submit proof of construction of works and application of water to beneficial use on or before **September 1, 2005**.

3. Project construction shall commence within one year from the date of permit issuance and shall proceed diligently to completion unless it can be shown to the satisfaction of the Director of the Department of Water Resources that delays were due to circumstances over which permit holder had no control.

4. After specific notification by the Department, the right holder shall install a suitable measuring device or shall enter into an agreement with the department to determine the amount of water diverted from power records and shall annually report the information to the Department.

5. The applicant shall submit to the Department the final design of the water use facilities including wastewater treatment and storm runoff facilities for the project for review and approval prior to construction.

6. This right when combined with all other rights shall provide no more than 0.02 cfs per acre nor more than 3.0 AFA per acre at the field headgate for irrigation of the authorized lands.

7. The right holder shall install and maintain a fish screen with 1/4 inch or smaller mesh at the point of diversion.

8. The right holder shall design and construct the diversion and fish screen to limit the approach velocity at the point of diversion to 0.5 feet per second or less.

9. The right holder shall design and construct the water use facilities to assure that the facilities are capable of complying with the water quality requirements of the Division of Environmental Quality. Within one year of this approval, the right holder shall provide evidence to the Department that the facility has been constructed to meet these compliance requirements. The Director can extend the time for demonstrating compliance upon written request of the applicant and a showing of good cause therefor.

10. Domestic use is for the equivalent of 350 residences and does not include water for lawn, garden, landscape, or other types of irrigation.

11. If the right holder develops the domestic use from groundwater, the domestic use authorized by this approval is rescinded and will be of no

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further force nor effect.

12. This permit replaces Permit No. 95-08762 and is not additive to it.

Signed this 14th day of September, 2000.

L. GLEN SAXTON
Hearing Officer

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CERTIFICATE OF SERVICE

I HEREBY CERTIFY that on this 14th day of September, 2000, the above and foregoing document was served upon the following by placing a copy of the same in the United States Mail, postage prepaid and properly addressed to the following:

CAG Investments, LLC
P.O. Box 3070
Coeur d'Alene, ID 83816

Mike Mihelich
Kootenai Environmental Alliance
P.O. Box 1598
Coeur d'Alene, ID 83814

Joseph Hassell
Inland Northwest Consultants
620 Post Street
Post Falls, ID 83854

Howard Funke
Coeur d'Alene Tribe
424 Sherman
Coeur d'Alene, ID 83814

Deborah J. Gibson

Deborah J. Gibson
Administrative Assistant
Water Allocation Bureau

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Responding To Preliminary Orders Issued By The Idaho Department Of Water Resources

The accompanying order is a **Preliminary Order** issued by the Idaho Department of Water Resources (department) pursuant to section 67-5243, Idaho Code. **It can and will become a final order without further action of the department unless a party petitions for reconsideration within fourteen (14) days after issuance as further described below:**

PETITION FOR RECONSIDERATION

Any party may file a petition for reconsideration of a preliminary order with the hearing officer within fourteen (14) days of the service date of this order. The hearing officer will act on a petition for reconsideration within twenty-one (21) days of its receipt, or the petition will be considered denied by operation of law. See section 67-5243(3) Idaho Code.

EXCEPTIONS AND BRIEFS

Within fourteen (14) days after (a) the service date of a preliminary order, (b) the service date of a denial of a petition for reconsideration from this preliminary order, or (c) the failure within twenty-one (21) days to grant or deny a petition for reconsideration from this preliminary order, any party may in writing support or take exceptions to any part of a preliminary order and may file briefs in support of the party's position on any issue in the proceeding to the Director. Otherwise, this preliminary order will become a final order of the agency.

If any party appeals or takes exceptions to this preliminary order, opposing parties shall have fourteen (14) days to respond to any party's appeal. Written briefs in support of or taking exceptions to the preliminary order shall be filed with the Director. The Director retains the right to review the preliminary order on his own motion.

ORAL ARGUMENT

If the Director grants a petition to review the preliminary order, the Director shall allow all parties an opportunity to file briefs in support of or taking exceptions to the preliminary order and may schedule oral argument in the matter before issuing a final order. If oral arguments are to be heard, the Director will within a reasonable time period notify each party of the place, date and hour for the argument of the case. Unless the Director orders otherwise, all oral arguments will be heard in Boise, Idaho.

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CERTIFICATE OF SERVICE

All exceptions, briefs, requests for oral argument and any other matters filed with the Director in connection with the preliminary order shall be served on all other parties to the proceedings in accordance with Rules of Procedure 302 and 303.

FINAL ORDER

The Department will issue a final order within fifty-six (56) days of receipt of the written briefs, oral argument or response to briefs, whichever is later, unless waived by the parties or for good cause shown. The Director may remand the matter for further evidentiary hearings if further factual development of the record is necessary before issuing a final order. The department will serve a copy of the final order on all parties of record.

Section 67-5246(5), Idaho Code, provides as follows:

> Unless a different date is stated in a final order, the order is effective fourteen (14) days after its issuance if a party has not filed a petition for reconsideration. If a party has filed a petition for reconsideration with the agency head, the final order becomes effective when:
>
> (a) the petition for reconsideration is disposed of; or
> (b) the petition is deemed denied because the agency head did not dispose of the petition within twenty-one (21) days.

APPEAL OF FINAL ORDER TO DISTRICT COURT

Pursuant to sections 67-5270 and 67-5272, Idaho Code, if this preliminary order becomes final, any party aggrieved by the final order or orders previously issued in this case may appeal the final order and all previously issued orders in this case to district court by filing a petition in the district court of the county in which:

i. A hearing was held,
ii. The final agency action was taken,
iii. The party seeking review of the order resides, or
iv. The real property or personal property that was the subject of the agency action is located.

The appeal must be filed within twenty-eight (28) days of this preliminary order becoming final. See section 67-5273, Idaho Code. The filing of an appeal to district court does not itself stay the effectiveness or enforcement of the order under appeal.

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FORM 202
1/96

Ident. No. 95-09045

STATE OF IDAHO
DEPARTMENT OF WATER RESOURCES

APPLICATION FOR PERMIT

To appropriate the public waters of the State of Idaho

RECEIVED
JUL 3 2000
DEPARTMENT OF WATER RESOURCES

1. Name of Applicant CAG Investments, LLC Phone (208) 755-3200
   Post Office address P.O. Box 3070, Coeur d'Alene, ID 83816
2. Source of water supply Lake Coeur d'Alene which is a tributary of Spokane River
3. Location of point of diversion is SW 1/4 of NE 1/4 of _____ 1/4, Govt. Lot One
   Sec. 16 Township 48N Range 04W B.M. Kootenai County; additional points of diversion if any: (none)
4. Water will be used for the following purposes:
   Amount 2.5 cfs (cfs or acre-feet per annum) for irrigation purposes from 3/15 to 11/15 (both dates inclusive)
   Amount 1.0 cfs (cfs or acre-feet per annum) for domestic purposes from 1/01 to 12/31 (both dates inclusive)
   Amount _____ (cfs or acre-feet per annum) for _____ purposes from _____ to _____ (both dates inclusive)
   Amount _____ (cfs or acre-feet per annum) for _____ purposes from _____ to _____ (both dates inclusive)
5. Total quantity to be appropriated is (a) 3.5 cfs (cubic feet per second) and/or (b) _____ (acre feet per annum)
6. Proposed diverting works:
   a. Description of ditches, flumes, pumps, headgates, etc. existing lake intake structure consisting on 2-12" suction pipes and pump vault located above shoreline.
   b. Height of storage dam _____ feet; active reservoir capacity _____ acre-feet; total reservoir capacity _____ acre-feet; period of year when water will be diverted to storage: _____ to _____ inclusive.
   c. Proposed well diameter is _____ inches; proposed depth of well is _____ feet.
   d. Is ground water with a temperature of greater than 85°F being sought? No
   e. If well is already drilled, when? _____; Drilling firm _____:
   Well was drilled for (well owner) _____
7. Time required for completion of works and application of water to proposed beneficial use is 5 years (*minimum 1 year*)
8. Description of proposed uses (*if irrigation only, go to item 9*):
   a. Hydropower; show total feet of head and proposed capacity if KW. _____
   b. Stockwatering; list number and kind of livestock. _____
   c. Municipal; show name of municipality. _____
   d. Domestic; show number of households. 350 equivalent residences
   e. Other; describe fully. _____

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9. Description of place of use:

a. If water is for irrigation, indicate acreage in each subdivision in the tabulation below.

b. If water is used for other purposes, place a symbol of the use (*example: D for Domestic*) in the corresponding place of use below. See instructions for standard symbols.

TWP	RGE	SEC	NE				NW				SW				SE				TOTALS
			NE	NW	SW	SE	NE	NW	SW	SE	NE	NW	SW	SE	NE	NW	SW	SE	
48N	04W	8			6	22					38	30		40	40	38	40	40	294
						D					D			D	D	D	D	D	
48N	04W	9					13		40	26	40	40	40	40			3		242
							D		D	D	D	D	D	D			D		
48N	04W	16		2	1		40	40	23	6									112
				D	D		D	D	D	D									
48N	04W	17	20																20
			D																

Total number of acres to be irrigated 668

10. Describe any other water rights used for the same purposes as described above.
Reference Permit #95-08762

11. a. Who owns the property at the point of diversion? CAG Investments, LLC

b. Who owns the land to be irrigated or place of use? CAG Investments, LLC

c. If the property is owned by a person other than the applicant, describe the arrangement enable the applicant to make this filing:

12. Remarks:
This application is to replace existing permit #95-08762 which will expire on 1/01/2001. This permit cannot be extended, and no beneficial use will be proven by the expiration date.

13. **MAP OF PROPOSED PROJECT ATTACHED** X Show clearly the proposed point of diversion, place of use, section number, township and range number.

BE IT KNOWN that the undersigned hereby makes this application for permit to appropriate the public waters of the State of Idaho as herein set forth.

INLAND NORTHWEST CONSULTANTS, BY
JWE. Howell, PE6966
(Applicant) AUTHORIZED AGENT

Received by DC Date 4/12/00 Time 4:27 pm Preliminary check by
Fee $ $160 Receipted by DC # W13589 Date 4/12/00
Publication prepared by DC Date 4/13/00 Published in COA Press 4/20+27/00
Publication approved Date 5/2/00

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Inland Northwest Consultants

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MAY 02 2000
IDWR/North

May 1, 2000

Mr. Bob Haynes
Idaho Department of Water Resources
1910 Northwest Blvd., Suite #210
Coeur d'Alene, ID 83814

Re: CAG Investments, LLC – Water Appropriation Permit #95-08762

Dear Bob,

Enclosed for your files is a *Limited Power of Attorney* signed by the Director of Operations for CAG Investments, L.L.C. This power of attorney allows INC to act on behalf of CAG in all matters pertaining to application and permitting with IDWR.

If you have questions or comments regarding the previously submitted application or the enclosed power of attorney, you are welcome to contact our office.

Best Regards,

Cindy Sherman

Cindy Sherman
Office Manager

Enclosure

Cc : CAG Investments, LLC
Wetzel & Wetzel

MICROFILMED
NOV 2 6 2003

620 Post Street, Post Falls, Idaho 83854 • (208) 773-8370 • Fax (208) 777-2128

LIMITED POWER OF ATTORNEY

KNOW ALL MEN by these presents that I, **George Schillinger, Director of Operations** for **CAG Investments, L.L.C.**, the undersigned, hereby make constitute and appoint **Inland Northwest Consultants, P.A.**, to act for me in my name, place and stead, for the purpose of:

Application and permitting processes dealing with water appropriation and the Idaho Department of Water Resources.

Subject to the foregoing limitations, I hereby grant full power and authority to **Inland Northwest Consultants, P.A.**, as my attorney in fact to sign all necessary documents pertaining to the IDWR application and permitting processes made in and by **CAG Investments, L.L.C.**

This Limited Power of Attorney shall terminate on 4·10·2002

DATED this 13th day of April, 2000.

George Schillinger, Director of Operations/CAG Investments, L.L.C.

STATE OF IDAHO)
: ss.
County of Kootenai)

On this 13th day of April, 2000, before me, Nancy E. Chambers, a Notary Public for the State of Idaho, personally appeared George Schillinger, known or identified to me to be the person whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same.

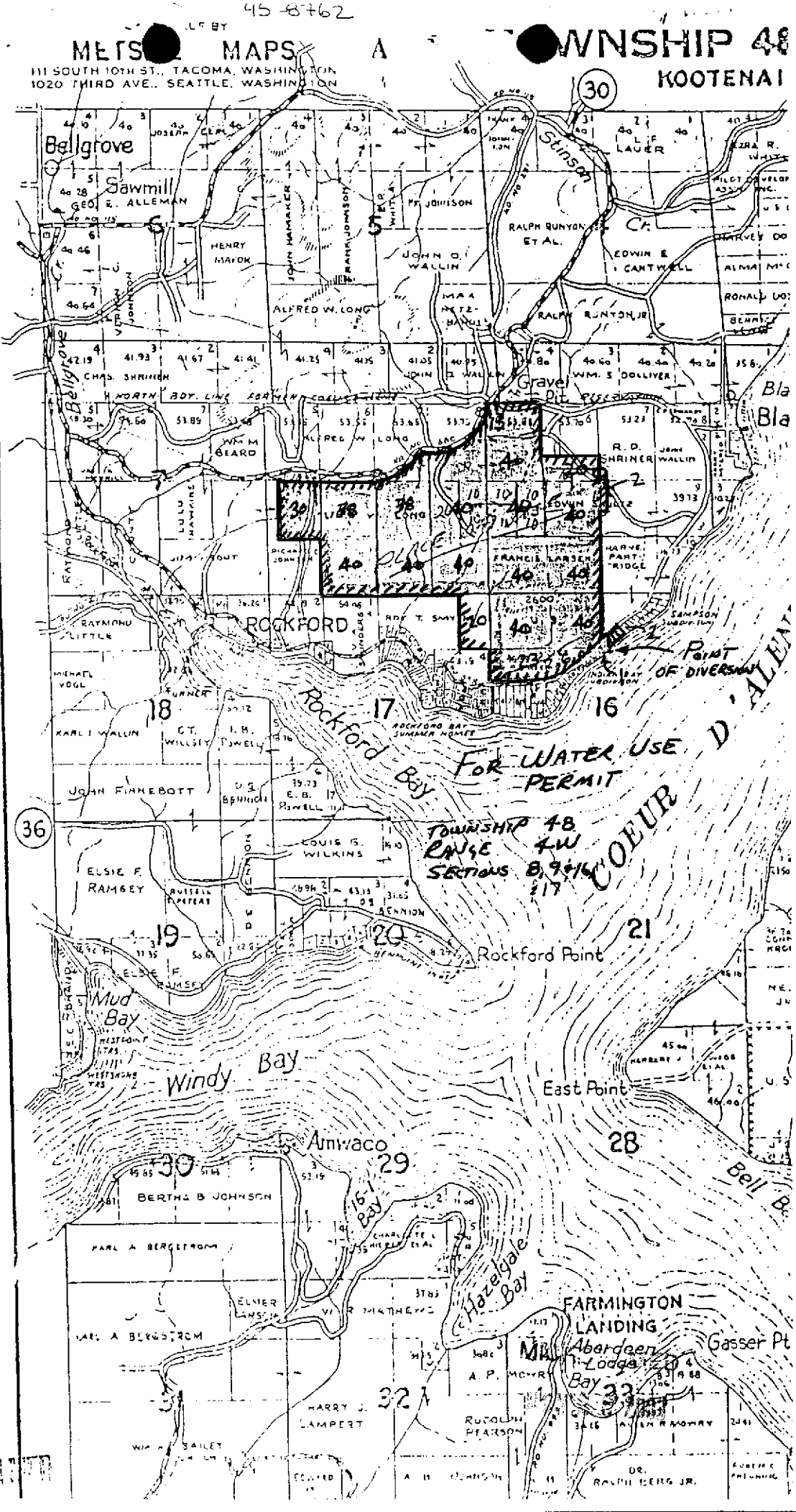
IN WITNESS WHEREOF I have hereunto set my hand and seal the day and year in this certificate first written above.

NANCY E. CHAMBERS
NOTARY PUBLIC
STATE OF IDAHO

Notary Public for Idaho
Residing in: Coeur d'Alene
Commission Expires: 10·31·2003

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NOV 2 6 2003

95-8762



MICROFILMED

RECEIPT
For Monies Paid
to the
Idaho Department of Water Resources

Receipt No:
N013589

Date:
Time: 4/12/2000
16:23:53

Received
From: INLAND NORTHWEST CONSULT

Type of Payment	Program Acct		Amount
WATER RIGHT PERMIT	65103	229 21 1155	160.00
		Total	$ 160.00

CHECK 6708

Region: NORTHERN Signature: _____

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NOV 2 6 2003

ANALYSIS SHEET FOR EXTENSION OF TIME

Permit No.: 95-9045 Reviewed By: dgibson Date: August 25, 2005

	Yes	No		Yes	No
Request received timely?	X		Is delay by a government agency?		
Appropriate fee	X		Is supporting documentation needed to support the file?		
Additional Amount Due:					
Receipt No.:	N013589, C078956		Has the permit been involved in litigation?		
Name and signature same as permit?	X		Is supporting documentation needed to support the file?		
Is address same as permit?	X		Is the project more than 25,000 acre feet for irrigation or 10,000 acre feet for a reservoir?		
Has adequate work been completed to demonstrate due diligence?	X				

Priority Calculation

Extension request received		08/25/2005	New proof due date	09/01/2010
Date proof due	-	09/01/2005		
Lapse notice sent	-			
No. of days late	=	0		
Holiday allowance	+			
Priority date	+	04/12/2000		
New priority date	=	04/12/2000		

Action Taken

Grant extension and extend proof deadline to 9/1/2010 based on due diligence.

State of Idaho
DEPARTMENT OF WATER RESOURCES
1301 North Orchard Street, P.O. Box 83720, Boise, Idaho 83720-0098
Phone: (208) 327-7900 FAX: (208) 327-7866

October 20, 2000

DIRK KEMPTHORNE
GOVERNOR

KARL J. DREHER
DIRECTOR

CAG INVESTMENTS LLC
PO BOX 3070
COEUR D ALENE ID 83816

RE: Permit 95-09045

Dear Permit Holder(s):

Enclosed please find approved Permit to Appropriate Water as referenced above.

If you have any questions regarding this permit, please contact the Department.

Sincerely,

for Jeff Peppersack, Manager
Water Right Permits Section

JP:klt

Enclosure

Scan from this point down Plus rest in pouch.

MICROFILMED
NOV 2 6 2003

State of Idaho
DEPARTMENT OF WATER RESOURCES
1301 North Orchard Street, P.O. Box 83720, Boise, Idaho 83720-0098
Phone: (208) 327-7900 FAX: (208) 327-7866

September 18, 2000

DIRK KEMPTHORNE
GOVERNOR

KARL J. DREHER
DIRECTOR

Mike Mihelich
Kootenai Environmental Alliance
P.O. Box 1598
Coeur D'Alene ID 83814

Howard Funke
Coeur D'Alene Tribe
424 Sherman
Coeur D'Alene ID 83814

Re: Permit No. 95-09045 in the name of CAG Investments, Inc.

Gentlemen:

On September 14, 2000, I sent you a transmittal letter with a Preliminary Order regarding the above-entitled matter. However, the transmittal letter may confuse you since an information sheet was not enclosed as the letter stated. I inadvertently used a form letter for a Preliminary Order, in which a formal hearing had been held, not a fact-finding hearing such as this one. Therefore, I ask that you substitute the transmittal letter of September 14, 2000 for the one enclosed.

Thank you for your assistance in this matter. If you have any questions, please feel free to contact me at (208) 327-7953.

Sincerely,

Deborah J. Gibson

Deborah J. Gibson
Administrative Assistant
Water Allocation Bureau

Encl.
c: Regional Office (w/enclosure)

MICROFILMED
NOV 26 2003

State of Idaho
DEPARTMENT OF WATER RESOURCES
1301 North Orchard Street, P.O. Box 83720, Boise, Idaho 83720-0098
Phone: (208) 327-7900 FAX: (208) 327-7866

DIRK KEMPTHORNE
GOVERNOR

KARL J. DREHER
DIRECTOR

September 14, 2000

Mike Mihelich
Kootenai Environmental Alliance
P.O. Box 1598
Coeur D'Alene ID 83814

Howard Funke
Coeur D'Alene Tribe
424 Sherman
Coeur D'Alene ID 83814

Re: Permit No. 95-09045 in the name of CAG Investments, Inc.

Gentlemen:

Enclosed for your information is a copy of the Preliminary Order issued in the above matter. This order is a result of the fact finding hearing conducted in Coeur d'Alene on August 21, 2000.

If you have any questions, please call me at (208)327-7953.

Sincerely,

Deborah J. Gibson

Deborah J. Gibson
Administrative Assistant
Water Allocation Bureau

Enclosures
Cc: Regional Office (w/enclosures)

MICROFILMED
NOV 2 6 2003

State of Idaho
DEPARTMENT OF WATER RESOURCES
1301 North Orchard Street, P.O. Box 83720, Boise, Idaho 83720-0098
Phone: (208) 327-7900 FAX: (208) 327-7866

DIRK KEMPTHORNE
GOVERNOR

KARL J. DREHER
DIRECTOR

September 14, 2000

Re: Permit No. 95-09045 in the name of CAG Investments, LLC.

Dear Interested Parties:

The Department of Water Resources (department) has issued the enclosed **Preliminary Order** pursuant to section 67-5243, Idaho Code. **It can and will become a final order without further action of the Department unless a party petitions for reconsideration or files an exception and/or brief as described in the enclosed information sheet.**

Please note that water right owners are required to report any change of water right ownership and/or change of mailing address to the department within 120 days of the change. Failure to report these changes could result in a $100 late filing fee. Contact any office of the department or visit our homepage on the Internet to obtain the proper reporting form.

If you have any questions, please call me at (208)327-7953.

Sincerely,

Deborah J. Gibson

Deborah J. Gibson
Administrative Assistant
Water Allocation Bureau

Enclosures
Cc: Regional Office (w/enclosures)

MICROFILMED
NOV 2 8 2000

Is your RETURN ADDRESS completed on the reverse side?

SENDER:

- Complete items 1 and/or 2 for additional services.
- Complete items 3, 4a, and 4b.
- Print your name and address on the reverse of this form so that we can return this card to you.
- Attach this form to the front of the mailpiece, or on the back if space does not permit.
- Write *"Return Receipt Requested"* on the mailpiece below the article number.
- The Return Receipt will show to whom the article was delivered and the date delivered.

I also wish to receive the following services (for an extra fee):

1. ☐ Addressee's Address
2. ☐ Restricted Delivery

Consult postmaster for fee.

3. Article Addressed to:

MIKE MIHELICH
KOOTENAI ENVIRONMENTAL
ALLIANCE
PO BOX 1598
COEUR D'ALENE ID 83814

95-01045

4a. Article Number

7099322000062688 1560

4b. Service Type

☐ Registered ☑ Certified
☐ Express Mail ☐ Insured
☐ Return Receipt for Merchandise ☐ COD

7. Date of Delivery

SEP 18 2000

5. Received By: *(Print Name)*

MIKE MIHELICH

8. Addressee's Address *(Only if requested and fee is paid)*

6. Signature: *(Addressee or Agent)*

X Mike Mihelich

PS Form **3811**, December 1994

Domestic Return Receipt

Thank you for using Return Receipt Service.

UNITED STATES POSTAL SERVICE

First-Class Mail
Postage & Fees Paid
USPS
Permit No. G-10

• Print your name, address, and ZIP Code in this box •

DEBORAH GIBSON
DEPARTMENT OF WATER RESOURCES
1301 N. ORCHARD ST.
BOISE, ID 83706-2237

RECEIVED
SEP 20 2000
Department of Water Resources

MICROFILMED
NOV 2 6 2002

3

Is your RETURN ADDRESS completed on the reverse side?

SENDER:

- Complete items 1 and/or 2 for additional services.
- Complete items 3, 4a, and 4b.
- Print your name and address on the reverse of this form so that we can return this card to you.
- Attach this form to the front of the mailpiece, or on the back if space does not permit.
- Write "*Return Receipt Requested*" on the mailpiece below the article number.
- The Return Receipt will show to whom the article was delivered and the date delivered.

I also wish to receive the following services (for an extra fee):

1. ☐ Addressee's Address
2. ☐ Restricted Delivery

Consult postmaster for fee.

3. Article Addressed to:

HOWARD FUNKE
COEUR D'ALENE TRIBE
424 SHERMAN
COEUR D'ALENE ID 83814

MICROFILMED

95-09045

4a. Article Number

7099322000062688 1553

4b. Service Type

☐ Registered ☑ Certified
☐ Express Mail ☐ Insured
☐ Return Receipt for Merchandise ☐ COD

7. Date of Delivery

9-18-00

5. Received By: *(Print Name)*

8. Addressee's Address *(Only if requested and fee is paid)*

6. Signature: *(Addressee or Agent)*

X Judith A. Harris

PS Form **3811,** December 1994

Domestic Return Receipt

Thank you for using Return Receipt Service.

U[redacted] STATES POSTAL SERVICE

First-Class Mail
Postage & Fees Paid
USPS
Permit No. G-10

• Print your name, address, and ZIP Code in this box •

DEBORAH GIBSON
DEPARTMENT OF WATER RESOURCES
1301 N. ORCHARD ST.
BOISE, ID 83706-2237

RECEIVED

SEP 20 2000

Department of Water Resources

MICRO[illegible]

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SENDER:

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- Complete items 3, 4a, and 4b.
- Print your name and address on the reverse of this form so that we can return this card to you.
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- Write "*Return Receipt Requested*" on the mailpiece below the article number.
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I also wish to receive the following services (for an extra fee):

1. ☐ Addressee's Address
2. ☐ Restricted Delivery

Consult postmaster for fee.

3. Article Addressed to:

JOSEPH HASSELL
INLAND NORTHWEST CONSULTANT
620 POST STREET
POST FALLS ID 83854

MICRO

95-09045

4a. Article Number

7099322000062688 1546

4b. Service Type

☐ Registered ☑ Certified
☐ Express Mail ☐ Insured
☐ Return Receipt for Merchandise ☐ COD

7. Date of Delivery

9-18-96

5. Received By: *(Print Name)*

JOSEPH C. HASSELL

6. Signature: *(Addressee or Agent)*

X

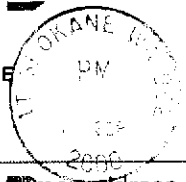
8. Addressee's Address *(Only if requested and fee is paid)*

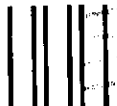
PS Form **3811**, December 1994

Domestic Return Receipt

Thank you for using Return Receipt Service.

U[illegible] STATES POSTAL SERVICE





First-Class Mail
Postage & Fees Paid
USPS
Permit No. G-10

• Print your name, address, and ZIP Code in this box •

DEBORAH GIBSON
DEPARTMENT OF WATER RESOURCES
1301 N. ORCHARD ST.
BOISE, ID 83706-2237

MICROFILMED

NOV 2 6 2003

RECEIVED

SEP 2 0 2000

Department of Water Resources



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- Complete items 3, 4a, and 4b.
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I also wish to receive the following services (for an extra fee):

1. ☐ Addressee's Address
2. ☐ Restricted Delivery

Consult postmaster for fee.

3. Article Addressed to:

CAG INVESTMENTS LLC
PO BOX 3070
COEUR D'ALENE ID 83816

4a. Article Number

7099322000062688 1539

4b. Service Type

- ☐ Registered
- ☑ Certified
- ☐ Express Mail
- ☐ Insured
- ☐ Return Receipt for Merchandise
- ☐ COD

MICROFILMED

95-09045

7. Date of Delivery

9-26-05

5. Received By: *(Print Name)*

8. Addressee's Address *(Only if requested and fee is paid)*

6. Signature: *(Addressee or Agent)*

X

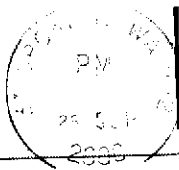
PS Form **3811**, December 1994

Domestic Return Receipt

Is your RETURN ADDRESS completed on the reverse side?

Thank you for using Return Receipt Service.

UNITED STATES POSTAL SERVICE



First-Class Mail
Postage & Fees Paid
USPS
Permit No. G-10

• Print your name, address, and ZIP Code in this box •

DEBORAH GIBSON
DEPARTMENT OF WATER RESOURCES
1301 N. ORCHARD ST.
BOISE, ID 83706-2237

RECEIVED
SEP 29 2000
Department of Water Resources
MICROFILMED

U.S. Postal Service
CERTIFIED MAIL RECEIPT
(Domestic Mail Only; No Insurance Coverage Provided)

7099 3220 0006 2688 1546

Article Sent To: Joseph Hassell

Postage	$
Certified Fee	
Return Receipt Fee (Endorsement Required)	
Restricted Delivery Fee (Endorsement Required)	
Total Postage & Fees	$

9/14/00
Postmark Here

Name (Please Print Clearly) (To be completed by mailer): Inland Northwest Consultants
Street, Apt. No.; or PO Box No.: 620 Post St.
City, State, ZIP+ 4: Post Falls, Id. 83854

PS Form 3800, July 1999 — See Reverse for Instructions

U.S. Postal Service
CERTIFIED MAIL RECEIPT
(Domestic Mail Only; No Insurance Coverage Provided)

7099 3220 0006 2688 1539

Article Sent To: CAG Investments LLC

Postage	$
Certified Fee	
Return Receipt Fee (Endorsement Required)	
Restricted Delivery Fee (Endorsement Required)	
Total Postage & Fees	$

9/14/00
Postmark Here

Name (Please Print Clearly) (To be completed by mailer):
Street, Apt. No.; or PO Box No.: P.O. Box 3070
City, State, ZIP+ 4: Coeur d'Alene Id. 83816

PS Form 3800, July 1999 — See Reverse for Instructions

U.S. Postal Service
CERTIFIED MAIL RECEIPT
(Domestic Mail Only; No Insurance Coverage Provided)

7099 3220 0006 2688 1553

Article Sent To: Howard Funke

Postage	$
Certified Fee	
Return Receipt Fee (Endorsement Required)	
Restricted Delivery Fee (Endorsement Required)	
Total Postage & Fees	$

Postmark Here

Name (Please Print Clearly) (To be completed by mailer): Coeur d'Alene Tribe
Street, Apt. No.; or PO Box No.: 424 Sherman
City, State, ZIP+ 4: Coeur d'Alene, Id. 83814

PS Form 3800, July 1999 — See Reverse for Instructions

U.S. Postal Service
CERTIFIED MAIL RECEIPT
(Domestic Mail Only; No Insurance Coverage Provided)

7099 3220 0006 2688 1560

Article Sent To: Mike Mihelich

Postage	$
Certified Fee	
Return Receipt Fee (Endorsement Required)	
Restricted Delivery Fee (Endorsement Required)	
Total Postage & Fees	$

Postmark Here

Name (Please Print Clearly) (To be completed by mailer): Kootenai Environ. Alliance
Street, Apt. No.; or PO Box No.: P.O. Box 1598
City, State, ZIP+ 4: Coeur d'Alene Id. 83814

PS Form 3800, July 1999 — See Reverse for Instructions

MICROFILMED
NOV 26 2003

Certified Mail Provides:

- A mailing receipt
- A unique identifier for your mailpiece
- A signature upon delivery
- A record of delivery kept by the Postal Service for two years

Important Reminders:

- Certified Mail may ONLY be combined with First-Class Mail or Priority Mail.
- Certified Mail is not available for any class of international mail.
- NO INSURANCE COVERAGE IS PROVIDED with Certified Mail. For valuables, please consider Insured or Registered Mail.
- For an additional fee, a Return Receipt may be requested to provide proof of delivery. To obtain Return Receipt service, please complete and attach a Return Receipt (PS Form 3811) to the article and add applicable postage to cover the fee. Endorse mailpiece "Return Receipt Requested". To receive a fee waiver for a duplicate return receipt, a USPS postmark on your Certified Mail receipt is required.
- For an additional fee, delivery may be restricted to the addressee or addressee's authorized agent. Advise the clerk or mark the mailpiece with the endorsement "Restricted Delivery".
- If a postmark on the Certified Mail receipt is desired, please present the article at the post office for postmarking. If a postmark on the Certified Mail receipt is not needed, detach and affix label with postage and mail.

IMPORTANT: Save this receipt and present it when making an inquiry.

PS Form 3800, July 1999 (Reverse) 102595-99-M-1938

Certified Mail Provides:

- A mailing receipt
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Important Reminders:

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PS Form 3800, July 1999 (Reverse) 102595-99-M-1938

MICROFILMED

APR 2 8 2003

APPLICATION FOR PERMIT
STATE OFFICE ANALYSIS
Reviewed by Sharla Curtis on 8/23/00

No. 95-09045 **Name:** CAG Inv. **Corp. Officers** need SofS ✓ **Ad ok** ✓ **Govt Lots** _____

AREA OF CONCERN: **No/Yes** _____ **Moratorium** _____ **GWMA** **TRUST/NON-TRUST**

GROUNDWATER: (√Flow Chart)

DRILLING PERMIT	
All wells	- 046(**P23**)
Basin 34	- 084 (if necessary)
Irr. w/in WD	- **P05**
WMD	- North/East/West
≤ 0.24 cfs/5 acres	- No MD
> 0.24 cfs/5 acres	- 067
~~WMD~~	
Supp irr (irr = only use)	- 065-104
Supp irr (+ other uses)	- 100-105
≤ 0.24 cfs/5 acres	- No MD
> 0.24 cfs/5 acres	- 01M

SURFACE WATER: (√Flow Chart)

F&G contacted	- Yes/No Response fish Concerns -
In/Above MSF	- WB9 W15 & W16 to be used
PLANNING REVIEW/RESPONSE	_____
In-stream development	- **P52**
WD	- R04 (WD# _____)
≤ 0.20 cfs/others	- 01H(P01), 01P or No MD
> 0.20 cfs	- 01J(**P08**)

SPRINGS/SINK, INACTIVE WD & REST OF STATE

≤ 0.24 cfs/5 acres	- No MD
>0.24 cfs/5 acres	- 01M or No MD

LOCATION:

Boise Front LoGeo	- 058 (<85 GW)
Mitigation	- 121
42-248 Area	- **P84** (20s-70s, 81-86)
Swan Falls Flag	- _____
Trust	- 051(**P74**) (consumptive uses)
Non-Trust	- 048-049 (consumptive uses or non-cons. > 1.0 cfs)

RIVER BASINS: (SW special considerations)

Snake R (01)	- W22(**P04**), N/A
(02,03)	- 007 (w/ remark WB9 if above Weiser)
Payette R (65)	- 047(**P04**) (Payette Lake)
Salmon R (70's)	- 029 (fish screens)
Weiser R (67)	- 086-087

USES:

~~STORAGE~~	- 18A-01H(**P01**),01P-18B(**P09**)-NA
IRR ≤ 5 ac	- R66/R67/R68/R69 (0.03 cfs/ac)
> 5 ac	- R62/R63/R64/R65 (0.02 cfs/ac)
STOCKWATER	- R37 (BLM/USFS)
MINING	- 054-106(**P10**)
FISH PROP	- 029(70'S only)-007-042-106 (**P10**)
HEAT/COOL	- R07(injection well)
FIRE PROT.	- 077

USES:

POWER	- 17H-17K (+uses)-08A-025(**P18**)-01N-106 (**P10**)
MUNICIPAL	
Restricted area	- 022,075
Irr., GW supp to SW	- 102
DOMESTIC ~~150~~ 350	N/A
Surface water	- WB5 (Big Wood or Boise above Star Bridge) 27A (Payette R)
>1 in restricted area	- 070-071-075(no parks/common areas, etc)
Irr use listed separate	- WB5
Moratorium approvable	- W03 (2500 gpd – meets domestic definition i.e. D/convenience store)

BENEFICIAL USE DUE: 9/01/2005

MISC CONDITIONS/REMARKS:

Protested	- 020-W19
Development Period	
≤ 1 yr	- **P16**
> 1 yr	- 26A(**P17**)
Ownership	- 004
Non-consumptive	- 027
Water Quality	- 106-R07
Multiple pd's per ¼¼	- W32
Subd lot desc (pd)	- W59
Subd lot desc (pu)	- W60
Use definitions	- W02 example – S/50 range
Pre-1987 development	- 068-074 (allow 120 days for proof due)
Single p/d intended	- 076

IRRIGATION SEASON 3/15 - 11/15 (Per updated map) **IRR VOLUME/ACRE** 3.0

OTHER CONDITIONS/REMARKS W15, W16 spec cond. from Glen

COMMENTS Marshall Chesrown Manager of LLC according to Sec of States office

[redacted] TRANSACTION REPORT

P.01

[redacted] AUG-22-00 TUE 08:39 AM

DATE START	RECEIVER	TX TIME	PAGES	TYPE	NOTE	M#
AUG-22 08:37 AM	912086861182---80935	31"	1	SEND	OK	

Letter FAX'D AND original
Sent by mail. Ket
8.22.00

MICROFILMED
NOV 26 2003

TO: GLEN SAXTON

FROM: DIANNE BALL at request of Bob Haynes

DATE: AUGUST 23, 2000

Typed August 23, 2000, from phone message left on Bob Haynes' voice mail - date of original meesage unknown to me. Dianne Ball

RE: 95-099045 - CAG Investments LLC

Phone message:

Hi, Bob, Neil Colwell with Avista Corporation.

Sorry it's taken me a while to get back to you -I've been sort of on an unplanned vacation this week combined with some jury duty.

At any rate, Avista won't be attending the meeting on Monday - You know, we don't see that we've got a role in this Water Rights request. Certainly we have a water right and if we ever need to enforce that right against juniors that would be our option but we don't think that at this juncture we need to participate with this. They've made a usage request, and I guess we feel like we're really not affected by that.

So, if you have any questions, please call me at 208 343 2831

I've got a conflict meeting, the Interim Committee on Electric Restructuring, of the legislature is meeting on Monday as well and at the same time. That's where I am going to be, and as I said, Avista didn't see the need to be represented at the meeting. If you have any questions or concerns, give me a call. Thanks for your letter, and heads up about the situation. Talk to you later. Bye, bye.

MICROFILMED
NOV 2 6 2003

State of Idaho
DEPARTMENT OF WATER RESOURCES
1301 North Orchard Street, P.O. Box 83720, Boise, Idaho 83720-0098
Phone: (208) 327-7900 FAX: (208) 327-7866

DIRK KEMPTHORNE
GOVERNOR

KARL J. DREHER
DIRECTOR

August 22, 2000

Tiffany Allgood
Coeur D'Alene Tribe
P.O. Box 408
Plummer, ID 83851

RE: APPLICATION FOR PERMIT NO. 95-09045 IN THE NAME OF CAG INVESTMENTS, LLC

Dear Ms. Allgood:

At the conclusion of the fact-finding hearing conducted yesterday in Coeur d'Alene in connection with the above referenced application for permit, you advised that you planned to send me a one hundred page executive summary of a report. I forgot to advise you that if you send me the report, you also need to provide it to the applicant and to the Kootenai Environmental Alliance c/o Mike Mihelich, P.O. Box 1598, Coeur d'Alene, ID 83816-1598.

If you have questions, please feel free to contact me.

Sincerely,

L. GLEN SAXTON, P.E.
Chief, Water Allocation Bureau

c: IDWR Regional Office
CAG Investments, LLC
Mike Mihelich
Howard Funke

MICROFILMED
FEB 26 2003

State of Idaho
Department of Water Resources



ROSTER OF ATTENDANCE

FACT FINDING HEARING IN THE MATTER OF APPLICATION FOR PERMIT NO. 95-09045 IN THE NAME OF CAG INVESTMENTS, LLC

Date: August 21, 2000

Time: 9:30 a.m.

Location: IDWR Conference Room
1910 NW Boulevard, Suite 210
Coeur d' Alene, ID 82814

Hearing Officer: L. Glen Saxton

** *Please Print* **

NAME	ADDRESS	REPRESENTING
MIKE MIHELICH	626 N 18TH ST CDA	K.E.A.
Howard Funke	424 Sherman CDA	CDA Tribe
Tiffany Allgood	PO BOX 408 Plummer ID 83851	Cd'A Tribe
Stacey Rutledge	424 Sherman CDA	CDA Tribe
JOE HASSELL	INLAND NORTHWEST CONSULTANTS.	DEV/APPLICANT
Marshall Cheesrown	P.O. BOX 3070 CDA	BlackRock Dev.

MICROFILMED
NOV 2 6 2003

State of Idaho
DEPARTMENT OF WATER RESOURCES
1301 North Orchard Street, P.O. Box 83720, Boise, Idaho 83720-0098
Phone: (208) 327-7900 FAX: (208) 327-7866

DIRK KEMPTHORNE
GOVERNOR

KARL J. DREHER
DIRECTOR

MEMORANDUM

To: L. Glen Saxton

From: Karl J. Dreher

RE: APPOINTMENT AS HEARING OFFICER - PROCEDURE RULE 410

Date: August 8, 2000

You are hereby appointed as hearing officer and are authorized to represent the department as provided by IDAPA Rule 37.01.01410 (Procedure Rule 410) in the following matter:

FACT FINDING HEARING IN THE MATTER OF APPLICATION FOR PERMIT NO. 95-09045 IN THE NAME OF CAG INVESTMENTS, LLC

Date: August 21, 2000

Time: 9:30 a.m.

Location: IDWR Conference Room
1910 NW Boulevard, Suite 210
Coeur d' Alene, ID 82814

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NOV 2 6 2003

RECEIVED

JUL 13 2000

DEPARTMENT OF WATER RESOURCES

WRI
PCA
WRA

IDAHO DEPARTMENT OF WATER RESOURCES
APPROPRIATION APPLICATION ANALYSIS SHEET

APPLICATION # 95-09045

INITIAL REVIEW

APPLICANT: CAG BY: [signature] DATE: 4/12/00

ITEM REQUIRED INFORMATION
1. (X) Name and Address
2. (X) Source
3. (X) Point of Diversion & County
4. (X) Quantity
   (X) Nature of Proposed Use
   (X) Period of Use
5. (X) Total Quantity
6. (X) Description of diverting works
7. (X) Time required for b/u
8. (X) Proposed use
9. (X) Place of use or acres irrigated
10. (X) Other water Rights
11. (Y) Ownership
12. (X) Map
    (X) Signature
    (Y) Fee (Amt, receipt, acknowledgement)

*** Send info sheet Y( ) N( )

PROCESSING
(Yes)(No) PRIORITY DATE: 4/12/00

__ X (Include Moratorium Remark)

__ X Statewide Advertising: (Diversion rate greater than 10 cfs or 1,000 af).

CA | Thurs | ok

ADVERTISE IN: KOOTENAI County

LETTERS SENT REQUESTING:

( ) Dam Information ( ) Fish Information

( ) Power Information ( ) Other: N/A

ADDITIONAL INFORMATION
(Yes)(No)

__ X Field check: by _____
__ __ Field report attached
__ __ Analysis Supp. attached(>5cfs/500af)
__ X Water delivered by water master?
Water District #_____

INFORMATION RECEIVED:

( ) Dam Information ( ) Fish Information

( ) Power Information ( ) Other: N/A

GROUNDWATER SECTION

WD Permit No.'s:	Type:	Fees	Receipt No.	Upgrade Needed?
__ __ __ ____	Dom.___ Non-Dom.___	Paid $_____	_____	Y ( ) N ( )
__ __ __ ____	Dom.___ Non-Dom.___	Paid $_____	_____	Y ( ) N ( )
__ __ __ ____	Dom.___ Non-Dom.___	Paid $_____	_____	Y ( ) N ( )

__ __ Groundwater management area
__ __ Critical ground water area
__ __ Well Drilling Permit required
__ __ Well Drilling Application and Fees received
__ X Well Drilling Application approved?

Remarks: NEED TO GET OFFICERS LIST

FINAL REGIONAL PROCESSING/REVIEW

(Yes)(No)

__ __ Notice of pending void order issued. Final order response date: ____/____/____
__ __ Further information required from applicant
5/2 __ Affidavit of publication received
5/2 __ Application published correctly. If not, record action taken: _____
4/14 __ Publication dates and paper recorded on application | Sr. Agent initial _____
__ __ Protests received, Final protest date: 5/8/00
__ __ Measuring device required
__ __ Measuring port required
__ __ Special conditions:

__ __ Special conditions of approval supplement and/or cover letter attached:

Approval Recommended by: _____ Date: ____/____/____

Inland Northwest Consultants

ENGINEERS • SURVEYORS • PLANNERS

June 13, 2000

Job No. 0072

RECEIVED
JUN 16 2000
IDWR/North

STATE OF IDAHO
Department of Water Resources
Northern Region, Suite #210
1910 Northwest Blvd.
Coeur d'Alene, ID 83814-2615

ATTN: Robert G. Haynes, Regional Manager

RE: Permit No. 95-09045
CAG Investments, LLC

Dear Mr. Haynes:

It is our understanding there were no timely protests filed during the appeal period for the reference permit. However, your office did receive a comment letter from the Department of Fish and Game as well as two letters of protest which were filed after the protest period. Those letters are from the Coeur d'Alene Tribe, May 24, 2000 and the Kootenai Environmental Alliance, May 25, 2000.

As you know, this permit merely replaces an existing right for the subject property (expiration situation - see below), and as such, does not materially add to those existing water rights in place at this time.

We should point out, the original water right was acquired by the previous owner, now deceased, who further purchased engineering design for the water system. He went on to see that the reinforced concrete inlet structure was constructed, piping appurtenances were installed, and grading was completed at the lakeshore site. The golf course was designed and mass grading operations were initiated uphill at the main site. For reasons beyond the scope of this letter, the project was suspended.

The current owner, applicant, has spent considerable resource to process a PUD (Planned Unit Development) through Kootenai County, and said PUD has been approved. This procedure has taken more

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NOV 2 8 2003

620 Post Street, Post Falls, Idaho 83854 • (208) 773-8370 • Fax (208) 777-2128

RECEIVED
JUN 16 2000
IDWR/North

than eighteen months which has delayed construction and, therefore, prompted this application to preserve the water right. The applicant is proceeding post-haste to complete, and open, the first phases of the project as quickly as is practical.

We offer the following information for your files in response to the three letters you received.

The intake facility within the lake will be carefully designed to use all openings of 1/4 inch or less, and sufficient total-area will be provided to keep intake velocities below 0.5 feet per second. These parameters will safeguard small fish in accordance with Idaho Code 36-906. Of course, it is in our client's best interest to keep any and all objects out of the water system and slower intake velocities are much more efficient. We will submit design drawings to IDFG for comment prior to construction.

At this time, there are 290 water rights on the lake totaling 67.1 cfs, including the unused right for the subject property. Also included in that total are two large rights which are not used. The City of Coeur d'Alene has a right for 27.1 cfs and the old Potlatch Mill (no longer in existence) had a right for 8.9 cfs, leaving a realistic water right total of 37.1 cfs. An average water right (less those known not to be in use) is 0.11 cfs, or 50 gallons per minute per right. There are only five rights over 1.0 cfs, including the subject property.

The lowest summer flows into the Spokane River have historically been above 350 cfs. Our water right represents only one percent of that figure. We should point out that within the 31 cfs of the existing rights, it is highly unlikely that many of the owners use anywhere near their allowable flows due to the nature of shoreline properties, i.e. 50 gallons per minute is a large flow of water compared to average domestic use and shoreline properties do not typically require extensive irrigation .

Regarding the existing water right for the subject property (for which we are re-applying), we offer the following information. If, in fact, the subject property used all the water necessary to irrigate <u>all</u> the land (not just the golf course) to grasses according to our local weather patterns, the annual draw down of Lake Coeur d'Alene would be 0.22 inch, or barely perceivable.

MICROFILMED
2003

However, not all the land will be irrigated. There are over 25 individual wetland areas and much of the existing landscape will be left in its natural state.

At the risk of being repetitive, we want to remind your Department that this application is only for the replacement of an existing water right which is due to expire (there is no increase or new impact upon the water resource). The owners of the property will gladly relinquish the original water right when this application is approved.

It is our professional opinion the water right for the subject property will have minimal effect on the quality of life on Lake Coeur d'Alene or the Spokane River, and furthermore said water right will not have a negative impact on the Spokane River flows.

We hope these comments provide adequate response to those issues raised in letters received by your office regarding the reference permit application. It is our understanding that this application package will be forwarded to Boise for approval. If you or any staff of the Department have any further question or comment on this matter feel free to contact our office at your earliest convenience.

Very Truly Yours,
Inland Northwest Consultants

JOSEPH E. HASSELL
PE 6966

JEH:slf

cc: George Schillinger, Black Rock
CAG Investments, LLC
Dana Wetzel

\00\0072-007-blackrock.LET

MICROFILMED
NOV 2 6 2003

June 2, 2000

Mr. Joe Hassell, P.E.
Inland Northwest Consultants
620 Post Street
Post Falls ID 83854

Re: Application for Permit No. 95-09045

Dear Mr. Hassell:

Enclosed are copies of letters from the Idaho Department of Fish and Game, the Coeur d'Alene Tribe, and the Kootenai Environmental Alliance, expressing concern about the impacts of the diversion proposed under the above referenced application.

Please provide us with your response to the concerns expressed in these letters so that they may be included in the Department's analysis of the application.

Also, it is my understanding that County approval for the project has been secured. If you have documents from the County showing approval, please provide copies of those for our files.

If you have any questions, please do not hesitate to contact me.

Sincerely,

Robert G. Haynes, P.E.
Regional Manager

RGH:db

Enclosures

MICROFILMED
2003



Kootenai Environmental Alliance

P.O. Box 1598 Coeur d'Alene, ID 83816-1598

Mr. Robert Haynes
Director
Idaho Department of Water Resources
Northern Region
1910 Northwest Boulevard
Coeur d'Alene, ID 83814

May 25, 2000

RECEIVED
MAY 26 2000
IDWR/North

Dear Mr. Haynes:

We were unable to comment on the Application for Permit, Ident No. 95-09045 before the comment period closed, but we have the following questions regarding water being withdrawn from Lake Coeur d'Alene.

1. It is our understanding that the CAG Investments permit would allow up to 3.5 cfs, or over two million gallons of water to be appropriated out of the Lake daily.
Does the Department have data that indicates how many existing permits allow between 1 cfs and 1.9 cfs to be appropriated daily? Are there any permits that allow between 2 cfs and 2.9 cfs to be appropriated daily? Besides CAG Investments, are there any other permits for 3 cfs or greater? If this data exists, is it available to the public?

2. Assuming most permits are active year round, does the Department estimate the amount of water being withdrawn from the Lake on a yearly basis?

3. If there is data in regards to question #2, are there any Department documents that have historical data for the estimated amount of water that has been withdrawn from the Lake each year since 1950? If there are such documents, are they available for public review?

Sincerely,

Mike Mihelich

Mike Mihelich Forestry and Water Committee

MICROFILMED
2003

REFERENCE:

COEUR D'ALENE TRIBE

850 A STREET
P.O. BOX 408
PLUMMER, IDAHO 83851
(208) 686-1800 • Fax (208) 686-1182

RECEIVED
MAY 26 2000
IDWR/North

May 24, 2000

Mr. Robert G. Haynes, P.E., Regional Manager
Idaho Department of Water Resources
1910 Northwest Boulevard, Suite 210
Coeur d'Alene, ID 83814

Subject: Coeur d'Alene Lake Water Right Application Number 95-09045, CAG Investments, LLC

Dear Mr. Haynes:

This letter serves as a protest by the Coeur d'Alene Tribe regarding the application to appropriate water from Lake Coeur d'Alene submitted by CAG Investments, LLC for the purpose of irrigating a golf course and 350 residences directly above Rockford Bay. The Tribe's cause for protest is written in terms of the 6 criteria that the Idaho Water Resources uses to evaluate protested applications. As you are aware the Tribe attempted to file a timely protest but was given incorrect dates of publication and deadline date for protest by the Idaho Water Resource Department. As a result of this misinformation the Tribe did not learn of the correct deadline date for protest until after the deadline had passed. The Tribe therefore requests this protest be deemed as timely filed.

1. Will the proposed appropriation injure other water rights? The Tribe believes that there is the possibility of injuring other water rights due to the volume of water that is proposed for use, especially during summer low water flows into Lake Coeur d'Alene and out to the Spokane River. There are also domestic water permits and intakes close to the proposed intake for CAG Investments, LLC which may be injured as well.
2. Is the water supply sufficient for the purpose for which it is sought to be appropriated? The Tribe believes that it is possible that the water supply is insufficient to support the 3.5 cubic feet per second (cfs) without affecting lake levels in and around Rockford Bay as well as the Spokane River. In addition, to the Tribe's knowledge, there has never been a minimum lake level established so it is difficult to know whether or not there is sufficient water for 3.5 cfs to be withdrawn. A permit to appropriate a volume of water as large as this should not be grated unless these questions are answered based upon sound scientific data.
3. Was the application made in good faith or for delay or speculative purposes? The Tribe does not wish to protest regarding this criteria.
4. Does the applicant have sufficient financial resources with which to complete the proposed project? The Tribe does not wish to protest regarding this criteria.
5. Will the proposed use conflict with local public interest, where the local public interest is defined as the affairs of the people in the area directly affected by the proposed use? The Tribe believes that granting a permit to appropriate water to irrigate a golf course and 350 residences from Lake

Coeur d'Alene conflicts with local public interest. The Tribe retains ownership of the southern third of Lake Coeur d'Alene, adjacent to Rockford Bay. The Tribe believes that the application for the water appropriation permit conflicts with the public interests of the citizens of the State of Idaho as well as Coeur d'Alene Tribal members. This conflict arises from the fact that the adjacent surface waters of the lake below Rockford Bay, from the mid-channel of the Coeur d'Alene River outfall into Lake Coeur d'Alene are Tribal and public resources under the jurisdiction and management of the Coeur d'Alene Tribe, and the application to beneficial use will occur within the boundary of the Coeur d'Alene Indian Reservation.

The conflict is increased by the fact the proposed use of the water is to irrigate a golf course and 350 residences directly upslope from Rockford Bay and the shores of Lake Coeur d'Alene. Fertilizers, pesticides and other pollutants will run downslope into Lake Coeur d'Alene in direct conflict with local public interest. Water quality has been a concern in Lake Coeur d'Alene for decades due to the importance of recreation, fisheries and other uses. There are potential human health risks regarding nutrients increasing the bioavailability of a large volume of heavy metals (i.e. lead, cadmium) deposited in the lakebed through mining activities. It is in the public and Tribal interest to safeguard water quality in Lake Coeur d'Alene. It is also possible that the four wells that have been developed on site for drinking water will not be sufficient to irrigate a golf course and 350 residences and, therefore, the threat of runoff into the lake can be minimized by not granting a surface water permit for lake water.

6. Will the proposed use be contrary to the conservation of water resources within the State of Idaho? The Tribe believes that, for the reasons stated above, the use of this large volume of water, and the impacts that the use will have on the water resources of the State of Idaho and the Coeur d'Alene Tribe, is contrary to the conservation of water resources. Additionally, the Tribe is concerned about the water intake adversely affecting the native fisheries in Lake Coeur d'Alene.

The Tribe is concerned about the long-term health and viability of Lake Coeur d'Alene for all of the local residents and visitors alike. The Tribe urges the State of Idaho Department of Water Resources to deny the application for permit number 95-09045 in order to protect the water resources for present and future generations. In the alternative, the Tribe requests the Department delay the decision until sufficient scientific data can be collected to show that the permit will not adversely affect the lake's water resources. In any event, permit approval should be withheld pending development of a government-to-government compact on water and lake management between the Tribe and the State of Idaho. If you would like to discuss this issue further, please contact Ms. Tiffany Allgood, the Tribe's environmental planner, at (208) 686-8802.

Sincerely,

Ernest L. Stensgar
Chairman

Cc: Howard Funke, Attorney; Tara Salisbury-Allgood, Attorney; Alfred Nomee, NR Director; Tiffany Allgood, EAP Coordinator

MICROFILMED
NOV 2 5 2003

May 23, 2000

Ms Tiffany Allgood
Coeur d'Alene Tribe
P O Box 408
Plummer ID 83851-0408

Re: CAG Investments LLC

Dear Ms Allgood:

This letter is written as summary of our telephone conversation yesterday regarding the Application for Permit for water from Lake Coeur d'Alene filed by CAG Investments LLC. It is my understanding that you had telephoned our office to request the final date for filing a protest to the issuance of a permit for CAG Investments LLC. You were incorrectly told by a member of my staff that the final date to protest was May 22 when in fact it was May 8. I want to apologize to you for that mistake. It was an honest mistake and the individual that you spoke to feels badly about it. As I told you, once the protest window is closed there is no way that I know of for a protest to be lodged. This process is governed by Section 42-203A of the Idaho Code.

I would still encourage you send a letter expressing the concerns that the Tribe has with this proposed use of water. The charge to the director of the department in considering whether to approve or deny an application is the same whether or not the application is protested. If the Tribe has information which bears on whether the application should be approved, the director would want to consider it in his analysis.

We also discussed the effect of the proposed irrigation on lake levels. CAG proposes a maximum irrigated area of 668 acres. The consumptive irrigation requirement for land in this area is about 13 inches per year. Therefore the amount of water consumptively removed from the lake would be about 750 acre-feet. The surface area of Lake Coeur d'Alene is about 40,000 acres. Seven hundred and fifty acre-feet removed from the lake would amount to less than one quarter of an inch from the surface of the lake.

If you want to discuss this matter further, please don't hesitate to contact me.

Sincerely,

Robert G Haynes, P.E.
Regional Manager

MICROFILMED
NOV 2 3 2009

IDAHO FISH & GAME
PANHANDLE REGION
2750 Kathleen Avenue
Coeur d'Alene, Idaho 83814

Dirk Kempthorne/Governor
Rod Sando/Director

April 28, 2000

Ms. Dianne Ball
Idaho Department of Water Resources
1910 Northwest Boulevard, Suite 210
Coeur d'Alene, ID 83814

RECEIVED
MAY - 4 2000
IDWR/North

Dear Dianne:

REFERENCE: WATER RIGHT APPLICATION ~~95-09405~~ 95-9045
CAG INVESTMENTS / CDA LAKE

We have reviewed the application by CAG Investments to divert up to 3.5 cfs from Coeur d'Alene Lake. In the past we have expressed concerns about large diversions from the lake because of uncertainty as to the impact on stream flows downstream from Post Falls Dam, where flow and temperature problems have contributed to the decline of the Spokane River fishery.

We are also concerned about the ability of the applicants to effectively screen their diversion intake to prevent the loss of fish through entrainment or impingement. Idaho Code 36-906 requires screening to prevent the loss of fish. The applicant will need to design an intake which has openings of 0.25 inches or less, and an approach velocity at the screen of 0.5 feet per second or less to comply with the code.

In previous discussions with IDWR over the effect of lake withdrawals on downstream flows, we have been advised that there is not a direct relationship between lake withdrawals and stream flow in the Spokane River. We remain concerned that the cumulative effect of withdrawals from the lake will ultimately have a negative impact on Spokane River flows.

If the applicants can demonstrate that their project will not have a negative impact on Spokane River flows, and that they can adequately screen the intake structure, we will have no objection to the issuance of a water right.

Thanks for the opportunity to comment.

Sincerely,

Greg Tourtlotte
Regional Supervisor

GIT:CEC:kh
C: Tracey Trent, IDFG, Boise

AFFIDAVIT OF PUBLICATION

STATE OF IDAHO, }
County of Kootenai, } ss.

Stacie Walker being first duly sworn upon oath deposes and says:

1. I am now and at all times hereinafter mentioned was a citizen of the United States, resident of the State of Idaho, over the age of twenty-one years and not a party of the above entitled action.

2. I am now and at all times hereinafter mentioned was the printer (principal clerk) of the "Coeur d'Alene Press," a newspaper printed and published daily except Sunday in Coeur d'Alene, Kootenai County, Idaho, and having a general circulation in said county.

3. The legal Notice

of which the annexed is a printed copy, was published in the regular Thursday issue of said newspaper for 2 consecutive weeks, commencing on the 20 day of April, 2000, and ending on the 27 day of April 2000, and such publication was made as often during said period as said daily newspaper was regularly issued.

4. That said newspaper has been continuously and uninterruptedly published in said Kootenai County, during a period of more than seventy-eight consecutive weeks immediately prior to the first publication of said notice.

(Stacie Walker)

Subscribed and sworn to before me this 27 day of April 2000.

Regina Mason
Notary Public for the State of Idaho,
residing at Coeur d'Alene, Idaho.

MY COMMISSION EXPIRES [illegible]

NOTICE OF APPLICATION FOR WATER RIGHT

The Following application(s) have been filed to appropriate the public waters of the State of Idaho:

95-09044

YOUNG, EUGENE
PO BOX 649
RATHDRUM, ID 83858
Source: SPRINGS — Tributary: UNNAMED STREAM
Diversion Pt: SWSWNE — Sec 26 T 52N R 05W in KOOTENAI County.
Use: IRRIGATION (0.030 CFS)
Total Diversion: (0.030 CFS)
Date Filed: 3/31/2000
In: KOOTENAI County
T52N R05W S26 SWNE NWSE
3.0 ACRES TOTAL

95-09045

CAG INVESTMENTS LLC
PO BOX 3070
COEUR D'ALENE, ID 83816
Source: COEUR D'ALENE LAKE — Tributary: SPOKANE RIVER
Diversion Pt: LOT 1 (SWNE) — Sec 16 T 48N R 04W in KOOTENAI County
Use: IRRIGATION (2.500 CFS)
DOMESTIC (1.000 CFS)
Total Diversion: (3.500 CFS)
Date Filed: 4/12/2000
In: KOOTENAI County

T48N R04W S08	SWNE	SENE	NESW	NWSW
	SESW	NESE	NWSE	SWSE
	SESE			
S09	NENW	SWNW	SENW	NESW
	NWSW	SWSW	SESW	SWSE
S16	NWNE	Lot 1 (SWNE)	NENW	NWNW
	SWNW	SENW		
S17	NENE			

668.0 ACRES TOTAL

For additional information concerning the property location, call the Northern Regional Office at (208) 769-1450.

The permit(s) will be subject to all prior water rights. Protests must be filed with the applicant and with the Director, Dept. of Water Resources, Northern Region, 1910 Northwest Blvd., Suite 210, Coeur d'Alene, Idaho 83814, together with a protest fee of $25.00 on or before MAY 8, 2000.

KARL J. DREHER, Director

Legal 911
April 20, 27, 2000

RECEIVED
MAY 02 2000
IDWR/North

95-09045

CAG INVESTMENTS LLC
PO BOX 3070
COEUR D ALENE, ID 83816

Source: COEUR D ALENE LAKE Tributary: SPOKANE RIVER

Diversion Pt: LOT 1 (SWNE) Sec 16 T 48N R 04W in KOOTENAI County.

Use: IRRIGATION (2.500 CFS)
DOMESTIC (1.000 CFS)
Total Diversion: (3.500 CFS)

Date Filed: 4/12/2000

In: KOOTENAI County

T48N R04W S08	SWNE		SENE	NESW	NWSW
	SESW		NESE	NWSE	SWSE
	SESE				
S09	NENW		SWNW	SENW	NESW
	NWSW		SWSW	SESW	SWSE
S16	NWNE	Lot	1(SWNE)	NENW	NWNW
	SWNW		SENW		
S17	NENE				

668.0 ACRES TOTAL

MICROFILMED
NOV 2 6 2003

April 14, 2000

CAG Investments LLC
PO Box 3070
Coeur d Alene ID 83816

Re: Water Appropriation Application No. 95-09045

Dear Gentlemen::

The Idaho Department of Water Resources hereby acknowledges receipt of the above referenced Application for Permit to Appropriate the Public Waters of the State of Idaho. To assist us in providing you with prompt, accurate service, please refer to the above referenced number in all future matters concerning this water right application. Enclosed for your file is Receipt Number N013578.

Your appropriation application is currently being prepared for advertising in the local county newspaper. This advertisement will be published for two consecutive weeks followed by a waiting period of ten days to allow for the submittal of protests. Normal processing time is approximately 3 to 4 months, if the application is not protested.

If the application is not protested, it will be forwarded to Boise to be considered for approval by the Director. State office personnel will then conduct a complete review, and you will be notified by mail of the outcome. However, if the application is protested during this waiting period, you will be sent a copy of the protest and instructions to aid you in resolving the protest without a hearing. All protests must be resolved before approval of the application can be made, so if the protestant does not voluntarily withdraw the protest, this department will conduct a conference and/or hearing on the matter.

You will receive your approved Application for Permit and instructions on filing the Proof of Beneficial Use from our State office in Boise.

If you have any questions or if I can be of any assistance please feel free to contact me at this office.

Sincerely,

ALLEN BEARDSLEE
Senior Water Resources Agent

AB:db

MICRO

NOV 2 6 2003

State of Idaho
DEPARTMENT OF WATER RESOURCES
NORTHERN REGION, Suite No. 210 • 1910 Northwest Blvd. • Coeur d'Alene, Idaho 83814-2615
(208) 769-1450 Fax (208) 769-1454

DIRK KEMPTHORNE
GOVERNOR

KARL J. DREHER
DIRECTOR

APRIL 13, 2000

Legal Notices Department
COEUR D ALENE PRESS
SECOND & LAKESIDE
COEUR D ALENE, ID 83814

Gentlemen:

Enclosed you will find a legal notice which we wish to have published on the dates indicated (once a week for two consecutive weekly issues) in your newspaper. If you cannot publish the notice on the proposed dates, please contact us immediately.

An affidavit of publication must be submitted to the Department along with the publication bill. Your cooperation is appreciated.

Please send the affidavit of publication and publication billing to this office before MAY 8, 2000.

Thanks

Yours truly,

Dianne Ball

DIANNE BALL
Administrative Assistant

Enclosure

LEGAL NOTICES:

This is an additional request for Water Right advertising. One was mailed in yesterday.

They can be combined into one advertisement by inserting this directly following the # 95-09044 Water Right for Eugene Young.

If you have any questions, please call when you receive this.

Thank You. Dianne Ball
769-1450

MICR

NOV 2 6 2001

NOTICE OF APPLICATION FOR WATER RIGHT

The Following application(s) have been filed to appropriate the public waters of the State of Idaho:

MICROFILMED
NOV 26 2003

95-09045

CAG INVESTMENTS LLC
PO BOX 3070
COEUR D ALENE, ID 83816

Source: COEUR D ALENE LAKE Tributary: SPOKANE RIVER

Diversion Pt: LOT 1 (SWNE) Sec 16 T 48N R 04W in KOOTENAI County.

Use: IRRIGATION (2.500 CFS)
DOMESTIC (1.000 CFS)
Total Diversion: (3.500 CFS)

Date Filed: 4/12/2000

In: KOOTENAI County

T48N R04W S08	SWNE		SENE	NESW	NWSW
	SESW		NESE	NWSE	SWSE
	SESE				
S09	NENW		SWNW	SENW	NESW
	NWSW		SWSW	SESW	SWSE
S16	NWNE	Lot	1(SWNE)	NENW	NWNW
	SWNW		SENW		
S17	NENE				

668.0 ACRES TOTAL

MICROFILMED
NOV 2 6 2003

For additional information concerning the property location, call the Northern Regional Office at (208) 769-1450.

The permit(s) will be subject to all prior water rights. Protests must be filed with the applicant and with the Director, Dept. of Water Resources, Northern Region, 1910 Northwest Blvd., Suite 210, Coeur d' Alene, Idaho 83814, together with a protest fee of $25.00 on or before MAY 8, 2000.

KARL J. DREHER, Director

Published: 4/20/2000 & 4/27/2000

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NOV 2 6 2003

Inland Northwest Consultants

ENGINEERS • SURVEYORS • PLANNERS

April 12, 2000

RECEIVED
APR 12 2000
IDWR/North

Bob Haynes
Idaho Department of Water Resources
1910 Northwest Blvd., Suite 210
Coeur D' Alene, ID 83814

Re: Water Appropriation Permit #95-08762 Renewal – CAG Investments, LLC

Dear Bob,

As discussed in our meeting on Friday April 7,2000, transmitted is an application for permit for the above referenced project. The purpose of the application is to **replace** the existing permit because no beneficial use will be established for that permit by the extended deadline of January 1, 2001. If the new permit is issued prior to the expiration date of the existing permit, it is our assumption that the new permit will supersede the existing permit.

Thank you for your time last Friday and your consideration of this application.

Sincerely,

Cindy Sherman for Joseph Hassell

Inland Northwest Consultants
Joseph E. Hassell, PE/PLS

Enclosure

Cc: CAG Investments, LLC
Wetzel & Wetzel
File

JEH:bdn

MICROFILMED
NOV 26 2003

620 Post Street, Post Falls, Idaho 83854 • (208) 773-8370 • Fax (208) 777-2128

INLAND NORTHWEST CONSULTANTS

Idaho Department of Water Resources
Reimbursed Client Exp

Blackrock

4/12/2000

6708

160.00

MICROFILMED
NOV 2 6 2003

WTB Checking

160.00

United States District Court,
D. Idaho.

In re Suit to Quiet Title to That Portion of The Bed And Banks of The Coeur D'alene Lake and St. Joe River Lying Within The Exterior Boundaries of The 1873 Coeur D'alene Reservation.
UNITED STATES of America, Plaintiff-Counterdefendant,
and
Coeur D'Alene Tribe, Plaintiff in Intervention Counterdefendant in Intervention,
v.
State of IDAHO, Defendant.

No. CV94-328-N-EJL.

July 28, 1998.

United States, in its own capacity and as trustee for Coeur d'Alene Indian Tribe, brought action against State of Idaho seeking to quiet title to lands submerged by Coeur d'Alene Lake and St. Joe River within exterior boundaries of Coeur d'Alene Indian Reservation. Tribe intervened as plaintiff. The District Court, Lodge, J., held that tribe owned lands in question.

Judgment for United States.

West Headnotes

[1] Navigable Waters ⚿36(1)
270k36(1)

Court deciding question of title to bed of navigable water must begin with strong presumption against defeat of state's title.

[2] Navigable Waters ⚿36(1)
270k36(1)

Whether title to submerged lands rests with state is ultimately matter of federal intent at time of transfer, which may be demonstrated by express statement or may be inferred from relevant evidence.

[3] Indians ⚿3(3)
209k3(3)

Principle of statutory construction resolves any ambiguities in agreements with United States in favor of Indian tribes.

[4] Indians ⚿12
209k12

[4] Navigable Waters ⚿36(1)
270k36(1)

In determining whether state's presumptive equal footing title to submerged lands within its borders has been defeated with respect to submerged lands on Indian reservation, court considers whether executive branch of federal government intended to include submerged lands within reservation when it negotiated treaty, whether Congress authorized or ratified executive reservation, and whether Congress intended to defeat future state's title to those lands.

[5] Indians ⚿12
209k12

[5] Navigable Waters ⚿36(1)
270k36(1)

Indian tribe, rather than State of Idaho, had title to lands submerged by Coeur d'Alene Lake and St. Joe River within exterior boundaries of Coeur d'Alene Indian Reservation; federal government representatives who negotiated reservation treaty intended to include submerged lands within reservation, and Congress subsequently ratified executive retention of those lands, demonstrating clear intent to defeat future State of Idaho's equal footing title.

*1094 Lois J. Schiffer, U.S. Dept. of Justice, Land & Natural Resources Division, Kevin K Washburn, U.S. Dept of Justice, Indian Resources Section, Envir. and Nat. Resources Div., Hank Meshorer, U.S. Dept. of Justice, Environ. & Nat. Resources Div., Washington, DC, for plaintiffs.

*1095 Steven W. Strack, DAG, Clive J. Strong, Matthew J. McKeown, Office of Attorney General, Natural Resources Division, Boise, ID, for defendant.

Raymond C. Givens, Brian J. Cleary, Givens, Funke & Work, Coeur d'alene, ID, for Plaintiff-Intervenor.

MEMORANDUM DECISION AND ORDER

LODGE, District Judge.

I. Introduction

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This case involves a dispute over the ownership of the bed and banks of Coeur d'Alene Lake and the St. Joe River (the "submerged lands") lying within the exterior boundaries of the present-day Coeur d'Alene Indian Reservation. The United States of America acting in its own capacity and as trustee for the Coeur d'Alene Tribe of Idaho (the "Tribe") initiated the current action against the State of Idaho seeking to quiet title to the submerged lands for the benefit of the Tribe and its members. In addition to its title claim, the United States prays for a declaratory judgment to establish the Tribe's exclusive use, occupancy and right to the quiet enjoyment of the submerged lands. Finally, the United States seeks a permanent injunction prohibiting the State from asserting any right, title or other interest to such lands.

By leave of the Court, the Tribe intervened to assert independently its beneficial interest in the submerged lands based on the theory of "recognized title" and, alternatively, to claim ownership to the same lands pursuant to unextinguished "aboriginal or Indian title." The State answered and counterclaimed, requesting that the title of the submerged lands be quieted in favor of Idaho. The matter was then tried before the Court without a jury. The Court's decision is set forth below and constitutes its findings of fact and conclusions of law.

II. Historical Background

The Tribe once inhabited more than 3.5 million acres in what is now northern Idaho and northeastern Washington. On June 14, 1867, President Andrew Johnson established by Executive Order a reservation for the Tribe. The 1867 reservation consisted for the most part of an area known as Hangman Valley, [FN1] lying to the southwest of Coeur d'Alene Lake (the "Lake"). The parties dispute whether the 1867 reservation included any portion of the submerged lands within its exterior boundaries but, at most, the reservation embraced only a small sliver of the Lake. The precise boundaries of the 1867 reservation never were established by survey, and the Tribe never formally accepted the reservation as its own.

FN1. The area known as Hangman Valley also is referred to in various exhibits as Hangman Creek Valley or Latah Valley or Paradise Valley or Palouse Valley.

On July 1, 1873, the Commissioner of Indian Affairs directed a three member Commission to visit non-treaty tribes in Idaho, including the Coeur d'Alenes, for the purpose of inducing the tribes "to abandon their roaming habits and consent to confine themselves within the limits of such reservation or reservations as may be designated for their occupancy." Ex. 309 at 1; Ex. 234 at 17, 385. As the result of negotiations between the Commission and the Tribe, an agreement was reached which entitled the Tribe to a reservation of approximately 598,000 acres and compensation for the relinquishment of all claims to the remainder of its aboriginal lands.

The reservation boundaries established by the 1873 agreement embraced the Hangman Valley, the Coeur d'Alene River (from its mouth to the Coeur d'Alene Mission of the Sacred Heart [FN2]), the St. Joe River (from its mouth to the present site ***1096** of St. Maries), and all but a small portion of the Lake. As such, the 1873 reservation included within its boundaries not only the area set aside by the 1867 Executive Order but also the Lake and other waterways as well as additional tracts of land. The 1873 agreement, however, required approval by Congress before it became binding on the parties.

FN2. The Coeur d'Alene Mission of the Sacred Heart is popularly known today as the Cataldo Mission. Historically, it also has been called the Sacred Heart Mission or the Old Coeur d'Alene Mission.

In a letter dated November 4, 1873, the Commissioner of Indian Affairs advised the Secretary of Interior of the 1873 agreement and recommended that "pending the action of Congress upon said agreement ... the President ... issue an Executive Order setting apart the same for the use of said Indians." Ex. 3240. On November 8, 1873, President Ulysses S. Grant established by Executive Order a reservation for the Tribe that mirrored exactly the legal boundaries delineated in the 1873 agreement:

> It is hereby ordered that the following tract of country in the Territory of Idaho be, and the same is hereby, withdrawn from sale and set apart as a reservation for the Coeur d'Alene Indians in said Territory, viz:
> Beginning at a point on the top of the dividing ridge between Pine and Latah (Hangmans) Creeks, directly south of a point on said last-named creek 6 miles above the point where the trail from Lewiston to Spokane Bridge crosses said creek; thence in a northeasterly direction in a direct line to the Coeur d'Alene Mission on the Coeur d'Alene River (but not to include the lands of said mission); thence in a westerly direction in a direct line to the point where the Spokane River heads in or leaves the Coeur

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d'Alene Lakes; thence down along the center of the channel of said Spokane River to the dividing line between the Territories of Idaho and Washington as established by the act of Congress organizing a Territorial government for the Territory of Idaho; thence south along said dividing line to the top of the dividing ridge between Pine and Latah (or Hangmans) Creeks; thence along the top of said ridge to the place of beginning.

Ex. 275 at 72. Although a purpose of the Executive Order was to temporarily set aside the reservation "pending the action of Congress," the 1873 agreement never was ratified by Congress.

The United States conducted a survey of the reservation in 1883. Once the boundaries had been established, Congress sought to extinguish the Tribe's aboriginal title to lands outside the reservation. In 1886, Congress authorized the Secretary of the Interior to negotiate with the Tribe "for the cession of their lands outside the limits of the present Coeur d'Alene reservation." Ex. 649. In 1887, the Tribe and representatives of the United States reached an agreement in which the Tribe ceded

all right, title, and claim which they now have, or ever had, to all lands in said Territories and elsewhere, except the portion of land within the boundaries of their present reservation in the Territory of Idaho, known as the Coeur d'Alene Reservation.

Ex. 215 at 68. The 1887 agreement provided that it "shall not be binding on either party until ratified by Congress." Id. at 69.

Before it had ratified the 1887 agreement, Congress authorized the Secretary of the Interior "to negotiate with the Coeur d'Alene tribe of Indians for the purchase and release by said tribe of such portions of its reservation not agricultural and valuable chiefly for minerals and timber as such tribe shall consent to sell." Ex. 2288 at 1002. The resulting negotiations lead to an agreement in 1889, in which the Tribe ceded the approximate northern third of the 1873 reservation to the United States. The portion of the reservation subject to the 1889 cession included within its boundaries the approximate northern two-thirds of the Lake. The 1889 agreement provided that it was "not *1097 binding on either party until ratified by Congress." Ex. 215 at 14.

Prior to congressional ratification of the 1887 and 1889 agreements, Idaho was admitted into the Union. As part of that process, Congress enacted the Idaho Statehood Act, which "accepted, ratified, and confirmed" the Idaho State Constitution. Ex. 221 at 215. The state constitution contains a section disclaiming the State's "right and title to the unappropriated public lands" and lands "owned or held by any Indians or Indian tribes." Ex. 2294 at 415. Shortly after Idaho secured statehood, Congress, on March 3, 1891, ratified the 1887 and 1889 agreements.

With two exceptions, the boundaries of the Coeur d'Alene Reservation remain the same today as established by the congressional ratification of the 1887 and 1889 agreements. In 1894, the Tribe agreed to cede to the United States a one- mile wide strip of the reservation, running from the mouth of the Coeur d'Alene River to the reservation's eastern boundary (the "Harrison cession"). And in 1908, Congress authorized the conveyance to the State of Idaho of land surrounding three small lakes, adjacent to the southern extreme of the Lake. Following its transfer by patent to the State of Idaho in 1911, this area became a public park ("Heyburn State Park").

III. Legal Framework

The United States and the Tribe (collectively, "the Plaintiffs") allege that the Executive Order of 1873 setting apart the reservation also reserved for the benefit of the Tribe the bed and banks of the Lake and other navigable waterways lying within the outer boundaries of the reservation. According to the Plaintiffs, Congress intended to retain, for the benefit of the Tribe, title to the submerged lands included within the reservation created by the 1887 and 1889 agreements. [FN3] In contrast, the State maintains that under the "equal footing" doctrine title to all submerged lands within the exterior boundaries of the 1873 reservation passed to the State of Idaho on July 3, 1890, when Idaho was admitted into the Union.

FN3. The United States' claims are specifically limited to the submerged lands included within the exterior boundaries of the present-day Coeur d'Alene Reservation. The Court by prior order denied the Tribe's request to broaden the quiet title action.

[1] The United State Supreme Court recently articulated the legal principles relevant to resolving a dispute over the ownership of submerged lands. In United States v. Alaska, 521 U.S. 1, 117 S.Ct. 1888, 138 L.Ed.2d 231 (1997), the Supreme Court emphasized the critical connection between the ownership of submerged lands and a State's sovereignty: "Ownership of submerged lands--which carries with it the power to control navigation, fishing,

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and other public uses of water--is an essential attribute of sovereignty." Id. at 1892; see also Idaho v. Coeur d'Alene Tribe of Idaho, 521 U.S. 261, 117 S.Ct. 2028, 2041-42, 138 L.Ed.2d 438 (1997). For this reason, and in order to maintain an "equal footing" with the original 13 colonies, a State is presumed upon admission to the Union to "succeed to the United States' title to the beds of navigable waters within [its] boundaries." Alaska, 117 S.Ct. at 1892. Accordingly, " '[a] court deciding a question of title to the bed of navigable water must ... begin with a strong presumption' against defeat of a State's title." Id. at 1906 (quoting Montana v. United States, 450 U.S. 544, 552, 101 S.Ct. 1245, 67 L.Ed.2d 493 (1981)).

Under the Constitution, however, the Federal Government can defeat a future State's title to land underlying navigable waters. The Property Clause, Art. IV, § 3, cl. 2, provides Congress with the power to dispose of submerged lands in pre-statehood territories by "granting submerged lands to private parties" or by reserving "submerged lands under federal control." Id. The congressional exercise of this power will not offend the Constitution so long as the conveyance or reservation is *1098 for "an appropriate public purpose." Id. at 1909. In this case, there is no doubt that the United States' alleged retention of the submerged lands for the benefit of the Tribe would serve an appropriate public purpose. See id. at 1907. The issue instead is whether the Federal Government in fact acted to reserve the disputed submerged lands.

[2] In this regard, the question of "[w]hether title to submerged lands rests with a State ... is ultimately a matter of federal intent." Id. In the least difficult case, the Federal Government's intent to defeat the future State's title is made clear by "an express reference to the bed beneath the waters ... in the grants establishing the reservation." United States v. Aranson, 696 F.2d 654, 664 (9th Cir.) (citing Montana, 450 U.S. at 552, 101 S.Ct. 1245), cert. denied, 464 U.S. 982, 104 S.Ct. 423, 78 L.Ed.2d 358 (1983). When the pertinent documents do not make express reference to the bed and banks, a conveyance or reservation may be implied but a court "will not infer an intent to defeat a future State's title to inland submerged lands 'unless the intention was definitely declared or otherwise made very plain.' " Alaska, 117 S.Ct. at 1906 (quoting United States v. Holt State Bank, 270 U.S. 49, 55, 46 S.Ct. 197, 70 L.Ed. 465 (1926)). Thus, the intent of the Federal Government to retain submerged lands may be demonstrated by an express statement or may be inferred from relevant evidence.

In a case such as this one, where it is alleged that the submerged lands were included within an Executive reservation, the inquiry as to federal intent involves three distinct questions. First, whether the actions of the Executive reflected a clear intent to include submerged lands within the reservation. See id. at 1907-09. Second, whether Congress authorized the Executive retention of the submerged lands or ratified the same. See id. at 1910-11. Third, and finally, whether Congress intended to defeat the future State's title to those lands. See id. at 1909-10. Evidence that bears directly on the resolution of these three questions includes (1) the language of the relevant documents, (2) the location of the reservation boundaries in relation to the submerged lands, and (3) the purpose of the reservation. See, e.g., id. at 1908. In contrast, evidence consisting solely of "the 'mere fact that the bed of a navigable water lies within the boundaries' " of a reservation will not overcome the presumption against defeat of a State's title. Id. at 1907 (quoting Montana, 450 U.S. at 554, 101 S.Ct. 1245).

[3][4] Special evidentiary considerations apply when it is alleged that an Executive reservation implements an agreement between the United States and a tribe. Specifically, Ninth Circuit cases have formulated a three-part test that bears on the first inquiry under Alaska as to whether the Executive intended to include submerged lands within the reservation. In an effort to give effect to the "principle of construction resolving any ambiguities in agreements with the United States in favor of the Indian tribes," Ninth Circuit decisions have allowed a plaintiff to establish federal intent on this issue by showing (1) the reservation included "within its boundaries a navigable water," (2) the tribe depended on the watercourse for a significant portion of the tribe's needs; and (3) the "Government was plainly aware of the vital importance of the submerged lands and the water resource to the tribe at the time of the [reservation]." [FN4] Muckleshoot Indian Tribe v. Trans-Canada Enter., Ltd., 713 F.2d 455, 457 (9th Cir.1983) (quoting Puyallup Indian Tribe v. Port of Tacoma, 717 F.2d 1251, 1258 (9th Cir.1983), cert. denied, 465 U.S. 1049, 104 S.Ct. 1324, 79 L.Ed.2d 720 (1984)), cert. *1099 denied, 465 U.S. 1049, 104 S.Ct. 1324, 79 L.Ed.2d 720 (1984); see also United States v. Aam, 887 F.2d 190, 194, 196-97 (9th Cir.1989). But see United States v. Pend Oreille Pub. Util. Dist. No. 1, 926 F.2d 1502, 1510-11 (9th Cir.) (holding that tribal dependence upon a river and the United States' awareness of dependence is not enough to establish federal intent to retain submerged lands for benefit of tribe), cert. denied, 502 U.S. 956, 112 S.Ct. 415, 116 L.Ed.2d 436 (1991).

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FN4. The Ninth Circuit has noted more than once that by articulating the three-part test it did not "mean to imply that only where these conditions are met is a conclusion that the United States granted the bed of a navigable water to an Indian tribe justified." Muckleshoot Indian Tribe, 713 F.2d at 458 n. 2.

Even if successful in satisfying the three-part test, and therefore demonstrating the Executive intent to reserve submerged lands, the plaintiff also must show that Congress authorized or ratified the Executive reservation and that Congress intended to defeat the future State's title to the submerged lands. See Alaska, 117 S.Ct. at 1909-11; Utah Div. of State Lands v. United States, 482 U.S. 193, 202, 107 S.Ct. 2318, 96 L.Ed.2d 162 (1987). The necessity of establishing congressional awareness and approval of an Executive decision to reserve submerged lands rests on the relationship between the "equal footing" doctrine and the allocation of federal power under the Constitution. The power of the Federal Government to defeat a future State's equal footing title resides ultimately with Congress. [FN5] See, e.g., Alaska, 117 S.Ct. at 1906, 1910-11 (stating that pursuant to the Property Clause Congress can reserve submerged lands under federal control); Utah Div. of State Lands, 482 U.S. at 200-01, 107 S.Ct. 2318 (explaining that the power to defeat a future State's title to submerged lands arises out of Congress' power under the Property Clause).

FN5. In the Muckleshoot and Puyallup cases the Ninth Circuit panels assumed that once the plaintiff demonstrated an Executive intent to include submerged lands within the reservation the ownership issue had been resolved. See Muckleshoot Indian Tribe, 713 F.2d at 457-458; Puyallup Indian Tribe, 717 F.2d at 1260-61 & n. 10. Subsequent Supreme Court cases have shown this to be an erroneous assumption. See, e.g., Alaska, 117 S.Ct. at 1906, 1910-11; Utah Div. of State Lands, 482 U.S. at 200-02, 107 S.Ct. 2318.

IV. Findings of Fact and Conclusion of Law

During a trial lasting nine days, the parties to this action presented evidence on the pertinent legal issues in the form of expert and lay testimony, written reports, scientific studies and historical documents. Having heard and/or reviewed all of the evidence, the Court sets forth its findings of fact and conclusions of law.

A. Executive Actions Reflect a Clear Intent to Include the Submerged Lands Within the 1873 Reservation.

[5] Applying the three-part test developed by the Ninth Circuit in Puyallup Indian Tribe, 717 F.2d at 1258, to the trial evidence, the Court finds that the first question under Alaska--whether the Executive intended to reserve the submerged lands--must be answered in the affirmative.

1. The reservation includes within its boundaries land under navigable waters.

The parties agree that the disputed submerged lands lie within the exterior boundaries of the present-day Coeur d'Alene Reservation. Similarly, the State does not contest the fact that the Lake and associated waterways are navigable bodies of water. After considering the evidence presented at trial, the Court finds that the Lake and the relevant portions of the Coeur d'Alene, St. Joe and Spokane Rivers were at all times navigable watercourses and that the Coeur d'Alene Reservation includes within its boundaries the disputed submerged lands. Test. of Hart, Tr. at 282-89; Test. of Fahey, Tr. at 1027-30, 1034; Ex. 209 at 47; Ex. 1319 at 1-4; Ex. 2310; Ex. 2313.

2. The Tribe depended on the Lake and associated waterways for a significant portion of the Tribe's needs.

The Coeur d'Alene Indians have occupied the area adjacent to the Lake and the Coeur d'Alene, St. Joe and Spokane Rivers *1100 since time immemorial. The Tribe traditionally survived by fishing, hunting and gathering. For the reasons set forth below, the Court finds the Lake and associated waterways were essential to the Tribe's traditional lifestyle.

Historically, the Coeur d'Alene Indians lived in a number of villages located around the Lake and along the rivers. The Tribe consumed resident trout and whitefish year-round. [FN6] The resident fishery was a main staple of the Tribe's diet. Among other methods of fishing, the Coeur d'Alenes constructed fish traps and weirs which were anchored in the bed and banks of the watercourses. In some cases these structures were extensive, spanning the width of a river. Surplus fish were sometimes dried for later use or traded to other tribes. Occasionally, tribal members also harvested crayfish and freshwater mussels. Test. of Hart, Tr. at 43-73; Hart Report (Ex. 1437) at 5- 28; Test. of Sprague, Tr. at 745-763, 765-69, 785; Sprague Report (Ex. 2404) at 31-33; Ex. 33 at 132-33, 148; Ex. 64 at 7; Ex. 115 at 38-41; Ex. 132 at 17-18; Ex. 133 at 37-38; Ex. 137 at 175-76; Ex. 139 at 10; Ex. 145 at 130- 33; Ex. 171 at 38-40, 55, 88, 94-95, 105-07; Ex.2030 at 104-16; Ex. 2272.

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FN6. Spokane Falls, on the Spokane River, prevented salmon and other anadromous fish from migrating upstream into the Coeur d'Alene drainage system. However, a salmon run did reach upper Hangman Creek. Tribal members also sometimes harvested salmon outside the Tribe's aboriginal territory. But the total contribution to the Tribe's diet was minimal; it is estimated the Coeur d'Alenes obtained less than 5 percent of their total caloric intake from salmon. Ex. 1435 at 18.

The Lake and associated rivers were commonly used to facilitate hunting activities. During communal hunts, deer were driven into a waterway and large numbers, sometimes hundreds, were killed by tribal members waiting in ambush. The Coeur d'Alenes also depended on the waterways to hunt small game, such as beaver, as well as migratory waterfowl. Test. of Hart, Tr. at 72-75; Hart Report (Ex. 1437) at 28-30; Test. of Sprague, Tr. at 769-75; Sprague Report (Ex. 2404) at 35-36; Ex. 105 at 27; Ex. 133 at 38-39; Ex. 171 at 101-03; Ex. 2271; Ex. 2271.

The Tribe gathered several plants growing in the marshes and wetlands of the Coeur d'Alene waterways. Most important among these was the water potato, a plant that was gathered annually by tribal members from the shallow waters of the Lake and rivers. The Coeur d'Alenes also collected rushes and tule from alongside the waterways for use in the construction of baskets, mats and the Tribe's lodges. Test. of Hart, Tr. at 80-81; Hart Report (Ex. 1437) at 33- 36; Test. of Sprague, Tr. at 777, 790; Sprague Report (Ex. 2404) at 33-34.

The watercourses provided the primary highways for travel, trade and communication. Canoes were prevalent and constructed in several distinct styles. Travel was measured in the days it took a canoe to get from point to point. Canoes also facilitated the Tribe's fishing and hunting activities. Test. of Hart, Tr. at 76-77; Hart Report (Ex. 1437) at 30-33; Test. of Sprague, Tr. at 780-85; Sprague Supplemental Report (Ex. 2405) at 3-6.

The Lake and rivers played an integral part in the Tribe's cultural activities. The waterways were tied to the Tribe's recreational pursuits, religious ceremonies and burial practices. In this respect, the Lake and rivers served not only as the means by which the Tribe ensured its corporeal survival, but also as the source of the Tribe's spiritual and cultural identity. Test. of Hart, Tr. at 81-87; Hart Report (Ex. 1437) at 34, 36-43; Test. of Sprague, Tr. at 786-89, 797-800; Sprague Report (Ex. 2404) at 48-50; Ex. 112 at 88-94.

The Tribe augmented its year-round dependence on the water resource by engaging in seasonal subsistence activities. In summer, the Coeur d'Alenes harvested camas, a plant yielding a fleshy bulb. Hangman Valley was the site of extensive camas *1101 fields and therefore an important area within the Tribe's aboriginal territory. Tribal members also harvested berries throughout the summer as they ripened at successive elevations. Test. of Sprague, Tr. at 776-78; Sprague Report (Ex. 2404) at 33; Ex. 133 at 21; Ex. 171 at 88-93

With the advent of the horse, some tribal members traveled to the Plains during the late fall to participate in an annual buffalo hunt. In this regard, the acquisition of the horse reduced somewhat the Tribe's reliance on fishing and small game hunting. Cox Report (Ex. 1437) at 11; Ex. 33 at 142-46; Ex. 171 at 151-52. However, the majority of Coeur d'Alenes continued to live along the waterways and engage in a traditional subsistence lifestyle. The pastoral influence arising from the introduction of the horse and buffalo hunt most significantly affected the villages located near the Spokane (Rathdrum) Prairie, but even at these sites tribal members continued to depend on the water resource. [FN7] Test. of Hart, Tr. at 87-89; Test. of Sprague, Tr. at 779-80, 804-07; Test. of Cox, Tr. at 1537-40,1574-75; Cox Report (Ex. 1437) at 12, 14-17, 27-28; Power Report (Ex. 2325) at 3-4; Ex. 26 at 10, 189- 90; Ex. 33 at 145-46; Ex. 137 at 175-76; Ex. 232 at 710-11.

FN7. The State contends that following the acquisition of the horse many tribal members relocated from stream side villages to open, grassy areas, adopted pastoralism, and abandoned the Tribe's traditional subsistence lifestyle. The weight of the evidence demonstrates, however, that the majority of Coeur d'Alenes continued to live along the waterways and depend on the water resource for food, fibre and transportation.

By the 1840's, the Coeur d'Alenes had begun to cultivate small garden plots, rarely exceeding an acre or two. The primary crops were potatoes and wheat. While the Tribe's agricultural endeavors augmented its traditional lifestyle, it did not supplant the Tribe's dependence on the waterways for a steady source of fish, fowl and plants. The limited quantities and seasonal availability of garden produce served at most as a supplement to the continuous and stable source of food and fibre provided by the water resource. Test. of Hart, Tr. at 145-46; Test. of Sprague, Tr. at 793, 833; Sprague Supplemental Report (Ex. 2405) at 3; Test. of

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Power, Tr. at 1489-92; Test. of Cox, Tr. at 1541-46, 1576-79; Cox Report (Ex. 1437) at 19-20, 23, 25; Ex. 101 at 158-61, 204; Ex. 2275 at 30; Ex. 2358 at 68, 73.

To summarize, the majority of the Tribe's population lived in villages located next to the Lake and rivers. The Tribe's proximity to the watercourses was no coincidence; the Lake and rivers provided resources that were essential to the Coeur d'Alenes' survival. The Tribe depended on the waterways for a year-round source of fish, small mammals, waterfowl and plant materials. The Tribe also depended on the waterways to facilitate the harvest of large mammals and to serve as a means of efficient transportation. Finally, the Tribe's spiritual, religious and social life centered around the Lake and rivers.

The Court's findings are based in part on the expert testimony of Mr. Richard Hart, Dr. Roderick Sprague, Dr. Thomas Power and Dr. Thomas R. Cox. [FN8] The opinions of these witnesses were well within their respective areas of expertise, supported by the documentary evidence and were not diminished on cross-examination. In addition, the Court's findings are supported by the various scientific studies and oral histories submitted by the parties. Archaeological, ethnographic and linguistic studies, as well as tribal traditions and histories, confirm that the Coeur d'Alenes located the majority of their villages along the Lake and rivers, and relied on the water resource to ensure their survival.

> FN8. The State introduced the expert testimony and report (Ex. 3235) of Dr. Kent D. Richards to show that the Tribe was not dependent on the Lake and rivers. However, Dr. Richards' opinions on this issue were significantly undermined on cross-examination and, in any event, the great weight of the evidence is to the contrary.

***1102** Based on the above findings, the Court concludes that the Tribe depended on the Lake and associated rivers for a significant portion of its needs. Cf. Aam, 887 F.2d at 196-97. The waterways were essential to the Tribe's livelihood, providing a reliable year-round source of food and fibre. See Alaska Pacific Fisheries v. United States, 248 U.S. 78, 89, 39 S.Ct. 40, 63 L.Ed. 138 (1918); Puyallup Indian Tribe, 717 F.2d at 1259; cf. Skokomish Indian Tribe v. France, 320 F.2d 205, 210-12 (9th Cir.1963), cert. denied, 376 U.S. 943, 84 S.Ct. 797, 11 L.Ed.2d 767 (1964). Furthermore, the Coeur d'Alenes "depended on watercourses, not only for food and materials, but also in their manner of self-identification, language and religious practices." Muckleshoot Indian Tribe, 713 F.2d at 458.

3. At the time of the 1873 Executive reservation, the Federal Government was plainly aware of the vital importance of the submerged lands and the water resource to the Tribe.

At the time of the 1873 Executive reservation, the Federal Government was plainly aware of the Tribe's dependence on the Lake and rivers. As discussed in detail below, the evidence shows that in 1873 the majority of tribal members continued to rely on the water resource for a significant portion of their needs. Moreover, events immediately preceding and following the 1873 agreement demonstrate that government officials were made aware of the Tribe's reliance on the waterways. The fact that the boundaries of the reservation, as determined by the 1873 agreement and endorsed by the Executive Order, were drawn to include the Lake and rivers leads the Court to conclude that a purpose of the 1873 Executive reservation was to retain the submerged lands for the benefit of the Tribe.

(a) The Tribe continued to be dependent on the water resource in 1873.

Non-Indian contact with the Tribe increased through the early and middle 1800's. Of particular importance to the Coeur d'Alenes was the arrival of Jesuit missionaries in 1842. During the next fifty years, the Jesuits exerted considerable influence over the Tribe's cultural development, often acting as advisors to the Tribe in its dealings with the Federal Government. In numerous and detailed recorded accounts, the Jesuit priests described the Tribe's traditional reliance on the Lake and rivers. Test. of Hart, Tr. at 92-110; Hart Report (Ex. 1437) at 52-68, 91-93; Test. of Sprague, Tr. at 747-48; Sprague Report (Ex. 2404) at 52-54.

In 1846, the Jesuits established the Mission of the Sacred Heart on the Coeur d'Alene River and with the help of tribal members began farming. Eventually, the Mission's farm totaled 200 acres. The agricultural production from the Mission farm, however, did not play a significant role in the Coeur d'Alenes' diet. Test. of Hart, Tr. at 164, 518-19, 1615-16; Hart Report (Ex. 1437) at 99; Test. of Sprague, Tr. at 804-06; Ex. 60 at 61-64; Ex. 1147 at 1-2; Ex. 2221 at 159; Ex. 2265 at 997; Ex. 2358 at 78-86. While many of the federal officials that interacted with the Coeur d'Alenes during the 1850's and early 1860's commented on the Tribe's agricultural efforts, they also noted the Tribe's use of the Lake and rivers. Hart Report (Ex. 1437) at 69-73,

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87-91, 96-98; Ex. 100 at 84; Ex. 168 at 135, 147-48; Ex. 208 at 372; Ex. 2222 at 366-68; Ex. 2338 at 30, 42, 49; Ex. 2409; Ex. 3029 at 36-40; Ex. 3033.

After completion of the Mullan Road in 1862, the Mission experienced an influx of emigrants, miners and other travelers. This proved to be the beginning of a gradual invasion of the Tribe's aboriginal territory. In 1867, apprehension over the effect of the Tribe's aboriginal title on non-Indian ownership claims prompted the President to establish a reservation for the Coeur d'Alenes. The 1867 reservation consisted for the most part of the area known as Hangman Valley and included only a small sliver of the Lake. Test. of *1103 Hart, Tr. at 132-33, 146-61; Hart Report (Ex. 1437) at 94-101, 102-07; Ex. 118 at 24-25; Ex. 227 at 192; Ex. 228 at 417-18; Ex. 239.

Apparently unaware of the 1867 Executive reservation, the Tribe in November of 1871 sent a petition to the Commissioner of Indian Affairs requesting a "charter to possess 20 or 25 miles square of land exclusively for us." Ex. 3066. The petition describes the relevant tract of land as "[t]hat- basin on both sides of Hang-man-creek called: Paradise Valley." Id. This description corresponds to the area known as Hangman Valley.

In late 1871 or early 1872, the Coeur d'Alenes became aware of the 1867 reservation and expressed their dissatisfaction with its boundaries. Ex. 307; Ex. 234 at 392. On November 18, 1872, tribal leaders sent a second petition to the Commissioner of Indian Affairs stating in part as follows:

> In our first petition we made no mention of our church nor of the two valleys of S. Joseph and Coeur d'Alene rivers, because in our ignorance we thought it a matter of course....
>
> As to the two valleys, we did not think to ask for them, though they have been from old the habitual residence of most of us; because being every spring under water, we thought no white man could ever settle there in fact there is none as yet: the few spots which usually escape being inundated, we have them fenced in and cultivated. What we are unanimous in asking, besides the 20 square miles already spoken of, are the two valleys, the S. Josephs, from the junction of S. and N. forks, and the Coeur d'Alene from the Mission inclusively. It would appear too much, and it would be so if all or most of it were fit for farming but the far greatest part of it is either rocky or too dry, too cold or swampy; besides we are not as yet quite up to living on farming: with the work of God we took labor too, we began tilling the ground and we like it: though perhaps slowly we are continually progressing; but our aided industry is not as yet up to the white man's. We think it hard to leave at once old habits to embrace new ones: for a while yet we need have some hunting and fishing.

Ex. 300. [FN9] The second petition makes three points relevant to the Court's present inquiry. First, the Tribe never entertained the possibility of withdrawing to a reservation that did not include the river valleys. Second, the Tribe considered the area adjacent to the waterways its home. Third, and most important, in 1872 the Tribe continued to rely on the water resource for a significant portion of its needs. Id.

> FN9. After considering all the evidence, the Court finds that the second petition was received by the Department of Interior on March 7, 1873. Ex. 2351; Test. of Richards, Tr. at 1427-33.

While the second petition makes clear the Tribe's continuous reliance on the Lake and rivers, other sources reporting on the Tribe's economic status during the late 1860's and early 1870's offer conflicting assessments. Several reports emphasize the Tribe's commitment to farming, Ex. 233 at 726; Ex. 303; Ex. 3239; Ex. 3245, while other accounts note the Tribe's continued reliance on fishing, Ex. 305; Ex. 232. Most important among the latter is a letter from David P. Thompson to the Commissioner of the General Land Office, dated May 6, 1873, urging that the 1867 reservation be enlarged to include the waterways because "[s]hould the fisheries be excluded there will in my opinion be trouble with these indians but should they be included and also the mission which should also be in the Reservation there will be no trouble." [FN10] Ex. 305. Also significant is the 1871 Agent report by W.P. Winas, observing that: "The Coeur d'Alenes reside on Spokane Prairie, and their number *1104 living in this Territory is about one hundred and fifty. They farm on a small scale, but subsist principally by hunting and fishing." [FN11] Ex. 232 at 711.

> FN10. In his letter, Thompson states that his information comes from Rev. Father Cataldo, who he "knows ... represents the views of the Indians." Ex. 305. Thompson's letter eventually was forwarded to the Commissioner of Indian Affairs. Ex. 306.

> FN11. Significantly, tribal members living on the Spokane Prairie were from that portion of the Tribe most willing to adopt an agrarian based lifestyle. See, e.g. Test. of Sprague, Tr. at 804-06; Test. of Cox, Tr. at 1537-40, 1574-75; Cox Report (Ex. 1437) at 12, 14-17, 27-28.

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Having considered all the evidence, the Court finds that at the time of the Executive reservation in 1873 the Tribe continued to be dependent on the Lake and rivers. Reports describing the Tribe's agricultural successes are in conflict with other official assessments, are not necessarily based on personal knowledge, and may be tainted by cultural and personal bias. Depictions of agricultural activity most likely are based on the Tribe's maintenance of garden plots, horses and, in some cases, cattle. Estimates of farmed acreage and agricultural output demonstrate that in the early 1870's the Coeur d'Alenes were not engaged in systematic farming practices. Test of Hart, Tr. at 524-25, 539-43, 1609-15, 1620-23; Test. of Sprague, Tr. at 830-33; Test. of Power, Tr. at 1480-92, 1496-1500; Power Report (Ex. 2325) at 4-8; Test. of Cox, Tr. at 1556-57; Cox Report (Ex. 1437) at 25; Ex. 232 at 711; Ex. 2340; Ex. 3034.

In this regard the Court rejects the State's contention that the "Big Move" to the Hangman Valley area occurred in the late 1860's and early 1870's, and that by 1873 the Tribe had converted to an agrarian based society, no longer dependent on the Lake and rivers. All competent evidence shows that the Tribe's "Big Move" to Hangman Valley started sometime after 1873 and that the Tribe's sole reliance on systematic agricultural practices did not become a reality until much later. E.g., Test of Hart, Tr. at 88-89, 1627-28; Ex. 60 at 61-69; Ex. 206 at 42, 44; Ex. 240 at 250; Ex. 243 at 212; 214; Ex. 245 at 205-06; Ex. 1147 at 1-21.

Other evidence indicates that in 1873 the Tribe continued to depend on the water resource for a significant portion of its needs. Ex. 305; Ex. 232 at 711. Most important, the second petition provides the Tribe's own assessment of its ability to live without the resources provided by the Lake and rivers. In no uncertain terms, the Coeur d'Alenes made it be known that their continued reliance on the waterways was necessary to ensure their survival. Ex. 300.

Based on all the above, the Court concludes that in 1873 the Lake and rivers were an essential part of the "basket of resources" necessary to sustain the Tribe's livelihood. While tribal members also engaged in gardening, gathering and hunting, the waterways provided a reliable, year-round source of food, fibre and transportation without which the Tribe could not have survived. Alaska Pacific Fisheries, 248 U.S. at 89, 39 S.Ct. 40; Puyallup Indian Tribe, 717 F.2d at 1259; Muckleshoot Indian Tribe, 713 F.2d at 458; cf. Aam, 887 F.2d at 196-97; Skokomish Indian Tribe, 320 F.2d at 209.

(b) The Federal Government was plainly aware of the Tribe's dependence on the Lake and rivers at the time of the Executive reservation in 1873.

On July 1, 1873, the Commissioner of Indian Affairs directed a three member Commission to visit non-treaty tribes in Idaho, including the Coeur d'Alenes, for the purpose of inducing the tribes "to abandon their roaming habits and consent to confine themselves within the limits of such reservation or reservations as may be designated for their occupancy." Ex. 309 at 1; Ex. 234 at 17, 385. The Commission members included J.P.C. Shanks, chairman of the House Committee on Indian Affairs, Thomas Bennett, Territorial Governor of Idaho, and John Monteith, Agent to the Nez Perce Indians. The Commission arrived at the Lake on July 23, 1873, spent two days examining the boundaries of the proposed reservation, and met in ***1105** council with the Tribe on July 25, 26 and 27. An agreement was signed on July 28, 1873. Ex. 315; Ex. 645.

The agreement called for setting aside a significantly larger portion of the Tribe's aboriginal territory than had been reserved by the 1867 Executive Order. Besides Hangman Valley, the boundaries of the proposed reservation enclosed all but a small portion of the Lake, the Coeur d'Alene River, from its mouth to the Sacred Heart Mission, the St. Joe River, from its mouth to the present-day site of St. Maries, and a tract of land lying to the south of the Spokane River. The precise boundaries of the expanded reservation were identified by reference to a legal description. Under the agreement, the eastern boundary of the reservation was to head north "in a direct line, to the Coeur d'Alene Mission, on the Coeur d'Alene river (but not to include the lands of said Mission)," with the northern boundary heading "thence in a Westerly direction, in a direct line, to the point where the Spokane River heads in or leaves the Coeur d'Alene lake; thence down along the center of the channel of said Spokane River to the dividing line between the Territories of Idaho, and Washington." In addition to expanding the boundaries of the reservation to include the Lake and rivers, the agreement also guaranteed "that the water running into said reservation shall not be turned from their natural channel where they enter said reservation." In exchange for this enlarged reservation, and other compensation, the Tribe agreed to relinquish all claims to the remainder of its aboriginal lands. The agreement provided that it was not binding on the parties until

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ratified by Congress. Ex. 645.

In a letter to the Commissioner of Indian Affairs, dated August 6, 1873, Agent Monteith listed four reasons for enlarging the boundaries of the 1867 reservation: first, an adjustment in the southwest boundary would include "several Indian farms" and exclude "four places belonging to white settlers;" second, running the eastern boundary north to the Mission "will leave some good farming land in the Upper Latah and will take in several farms around the new Mission on the Coeur d'Alene river;" third, "by running down the Spokane [the Tribe] can put the mills at the upper falls at much less expense than building a steam mill;" and fourth, "[b]y following the Washington and Idaho line to the dividing ridge between the Latah and Pine Creek it will include all Indian farms in Idaho and leave out all white settlements." Ex. 315. Although three of the four reasons for expanding the reservation focus on the location of agricultural lands, other than the specific areas identified by Monteith, the majority of the expanded reservation was not suitable for farming. [FN12] Ex. 300; Ex. 305; Ex. 2316(B).

> FN12. Much of the land added by the 1873 agreement was later characterized by the Federal Government as not suitable for agriculture. Ex. 213 at 4, attach; Ex. 215 at 2, 4.

In response to public criticism, Governor Bennett also sought to justify the Commission's decision to agree to an enlarged reservation. In a letter to the Idaho Signal, dated October 4, 1873, Governor Bennett stated: "We found that the Indians demanded an extension of their reservation so as to include the Catholic Mission and fishing and mill privileges on the Spokane River." Ex. 704 (emphasis in original).

On November 4, 1873, the Commissioner of Indian Affairs sent a letter to the Secretary of Interior that described the boundaries of the proposed reservation and then stated:

> In order that the tract thus described may be protected from trespass by white persons pending the action of Congress upon said agreement, I have the honor to recommend that the President be requested to issue an Executive Order setting apart the same for the use of said Indians.

Ex. 3240. Incorporating the legal description from the 1873 agreement, President *1106 Ulysses S. Grant, on November 8, 1873, "ordered that ... the same is hereby withdrawn from sale and set apart as a reservation for the Coeur d'Alene Indians." Ex. 275 at 72.

In 1883, the Federal Government surveyed the boundaries of the 1873 reservation. Consistent with the description of the boundaries set forth in the 1873 agreement and adopted by the Executive Order, the instructions to the surveyor directed him to run the northern boundary across the Lake from the Sacred Heart Mission to the head of the Spokane River. By locating the northern boundary across the Lake, a portion of the Lake's north end was excluded from the reservation. Surveying a boundary across a navigable waterway was contrary to the usual practice of meandering a survey line along the mean high water mark. The 1883 survey fixed the reservation's total area at 598,499.85 acres, a calculation that included submerged lands under the Lake and rivers within the boundaries of the reservation. Test. of Willett, Tr. at 887-99; Hart Report (Ex. 1437) at 354-62; Ex. 213; Ex. 699.

Based on the foregoing, the Court concludes that in 1873 the Federal Government was plainly aware of the Tribe's dependence on the Lake and rivers. As recounted above, from first contact with the Coeur d'Alenes, government officials noted the Tribe's reliance on the water resource. Any uncertainty concerning the extent of the Tribe's dependence on the Lake and rivers in 1873 was dispelled by the Tribe's request in the second petition for inclusion of the waterways in an expanded reservation. Most important, during the 1873 negotiations the Coeur d'Alenes reiterated their demand that the 1867 reservation be enlarged to include the Tribe's traditional fishing grounds. According to Governor Bennett, the expanded boundaries fixed by the 1873 agreement reflected the United States' realization that the Coeur d'Alenes required a reservation that included the Tribe's fishery. Thus, at the time of the 1873 reservation the "Government's Indian agents understood that 'the capture of fish was an essential source of the Indians' food supply.' " [FN13] Muckleshoot Indian Tribe, 713 F.2d at 458; see also Puyallup Indian Tribe, 717 F.2d at 1259-61.

> FN13. Contrary to the State's argument, the Plaintiffs are not required to show that the President, Secretary of Interior or Commissioner of Indian Affairs actually knew of the Tribe's dependence on the waterways. It is necessary only to show that the government's agents involved in the events giving rise to the reservation or grant of the submerged lands were plainly aware of the Tribe's dependence. See Muckleshoot Indian Tribe, 713 F.2d at 457-58; Puyallup Indian Tribe, 717 F.2d at 1259-61

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The Plaintiffs have established each component of the three-part test developed by the Ninth Circuit in Puyallup Indian Tribe, 717 F.2d at 1258. The parties agree, and the Court finds, that the disputed submerged lands lie beneath navigable waters and within the exterior boundaries of the present-day Coeur d'Alene Reservation. The great weight of the evidence demonstrates that in 1873 the Tribe depended on the water resource for a significant portion of its needs. Finally, the evidence shows that the Federal Government was plainly aware of the Tribe's dependence at the time of the Executive reservation. See Puyallup Indian Tribe, 717 F.2d at 1259-61; Muckleshoot Indian Tribe, 713 F.2d at 456-58; cf. Aam, 887 F.2d at 196-97; Aranson, 696 F.2d at 666; Skokomish Indian Tribe, 320 F.2d at 210-12. By satisfying the Puyallup test, the Plaintiffs have successfully demonstrated that the Executive intended to reserve for the benefit of the Tribe the submerged lands within the 1873 reservation. See Puyallup Indian Tribe, 717 F.2d at 1258- 61; Muckleshoot Indian Tribe, 713 F.2d at 457-58.

(c) Compelling evidence and/or a public exigency supports the conclusion that the Federal Government intended to include the submerged lands within the 1873 reservation.

At least one Ninth Circuit case holds that in addition to satisfying the Puyallup *1107 test a plaintiff must present "compelling evidence" to show a "public exigency" justified the Federal Government's retention of submerged lands for the benefit of a tribe. Pend Oreille Pub. Util. Dist. No. 1, 926 F.2d at 1510-11. The United States Supreme Court, however, recently explained that a plaintiff has no such burden. In Alaska, the Supreme Court expressly rejected the notion that to succeed on a quiet title action a plaintiff must prove that a "public exigency" supported the reservation of submerged lands. 117 S.Ct. at 1909, 1915.

But even if controlling law required the Plaintiffs to show a "public exigency" existed at the time of the 1873 reservation, there is sufficient evidence to support a finding on this issue. Both the Supreme Court and the Ninth Circuit have held that a tribe's dependence on submerged lands constitutes a "public exigency." E.g., Montana, 450 U.S. at 556, 101 S.Ct. 1245; Aam, 887 F.2d at 197-98; Aranson, 696 F.2d at 666; Confederated Salish & Kootenai Tribes of Flathead Reservation, Mont. v. Namen, 665 F.2d 951, 962 (9th Cir.), cert. denied, 459 U.S. 977, 103 S.Ct. 314, 74 L.Ed.2d 291 (1982). Because the Plaintiffs in this case have shown that the Tribe's survival was dependent on the retention of the disputed submerged lands, they also have shown that a "public exigency" supported the Executive reservation of those same lands. See, e.g., Alaska Pacific Fisheries, 248 U.S. at 89, 39 S.Ct. 40; Namen, 665 F.2d at 962; cf. Montana, 450 U.S. at 556, 101 S.Ct. 1245.

Furthermore, in this case the evidence is sufficient to establish the existence of other circumstances that also constitute a "public exigency." The facts demonstrate that an influx of non-Indians into the Tribe's aboriginal territory prompted the Federal Government to negotiate with the Coeur d'Alenes in an attempt to confine the Tribe to a reservation and to obtain the Tribe's release of its aboriginal lands for settlement. Before it would agree to these conditions, however, the Tribe demanded an enlarged reservation that included the Lake and rivers. Thus, the Federal Government could only achieve its goals of promoting settlement, avoiding hostilities and extinguishing aboriginal title by agreeing to a reservation that included the submerged lands. Under similar circumstances, courts have found a "public exigency" sufficient to justify the Federal Government's decision to reserve the submerged lands. See Pend Oreille Pub. Util. Dist. No. 1, 926 F.2d at 1510-11; Puyallup Indian Tribe, 717 F.2d at 1258-61; Muckleshoot Indian Tribe, 713 F.2d at 457-58.

Separate and apart from the evidence supporting a "public exigency" and the three-part Puyallup test, there is "compelling evidence" demonstrating the Federal Government's intent to reserve the submerged lands for the benefit of the Tribe. Cf. Pend Oreille Pub. Util. Dist. No. 1, 926 F.2d at 1510-11 (holding that evidence of tribal dependence upon a river and the United States' awareness of that dependence is insufficient to satisfy plaintiff's burden without additional "compelling evidence" of federal intent to retain submerged lands for benefit of tribe). [FN14] Under the analysis employed by the Supreme Court in Alaska, the language of the relevant documents, the location of the reservation boundaries in relation to the submerged lands and the purpose of the reservation are all highly relevant to ascertaining the intention of the Federal Government. See, e.g. 117 S.Ct. at 1908. In this case, evidence relating to each consideration shows that the actions of the Executive reflected a clear intent to include the submerged lands within the reservation.

FN14. The panel's utilization of a "compelling evidence" standard in Pend Oreille Pub. Util. Dist. No.

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> 1 is an anomaly; no other Ninth Circuit decision and no Supreme Court opinion has ever employed a "compelling evidence" standard in a submerged land case.

The Supreme Court's submerged land cases "establish that the fact that navigable *1108 waters are within the boundaries of a conveyance or reservation does not in itself mean that submerged lands beneath those waters were conveyed or reserved." Id. On the other hand, where an Executive order setting aside a reservation does more than "merely define a boundary that encloses a body of navigable water," the description of the reservation's boundaries in relation to the submerged lands may signal an intent to retain federal ownership. Id. Here, the 1873 Executive Order uses the Coeur d'Alene River, Spokane River and Lake as reference points for describing the boundaries of the reservation. Moreover, the 1873 agreement guarantees "that the water running into said reservation shall not be turned from their natural channel where they enter said reservation." Ex. 645. Reference to these water features in the 1873 agreement and Executive Order suggests a federal intent to include submerged lands within the reservation. See Alaska, 117 S.Ct. at 1908, 1914; Namen, 665 F.2d at 962.

Even more important, the 1873 Executive Order expressly describes a northern boundary that runs across the waters of the Lake and down the center of the Spokane River. Fixing a boundary line across a navigable body of water was contrary to the usual practice of meandering a boundary along the mean high water mark. See Skokomish Indian Tribe, 320 F.2d at 207. By defining the northern boundary in terms of the waterways, the Executive Order necessarily included within the reservation the lands beneath the Lake and Spokane River lying to the south of the boundary, and excluded from the reservation submerged lands lying to the north of the boundary. "It would have been pointless, and quite likely deceptive, to have the northern boundary of the reservation bisect [the] Lake unless it was intended to convey title to the southern [portion] of that lake to the Indians." Namen, 665 F.2d at 962. [FN15] Significantly, the official survey calculated the reservation's total area at 598,499.85 acres, a figure that included the submerged lands within the reservation boundaries. Cf. Skokomish Indian Tribe, 320 F.2d at 209 (stating that failure to include submerged lands in reservation's acreage computation indicates there was no intention to set aside those lands for tribal use). Thus, the clear intent to retain the submerged lands can be found in the 1873 Executive Order, which "by its 'terms embraces the land under the waters of the ... [L]ake.' " Pend Oreille Pub. Util. Dist. No. 1, 926 F.2d at 1511 (quoting Montana, 450 U.S. at 552, 101 S.Ct. 1245 and citing Namen, 665 F.2d at 962); see also Alaska, 117 S.Ct. at 1908, 1914.

> FN15. In Namen the Ninth Circuit also noted that had the Federal Government "intended not to convey the southern half of the lake to the Indians, it could easily have defined the Reservation's northern boundary, upon reaching the west shore of the lake, as running along the shore of the southern half of [the] Lake." 665 F.2d at 962 n. 28. The same can be said here: if the intent was to exclude submerged lands from the 1873 reservation, the Federal Government could have defined the northern boundary, upon reaching the Mission, as running along the shore of the southern part of the Lake to the head of the Spokane River. See Test. of Willett, Tr. at 899.

Under Alaska, the purpose of the reservation also "is a critical factor in determining federal intent." 117 S.Ct. at 1908. Looking first to the Executive Order for any statement of purpose, it announces that the area described in the 1873 agreement is "withdrawn from sale and set apart as a reservation for the Coeur d'Alene Indians." Ex. 275 at 72. Focusing on the language of the Executive Order that withdraws the reserved land from sale and on language from an official report that explains the reservation had been set aside "in order that white persons may be prohibited from settling thereon," Ex. 234 at 392; Ex. 3240, the State argues that the Executive Order did not include submerged lands within the reservation because such lands are not subject to sale or settlement. The State reads the Executive Order too narrowly. Although the Executive *1109 Order did seek to preclude appropriation of lands within the reservation, it also had a much broader purpose: to create a reservation for the exclusive use of the Tribe "pending the action of Congress upon [the 1873] agreement." Ex. 3240; see also Ex. 275 at 72; Ex. 324 at 385. Because the reservation was not designed solely to prevent appropriation of lands, the Court must look to the purpose of the 1873 agreement to determine whether the reservation embraced submerged lands.

In 1873 the Federal Government sought an agreement with the Coeur d'Alenes in order to confine the Tribe to a reservation and extinguish the Tribe's aboriginal title. Ex. 228; Ex. 324 at 385, 392; Ex. 704. The Tribe had refused to settle within the confines of the 1867 reservation. Ex. 307; Ex. 234 at 392. Thus, the Federal Government could only achieve its goals--to extinguish aboriginal title and free tribal lands for

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settlement--by agreeing to an expanded reservation. In this regard, the Coeur d'Alenes demanded an enlarged reservation that included the Tribe's fishing grounds, a mill site and the Mission. Ex. 300; Ex. 315; Ex. 704. The Tribe's demand for its fishing grounds and a mill site could not be satisfied without an agreement that included within the reservation the land under the Lake and rivers. That the Federal Government did in fact agree to reserve the submerged lands for the benefit of the Tribe is demonstrated by the following factors: 1) the United States was aware that the waterways were essential to the Tribe's livelihood; 2) the boundaries of the enlarged reservation were drawn to include the Lake and rivers; 3) the expanded reservation did not add significantly to the agricultural land base already reserved by the 1867 Executive Order; 4) the description of the reservation's boundaries by its terms embraced the submerged lands; and 5) a member of the Commission, Governor Bennet, acknowledged that the expansion of the reservation was for the purpose of meeting the Tribe's demand for its fishing grounds and a mill site. Cf. Skokomish Indian Tribe, 320 F.2d at 210 (denying tribal title to submerged lands after explaining "that the [Skokomish] reservation was intended only as a residence, and the Indians were to remain free to roam and fish at their usual places"). [FN16] This evidence leads the Court to conclude that a purpose of the 1873 agreement was to provide the Tribe with a reservation that granted tribal members exclusive use of the water resource. Because an object of the 1873 Executive Order was, in part, to create a reservation for the Coeur d'Alenes that mirrored the terms of the 1873 agreement, a purpose of the Executive Order was to reserve the submerged lands under federal control for the benefit of the Tribe. See, e.g., Puyallup Indian Tribe, 717 F.2d at 1260-61.

> FN16. In contrast to the intended purpose of the reservation created for the Indians in Skokomish Indian Tribe, here a reason for expanding the reservation to include the Tribe's fishery was precisely so that tribal members could be confined within its boundaries. Indeed, Commission member Governor Bennet had earlier stated his belief that to avoid conflicts with whites an Indian reservation must include the areas relied upon by a tribe for hunting and fishing. Eg. Ex. 1346.

In sum, the intent of the Federal Government to include submerged within the 1873 reservation can be garnered from numerous sources. The evidence supports a finding in favor of the Plaintiffs on each element of the three-part Puyallup test. There also is sufficient evidence to demonstrate a "public exigency" existed at the time of the 1873 reservation. In addition, the terms and purpose of the 1873 agreement and Executive Order provide "compelling evidence" of a federal intent to reserve the submerged lands. The Court therefore concludes that the actions of the Executive reflected a clear intent to retain for the benefit of the Tribe the submerged lands within the 1873 reservation.

B. Congress Ratified the 1873 Executive Reservation of Submerged Lands and Demonstrated a Clear Intent to Defeat Idaho's Title.

Although a purpose of the Executive Order was to set apart a reservation for *1110 the Coeur d'Alene Indians "pending the action of Congress," the 1873 agreement never was ratified by Congress. Nevertheless, the Executive Order effectively conveyed to the Tribe a beneficial interest in the reservation's lands. Puyallup Indian Tribe, 717 F.2d at 1261 n. 10. Until Congress approved the Executive reservation, however, the Tribe's property right was "subject to termination at the will of either the executive or Congress." Sioux Tribe of Indians v. United States, 316 U.S. 317, 331, 62 S.Ct. 1095, 86 L.Ed. 1501 (1942). Similarly, without congressional approval of the Executive retention of submerged lands, the Tribe's beneficial ownership of those lands could not defeat the future State of Idaho's equal footing title. Alaska, 117 S.Ct. at 1910-11, 1915-17. Because the Plaintiffs do not contend that prior to 1873 Congress had authorized the Executive reservation of submerged lands, it is necessary to review events subsequent to the Executive Order of 1873 to determine whether Congress ratified the inclusion of the submerged lands within the reservation and demonstrated a clear intent to defeat the State's title to those lands. See id.

1. Prior to Idaho's statehood, Congress was on notice that the Executive had reserved submerged lands for the benefit of the Tribe and Congress ratified the Executive retention of those lands, demonstrating a clear intent to defeat the future State of Idaho's equal footing title.

In an effort to secure permanent status for the 1873 reservation and obtain compensation for the loss of tribal lands to miners, settlers and other emigrants, the Tribe on March 23, 1885, submitted a petition to the Federal Government requesting that a Commission visit the Coeur d'Alenes to "make with us a proper treaty of peace and friendship ... by which your Petitioners may be properly and fully compensated for such portion of their lands not now reserved to them; [and] that their present reserve may be confirmed to

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them." Ex. 206 at 42. In response, Congress authorized the Secretary of the Interior to negotiate with the Tribe "for the cession of their lands outside the limits of the present Coeur d'Alene reservation." Ex. 649. On March 26, 1887, the Tribe and representatives of the United States reached an agreement in which the Tribe ceded

> all right, title, and claim which they now have, or ever had, to all lands in said Territories and elsewhere, except the portion of land within the boundaries of their present reservation in the Territory of Idaho, known as the Coeur d'Alene Reservation.

Ex. 215 at 68. In exchange, the Federal Government promised "that the Coeur d'Alene Reservation shall be held forever as Indian land and as homes of the Coeur d'Alene Indians." Id. The 1887 agreement provided that it "shall not be binding on either party until ratified by Congress." Id. at 69.

During this same time period, non-Indians continued to encroach on tribal lands and increasingly make use of the Lake and rivers. Beginning in 1880, steamboats operated on the Lake, delivering miners and supplies to a landing near the Old Coeur d'Alene Mission. Because government officials considered the Lake and rivers lying within the outer boundaries of the 1873 reservation to be "Indian country," the transportation or distribution of liquor on board the steamboats constituted a violation of the Intercourse laws. [FN17] Ex. 362; Ex. 364; Ex. 366; Ex. 370; Ex. 411; Ex. 2256; Ex. 3148; Ex. 3152. In one instance, the Acting Inspector General noted that "with the exceptions of a few indentations on its northern coast, the entire lake of Coeur d'Alene ... lay wholly within the Coeur d'Alene Indian Reservation," and then went on to recommend that a steamboat *1111 be seized when he observed "an open bar was kept on the boat, at which drinks or various sorts of liquor, were very freely and frequently sold." [FN18] Ex. 426.

> FN17. The Trade and Intercourse Act of 1834 "specifically penalized both the introduction of liquor into Indian country and the operation of a distillery therein." Rice v. Rehner, 463 U.S. 713, 722 n. 8, 103 S.Ct. 3291, 77 L.Ed.2d 961 (1983).

> FN18. The Secretary of War informed the Secretary of the Interior of the Acting Inspector General's recommendation and apparently the matter was discussed at a Cabinet meeting held on August 10, 1886. Ex. 418; Ex. 427. The day after the Cabinet meeting the Secretary of the Interior referred to the Commissioner of Indian Affairs, for immediate report and recommendation, this "violation of law relating to the sale of liquor on Indian reservations." Ex. 428.

In a similar manner, government officials treated non-Indians engaged in recreational use of the Lake and rivers as trespassers. Those trespassers found fishing within the boundaries of the reservation were ejected. In one report, a government official noted he had "removed from the Coeur d'Alene Lake & its tributary waters one hundred and fourteen (114) persons [who] were engaged in Camping & Fishing." Ex. 429; see also Ex. 2261.

Trespass on both the uplands and waterways of the reservation became so serious it was brought to the attention of Colonel Carlin, the commanding officer of Fort Sherman. Ex. 463; Ex. 465; Ex. 467; Ex. 468. Colonel Carlin, however, resisted employing his troops to remove the trespassers. He first suggested that the northern boundary of the reservation had not been properly surveyed, Ex. 470; Ex. 474; Ex. 2261, and argued for an adjustment in the reservation boundaries because "it must be apparent to the government that some provision must be made by which the white people can enjoy at least a portion of the lake there and its waters for pleasure as well as business," Ex. 2261. Finally, in a letter addressed to the Commissioner of Indian Affairs, dated December 19, 1887, Colonel Carlin recommended "that by executive and congressional action combined the lines [of the reservation] be changed" to locate the northern boundary line in the center of the Coeur d'Alene River, from the Mission to the river's mouth, and in the middle of the Lake, from the mouth of the Coeur d'Alene River to the head of the Spokane River. Ex. 480; Ex. 2333(map). Colonel Carlin explained that the new boundaries he proposed "would throw open to the public a part of the Lake for purposes of navigation and pleasure [and] would also throw open to the public the tract of land lying between Coeur d'Alene River and the Lake which is known to be valuable for its minerals but nearly worthless for agriculture." Ex. 480.

In an apparent effort to clarify the status of the Lake and rivers, the Senate, on January 25, 1888, passed a resolution which repeated the allegations made by Colonel Carlin and others, [FN19] and requested a response from the Secretary of Interior:

> FN19. In a petition to Congress, dated February 1, 1887, the Idaho Territorial Legislature asked that the northeast portion of the 1873 reservation be restored to the public domain and noted that "a navigable river [the Coeur d'Alene River] traverses said portion of the reservation from east to west." Ex. 3154 at 53.

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Whereas it is alleged that the present area of the Coeur d'Alene Indian reservation, in the Territory of Idaho, embraces 480,000 acres of land ... [and] that Lake Coeur d'Alene, all the navigable waters of Coeur d'Alene River, and about 20 miles of the navigable part of St. Joseph River, and part of St. Mary's, a navigable tributary of the Saint Joseph, are embraced within this reservation, except a shore-line of about 3 1/2 miles at the north end of the lake ... that all boats now entering such waters are subject to the laws governing Indian country and all persons going on such lake or waters within the reservation lines are trespassers; and
Whereas it is further alleged that the Indians now on such reservation are located in the extreme southwest corner of the same ... and it being further alleged that all part of such reservation *1112 lying between Lake Coeur d'Alene and Coeur d'Alene River and that part between the Coeur d'Alene River and St. Joseph River is a territory rich in the precious metals and at the same time being of no real use or benefit to the Indians: Therefore,
Resolved, That the Secretary of the Interior be, and he is hereby directed to inform the Senate as to the extent of the present area and boundaries of the Coeur d'Alene Indian Reservation ... whether such area includes any portion, and if so, about how much of the navigable waters of Lake Coeur d'Alene and of Coeur d'Alene and St. Joseph Rivers ... also whether, in the opinion of the Secretary, it is advisable to throw any portion of such reservation open to occupation and settlement under mineral laws of the United States, and if so, precisely what portion; and also whether it is advisable to release any of the navigable waters aforesaid from the limit of such reservation.
Ex. 187 at 693.

Responding on behalf of the Secretary of the Interior, the Commissioner of Indian Affairs, on February 7, 1888, reported to the Senate that "the reservation appears to embrace all the navigable waters of Lake Coeur d'Alene, except a very small fragment cut off by the north boundary of the reservation which runs 'in a direct line' from the Coeur d'Alene Mission to the head of Spokane River." Ex. 213 at 3. After describing the "proportion of the reservation" suitable for agriculture, grazing and mining, the Commissioner reiterated the question posed by the Senate resolution: whether it would be "advisable to throw any portion of the said reservation open to the occupation and settlement ... and, if so, precisely what portion, and whether it is desirable to release any of the navigable waters." Id. at 3-4. Based on his opinion "that the reservation might be materially diminished without detriment to the Indians," the Commissioner recommended "that changes could be made in the boundaries for the release of some or all of the navigable waters therefrom, which would be of great benefit to the public." Id. at 6. Although the Commissioner was "unable to say ... [j]ust what portion of the reservation and navigable waters should be segregated from the reservation," he thought it could "be determined by negotiations with the Indians." Id. The Commissioner concluded his report by opining that after ratification of the 1887 agreement "it will be an easy matter to negotiate with [the Tribe] for the cession of such portions of their reservation as they do not need, including all or a portion of the navigable waters, upon fair and very reasonable terms." Id. The Commissioner attached to his report a map of the 1873 reservation which depicted the Lake and rivers in relation to the reservation's boundaries and which displayed the total area of the reservation at 598,499.85 acres.

It was against this backdrop that Congress in 1888 debated the merits of the 1887 agreement. A 1890 House Report explained that the Fiftieth Congress (1888 session) decided against ratifying the 1887 agreement

> for sundry reasons, among which was a desire on the part of the United States to acquire an additional area, to wit, a certain valuable portion of the reservation specially dedicated to the exclusive use of said Indians under an Executive order of 1873, and which portions of said lands, situate on the northern end of said reservation, is valuable and necessary to the citizens of the United States for sundry reasons. It contains numerous, extensive, and valuable mineral ledges. It contains large bodies of valuable timber .... It contains a magnificent sheet of water, the Coeur d'Alene Lake, and its chief tributary, to wit, the Coeur d'Alene River ....
> Ex. 206 at 4.

While withholding its approval of the 1887 agreement, Congress took steps "to acquire ... the northern end of [the 1873] *1113 reservation." Id. On March 2, 1989, Congress passed the annual Indian Appropriations Act, which included a provision that authorized the Secretary of the Interior "to negotiate with the Coeur d'Alene tribe of Indians for the purchase and release by said tribe of such portions of its reservation not agricultural and valuable chiefly for minerals and timber as such tribe shall consent to sell." Ex. 2288 at 1002.

In August and September of 1889, a three member

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Commission met with tribal leaders and negotiated for the release of the reservation's northern end. The minutes of the negotiations reveal that the location of the new boundaries in relation to the Lake and rivers was a matter of concern to both the Tribe and United States. Known for their sagacity, and aware of the Federal Government's tendency to disregard its commitments to the Indian tribes, the Coeur d'Alenes insisted on defining the terms of any new agreement with precision. [FN20] At one point during the negotiations, General Simpson, the government's chief spokesman, told tribal leader Chief Seltice that "the Lake belongs to you as well as to the whites--to all, every one who wants to travel on it." Ex. 215 at 9. Seltice replied: "That is your idea about the boundary. You know we do not understand papers; in taking it that way we will not know the boundaries." Id. General Simpson then offered the United States' proposal for a diminished reservation and prefaced his description of its boundaries by stating: "You all know where the St. Joseph River is. We do not want any of that." Id. The government's proposal called for a new northern boundary that ran east from the Idaho/ Washington territorial line to the west shore of the Lake, meandered the lake shore south to a point directly opposite the mouth of the Coeur d'Alene River, and "thence due east across said lake." Id. Thus, the boundary line was drawn so as to bisect the Lake, with the northern two-thirds of Lake excluded from the reservation and the southern one-third of the Lake included within the new reservation boundaries. See id. at 14, attach.(map). General Simpson explained to the Tribe that under the government's proposal "if we buy this land [the northern end of the 1873 reservation] you still have the St. Joseph River and the lower part of the lake and all the meadow and agricultural land along the St. Joseph River." Id. at 9. With some modification, this proposal became the basis of an agreement signed on September 9, 1889. [FN21] The agreement provided that it was "not binding on either party until ratified by Congress." Id. at 14.

FN20. The Tribe's hard bargaining practices inspired French trappers to call tribal members "Coeur d'Alenes," which translates directly to "Heart of an Awl," but was commonly interpreted as meaning "Pointed Hearts." The name symbolized the trappers' perception that tribal members negotiated with a "hard heart." Hart Report (Ex. 1437) at 48-49.

FN21. Under the government's original proposal, the new boundary line, after crossing the Lake, was to meander "southerly along the east shore of said lake to a point 1 mile north of the St. Joseph River," and then head east to the eastern boundary. Ex. 215 at 9. Under the final agreement, the new boundary line ran "to a point due west of the mouth of the Coeur d'Alene River, where it empties into the said lake; thence in a due east line until it intersects with the eastern boundary of the said reservation." Id. at 3, 13, 14, attach.(map).

In a 1889/90 Report of the Secretary of the Interior to the House of Representatives, the 1889 agreement is described as an agreement "whereby the Indians agreed to sell a considerable portion of their reservation (in the northern part), valuable chiefly for minerals and timber, and embracing by far the greater portion of the navigable waters of the reservation." Ex. 250 at 22; see also Ex. 206 at 4.

Prior to congressional approval of the 1887 and 1889 agreements, Idaho became a state. As part of that process, Congress passed the Idaho Statehood Act, which admitted Idaho "into the Union on an equal footing with the original States in all respects whatever; and ... accepted, ratified, *1114 and confirmed" the Idaho State Constitution. Ex. 221 at 215. The state constitution contains a section disclaiming

> all right and title to the unappropriated public lands lying within the boundaries [of Idaho], and to all lands lying within [Idaho] owned or held by any Indians or Indian tribes; and until the title thereto shall have been extinguished by the United States, the same shall be subject to the disposition of the United States, and said Indian lands shall remain under the absolute jurisdiction and control of the congress of the United States.

Ex. 2294. Shortly after Idaho secured statehood, Congress, on March 3, 1891, ratified the 1887 and 1889 agreements. Ex. 3255.

Taken together, these events establish that Congress ratified the Executive reservation of the submerged lands and demonstrated the clear intent to defeat the future State of Idaho's title to those lands. The evidence shows that prior to Idaho's statehood, Congress was on notice that the Executive Order of 1873 reserved for the benefit of the Tribe the submerged lands within the boundaries of the Coeur d'Alene Reservation. The Senate pointedly asked the Secretary of Interior to confirm whether the Tribe retained control over the "navigable waters of Lake Coeur d'Alene and of Coeur d'Alene and St. Joseph Rivers." Ex. 187 at 693. The Commissioner of Indian Affairs, responding in detail, answered in the affirmative. [FN22] It is difficult to imagine a set of circumstances that could with any greater certainty place before Congress the fact that the 1873 reservation included the land beneath the Lake and

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rivers. [FN23] Cf. Alaska, 117 S.Ct. at 1916-17 (finding Congress was on notice that an application reflected the Secretary of Interior's intent to reserve submerged lands where the action of making the application had been publicly announced, formal notice of the application had been published in the Federal Register and the Secretary had submitted a map to Congress showing the application area embraced submerged lands).

FN22. The House of Representatives also was on notice that the Executive reservation included the submerged lands. Ex. 206 at 4; Ex. 250 at 21-22.

FN23. The actions by the Federal Government during the years following the 1873 agreement and Executive Order, which in all respects treat the submerged lands within the reservation as belonging to the Coeur d'Alenes, confirm the Executive intent in 1873 to retain those lands for the benefit of the Tribe. Alaska Pacific Fisheries, 248 U.S. at 89-90, 39 S.Ct. 40 (finding support for conclusion that the Federal Government intended to reserve submerged lands for benefit of Indians in subsequent conduct that treated the reservation as including submerged lands).

With this knowledge, Congress validated the Executive reservation of the submerged lands by enacting appropriation statutes that authorized government representatives to negotiate with the Coeur d'Alenes for a cession of tribal property. Ex. 99 at 272-73; Ex. 649; Ex. 2288. Most important, after the Commissioner of Indian Affairs had in no uncertain terms informed Congress that the Executive reservation included the submerged lands, Congress enacted a provision which authorized the Secretary of the Interior "to acquire ... the northern end of said reservation." Ex. 206 at 4. By authorizing the Federal Government to negotiate with the Tribe for a release of the submerged lands, Congress acknowledged that the Executive Order of 1873 had effectively conveyed beneficial ownership of those lands to the Coeur d'Alenes. Accordingly, the Court concludes that Congress recognized and then ratified the Executive reservation of the submerged lands for the benefit of the Tribe. [FN24] See, e.g., Alaska, *1115 117 S.Ct. at 1911, 1915-17 (holding that once Congress is on notice that the Executive intended to reserve submerged lands, subsequent action by Congress that recognizes federal retention of those lands constitutes a ratification of the Executive action, and citing Holden v. Joy, 17 Wall. 211, 247, 21 L.Ed. 523 (1872) ("rejecting Property Clause challenge to President's treaty with Cherokee Nation; although terms of treaty exceeded express delegation of authority by Congress to the President, Congress had 'repeatedly recognized' the validity of the treaty by enacting appropriation statutes")); see also Shoshone Tribe of Indians v. United States, 299 U.S. 476, 494-96, 57 S.Ct. 244, 81 L.Ed. 360 (1937).

FN24. The United State contends that despite the explicit language contained in both the 1887 and 1889 agreements, stating that they shall not be "binding on either party until ratified by Congress," each agreement became effective on the date signed. The Court need not decide this issue. The date that either agreement became effective is relevant to determining when, if ever, the Tribe ceded its title to certain lands. But because this case is limited to resolving ownership claims of submerged lands that never were ceded, the Court must only decide whether Congress ratified the Executive reservation of those lands prior to Idaho's statehood. As discussed above, the Court concludes that Congress ratified the inclusion of the submerged lands before Idaho became a state.
In the alternative, the United States asserts that the General Allotment Act of 1887 (the "Dawes Act") constituted congressional recognition of all Executive order reservations. Unfortunately for the government, the United States Supreme Court already has rejected this argument. Sioux Tribe of Indians, 316 U.S. at 330, 62 S.Ct. 1095 (holding that the Dawes Act "did not amount to a recognition of tribal ownership"). It is noteworthy, however, that in 1890 the Commissioner of Indian Affairs also believed that the Dawes Act constituted a blanket recognition of all Executive reservations. He specifically related the purported effect of the Dawes Act to the status of the Coeur d'Alene Reservation: "The permanency of this tenure is further shown by the act of Congress authorizing and directing the Secretary of the Interior to negotiate with the Coeur d'Alene tribe of Indians in Idaho for the purchase and release of a portion of their reservation which was established by executive order ...." Ex. 1313. This is one more indication that Congress could have authorized the Secretary to negotiate with the Tribe for the release of the Lake and rivers only if at the same time Congress recognized the Tribe's beneficial ownership of the submerged lands.

By explicitly recognizing, prior to Idaho's statehood, an Executive reservation that included submerged lands, Congress demonstrated the clear intent to defeat the State's equal footing title. See Alaska, 117 S.Ct. at 1910-11 (explaining that Congress has demonstrated the clear intent to defeat a state's equal footing title if prior to statehood Congress recognizes an executive reservation of submerged lands for a purpose that requires federal ownership). Retention of the submerged lands was necessary to achieve the United States' objective, id at 1910, and Congress clearly contemplated continued federal ownership of those

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lands, id. at 1917. The 1889 agreement by its terms anticipates that the Tribe will remain the beneficial owner of the southern third of the Lake. The northern boundary line of the diminished reservation was drawn so as to bisect the Lake, and the minutes of the 1889 negotiations confirm that the placement of the boundary line was for the purpose of establishing the Tribe's rights to the Lake and rivers. This is "compelling evidence" that the United States intended for the Tribe to hold a beneficial interest in the submerged lands under the southern third of the Lake. See, e.g., Namen, 665 F.2d at 962 & n. 28. Congress could not have carried into effect the terms of the 1889 agreement without retaining title to the submerged lands. Congress clearly demonstrated its intent to reserve the submerged lands under federal control by ratifying the Executive inclusion of the submerged land within the 1873 reservation. [FN25] See Alaska, 117 S.Ct. at 1910-11, 1915-17.

FN25. The issue at this point of the analysis is not, as the State seems to imply, whether the Federal Government intended to include submerged lands within the 1873 reservation or whether a "public exigency" supported such an inclusion; those questions were asked and answered in relation to the point in time that the Executive acted to create the reservation. See, e.g., Alaska, 117 S.Ct. at 1908-09, 1914-15. Instead the inquiry must now focus on whether Congress realized that in 1873 the President "construed his reservation authority to extend to submerged lands and had exercised that authority to set aside uplands and submerged lands" for the benefit of the Tribe and, if so, whether Congress ratified the Executive action and demonstrated the clear intent to defeat the State's title to those lands. Id. at 1911. As a practical matter, and as is true here, the congressional approval of an Executive reservation of submerged lands for a purpose that is inimical to State ownership often will also amount to a demonstration of Congress' intent to defeat the State's equal footing title. See id. at 1911-12, 1915-17; cf. Utah Div. of State Lands, 482 U.S. at 198-207, 107 S.Ct. 2318 (explaining that where Congress has delegated to the Executive the power to reserve lands and there is no unambiguous evidence that members of Congress understood subsequent Executive reservations included submerged lands and purpose of reservation did not require federal ownership, plaintiff must show Congress "affirmatively intended to defeat the future State's title to such land").

*1116 In the Idaho Statehood Act, Congress made explicit the intent to defeat Idaho's title to the submerged lands. In that statute, Congress admitted Idaho into the Union "on an equal footing with the original states," subject to the disclaimer clause of the Idaho State Constitution, which renounced the State's "right and title to the unappropriated public lands" and lands "owned or held by any Indians or Indian tribes." Ex. 2294. In this respect, the Idaho Statehood Act "operated to confirm [Idaho's] title to equal footing lands ... unless the United States clearly withheld submerged lands ... prior to statehood." Alaska, 117 S.Ct. at 1917; see also United States v. Gardner, 107 F.3d 1314, 1319-20 (9th Cir.1997) (explaining that disclaimer clause is a recognition of preexisting United States title), cert. denied, 522 U.S. 907, 118 S.Ct. 264, 139 L.Ed.2d 191 (1997); cf. Aam, 887 F.2d at 198 (concluding that submerged lands were not "held" by tribe within meaning of disclaimer clause because tribe had not shown Federal Government reserved submerged lands for benefit of tribe). As explained above, the Executive Order of 1873 reflected a clear intent to reserve the submerged lands for the benefit of the Tribe and prior to Idaho's statehood Congress ratified the reservation of those lands. Thus, at the time Idaho secured statehood, the United States had clearly retained title to the submerged lands and conveyed a beneficial interest to the Tribe, thereby withholding, pursuant to the Idaho Statehood Act, the transfer of those lands to the State. See Alaska, 117 S.Ct. at 1916-17; cf. Utah Div. of State Lands, 482 U.S. at 202, 208, 107 S.Ct. 2318.

2. The Plaintiffs have overcome the strong presumption of State ownership by demonstrating that the Federal Government intended to include the submerged lands within the Coeur d'Alene Reservation and that Congress intended to defeat the State's title to those lands.

In sum, the Court concludes that the United States retained, for the benefit of the Tribe, the submerged lands within the exterior boundaries of the present-day Coeur d'Alene Reservation. [FN26] Application of the three- part Puyallup test to the trial evidence demonstrates that the Federal Government clearly intended to include the submerged lands within the 1873 reservation. The evidence also shows a "public exigency" supported the Executive reservation of the submerged lands for the benefit of the Tribe. In addition, the terms and purpose of the 1873 agreement and Executive Order provide "compelling evidence" of a federal intent to reserve the submerged lands. The response of the Commissioner of Indian Affairs to the Senate resolution put Congress on notice that submerged lands had been included in the 1873 reservation. The fact that Congress directed the Secretary of the Interior to negotiate with the Tribe for a release of the submerged lands reflected Congress'

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intent to ratify the inclusion of submerged lands within the reservation and to defeat the State's title to those lands. In the Idaho Statehood Act, Congress confirmed that the Federal Government retained title *1117 to the submerged lands for the benefit of the Tribe. [FN27]

FN26. The Court's decision is expressly limited to a determination of the ownership of the submerged lands lying within the present-day boundaries of the Coeur d'Alene Reservation.

FN27. In light of the Court's conclusion, it need not decide whether the doctrine of aboriginal title applies to submerged lands and, if so, whether the Tribe's aboriginal title to the submerged lands remains unextinguished.

C. Subsequent Events Substantiate That the Title to the Submerged Lands Did Not Pass to Idaho at Statehood.

Events subsequent to Idaho's admission into the Union support the conclusion that title to the submerged lands did not pass to Idaho at statehood. See Alaska Pacific Fisheries, 248 U.S. at 89-90, 39 S.Ct. 40 (finding support for conclusion that the Federal Government intended to reserve submerged lands for benefit of Indians in subsequent conduct that treated the reservation as including submerged lands). In 1893 and 1894, the Federal Government and the Tribe engaged in negotiations for the relinquishment of an area adjacent to the mouth of the Coeur d'Alene River. During the negotiations, the parties frequently referred to the fact that the 1889 agreement created a boundary line in relation to the Lake and mouth of the Coeur d'Alene River. See Hart Report (Ex. 1437) at 246-67; Ex. 207; Ex. 604. In a final agreement, the Tribe agreed to cede to the United States a one-mile strip of land, running from the mouth of the Coeur d'Alene River to the reservation's eastern boundary (the "Harrison cession"). Ex. 207.

The boundaries of the Harrison cession clearly reflect the Tribe's beneficial ownership of land underlying the Lake. The mile wide western boundary line is located in the Lake; the southern boundary begins at a right angle to the western boundary and runs east for more than a mile across the Lake. Ex. 140; Ex. 2334. A cession that included the lake bed would not have been necessary if title to the submerged lands had passed to Idaho at statehood.

V. ORDER

Based on the foregoing, and the Court being otherwise fully advised in the premises, IT IS HEREBY ORDERED that:

1. Title is quieted in favor of the United States, as trustee, and the Coeur d'Alene Tribe of Idaho, as the beneficially interested party of the trusteeship, to the bed and banks of the Coeur d'Alene Lake and the St. Joe River lying within the current boundaries of the Coeur d'Alene Indian Reservation;

2. The United States, as trustee, and the Coeur d'Alene Tribe of Idaho, as the beneficially interested party of the trusteeship, are entitled to the exclusive use, occupancy and right to the quiet enjoyment of the bed and banks of the Coeur d'Alene Lake and the St. Joe River lying within the current boundaries of the Coeur d'Alene Indian Reservation; and

3. The State of Idaho is permanently enjoined from asserting any right, title or otherwise interest in or to the bed and banks of the Coeur d'Alene Lake and the St. Joe River lying within the current boundaries of the Coeur d'Alene Indian Reservation.

IT IS FURTHER ORDERED that the State of Idaho's counterclaim is DENIED.

IT IS FURTHER ORDERED that within fourteen (14) days of the date of this Order, the Plaintiffs shall submit a proposed judgment and decree.

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Case Name:
USA V IDAHO 9835847
Case Number: 98-35831
Date Filed: 05/02/00

FOR PUBLICATION

UNITED STATES COURT OF APPEALS
FOR THE NINTH CIRCUIT

UNITED STATES OF AMERICA, In re suit to quiet title to that portion of the bed and banks of Coeur d'Alene Lake and the St. Joe River lying within the exterior boundaries of the 1873 Coeur d'Alene Reservation,

Plaintiff-counter-defendant, Appellee,

v.

STATE OF IDAHO,

Defendant-counter-claimant, Appellant-Cross-Appellee,

v.

COEUR D'ALENE TRIBE OF IDAHO, Plaintiff-intervenor, Appellee-Cross-Appellant.

Nos. 98-35831
98-35847
D.C. No.
CV-94-00328-EJL
OPINION

Appeals from the United States District Court
for the District of Idaho
Edward J. Lodge, District Judge, Presiding

Argued and Submitted
December 9, 1999--Seattle, Washington

Filed May 2, 2000

Before: Thomas M. Reavley,1 Stephen Reinhardt, and M. Margaret McKeown, Circuit Judges.

1 The Honorable Thomas M. Reavley, Senior United States Circuit Judge for the United States Court of Appeals, Fifth Circuit, sitting by designation.

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Opinion by Judge McKeown

COUNSEL

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OPINION

McKEOWN, Circuit Judge:

At issue in this case is the ownership of submerged lands

lying within the present-day boundaries of the Coeur d'Alene Indian Reservation, which was originally set aside by executive order in 1873. After a nine-day trial involving multiple expert and lay witnesses, extensive written reports, scientific studies, and historical documents, the district court issued a lengthy and meticulous decision in which it concluded that the United States retained these submerged lands for the benefit of the Coeur d'Alene Indian Tribe (the "Tribe"). The court thus entered an order quieting title to the beds and banks of the Coeur d'Alene Lake (the "Lake") and the St. Joe River2 (collectively, the "submerged lands") in favor of the United States, as trustee, and the Tribe, as the beneficially interested party of the trusteeship. The State of Idaho (the "State") appeals that order along with related orders giving the Tribe exclusive right to these submerged lands. We affirm the judgment of the district court. Congress's course of conduct in the late 1880s--in the years immediately preceding Idaho's statehood in 1890--demonstrates that it intended to defeat the State's title to submerged lands within the 1873 reservation.

The Tribe cross-appeals the district court's refusal to adjudicate the ownership of other submerged lands located within what is now Heyburn State Park (the "Park"). These lands were part of the Tribe's reservation until 1911, when the United States conveyed them to Idaho to establish a park. We affirm the court's decision with respect to the Park because the complaint, read as a whole, excludes lands within the Park and the United States expressly disclaimed any intent to quiet title to such lands.

BACKGROUND

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The district court's extensive Memorandum Decision and Order lays out the general historical backdrop to this case as well as extensive findings of fact. The State has not challenged the district court's factual findings, nor has it chal-

2 Referred to in certain historical documents as the St. Joseph River.

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lenged the court's conclusion that executive actions reflect a clear intent to include the submerged lands within the 1873 reservation.3 We thus discuss the factual background only as it relates to the main issue in this case, namely, whether Congress intended to defeat the State's title to these submerged lands.

In 1867, more than thirty years before Idaho became a state, a reservation embracing at best a small portion of the Lake was established by executive order. The Tribe was not even aware of this order until after it sent a petition in 1871 to the Commissioner of Indian Affairs (the "Commissioner") requesting a charter for a reservation. Thereafter, the Tribe refused to settle within the confines of the 1867 reservation because it did not include the Tribe's mission or waterways. After learning of the 1867 executive order, the Tribe sent a second petition, in 1872, to the Commissioner, requesting inclusion of the mission and the St. Joe and Coeur d'Alene river valleys. The Tribe's request was based in part on its continuing dependence on water resources; as it noted in its petition, "for a while yet we need have some hunting and fishing."

Congress responded in 1873 by authorizing a commission to negotiate with the Tribe for settlement on a reservation. After negotiations, the Tribe agreed to settle within an area considerably larger than the 1867 reservation. The new boundaries included the Coeur d'Alene and St. Joe Rivers as well as the vast majority of the Lake (the "1873 reservation"). An executive order, dated November 8, 1873,4 set aside this area for the Tribe pending ratification of the 1873 agreement,

3 For purposes of this appeal, the State concedes that the 1873 executive order was intended to reserve title to the submerged lands for the benefit of the Tribe.

4 Executive Orders Relating to Indian Reservations, From May 14, 1855 to July 1, 1912, Washington, D.C., Government Printing Office (1912) at 72.

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which was contingent on congressional approval, but such approval never came. All subsequent executive and congressional action taken with regard to the reservation nonetheless operated from the understanding that its boundaries were as stated in the 1873 agreement and executive order. 5

In 1885, spurred by concerns due to increasing white settlement pressure, the Tribe again contacted the Commissioner, requesting confirmation of the 1873 reservation and compensation for lands outside that reservation but within the Tribe's

aboriginal territory. Congress responded in 1886 by authorizing negotiations with the Tribe "for the cession of their lands outside the limits of the present Coeur d'Alene reservation." Act of May 15, 1886, 24 Stat. 29, 44. Negotiations were undertaken in 1887, and the Tribe agreed to cede its aboriginal title "to all lands in said Territories and elsewhere, except the portion of land within the boundaries of their present reservation in the Territory of Idaho, known as the Coeur d'Alene Reservation" (the "1887 agreement"). Act of March 3, 1891, 26 Stat. 989, 1027 (reciting 1887 agreement). This agreement, like the 1873 agreement, required ratification.

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5 For instance, an 1883 government survey located the reservation's northern boundary across the Lake, consistent with the 1873 agreement and executive order; the Executive dealt with both commercial and recreational use of the Lake by non-Indians on the assumption that the laws governing Indian territory governed; Congress spoke of the 1873 reservation as "set apart for the use of the Coeur d'Alene Indians by executive order" and described its borders in an 1888 act granting a railroad a conditional right-of-way through the reservation, Act of May 18, 1888, 25 Stat. 160; Congress referenced the 1873 boundaries in its 1886 authorization of negotiations "for the cession of their lands outside the limits of the present Coeur d'Alene reservation," Act of May 15, 1886, 24 Stat. 29, 44; and Congress again referenced the 1873 boundaries in its 1889 authorization of negotiations "for the purchase and release by said tribe of such portions of its reservation not agricultural and valuable chiefly for minerals and timber as such tribe shall consent to sell . . . . " Act of March 2, 1889, 25 Stat. 980, 1002.

While the 1887 agreement was pending before Congress, pressure to open up at least part of the reservation to the public (particularly the Lake), prompted the Senate to pass a resolution in 1888 inquiring of the Secretary of the Interior about the boundaries of the Tribe's reservation and "whether such area includes any portion, and if so, about how much of the navigable waters of Lake Coeur d'Alene, and of Coeur d'Alene and St. Joseph Rivers." S. Res. Mis. Doc. No. 36, 50th Cong. (1888). The Senate also sought advice about "whether it is advisable to release any of the navigable waters aforesaid from the limits of such reservation." Id. Two weeks later, the Secretary replied, stating that the 1873 reservation included the submerged lands at issue and attaching a report by the Commissioner; this report informed Congress that "the reservation appears to embrace all the navigable waters of Lake Coeur d'Alene, except a very small fragment cut off by the north boundary of the reservation" and that portions of the Coeur d'Alene and St. Joseph Rivers flowed through the reservation. Letter from the Secretary of the Interior, S. Ex. Doc. No. 76 at 3, 50th Cong. (1888). The Commissioner opined that "changes could be made in the boundaries for the release of some or all of the navigable waters" and that it would be "an easy matter" to negotiate a cession of the reservation, "including all or a portion of the navigable waters, " once the 1887 agreement had been ratified. Id. at 2.

After receiving this response, Congress authorized a third round of negotiations, this time "for the purchase and release by said tribe of such portions of its reservation not agricultural and valuable chiefly for minerals and timber as such tribe shall consent to sell . . . ." Act of March 2, 1889, 25 Stat. 980, 1002. Following negotiations, the Tribe agreed to cede the

approximate northern third of its 1873 reservation to the United States; this area included roughly the northern two-thirds of the Lake (the "1889 agreement"). 6 Act of March 3,

6 The Tribe's chief insisted on carefully defining the new proposed boundaries, rejecting the suggestion that the "lake belongs to [the Tribe]

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1891, 26 Stat. 989, 1030 (reciting 1889 agreement). The 1889 agreement, like the 1873 and 1887 agreements, required ratification, and, as a condition, the Tribe insisted that the 1887 agreement be ratified. The map submitted to Congress along with the written terms of the agreement showed the boundary of the reservation as bisecting the Lake from west to east at its southern third.

Congress formally ratified both the 1887 and 1889 agreements, but not until 1891, Act of March 3, 1891, 26 Stat. 989, nine months after Idaho's admission to the Union. Idaho Admission Bill, Act of July 3, 1890, 26 Stat. 215. This statehood act also "accepted, ratified, and confirmed " the Idaho constitution, id. S 1, which disclaims the State's "right and title to . . . all lands lying within said limits owned or held by any Indians or Indian tribes." IDAHO CONST. art. XXI, S 19.

Prior to Idaho's admission, the House introduced and the Senate passed separate but identical bills7 ratifying the 1887 and 1889 agreements, but due to uncertainty in the House over whether the bills were the same, the House tabled the Senate bill pending investigation of this question, 21 CONG. REC. 5905 (1890), which was ultimately resolved in the affirmative, H.R. REP. NO. 2988, 51st Cong., at 1 (1890). Two House reports, which recommended passage of the bill, see id. and H.R. REP. NO. 1109, 51st Cong., at 5 (1890),8 and which indicate recognition of the submerged lands as part of the Tribe's reservation at the time of statehood, further explained

as well as to the whites." Message from the President of the United States, S. Ex. Doc. No. 14, 51st Cong. (1889), at 9. A government negotiator then explained the proposed boundaries as follows: "[I]f we buy this land you still have the St. Joseph River and the lower part of the lake and all the meadow and agricultural land along the St. Joseph River." Id.
7 H.R. 7703, 51st Cong. (1890); S. 2828, 51st Cong. (1890), 21 CONG. REC. 5769 (1890).
8 H.R. REP. NO. 2988 contains a reprint of H.R. REP. NO. 1109.

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that the 1887 agreement had not been ratified when first presented

> for sundry reasons, among which was a desire on the part of the United States to acquire an additional area, to wit, a certain valuable portion of the reservation specifically dedicated to the exclusive use of said Indians under an Executive order of 1873 . . . [that] contains a magnificent sheet of water, the Coeur d'Alene Lake, and its chief tributary, to wit, the Coeur d'Alene River, over the waters of which steamers now ply daily . . . . It also controls the out-

let of said lake, to wit, the Spokane River.

H.R. REP. NO. 1109, at 4, reprinted in H.R. REP. NO. 2988, at 5.

Today, the boundaries of the reservation remain as established in the 1887 and 1889 agreements, with two exceptions: 1) the Harrison cession (negotiated by agreement in 1894), a strip of land running from the mouth of the Coeur d'Alene River to the reservation's eastern boundary and including a defined chunk of the Lake; and 2) the Park, an area transferred to Idaho by Congress in 1911 and embracing three smaller lakes adjacent to the southern end of the Lake.

The United States, seeking to quiet title to submerged lands within the present-day reservation, initiated this action in its own capacity and as trustee for the Tribe. The district court granted the Tribe's motion to intervene, subject to the limitation that the suit would encompass only those submerged lands put at issue by the parties' pleadings. The court declined the Tribe's request that it adjudicate the ownership of submerged lands within the Park.

Following trial, the district court ruled in favor of the United States and the Tribe on the quiet title action. The court found that the submerged lands lay within the boundaries of

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the present-day reservation, that in 1873 the Tribe depended on the Lake and associated rivers for a significant portion of its fishing needs, and that in 1873 the federal government was aware of this dependence. The court then concluded that the Executive intended to reserve submerged lands within the 1873 reservation for the benefit of the Tribe. The State has challenged neither these factual findings nor the court's legal conclusion on executive intent.

The court also found that Congress was on notice, prior to Idaho statehood, that the Executive had reserved the submerged lands within the 1873 reservation for the benefit of the Tribe; that the "northern boundary line of the diminished reservation was drawn [in the 1889 agreement] so as to bisect the Lake"; and that the minutes of the 1889 negotiations showed that this placement was "for the purpose of establishing the Tribe's right to the Lake and rivers." Looking at events between 1873, after the executive order established the reservation within which the Tribe had agreed to settle, and 1890, the year Idaho entered the Union, the court concluded that Congress ratified the 1873 executive reservation of submerged lands. The court explained that "[b]y explicitly recognizing, prior to Idaho's statehood, an Executive reservation that included submerged lands, Congress demonstrated a clear intent to defeat the State's equal footing title. " It is this conclusion that the State challenges on appeal.

ANALYSIS

We review de novo the district court's interpretation of treaties, statutes, and executive orders. See Confederated Tribes of Chehalis Indian Reservation v. Washington , 96 F.3d 334, 340 (9th Cir. 1996); United States v. Washington, 157

F.3d 630, 642 (9th Cir. 1998) (meaning of treaty language is question of law, reviewed de novo). Findings of historical fact, including the district court's findings regarding treaty negotiators' intentions, are reviewed for clear error. See United States v. Washington, 157 F.3d at 642. Because the

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State does not appear to have challenged any of the court's underlying factual findings, we accept the facts as given and note that they are amply supported by the record.

Juxtaposed in this case are two principles, both of which must be accorded due weight: the canon of construction favoring Indians and the presumption under the Equal Footing Doctrine that a State gains title to submerged lands within its borders upon admission to the Union. See Puyallup Indian Tribe v. Port of Tacoma, 717 F.2d 1251, 1257 (9th Cir. 1983) (stating that, "when faced with a claim [to submerged lands] by an Indian tribe . . . , we must accord appropriate weight to both the principle of construction favoring Indians and the presumption that the United States will not ordinarily convey title" to such lands).

[1] The Supreme Court's trilogy of decisions in United States v. Alaska, 521 U.S. 1 (1997), Utah Division of State Lands v. United States, 482 U.S.193 (1987), and Montana v. United States, 450 U.S. 544 (1981), provides the framework for analyzing whether a state's presumptive title to submerged lands within its borders has been defeated. In Alaska, the Supreme Court reaffirmed the two-prong test set forth in Montana and Utah for determining whether a state's presumptive equal footing title to submerged lands within its borders has been defeated. As framed by the Supreme Court, the question before us is "whether the United States intended to include submerged lands within the [reservation] and to defeat [Idaho's] title to those lands. See Alaska , 521 U.S. at 36.

[2] Although executive action has now been held sufficient to establish the first prong, the second prong requires a showing of congressional intent. See Alaska, 521 U.S. at 40-41, 44. Nothing in Alaska requires that congressional action take the form of explicit congressional ratification of an agreement reserving or conveying title to particular submerged lands. Rather, the Supreme Court has framed the question as whether Congress intended to defeat the state's title to the

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lands at issue, see id. at 36; Utah, 482 U.S. at 202; notably, the Supreme Court has not required that the requisite intent be established in any specific, formulaic way, focusing instead on whether the congressional action at issue showed an affirmative intent to defeat state title, that is, whether the "intention was definitely declared or otherwise made very plain." United States v. Holt State Bank, 270 U.S. 49, 55 (1926). As the Court in Alaska pointed out in rejecting the state's argument to the contrary:

> [T]here would have been no barrier to Congress retaining a petroleum reserve, including submerged

> lands, at the point of Alaska's statehood, provided it satisfied Utah['s] . . . requirements of demonstrating a clear intent to include submerged lands within the Reserve's scope and a clear intent to defeat Alaska's title. It follows that Congress could achieve the same result by explicitly recognizing, at the point of Alaska's statehood, an executive reservation that clearly included submerged lands.

Alaska, 521 U.S. at 44.

Given the State's concession, for purposes of this appeal, that the 1873 executive order was intended to convey or reserve title to submerged lands, we focus on the second prong--whether Congress demonstrated an intent to defeat the State's title to the submerged lands. We conclude that Congress's actions prior to statehood clearly indicate its acknowledgment, express recognition, and acceptance of the executive reservation, thereby establishing its intent to defeat the State's title. Accordingly, we affirm the district court's ruling quieting title to submerged lands within the present-day Coeur d'Alene Reservation for the benefit of the Tribe. In light of our decision, we need not reach the Tribe's alternative arguments for affirmance.

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I. The State's Appeal--Submerged Lands

Relying on the events leading up to and surrounding the 1889 negotiations, the district court held that Congress demonstrated a clear intent to defeat the State's equal footing title. In particular, the court found that Congress was on notice that the executive reservation included submerged lands and that its 1889 authorization of negotiations with the Tribe for a cession of tribal property constituted recognition and validation of the executive reservation. Idaho argues that none of the events leading up to its statehood in 1890 constitute affirmative ratification of the executive intent to convey or reserve the submerged lands and thus cannot show congressional intent to defeat state title to these lands.

[3] In any submerged lands/equal footing case, a court must begin with a strong presumption against defeat of a state's title. See Alaska, 521 U.S. at 34. The Supreme Court has emphasized, however, that the question of whether title to submerged lands rests with a state is "ultimately a matter of federal intent." Id. at 36.

In Alaska itself, the Court held that the United States reserved title to the submerged lands within a petroleum reserve created by executive order 35 years prior to Alaska's statehood, see id. at 32-46, and to submerged lands within a wildlife refuge set aside by agency action (via an application and regulations) prior to statehood but not approved until after statehood, see id. at 46-61. In finding that the United States intended to include submerged lands within these reserved areas and to defeat state title to the lands, the Court emphasized that: 1) the reserves' boundaries were drawn so as necessarily to include the submerged lands, see id. at 36, 51; 2) the purpose of the reserves would have been defeated had the lands not been included, see id. at 39, 51-52; and 3) Congress

included language in the Alaska Statehood Act indicating that it retained Enclave Clause authority to the petroleum reserve,

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see id. at 41-42, and title to lands withdrawn or otherwise set aside as refuges for the protection of wildlife, see id. at 55-56.

[4] In this case, several similar factors counsel the same result.9 First, in both 1873 and 1889, the boundaries of the reservation were drawn so as necessarily to include submerged lands. Second, the purpose of the reservation would have been defeated had it not included these lands. Third--and this is the crux of the case--the series of congressional actions taken in the late 1880s (ascertaining that the Executive construed the reservation to include submerged lands and authorizing negotiations to recover whatever portion of the lands the Tribe was willing to sell) shows that Congress acknowledged that beneficial ownership of the lands had already passed to the Tribe. Congress's post-statehood actions also reflect recognition and confirmation of the passage of submerged lands to the Tribe. Both before and after statehood, Congress affirmatively treated the submerged lands as reserved for the Tribe.

We begin with the manner in which the boundaries of the reservation were determined. The reservation, which physi-

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9 We recognize that, in Alaska , the Supreme Court discussed the first two factors identified here--namely, the purpose of the reserves and the fact that their boundaries were drawn so as necessarily to include submerged lands--mainly with respect to whether the United States intended to include the submerged lands within the reserves. These factors likewise support a finding of executive intent to include in this case, as the State concedes for purposes of appeal. We also discuss these factors with respect to the "intent to defeat" prong for two reasons. First, the State argued that Alaska involved a "unique combination of necessity, purpose, and explicit statutory language" and also argued that the district court short-circuited the "purpose" analysis by "failing to determine Congress'[s] understanding of the purpose of the Reservation at the time of the alleged ratification of the 1873 Executive order. " Second, under the circumstances of this case, Congress's knowledge of the scope of the executive reservation--in particular, the boundaries of the reservation and the fact that they included submerged lands--is crucial. Accordingly, it is helpful to outline precisely what information Congress had before it.

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cally encompassed the submerged lands at issue, was created by a pre-statehood, 1873 executive order that drew the boundaries so as necessarily to include submerged lands. Crucial to the Tribe's acceptance of the 1873 reservation, as the district court found and the State does not dispute, was the inclusion of submerged lands. In addition, and significantly, when the 1873 boundaries were renegotiated in 1889, the "northern boundary line of the diminished reservation was drawn so as to bisect the Lake" specifically "for the purpose of establishing the Tribe's right to the Lake and rivers." The State likewise does not dispute this factual finding.

Both the Tribe and the agents sent out at the behest of Con-

gress in 1889 understood the reservation to encompass submerged lands. As noted, the reservation's boundaries were redrawn by the 1889 agreement to split the lake--a fact recognized in the legal descriptions of the cession, the verbal explanation given to the Tribe,10 and the maps submitted to Congress. As we recognized in another case in which we upheld tribal claims to submerged lands under the half of a lake within the borders of a reservation, "[i]t would have been pointless, and quite likely deceptive, to have the northern boundary of the reservation bisect Flathead Lake unless it was intended to convey title to the southern half of that lake to the Indians." Confederated Salish & Kootenai Tribes v. Namen, 665 F.2d 951, 962 (9th Cir. 1982) (further noting that "the most natural and intelligible way of understanding the boundary description is to infer an intent to convey the southern lake bed" and adopting this interpretation "in view of the Supreme Court's very frequent admonitions that doubtful language in Indian treaties must be construed in favor of the Indians and given the sense the Indians would have understood it to convey"). This observation is equally pertinent

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10 After the Tribe specifically rejected the suggestion that the "lake belongs to [it] as well as to the whites," a government negotiator told the Tribe that it "would still have the St. Joseph River and the lower part of the lake . . . ."

here, where the natural reading of all available documentation points to a purposeful division of the Lake.

[5] Considering together the district court's undisputed factual findings, the canon favoring Indians, and the fact that both the 1873 and 1889 agreements drew boundary lines across the lake--an unusual practice, as the district court pointed out--the executive reservation and subsequent renegotiation could only have been meant and understood to convey title to submerged lands within the reservation's borders.

[6] This conclusion finds further support in the fact that the purpose of the reservation would have been defeated had it not included submerged lands. As the district court found, and as the State does not challenge, the Tribe was dependent on its fisheries in 1873. The Tribe successfully insisted, both in 1873 and 1889, upon a reservation drawn to include submerged lands. In 1873, the reservation was expanded from its 1867 borders because the Tribe refused to settle on lands that did not encompass the Lake and its associated waterways. In 1889, the borders of the reservation were contracted and redrawn--but redrawn so as to ensure that the Tribe still had beneficial ownership of the southern third of the Lake as well as the portion of the St. Joe River within the 1873 reservation.

The State's argument that the district court should have determined the purpose of the reservation as understood by Congress (rather than the Executive), and as so understood in 1889 (rather than 1873) lacks support in the case law. In Alaska, where the Supreme Court relied heavily on the purpose of the reserves at issue, the Court did not require either that Congress itself apprehend the purpose or that the purpose be extant at the time of congressional action. See Alaska, 521 U.S. at 39, 51-52. The Court examined the purpose of the

petroleum reserve, for instance, with regard to the government's goal in 1923, when the Executive reserved the lands, rather than by reference to 35 years later when Congress passed the statehood act referencing its authority over the

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reserve. See id. at 39, 41-42. What mattered was that Congress recognized that the executive reservation included submerged lands, not that it knew or acknowledged the executive purpose in reserving them.11 See id. at 44 (providing for a showing that title to submerged lands does not pass to a state where Congress "explicitly recogniz[ed], at the point of . . . statehood, an executive reservation that clearly included submerged lands"). Thus, it is irrelevant that Congress may have believed the Tribe to have wholly or mainly converted to an agricultural lifestyle by 1889. Here there is no dispute that the government's negotiators and agents were aware of the Tribe's dependence on fishing in 1873. Indeed, even Congress was specifically on notice of this dependence as a result of the Tribe's second, 1872 petition. What matters, however, is Congress's awareness that the 1873 reservation included submerged lands, an issue about which there can be no doubt given the response to the 1888 resolution.

Turning now to the actions Congress took with respect to the reservation in the late 1880s, we conclude that this series

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11 Even cases specifically addressing tribal claims of right to submerged lands do not require that Congress apprehend the purpose of the reservation at the time it takes action recognizing the executive reservation. Rather, they focus on what the "United States " or the "government" knew as of the initial reservation. See, e.g., United States v. Aam, 887 F.2d 190, 195, 197 (9th Cir. 1990) (stating that "where courts have reviewed tribal claims of beneficial title to land under navigable waters, the inquiry focused on the circumstances surrounding the creation of the reservation" and noting "insufficient proof that the United States [by its officials or agents] perceived that the tribe depended on those particular tidelands"); Muckleshoot Indian Tribe v. Trans-Canada Enterprises, Ltd., 713 F.2d 455, 458 (9th Cir. 1983) (stating that "the United States was clearly aware that the focus of the Muckleshoot's world was on the rivers along which they lived"; that "[t]he Government knew, at least by the date of the 1874 Executive Order expanding the Muckleshoot Reservation, that the Indians depended on watercourses"; and that "[t]he Government's Indian agents understood that [t]he capture of fish was an essential source of [the Indians'] food supply") (internal quotations omitted); Puyallup Indian Tribe, 717 F.2d at 1258 (noting "the Government's awareness of the importance of the water resource to the Tribe").

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of actions demonstrates acknowledgment, recognition, and acceptance of the boundaries of the 1873 reservation, which Congress knew the Executive had construed to include submerged lands, thereby showing the requisite intent to defeat state title.

Formal ratification, prior to statehood, of the 1887 and 1889 agreements is not necessary for a finding of congressional intent to defeat state title.12 Neither the Supreme Court nor any of our cases require such a showing. Rather, the test is

whether Congress clearly intended to defeat the State's title to submerged lands. Here, Congress's course of conduct in ascertaining in 1888 that the Executive construed the reservation to include submerged lands and then authorizing negotiations in 1889 to purchase and thereby recover whatever

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12 Nor is inclusion of language in a statehood act--here the Idaho Admission Bill--specifying congressional intent to defeat state title necessary to a finding that Congress did, in fact, intend to defeat a state's title to particular submerged lands. In Alaska, the Supreme Court looked to the Alaska Statehood Act as a source of congressional intent in concluding that Congress intended to defeat Alaska's title to the petroleum reserve and wildlife refuge. See Alaska, 521 U.S. at 41-42, 55-56. Statehood acts, however, do not--and have never been held to--serve as exclusive sources of congressional intent with respect to the question of congressional intent to defeat state title.

We also note that there is significantly more evidence of congressional intent with regard to the submerged lands in this case than with regard to the wildlife refuge in Alaska. The Supreme Court found clear intent to defeat Alaska's title to the submerged lands within this wildlife refuge as a result of a fairly general provision of the Alaska Statehood Act. Under that provision, the United States retained "lands withdrawn or otherwise set apart as refuges or reservations for the protection of wildlife." Id. at 47, 55. Not only had the refuge in Alaska not yet been approved at the time of statehood--an administrative application for withdrawal of the lands in the proposed refuge was still pending when Congress passed the statehood act and when Alaska subsequently entered the Union--but Congress took no action either prior to or at statehood specifically with regard to the refuge at issue. By contrast, in this case, before statehood, Congress was often and actively involved in deciding the fate of the submerged lands within the Tribe's reservation.

portion of those lands the Tribe was willing to sell demonstrates its acknowledgment that beneficial ownership of the lands had passed to the Tribe.

As the district court found, when Congress authorized these negotiations, it was clearly on notice that the 1873 executive reservation included submerged lands within its confines.13 Congress also had the unratified 1887 agreement before it, an agreement that referenced the Tribe's "present[1873] reservation in the Territory of Idaho, known as the Coeur d'Alene Reservation" and that secured the cession, pursuant to Congress's 1886 authorization, of aboriginal lands "outside the limits of the present [1873] Coeur d'Alene reservation."

Although Congress had the opportunity and the power to repudiate the executive reservation and the 1887 agreement, it did not do so. Instead, in 1889 it took affirmative action, choosing to authorize negotiations--with few limitations aside from an instruction to acquire non-agricultural lands14 --"for the purchase and release by said tribe of such portions of its reservation . . . as such tribe shall consent to sell"

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13 Similarly, Congress's 1888 passage of an act granting a railroad a right-of-way through the reservation, identified as "set apart for the use of the Coeur d'Alene Indians by executive order, commonly known as the Coeur d'Alene Reservation," and conditioned on the Tribe's consent, also supports congressional recognition of the 1873 reservation, which [illegible]

gress by this point knew included submerged lands.
14 The events surrounding the authorization clearly show that the main purpose of the new negotiations was to regain from the Tribe whatever submerged lands it was willing to sell. The State itself notes that "as the district court recognized, the 1889 . . . Act was an authorization `to negotiate with the Tribe of a release of the submerged lands' " (quoting district court decision). Relevant events include the 1888 resolution; the response to that resolution; the events leading up to the resolution, such as the pressure, brought to Congress's attention, to open up the Lake; the negotiations themselves, which focused heavily on boundaries as they affected submerged lands; and a subsequent report from the Department of the Interior, which noted that little agricultural land had been acquired. See Message from the President, S. Ex. Doc. No. 14, at 2.

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(emphasis added). Act of March 2, 1889, 25 Stat. 980, 1002. The express reference to the reservation as the Tribe's reservation, explicit recognition that the choice to sell was the Tribe's, and reference to tribal release of portions of its reservation all manifest an awareness and acceptance by Congress of the boundaries of the 1873 reservation--boundaries that included submerged lands. This series of events indicates that Congress accepted the Secretary's advice to leave any cession up to negotiations. Indeed, the fact that Congress decided to make its authorization open-ended reinforces the district court's conclusion that Congress recognized and accepted the Tribe's beneficial ownership of all lands--including submerged lands--within the 1873 reservation; it also shows Congress's recognition of the uncertainty of regaining any land at all, and its particular desire to recover whatever submerged lands it could.

[7] In short, Congress "otherwise made very plain," Holt State Bank, 270 U.S. at 55, its intention regarding the submerged lands. With the 1887 agreement and the response to the 1888 resolution before it, Congress, fully aware of the boundaries of the 1873 reservation and the extent of the submerged lands that were within it, sought to modify the boundaries described in the agreement--and it sought to do so via purchase rather than the simpler expedient of rejecting the executive reservation. Although Congress may have been unhappy to learn that the executive reservation included submerged lands, its actions show recognition and acceptance of the passage of beneficial ownership to the Tribe, for it sought to regain as much submerged land as possible. The affirmative course of action on which Congress embarked in 1889 -- open-ended negotiations to purchase whatever non-agricultural land, particularly submerged lands, the Tribe was willing to cede--presupposes that beneficial ownership of all land within the 1873 reservation, including submerged lands, had already passed to the Tribe.

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To the extent that the State argues that reversal is necessary because the district court erred in relying on the disclaimer clause in the Idaho constitution,15 we reject this challenge. We do not read the district court's brief discussion of this clause as integral to its ruling. Nor, for that matter, do we believe reliance on the clause is necessary to affirm the judgment qui-

eting title to submerged lands within the present-day reservation. To the extent the clause is considered at all, however, it weighs in favor of the conclusion we have reached, for it disclaims title to land "held by" Indians. The lands in question were held by the Tribe, and Congress affirmed this provision when it ratified the Idaho constitution.16

We also note that although Congress has never undertaken by general laws to dispose of submerged lands, this case involves much more than a simple disclaimer clause or a general reference in the Idaho Admission Bill to accepting, ratifying, or confirming the Idaho constitution. Congress was heavily involved in deciding the fate of the submerged lands set aside for the Tribe's benefit by executive order. Congress

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15 This clause, found in article XXI, S 19, of the Idaho constitution, reads: ". . . . And the people of Idaho do agree and declare that we forever disclaim all right and title . . . to all lands lying within said limits owned or held by any Indians or Indian tribes[.]"

16 That such a disclaimer clause may be declaratory, conferring no new right or power on the United States, is immaterial. The substance of a declaratory clause is not meaningless, even if the clause itself is unnecessary in that it merely recognizes a preexisting interest. See United States v. Gardner, 107 F.3d 1314, 1320 (9th Cir. 1997) (finding constitutional clause disclaiming title to unappropriated public lands and explaining that although the U.S. "did not need the disclaimer clause to gain title to the public lands in Nevada," such a declaratory clause of a preexisting U.S. right to administer its property is valid).

We also reject as inapplicable to this case the State's argument that Congress cannot require states to disclaim rights of sovereignty as the price of admission to the Union. Congress did not do so here. All Congress did was to acknowledge and ratify, through its course of conduct, the executive reservation of certain submerged lands for the benefit of the Tribe.

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treated the submerged lands as beneficially owned by the Tribe--to the point of authorizing negotiations for cession of whatever portion of the Tribe's submerged lands it was willing to sell. The State's citation to Alaska v. Ahtna, Inc., 891 F.2d 1401 (9th Cir. 1989), is not instructive. There a provision in the Alaska constitution disclaiming all right and title to property that "may be held" by or in trust for natives stood alone, with no prior or specific congressional action referencing the submerged lands at issue, see id. at 1405-06; in addition, the executive conveyance in Ahtna did not occur until well after Alaska's statehood. See id. at 1403.

Finally, we note that in addition to the series of congressional actions prior to Idaho's statehood, Congress's post-statehood actions also reflect recognition and confirmation that submerged lands had passed to the Tribe prior to Idaho's statehood. Although these post-statehood events are not in themselves demonstrative of pre-statehood intent, nor are they central to our decision, neither can they be wholly ignored.17

[8] Among these events, the most notable is the 1894 Harrison cession, which was ratified just five years after the 1889 authorization to negotiate. The United States negotiated with the Tribe for the cession of a narrow strip of land extending

from the Lake to the eastern boundary of the reservation. Dur-

17 Although the State suggests that post-statehood events may not be considered in assessing congressional intent, we are aware of no rule forbidding consideration of such events. Indeed, the case law may suggest the contrary. See Alaska Pacific Fisheries v. United States, 248 U.S. 78, 89-90 (1918) (finding support for conclusion that Congress intended to include submerged lands within reservation in subsequent conduct whereby reservation was treated as including submerged lands). Cf. Aam, 887 F.2d at 194 (district court did not abuse its discretion in finding that matters occurring after Washington's admission in 1889 were too remote to be probative of the intent of the parties to an 1855 treaty or of the Secretary's intent upon enlargement of the reservation in 1864). Notably, Aam does not set forth any general rule barring post-statehood evidence, and it is also readily distinguishable, for the substantial time gap--40 years--motivating the Aam decision is not present here.

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ing the negotiations, the parties referred to the 1889 agreement as having created a boundary line in relation to the Lake, and they explicitly included a corner of the Lake in the cession. A cession that included a portion of the lake bed would not have been necessary absent a contemporary understanding that the Tribe had beneficial ownership of the bed. Moreover, as was the case with the 1889 agreement, the map submitted to Congress depicted the cession as including part of the bed, literally creating a right angle in the water. This post-statehood acknowledgment of tribal ownership of the lake bed is further confirmation, or reaffirmation, of the status of the submerged lands within the reservation. It is tantamount to a memorialization of prior events, especially given that nothing occurred between statehood and the negotiations for the Harrison cession that altered the ownership situation. Just as Congress would not have negotiated with the Tribe for land the Tribe did not own, so too the United States, on behalf of the Tribe, would not have ceded to the State land that the State already owned.

The same can be said for the course of events leading to the creation of the Park. In 1908, Congress withdrew from allotment, for use as a park, a portion of the reservation embracing three smaller lakes adjacent to the southern end of the Lake, and in 1911 it formally transferred this area to the State. There would have been no need for the United States to withdraw the lands comprising the Park from the reservation and no need for the United States to convey these lands by patent to the State if the State already owned them. We thus have another significant example of the contemporary understanding of all parties concerned with regard to the Tribe's beneficial ownership of submerged lands within its reservation.

II. The Tribe's Cross-Appeal--Heyburn State Park

The cross-appeal raises the question of whether the district court erred in refusing to decide ownership of submerged lands within the Park. We must decide whether the parties'

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pleadings18 --specifically, the United States' complaint and

the State's counterclaim--put at issue submerged lands within the Park. Resolution of this question requires a careful and commonsense reading of the pleadings. We reject the cross-appeal because the complaint, read as a whole, does not include lands within the Park and the United States disavowed any intent to quiet title to submerged lands within the Park. Further, the relief the State seeks in its counterclaim largely mimics the United States' prayer for relief, and the State has likewise disclaimed any intent to litigate issues beyond those raised in the United States' complaint. Accordingly, we conclude that the district court properly declined to adjudicate the ownership of these submerged lands.

Neither the complaint nor the counterclaim put submerged lands within the Park at issue. The complaint, taken as a whole, is most naturally read to exclude these lands. First, it specifically identifies the lands that comprise the Park as having been "withdr[awn] from allotment" and "reserved" by the United States. It then juxtaposes these lands, along with other lands that the Tribe ceded to the United States, with lands identified as "still remaining within the Coeur d'Alene 1873 Reservation." The implication is that the United States sought to exclude any lands within the Park from the ambit of the complaint. In addition, the complaint's prayer for relief repeatedly makes reference to the "approximate southern one-third of Coeur d'Alene Lake as well as those portions of the beds and banks of the St. Joe River located within the 1873 Coeur d'Alene Indian Reservation." That the complaint references a specific part of the Lake and the St. Joe River while

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18 In construing the parties' pleadings, we bear in mind that the current physical situation in and around the Park differs from the situation that existed in 1873, at the time of the executive reservation, and in 1908 and 1911, the years, respectively, that the Park was authorized and conveyed to the State. Due to the construction of a dam, three small lakes have combined with the Lake into one large body of water. We read the United States' complaint in light of the physical situation as it existed prior to the construction of the dam.

mentioning none of the three lakes that were the subject of the conveyance to the State strongly suggests that the United States sought to exclude the Park from this quiet title action.

Our reading of the complaint is supported by the conduct of the United States throughout this litigation. Significantly, the United States has pursued this action, both in the district court and on appeal, only as to submerged lands within the present-day boundaries of the reservation. Indeed, at the district court level, the United States expressly disavowed any claim to submerged lands within the Park. Under these circumstances, we will not read the more general language in the complaint's caption and preliminary statement, which refer to portions of the Lake and St. Joe River within the exterior boundaries of the 1873 reservation, as extending to submerged lands within the Park.

We also reject the Tribe's argument that the State itself put submerged lands within the Park at issue via a counterclaim in which it asserted that it was "entitled to a judgment . . . quieting its title to the beds and banks of those portions of Lake

Coeur d'Alene and the St. Joe River located within Heyburn State Park."19 Although the counterclaim incorporates the allegations in an affirmative defense claiming title to "all lands within" the Park, the State's prayer for relief largely mimics the United States' prayer, which is far narrower than the affirmative defense. In its prayer for relief, the State seeks to quiet title to "those portions of Lake Coeur d'Alene and the St. Joe River within the present boundaries of the Coeur d'Alene Reservation and Heyburn State Park." Notably, and in contrast to its affirmative defense, the State does not name in its prayer for relief any of the three lakes originally embraced by

19 The State's answer included two sections referencing the Park: 1) an affirmative defense in which the State claimed title to "all lands within Heyburn State Park as a result of . . . federal actions" authorizing the Park and conveying its lands to the State by patent; and 2) the above-quoted counterclaim. Only the counterclaim is at issue.

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the Park, and it has consistently disclaimed any attempt to litigate any issue beyond that raised in the United States' complaint.

Because the United States disavowed any claim to submerged lands within the Park, the State disavowed intent to litigate any issue beyond that raised by the United States, and a fair reading of the relief requested in both the complaint and counterclaim does not, under the circumstances, encompass lands within the Park, the district court properly declined to adjudicate the ownership of submerged lands within the Park.

AFFIRMED.

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REFERENCE:

COEUR D'ALENE TRIBE

850 A STREET
P.O. BOX 408
PLUMMER, IDAHO 83851
(208) 686-1800 • Fax (208) 686-1182

May 24, 2000

Mr. Robert G. Haynes, P.E., Regional Manager
Idaho Department of Water Resources
1910 Northwest Boulevard, Suite 210
Coeur d'Alene, ID 83814

Subject: Coeur d'Alene Lake Water Right Application Number 95-09045, CAG Investments, LLC

Dear Mr. Haynes:

This letter serves as a protest by the Coeur d'Alene Tribe regarding the application to appropriate water from Lake Coeur d'Alene submitted by CAG Investments, LLC for the purpose of irrigating a golf course and 350 residences directly above Rockford Bay. The Tribe's cause for protest is written in terms of the 6 criteria that the Idaho Water Resources uses to evaluate protested applications. As you are aware the Tribe attempted to file a timely protest but was given incorrect dates of publication and deadline date for protest by the Idaho Water Resource Department. As a result of this misinformation the Tribe did not learn of the correct deadline date for protest until after the deadline had passed. The Tribe therefore requests this protest be deemed as timely filed.

1. Will the proposed appropriation injure other water rights? The Tribe believes that there is the possibility of injuring other water rights due to the volume of water that is proposed for use, especially during summer low water flows into Lake Coeur d'Alene and out to the Spokane River. There are also domestic water permits and intakes close to the proposed intake for CAG Investments, LLC which may be injured as well.
2. Is the water supply sufficient for the purpose for which it is sought to be appropriated? The Tribe believes that it is possible that the water supply is insufficient to support the 3.5 cubic feet per second (cfs) without affecting lake levels in and around Rockford Bay as well as the Spokane River. In addition, to the Tribe's knowledge, there has never been a minimum lake level established so it is difficult to know whether or not there is sufficient water for 3.5 cfs to be withdrawn. A permit to appropriate a volume of water as large as this should not be grated unless these questions are answered based upon sound scientific data.
3. Was the application made in good faith or for delay or speculative purposes? The Tribe does not wish to protest regarding this criteria.
4. Does the applicant have sufficient financial resources with which to complete the proposed project? The Tribe does not wish to protest regarding this criteria.
5. Will the proposed use conflict with local public interest, where the local public interest is defined as the affairs of the people in the area directly affected by the proposed use? The Tribe believes that granting a permit to appropriate water to irrigate a golf course and 350 residences from Lake

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Coeur d'Alene conflicts with local public interest. The Tribe retains ownership of the southern third of Lake Coeur d'Alene, adjacent to Rockford Bay. The Tribe believes that the application for the water appropriation permit conflicts with the public interests of the citizens of the State of Idaho as well as Coeur d'Alene Tribal members. This conflict arises from the fact that the adjacent surface waters of the lake below Rockford Bay, from the mid-channel of the Coeur d'Alene River outfall into Lake Coeur d'Alene are Tribal and public resources under the jurisdiction and management of the Coeur d'Alene Tribe, and the application to beneficial use will occur within the boundary of the Coeur d'Alene Indian Reservation.

The conflict is increased by the fact the proposed use of the water is to irrigate a golf course and 350 residences directly upslope from Rockford Bay and the shores of Lake Coeur d'Alene. Fertilizers, pesticides and other pollutants will run downslope into Lake Coeur d'Alene in direct conflict with local public interest. Water quality has been a concern in Lake Coeur d'Alene for decades due to the importance of recreation, fisheries and other uses. There are potential human health risks regarding nutrients increasing the bioavailability of a large volume of heavy metals (i.e. lead, cadmium) deposited in the lakebed through mining activities. It is in the public and Tribal interest to safeguard water quality in Lake Coeur d'Alene. It is also possible that the four wells that have been developed on site for drinking water will not be sufficient to irrigate a golf course and 350 residences and, therefore, the threat of runoff into the lake can be minimized by not granting a surface water permit for lake water.

6. Will the proposed use be contrary to the conservation of water resources within the State of Idaho? The Tribe believes that, for the reasons stated above, the use of this large volume of water, and the impacts that the use will have on the water resources of the State of Idaho and the Coeur d'Alene Tribe, is contrary to the conservation of water resources. Additionally, the Tribe is concerned about the water intake adversely affecting the native fisheries in Lake Coeur d'Alene.

The Tribe is concerned about the long-term health and viability of Lake Coeur d'Alene for all of the local residents and visitors alike. The Tribe urges the State of Idaho Department of Water Resources to deny the application for permit number 95-09045 in order to protect the water resources for present and future generations. In the alternative, the Tribe requests the Department delay the decision until sufficient scientific data can be collected to show that the permit will not adversely affect the lake's water resources. In any event, permit approval should be withheld pending development of a government-to-government compact on water and lake management between the Tribe and the State of Idaho. If you would like to discuss this issue further, please contact Ms. Tiffany Allgood, the Tribe's environmental planner, at (208) 686-8802.

Sincerely,

Ernest L. Stensgar
Chairman

Cc: Howard Funke, Attorney; Tara Salisbury-Allgood, Attorney; Alfred Nomee, NR Director; Tiffany Allgood, EAP Coordinator

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THE Idaho SPOKESMAN-REVIEW
AN EDITION OF THE SPOKESMAN-REVIEW

Neighbors appealing subdivision

Suit claims zoning ordinances violated in Cougar Bay decision

By Angie Gaddy
Staff writer

COEUR d'ALENE — The opponents of a planned subdivision overlooking Cougar Bay have appealed the Kootenai County Commission's decision to approve the development.

In a lawsuit filed last Thursday in 1st District Court, the Rural Kootenai Organization says commissioners should not have approved The Ridge at Cougar Bay last month. The group had 28 days to appeal the commissioners' decision, said Jan Gera, with the Kootenai County Planning office.

The plan calls for 92 homes on 118 acres overlooking the largely undeveloped area of Lake Coeur d'Alene.

Neighbors have battled the project for seven years, taking the case all the way to the Idaho Supreme Court.

At issue was whether developer Mike McCormack could use a strip of federal Bureau of Land Management property as open space.

Last December, the Supreme Court ruled county commissioners must reconsider the development without allowing 80 acres of submerged public land to be used as open space.

In their suit, the neighbors say the commissioners violated county zoning ordinances when they approved the subdivision.

Chuck Sheroke, the group's attorney, said they have concerns about the commissioners' procedures for approving the development.

He said their time to voice concerns at the meeting was limited, but the developer's time was not. He said that the group was also not able to look at the plans.

"We had no opportunity to review it," Sheroke said.

McCormack said he believes the appeal is just another attempt to stall the development.

"Honestly, it's just a delay," he said. "That doesn't mean we won't go ahead."

McCormack said he hopes to begin groundwork within the next six months.

"They're harassing us is what it is. I feel sorry for any other applicants who have to go through the process."

THE Idaho SPOKESMAN-REVIEW
AN EDITION OF THE SPOKESMAN-REVIEW

Nudist resort given approval

By Thomas Clouse
Staff writer

Split vote huge relief to couple who started 75-acre resort off Conklin Park Road

COEUR d'ALENE — In a split vote Wednesday, Kootenai County commissioners approved a resort near Worley that hopes to cater to nude recreationists.

The 2-1 vote to approve Sun Meadow Resort was a huge relief to owners Tom and Linda Janson, who have sunk their life savings and retirement into the plan.

"I was pretty confident that they would do the right thing," Tom Janson said of the commissioners. "I know (Commissioner) Ron Rankin was trying to find some reason to deny it because he has moral issues. "But if you look into it, the moral issues don't come into play. I think we would have less moral problems if (the public) had better body acceptance."

The Jansons have already started building their 75-acre resort off of Conklin Park Road, between Worley and Lake Coeur d'Alene.

The development includes 43 recreational vehicle hookups, 10 rental cabins and a 16,000-square-foot lodge with 10 rooms. The adjacent Sun Meadow Estates would include 16 residential lots.

The commission voted last year to approve the resort and subdivision. After that decision, critics of the plan discovered Internet advertising that indicated the Jansons had plans for a nudist resort.

Continued: **Resort/B8**

Resort: Worry about impact on rural area

Continued from B1

Neighbors appealed the case, and 1st District Judge Charles Hosack sent the project back to the county commissioners, saying the Jansons had a duty to tell county officials about the "potential intended uses" of their property.

Rankin, who voted for the project last year, said he had concerns about the project's impact on the rural area even before nude recreation became a factor.

On Wednesday, Rankin made a motion to deny the permits for the resort and subdivision.

"I believe because of the public perception of this (nudist colony) being a nuisance, that this would have an adverse affect on values of the surrounding property," Rankin said.

Commissioner Dick Compton, who made the motion to approve the project, said he voted for the project the first time because it was a good plan.

"Then we found out they might be inclined to take their clothes off," Compton said. "There is no evidence that property values would be reduced.

"My decision was based on the fact that the (planned unit development) met all the zoning ordinances."

Commissioner Dick Panabaker said the project should be judged on whether it fits within county planning guidelines.

"There has been no nudity, no violation of state law," Panabaker said. "The perception may or may not be there that this will be a problem."

If any legal problems surface in the future, they will be handled by the courts, not by county planners, he said. Panabaker then seconded Compton's motion to approve.

Janson hopes to have "clothing mandatory" family nights, corporate parties and retreats at the resort. The only nude recreation would come from the association members, he said.

The homes in the subdivision will not be part of the nude recreation facilities.

The commissioners visited the site last month to check the privacy aspect of the resort and to look at the already completed work.

Crews have planted about 6,000 trees around the subdivision and another 3,000 near the resort. Berms were also built to conceal the project.

Before any nude recreation takes place, Janson says he will finish the project and have it certified by the American Association of Nude Recreation.

Chuck Matheson, a Coeur d'Alene Tribal Council member, said he was disappointed with the commission's vote.

The tribe fought the project based on land-use issues before the nudist colony controversy erupted.

"Our main concern was with Mother Earth. If you put a couple 100 people out there, obviously deer and elk won't go there," he said. "The only problem we had about the nudist aspect was that they weren't up front with everybody."

Janson said he planted clover and fescue and has recently seen more wildlife on the acreage than before they started building.

He hopes to have an open house in September to let neighbors and people in the Worley-Plummer area visit the resort.

Janson had hoped to open the resort next spring, but the appeal from its neighbors has stalled the project by more than a year.

"If their objective was to hurt us, they hurt us," Janson said. "It cost a whole lot more money than legal fees. But we are still going to get it done."

LAKE WATER QUALITY ASSESSMENT

COEUR D'ALENE LAKE

Benewah & Kootenai Counties, Idaho

January, 1991

pg 21, 25 & 39

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LAKE WATER QUALITY ASSESSMENT

COEUR D'ALENE LAKE

Benewah & Kootenai Counties, Idaho

January, 1991

Compiled by:
Ed Javorka, Coeur d'Alene Basin Interagency Group

for

COEUR D'ALENE TRIBE OF IDAHO

Tribal Headquarters--Coeur d'Alene Subagency
Plummer, Idaho 83851

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LAKE WATER QUALITY ASSESSMENT

COEUR D'ALENE LAKE, IDAHO

PURPOSE

Purpose of this assessment is to:

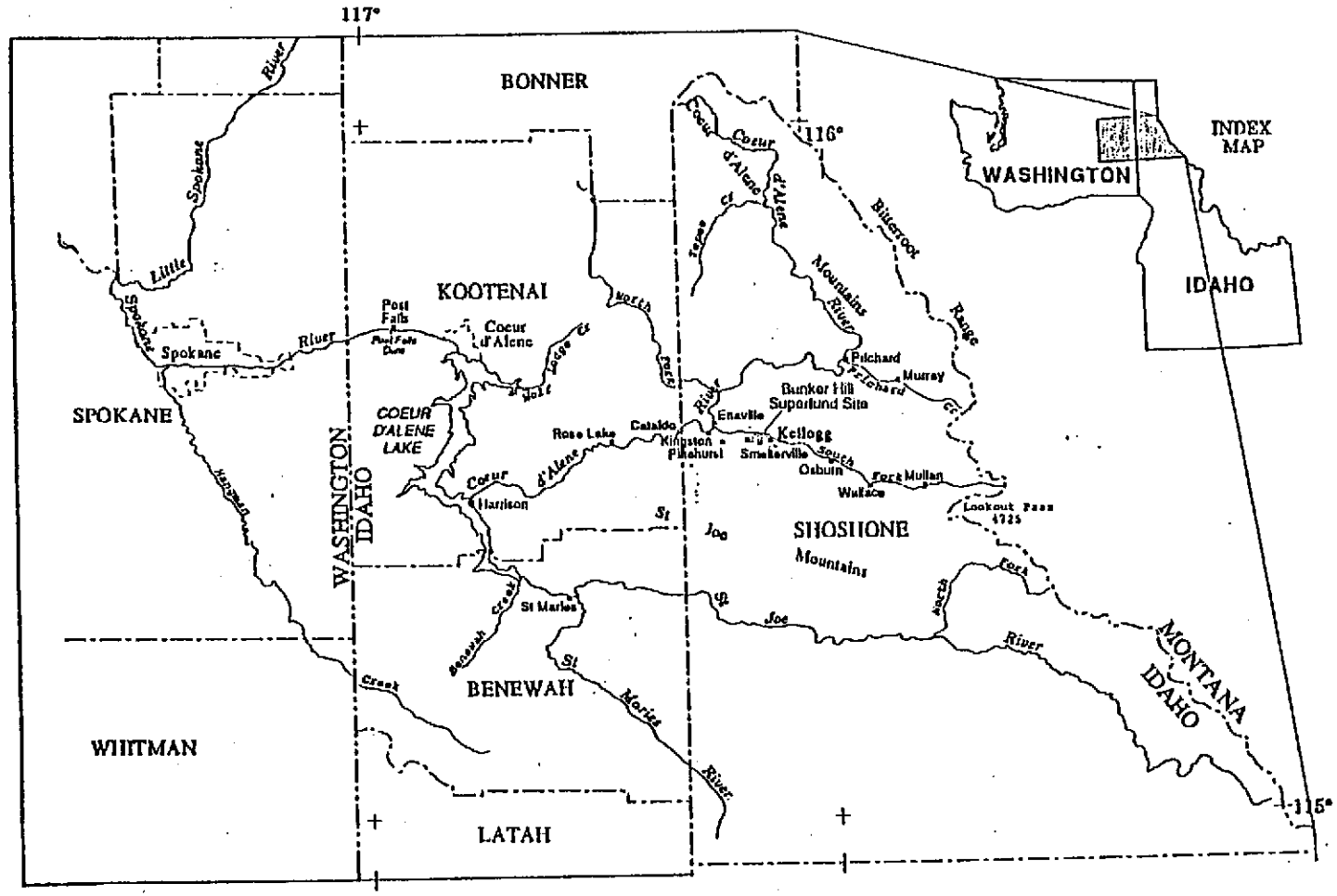
- summarize the available information and data on Coeur d'Alene Lake and its watershed;
- provide a description of the lake, water quality, water quality standards, uses and impairments;
- identify trends or possible changes in pollution sources or levels which may result in a loss or decline in future beneficial uses.

SECTION I: INTRODUCTION AND DESCRIPTION

Coeur d'Alene Lake (locally called Lake Coeur d'Alene) is located in the northern panhandle of Idaho, in Kootenai and Benewah Counties. Almost all of the lake lies in Kootenai County, with the approximate center of the lake located at Latitude 47°40', Longitude 116°45'. The city of Coeur d'Alene abuts the lake on the northern shore, just east of the outlet. The lake is about 24 miles in length with an average width of 2 miles, and is bounded by a shoreline of approximately 133 miles (Parker, 1972).

Although Coeur d'Alene Lake is a natural lake, its size, depth, shoreline configuration and limniological characteristics are impacted by a hydroelectric dam located near Post Falls, Idaho.

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Base compiled from U.S. Geological Survey
State base maps 1:1,000,000

Figure 1.--Location of Coeur d'Alene Lake.

This dam, owned and operated by the Washington Water Power Company, has controlled the lake level since 1906. The maximum pool elevation is 12 feet.

The construction of this dam and hydroelectric facility on the Spokane River significantly contributed to the present size of the lake at its southern tip. Thousands of acres were flooded when the dam's control gates were closed. This shallow, southern portion of the lake includes four smaller lakes--Chatcolet, Round, Hidden and Benewah. Under normal summer levels these lakes appear as one body of water, fully accessible by boat from the main body of the lake. These smaller "lakes" are much shallower than the main lake; one author described this four-lake area as a "huge marsh bisected by the St. Joe River" (Rabe, 1974). Figure 2 shows the relationship of these four small, shallow lakes to the main lake and the Coeur d'Alene Indian Reservation boundary.

The lower Coeur d'Alene River and Coeur d'Alene Lake vicinity have been the preferred homeland for the Coeur d'Alene Tribe for hundreds of years. In the early 1840's, about 2000 native Americans inhabited the area, with a number of them located along Coeur d'Alene Lake's eastern shore (Rabe, 1974). The current Tribal Reservation boundary encompasses about one-third of the lake's southern shores, but the Tribe does not exercise any direct control over the lake or fishery resource.

Coeur d'Alene Lake remains an important social, cultural and food resource for the Coeur d'Alene Tribe. The Tribe has been cooperating with the Northwest Power Planning Council and Bonneville Power Administration in an attempt to mitigate lost

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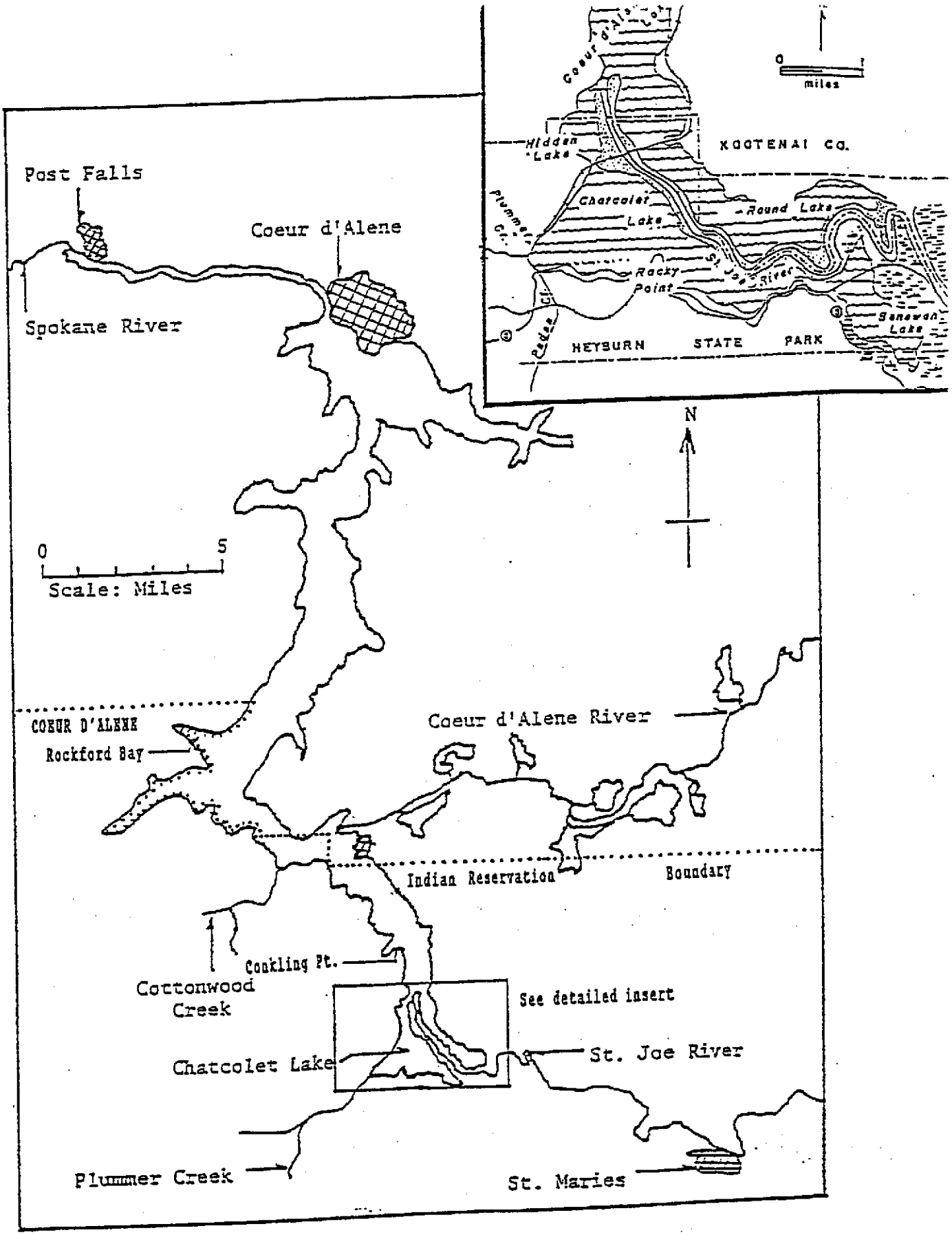


Figure 2.--Coeur d'Alene Lake

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resources resulting from dam construction. Rehabilitation of degraded fish habitat and construction of a cutthroat and bull trout hatchery have been approved (Scholz, 1989).

Coeur d'Alene Lake has special status in Idaho statutes. Under Idaho Code section 70-201 (enacted in 1931), a special lake commission was authorized. The commission's purpose is to investigate how to eliminate or prevent industrial wastes and pollution in the Coeur d'Alene River and Lake. In 1927, under Idaho Code section 67-4304, the waters of Coeur d'Alene, Pend Oreille and Priest Lakes were placed in trust for the people of Idaho. These lake waters are to be preserved for "scenic beauty, health, recreation, transportation and commercial purposes...", and were declared to be beneficial uses (Turner, 1990). The Idaho Department of Lands administers and controls uses and infringements of the lake's bed, banks and surface waters.

A 1983 Idaho Lake classification project identified Coeur d'Alene Lake as one of 6 lakes (from a total group of 85 Idaho lakes) in Priority 1. This top priority group highlights lakes that should receive immediate management consideration for protective or corrective measures. Coeur d'Alene Lake was include in this top listing due to its "high economic and sociologic importance....to the region. It is a very heavily used lake for recreation" (Milligan, 1983). Although this same classification study ranked Coeur d'Alene Lake in the "best" one-third in respect to a trophic status index, it is second only to Hayden lake (in the entire state) in Milligan's shoreline development index, and in the top 7 lakes in respect to lake use potential (Milligan, 1983).

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Lake Chatcolet is also ranked as a Priority 1 lake in Milligan's classification report, primarily because of its central importance to Heyburn State Park, plus a "high use" and a "high management" potential. Benewah Lake was prioritized in Group 3. Lakes in this group are either oligotrophic or eutrophic where uses do not justify concern for water quality improvements; this lake has a mean depth of only 0.8 meters (2.6'), and appears to be more wetland that lake (Milligan, 1983).

The entire lake complex (including the four lakes described previously) is extremely popular for motor and sail boating, fishing, water skiing and swimming. Although accurate recreational use statistics are not available, Coeur d'Alene Lake is the most heavily-used waterway in north Idaho, and probably is in the top 2-3 recreation use lakes in the state of Idaho. Public use facilities include:

26	Public boat launch/dock facilities
4	Public beaches
2	State parks
1	National forest campground

A major, internationally-known year-round destination resort complex on the lake's north shore continues to grow, attracting increasing numbers of tourists and lake users. Probably no other lake in Idaho is experiencing more of an increase in use and attention by out of area tourists and visitors.

Coeur d'Alene Lake has become a prime recreational, residential and summer-home site because of its beautiful setting, high-quality fishery, and proximity to the cities of Spokane

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(metropolitan-area population 285,000) and Coeur d'Alene (population 25,000). Population growth within 50 miles of the lake was 24 percent between 1970 and 1980; by 1980 the lakes's 133 mile shoreline was 80 percent developed (Milligan, 1983). Population growth and development in the Coeur d'Alene area has continued among the highest in Idaho and the Northwest. The 1990 Census results show Kootenai County's population at 69,800, a 16.8 percent increase over 1980. By comparison, Idaho's population grew at a rate of 6.7 percent.

The Idaho Department of Fish and Game considers the fishery to be one of the most important in the state. Economic value of the Coeur d'Alene Lake fishery was $3 million dollars in 1979 with 350,000 hours of effort expended by fishermen (Woods, 1989).

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SECTION II: LAKE AND WATERSHED CHARACTERISTICS

It is difficult to generalize about Coeur d'Alene Lake if the four floodplain lakes at the mouth of the St. Joe River are included. It is the second largest Idaho lake with 32,000 acres (Bear Lake is larger, but a significant portion is in Utah). Table 1 summarizes some of the details of the main lake and four flood plain lakes.

Table 1.

COEUR D'ALENE LAKE SIZE AND DEPTH

Lake	Maximum Depth	Mean Depth	Size	Volume
Main Lake Body	180' (55.0)[1]	98' (30.0)[1]	32000	238,500
Chatcolet Lake	36' (11.0)	11' (3.3)	1743	23,000
Benewah Lake	14' (4.3)	2.6' (0.8)	341	----
Round Lake	----	----	1001	----
Hidden Lake	----	----	130	----

Milligan, 1983.
Depth: feet and (meters)
Size: acres Volume: acre feet
(1) 200' (61 m) and 70'(21.2 m) according to Woods, 1989.

The lake is located in the 17,300 square-kilometer (4,275,000 acres) Spokane River drainage basin (fig. 1), which drains to the Columbia River in eastern Washington. The lake's 9,600 square-kilometer drainage basin lies within the Northern Rocky Mountain Physiographic Province which is characterized by high, massive mountains and deep, intermountain valleys. Elevations range from 648 meters (2125') at the surface of Coeur d'Alene Lake to 2,344 meters (7690') on the Bitterroot Divide near St. Joe Lake (Woods, 1989). Coniferous forests cover the majority of the watershed.

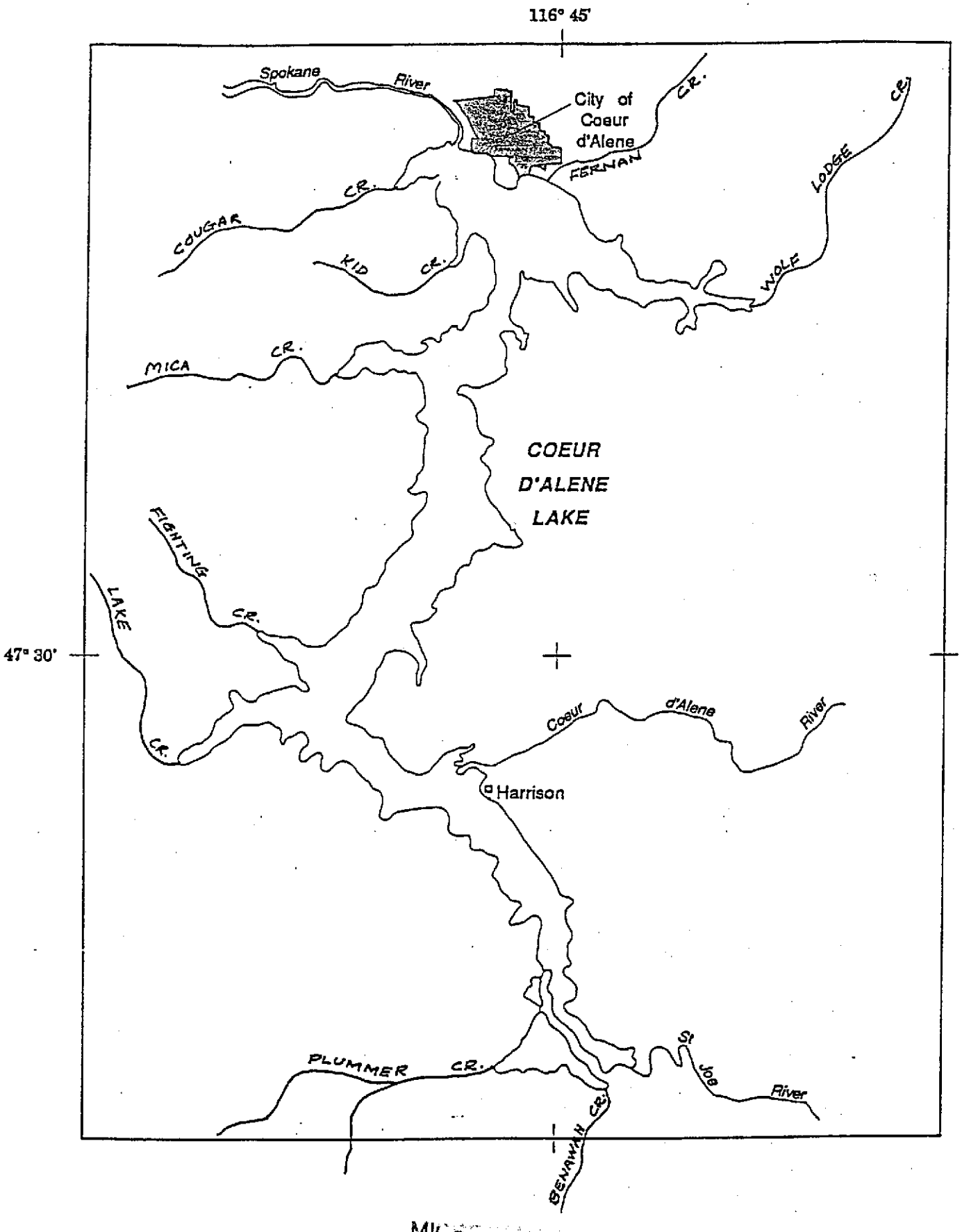
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The area receives some of the largest amounts of precipitation in Idaho. Coeur d'Alene has a mean annual precipitation of 655 millimeters (26") whereas Wallace receives 971 millimeters (38"). About 70 present of the annual precipitation occurs as snow during October to April. Although winter temperatures at Coeur d'Alene Lake are often below freezing, the lake infrequently freezes except in its shallow bays (Woods, 1989).

The surface water flow into the lake is via two major rivers, the Coeur d'Alene and St. Joe, as well as numerous minor tributaries such as Wolf Lodge, Lake, Plummer and Benewah Creeks (Figure 3). The lake's outlet is the Spokane River, which is regulated by the Post Falls dam for hydroelectric production and flood control. Retention time in the lake is 0.48 year (Woods, 1989). The two large rivers contribute 94 percent of the 6,335 cubic feet/second (cfs) of inflow to the lake. The lake's volume is about 238,500 acre feet (Meckel Engineering et al., 1983).

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COEUR D'ALENE LAKE
MAJOR DRAINAGE BASINS



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Table 2.

Tributaries of Coeur d'Alene Lake, Idaho

Watershed	Size			Discharge		
	Acres	Sq.Mi.	Sq. Km.	(1) Annual Inflow	(2) Mean Flow	(1) Annual Outflow
St. Joe River	1,107,000	1,730	4,480	2.45	3,394	----
Coeur d'Alene River	946,000	1,480	3,830	2.28	2,556	----
Wolf Lodge Creek	37,800	59	153	---	52	----
Benewah Creek	33,900	53	137	---	25	----
Lake Creek (3)	24,900	34	89	---	23	----
Plummer Creek	27,700	43	112	---	11	----
Other	254,700	398	1,031	---	273	----
Spokane River (Outlet)	----	----	----	---	6,234	5.69
	2.432					

Sources: Woods, 1989; USGS, 1990; Meckel Engineering et al., 1983; IDHW/DEQ, 1990 and 1990 a.
(1) billion cubic meters (2) cubic feet/second (3) 5,700 acres in Washington

Coeur d'Alene River Basin

This watershed is located almost entirely in Kootenai and Shoshone Counties (98 percent); two small portions fall within Bonner and Benewah Counties. The two major subunits - North Fork and South Fork - are generally mountainous and steep with narrow valleys. Almost all of these upper drainages are heavily forested with mixed conifer stands. From Wallace on the South Fork and downstream to the lake, the valley bottom broadens considerably, and incorporates an extensive flood plain. Less than 5 percent of the entire watershed is in pasture, hay, cropland, urban, mining or

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other land use. Over 90 percent is controlled by federal or state agencies. Approximately 22,000 acres (in Kootenai and Benewah Counties) are within the Coeur d'Alene Indian Reservation boundary.

Mountain areas are composed mostly of metamorphic and metasedimentary rock formations. Mountain soils are generally productive, well-drained, deep to very deep soils formed in volcanic ash and loess over weathered metasedimentary and granitic rock. Several thousand acres (4370 acres in Kootenai County alone) of "slickens" soils are found in the river bottom from Kellogg downstream to the lake. These flood plain deposits consist of mine tailings and alluvium from yearly overflow. Typically this material is ground rock mixed with soil and organic materials; the salinity and high concentrations of trace minerals (zinc, lead, cadmium et al.) create detrimental conditions for plant growth and most uses (Soil Conservation Service, 1981). These river bottom mine tailing deposits plus related trace metal pollution from the Silver Valley mining district and Bunker Hill Superfund Site play a critical role in the lake's water quality and aquatic habitat.

St. Joe River Basin

This larger watershed enters Coeur d'Alene lake at its extreme southern end. The geology, physiography and general soils situation are broadly similar to the Coeur d'Alene River watershed, particularly in the upper drainage mountain slopes. Portions of the St. Maries subdrainage incorporate deep loess soils with volcanic ash influence similar to the Palouse-type soils that surround the lake itself (Soil Conservation Service, 1984).

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A unique feature of the St. Joe River is a narrow, levee-like delta that juts into the lake system for several miles (Figure 2). These winding embankments separate Chatcolet, Hidden and Benewah Lakes (on the south) from Round Lake and the main lake on the north. This narrow meandering delta constrains the colder, slow-moving flow of the river and prevents mixing with the warm and shallow lake water until it is well into the lake. Wind and wave action plus annual water level fluctuations have substantially increased erosion and sloughing of the narrow river banks, adding to the lakes' sediment load (Stevens et al., 1973).

The impacts of St. Joe River flows upon Chatcolet Lake were examined in 1989. Results indicate that the St. Joe does not effect concentration of phosphorus or sediment in Chatcolet Lake (IDHW, 1990a).

Westside, Lake and Plummer Creek Watersheds

Practically all of the small watersheds west of Coeur d'Alene Lake (including Chatcolet and Benewah Lakes) are predominantly deep soils of loess and/or ash origin. The entire western slope of the lake is heavily modified by agricultural, grazing, silvicultural uses and urbanization, with numerous highways and roads. Most of this area is in private, small ownerships. Cumulative impact from sediment and nutrients in these numerous, small watersheds may be as critical to the long-term health of the lake as the two larger river basins.

Lake and Plummer Creeks on the west/southwest slopes of Coeur d'Alene lake (totalling about 56,600 acres) represent a significantly different watershed situation than the two large

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watersheds previously described. The upper basins, north slopes and stream bottoms are generally forested lands, but 43 percent of these watersheds are intensively developed for cropland, pasture, hay or urban uses. Soils are mostly deep/very deep loess or volcanic ash deposits on undulating to hilly, very steep slopes (IDHW 1990, 1990a; Soil Conservation Service, 1984).

Both of these drainage systems measurably effect suspended sediment and nutrient loading of Coeur d'Alene Lake or Lake Chatcolet, and contribute to the overall nonpoint pollution problem for the total lake system (IDHW 1990, 1990a; Benewah Soil & Water Cons. Dist., 1990). A water quality study of 5100 acres along the lake's western shores (located between Lake and Plummer Creeks) further substantiates the impacts of agricultural uses on these very productive but erosive soils (DeSmet, 1986).

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Section III: CURRENT WATER QUALITY

Meckel et al. provides a good summary description of Lake Coeur d'Alene in the 1983 Kootenai County Lakes Master Plan:

"The southernmost portion of the lake is shallow, less than 7 meters, and dense growths of macrophytes occur from mid-summer to early fall. Nutrients are abundant and the warm shallow waters well mixed. Phytoplankton communities are poorly developed, possibly because of competition from the dominant macrophytes. Data indicate that this part of the lake is strongly mesotrophic, the shallowest areas eutrophic.

The portion of the lake extending south from Rockford Bay to Conkling Park is mesotrophic (Parker, 1972), has an average depth of more than 15 meters, and is rich in nutrients. It supports a dense diatom population, with development of a blue-green algal community in August.

The northern half of the lake, from the city of Coeur d'Alene (including the Post Falls reservoir) south to East Point, is oligotrophic. Open-water depths average greater than 20 meters, and nutrient concentrations are moderately low. The plankton community is composed of low concentrations of diatoms. Although classified oligotrophic, certain of the shallower bays in this part of the lake have recently exhibited eutrophic characteristics in late summer. In the past these bays have been defined as mesotrophic.

The algal community in the lake typically shifts from diatoms in spring and early summer to blue-greens in the southern portion until August. This suggests that the shift may be related to water temperature. The most numerous phytoplankton are the yellow-green algae, Chrysophyta. These include the diatoms Melosira, Tabellaria, Asterionella, Synedra, and Fragilaria. Green algae, Chlorophyta, are less abundant, the most common species being Phacotus, Chlamydomonas, Ankistrodesmus, Cryptomonas, Chroomonas, Genicullaria, and Chlorella. Blue-green algae, Cyanophyta, present

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in late summer include Aphanizomenon flos-aquae, with some Nostoc and Anabaena.

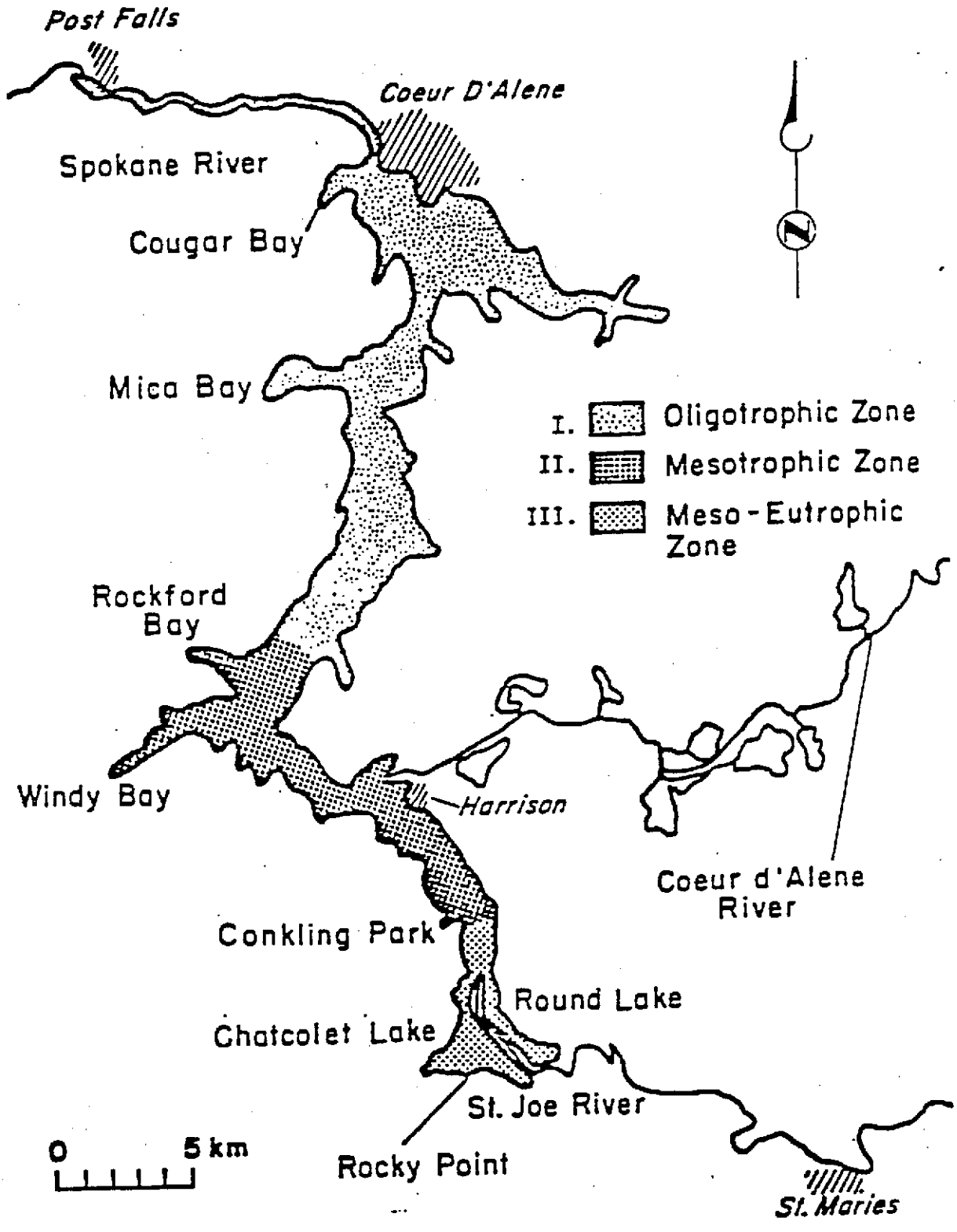
Rooted aquatic plants such as Potamogeton, Meriophyllum, and Anarchis form dense communities in shallow areas of the lake. These are particularly abundant in the southern portion of the lake, where a combination of high nutrient concentrations, deep light penetration, and silty substrate provides a desirable habitat for macrophytes. Further north the water is deeper, and rocky shores offer less suitable substrate, making macrophytes much less abundant."

The most serious water quality problem in the lake - according to Meckel et al. is the high zinc concentrations resulting from mining activities in the Silver Valley (South Fork Coeur d'Alene River). A 1974 EPA report suggested that high concentrations of heavy metals in the lake may be suppressing primary production. Their data showed zinc concentrations at the lake outlet in excess of levels considered toxic to salmonids (300 ug/L). The lake was found to serve as a sink for zinc, lead, cadmium, and phosphorus. Although the installation of settling ponds by mining companies in 1968 reduced suspended solids loading in the river and lake, concentrations of heavy metals have not significantly changed. Most metals enter the lake in the dissolved state. In the past, metals adsorbed onto clay particles which eventually settled to the bottom; metals now remain in the water column for a longer period of time (Meckel et al., 1983).

A 1987 reconnaissance study of Coeur d'Alene Lake by the U.S. Geological Survey analyzed deep water parameters from Conkling Point northward. Secchi disc results in the lake's central and

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Figure 4.



Trophic Areas (I--oligotrophic; II--mesotrophic; III--strongly mesotrophic) of Coeur d'Alene (Parker, 1972)

SOURCE: Meckel Engineering et al., 1983

southern portions were typical of mesotrophic conditions, whereas oligotrophic conditions predominated in the north. Hypolimnetic DO levels as low as 4.1 mg/L in November and frequent supersaturated DO Concentrations from June-August indicated nutrient enrichment. Hypolimnetic concentrations of total zinc exceeded both EPA chronic and acute toxicity criteria for freshwater aquatic life throughout the studied area (Woods, 1989).

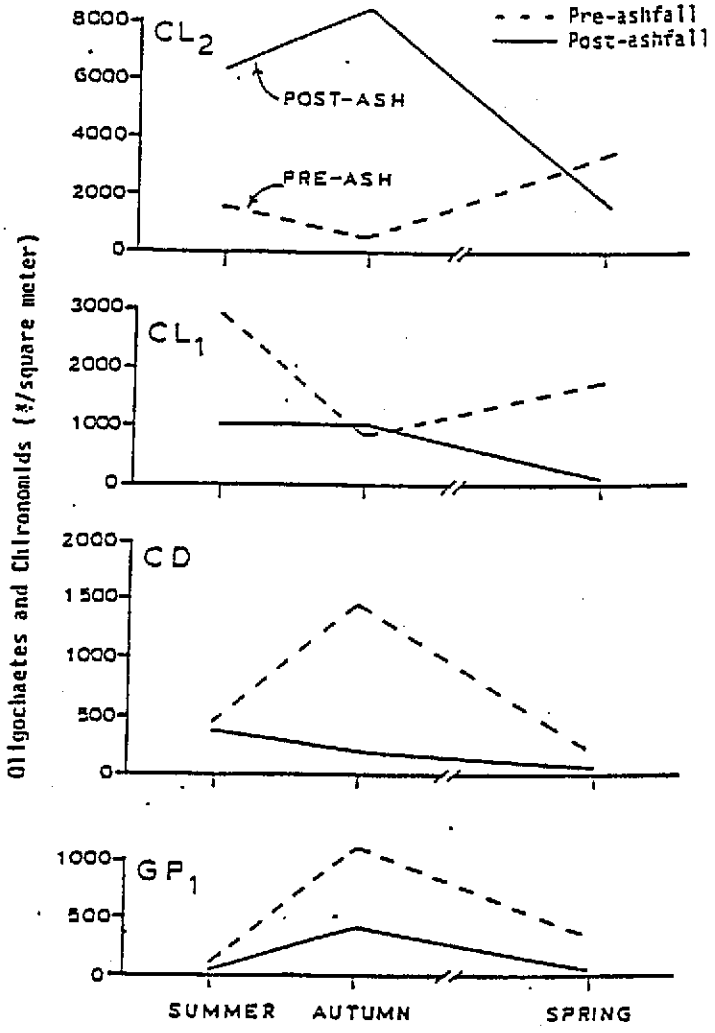
Several past studies have measured and verified the presence of thermal stratification (thermocline) in this lake. In 1973, Funk and other reported thermal stratification from late June to mid-October. Rieman's 1979 efforts found stratification from May until early October; 1987 information by Woods shows stratification from late May through October (Woods,1989).

The only nutrient loading study of Coeur d'Alene Lake was done in 1975 as part of the EPA's National Eutrophication Survey. This study classified the lake as a whole mesotropic but recommended additional study of nutrient loading sources and quantification. Rieman reported a severe DO deficit in the lake during the summer of 1979 (Woods, 1989). Earlier work by Funk showed nutrient levels in the lake increasing from north to south. On the basis of his data Parker classified portions of the lake oligotrophic, mesotrophic and meso-eutrophic (Meckel et al., 1983). Figure 4 displays Parker's designations.

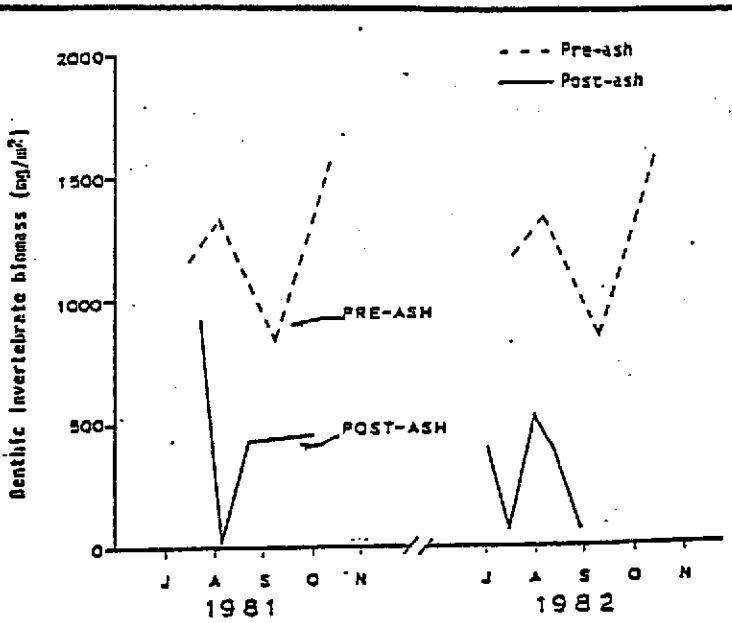
Studies by Skille et al. (1983) in 1981 and 1982 showed lead and cadmium levels in the water column were below detection limits. Water column zinc concentrations were highest in the Coeur d'Alene River and delta; zinc was not detected int the St. Joe River.

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Pre- (1971-1972) and post-ashfall (1981-1982) oligochaete and chironomid abundance estimates at Chatcolet Lake shallow (CL2) and deep (CL1), Coeur d'Alene River delta (CD), and Gasser Point deep (GP1).



Pre- (1960) and post-ashfall (1981-1982) benthos biomass estimates in the lower St. Joe River; the biomass for a given date represents the mean of the biomass estimates for SR1, SR2 and SR3 on that date.

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Skille et al., 1983.

Heavy metals in the water column were lower in this study than previously reported by Wissman in 1972. Zinc concentration reportedly decreased from 2.70 to 0.73 mg/L and 0.40 to 0.25 mg/L in the Coeur d'Alene River and lake, respectively.

Sampling in 1981-1982, when compared to previous data from Winner (1972) and Davis (1961), showed no significant changes in the composition and abundance of phytoplankton, zooplankton or benthic invertebrate communities in the lake system studied by Skille (1983). Figure 5 displays relative abundance and biomass at sampling locations in Chatcolet Lake, lower St. Joe River and Coeur d'Alene Lake. Tables 9-13 (Appendix) provide comparative data for (1960-1982 period) turbidity, Secchi disc, temperature, dissolved oxygen, conductivity and pH for several lake and river locations. Woods' 1987 reconnaissance effort measured deep water concentration of cadmium and lead as well as zinc. On a few occasions total cadmium reached 1 ug/L, a level exceeding acute and chronic criteria for freshwater life. Concentrations of total lead exceeded acute toxicity criterion of 14 ug/L in several samples at the extreme north end of the lake (Woods, 1989).

Sampling and analysis by Beckwith in 1984-85 in Coeur d'Alene Lake showed no change in lake water quality directly attributable to agricultural runoff in small, western bays (16:1, Cave, Aberdeen Lodge), probably due to the dilution of runoff upon entry into the lake. Results also showed zinc concentrations high enough to probably inhibit algae growth, and that the Coeur d'Alene and St. Joe Rivers "profoundly influence lake water quality", particularly during spring runoff (DeSmet, 1986).

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Parker reported uniform temperatures throughout the lake for several deep water stations. The shallower waters in the south end appeared to warm earlier in the season. A shift from diatom populations to blue-green algal forms appeared in July in the south end of Coeur d'Alene Lake but lagged until August in the north. The southern lake area exhibited lower transparency values and frequently appeared more turbid than northern portions of the lake. Streams runoff caused "extreme turbidity" in Chatcolet Lake in February (Parker, 1972).

Nutrient load data from 1971 for Coeur d'Alene Lake showed overall averages of 0.177 mg/L nitrates and 0.01 mg/L nitrates and 0.51 mg/L phosphates. Phosphate data were approximately 2-5 times greater than the world averages given by Reid (1961) - 0.01-0.03 mg/L for most freshwater lakes. The deeper, large volume of water in the northern section of the lake may act as a semi-permanent sink for dissolved phosphate (Parker, 1972).

"Eutrophication has definitely begun in the N.E. Worley bays (Cave, Aberdeen lodge, 16 to 1 Bays) as well as many other bays on Lake Coeur d'Alene" (DeSmet, 1986). The process is accelerated by nutrient loading, particularly agriculture. The N.E. Worley study (1984/85) showed stream nitrogen loading 15-30 times higher than recommended EPA in-stream criteria, and typical phosphorus loading 2-3 times greater than EPA criteria (DeSmet, 1986).

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Coeur d'Alene Lake - Windy Bay

Lake Creek study results indicate Windy Bay is mesohophic or moderately enriched. Suspended sediment at the mouth of Lake Creek (in Windy Bay) had higher suspended sediment levels throughout the study period (12/88-11/89) than ambient lake concentrations. Water temperature/dissolved oxygen (DO) profile measured one mile out (toward the main body of Coeur d'Alene Lake from mouth of Lake Creek) showed water quality violations of both DO and temperature standards coinciding with the stratification period. This station exceeded the salmonid spawning standard for temperature from June - September, and the DO standard (minimum of 6 mg/L) once in September (IDHW, 1990).

The average Secchi disc measurements at both Windy Bay stations in 1989 were representative of a mesotrophic lake. Turbidity peaked following spring runoff and generally dropped off for rest of the year. Generally there was a positive correlation between suspended sediment and turbidity.

Lake bottom sediments in Windy Bay showed an average thickness of sediment over the volcanic ash layer (Mt. Saint Helens, 5/80) of 1.0 foot at the three sites near the mouth of Lake Creek. The other site (unaffected by Lake Creek) showed deposition of 0.2'. Based on this data Lake Creek delivered 0.8 foot of sediment in a 9 year period (IDHW, 1990).

Southern shallow areas in Coeur d'Alene Lake are quite extensive and provide for less nutrient dilution. Deep light penetration and silty lake sediments provide an optional habitat for growth of algae and rooted macrophytes; dense communities of

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Potamogeton, Meriophyllum and Anacharis abound in shallow area of Chatcolet, Round and Benewah Lakes. However, the lowest levels of planktonic algae were observed in this area. Field observations of Chatcolet, Round and Benewah Lakes indicated over 60 percent of the water area with very dense macrophyte growth. These waters were characterized as "strongly mesotrophic", and most shallow areas "heavily enriched and eutrophic" (Parker, 1972).

Chatcolet Lake

Observations and measurements made in the 1988-89 water year showed a significant oxygen decline in the hypolimnion of Chatcolet lake. A low of 0.5 mg O_2/L was reached a half-meter off the lake bottom. The oxygen demand source was not identified (IDHW, 1990a).

Sediment sampling in the lake off the mouth of Plummer Creek (in its channel) produced an accumulation rate of 2.4 cm/year (1 inch/year). This is probably on the low side for that site since some scour would likely occur. Another sampling not directly influenced by the stream showed an accumulation rate of 0.1 cm/year. The study concluded that this rapid deposition rate will eventually result in wetland loss and further encroachment of the Plummer Creek "delta" into Chatcolet Lake (IDHW, 1990a).

The Plummer Creek/Chatcolet Lake water quality study described the lake as "largely mesotrophic, with some tendency toward eutrophic conditions." This result is based on Carlson's trophic state indices and relationship of total phosphorus, chlorophyll *a* concentrations and Secchi disc transparency data. However, study results indicate suspended sediments in the lake caused the

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variations in phosphorus and transparency and influenced the trophic state rather than algal biomass (IDHW, 1990a).

Increased sedimentation and nutrient levels from the Plummer Creek watershed have dramatically affected Lake Chatcolet and Heyburn State Park. Bass spawning habitat has been lost in the mouth of the creek; lake depth is steadily decreasing, with increased aquatic plant growth and boat access limitations. These impacts are occurring well out into the lake. Animal and bird habitat is being altered. During low water periods, vast mud flats have replaced open water. Changes are noticeable on a year-to-year basis as compared to natural changes which normally take decades (Benewah SCD, 1990).

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SECTION IV: SOURCES OF POLLUTION

NONPOINT SOURCES

Probably the most significant pollution consideration in Coeur d'Alene Lake is the high concentrations of trace (heavy) metals in the lake sediments, and the potential for release of these metals back into the water column. Trace elements of zinc, lead and cadmium are the most significant in respect to concentrations and potential hazards or impacts upon freshwater biota, terrestrial biota and man. These metals and others (see Tables 3,4) were introduced into the Coeur d'Alene River and lake system as a consequence of a hundred years of mining, ore-processing and smelting in the Silver Valley. An estimated 115 million tons of mine tailings were produced in the South Fork Coeur d'Alene River Basin. Much of these metal-contaminated tailings (72 million tons) were discharged or flowed directly into the river (U.S. Geological Survey, 1990).

Prior to 1968 when settling ponds were installed, mine tailings (composed of very fine particles) were dumped directly into the South Fork. This resulted in silty water extending down the river system and well out into Coeur d'Alene Lake (Spruill, 1990). Much (or most) of the metal-laden silt and fine sand of the lake bottom probably were deposited before 1968. However, large deposits of tailings remain in and along the South Fork and lower Coeur d'Alene River; these tailings and their load of zinc, lead, cadmium and other trace metals are easily washed downstream by storms and spring floods. Neufeld (1987) estimated 10,000 acres of

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Summary of Lead, Cadmium, Zinc Levels in
Coeur d'Alene Basin Sediments

Location	Sedimentary Elements (ug/g) Lead	Cadmium	Zinc
Lake Coeur d'Alene Northern Part	1146-5732	7-8	16-87
Central Part (Coeur d'Alene River Delta)	4158	8	3680
South Part	10-367	0.6-10	77-1310
Lateral Lakes			
Anderson Lake	2492	10	2180
Thompson Lake	3386	9	2560
Lower Coeur d'Alene River	2310-3992	5-8	50-90
South Fork Coeur d'Alene River	298-7897	3-5	0.1-232
U.S.A. Median (Lyman et al. 1987)	16	1	4
95 Percent of U.S.A. sediments below	199	12	39

Hornig et al., USEPA, 1988

Krieger, 1990.

Table 4.

Mean heavy metal concentrations in the parent sediment (mg/kg) and water column (mg/l) at 6 sites in the Coeur d' Alene Lake system, 1981-1982, (values preceded by < are detection limit values; the precision for an element at detection limit is ± 50%).

Sampling Site	Sediment Zinc	Lead	Cadmium	Water Zinc	Lead	Cadmium
Browns Bay	2,377	1,382	40	0.14	<0.50	<0.03
Gasser Point	2,670	2,500	50	0.19	<0.50	<0.03
CDL River delta I	3,347	8,620	36	0.70	<0.05	<0.03
CDL River delta III	3,330	7,286	49	0.36	<0.05	<0.03
CDL River mile 133	2,423	5,002	43	0.73	<0.50	<0.03
St. Joe River mile 8	48	83	2	<0.02	<0.50	<0.03

Skille, 1983.

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wetlands have been impacted. Each year new deposits of mine sediments flush into the lake. Deposition rates are notably less than before 1968, but it has not stopped.

Since 1968 the principal form of transported trace metals, sulfate and other pollutants from the mining district into the river and lake has probably been dissolved rather than suspended loads. Data to verify or quantify this conclusion is tenuous, but appears consistent with suspended sediment observations in the river and lake (Spruill, 1990).

An extensive delta at the mouth of the Coeur d'Alene River is largely mine tailing sediments. Trace metal loading in this delta was comparable to measurements in tailings upstream along the South Fork. In the early 1970's high concentrations of trace metals were measured (by Funk and others) in lake sediments from the northern two-thirds of Coeur d'Alene Lake. Environmental Protection Agency lake sediment testing (1986) revealed concentrations of arsenic, cadmium, copper, lead and zinc - far in excess of sediment loading nationwide. Table 5 displays the results of 170 Coeur d'Alene Lake surficial-sediment samples gathered in August, 1989 by the U.S. Geological Survey. Total concentrations of arsenic, cadmium, mercury, lead and zinc were particularly high (U.S. Geological Survey, 1990).

A comparison of lead, cadmium and zinc levels in the lake and upstream locations (Krieger, 1990) is shown in Table 3. These values represent the amount of lead in the first six inches of the silt column. More recent studies demonstrate that trace element of concentrations more than 1000 mg/kg exist in certain locations in

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Table 5.

Percentile values for major and trace elements and total organic carbon for 170 surficial lakebed samples taken from Coeur d'Alene Lake in August 1989.

Percentiles / Elements	5th	10th	20th	40th	60th	80th	90th	95th	99th	99.9th
TOC Wt. %	1.0	1.4	1.6	2.0	2.4	2.6	3.5	5.6	11.9	15.6
Ag ppm	1.6	2.0	3.0	4.0	6.0	9.0	11	12	20	21
Cu ppm	20	30	45	64	77	99	110	126	178	215
Pb ppm	23	84	940	1600	2100	2700	3600	4200	7100	7700
Zn ppm	105	540	2300	3200	3900	5400	6200	6900	9000	9100
Ni ppm	10	12	16	20	23	25	28	30	35	36
Co ppm	7	10	13	22	29	32	36	38	40	43
Cd ppm	6	19	30	45	69	95	120	131	157	157
Cr ppm	22	28	33	40	44	48	52	54	59	63
Hg ppm	0.05	0.10	0.70	1.30	2.10	2.90	3.50	3.90	4.80	4.90
As ppm	4.5	9.0	40	96	157	230	308	474	602	660
Sb ppm	0.7	2.0	9.0	16	23	35	45	56	85	96
Se ppm	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.6
Fe Wt. %	2.7	3.1	4.0	4.6	5.1	5.7	7.3	9.4	13.5	16.4
Mn Wt. %	0.04	0.07	0.18	0.49	0.74	0.98	1.31	1.73	2.20	2.46
Al Wt. %	4.1	5.1	6.7	7.8	8.2	8.4	8.5	8.7	8.9	9.0
Ti Wt. %	0.16	0.22	0.30	0.34	0.35	0.39	0.44	0.51	0.61	0.64

U.S. Geological Survey, 1990

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the lower Coeur d'Alene River bottomlands at depths of 8-10 feet below the surface (Spruill, 1990).

The most significant trace metal sediment deposits in the lake are found from the vicinity of the Coeur d'Alene River delta northward. Most sampling has occurred in deep water locations; concentrations of trace metals in the lake's numerous bays are generally unavailable. A study to determine the limnological effects of volcanic ash deposition in the lake area showed the lake/river sediment loading south of the river delta (at Browns Bay and St. Joe River) as compared with the delta and northern sampling data (Table 4). This study concluded that lake sediment metal levels declined in the decade prior to 1981, apparently as a result of tailings ponds and a reduction of heavy metal discharge into the Coeur d'Alene River (Skille, 1983). Trace metal sediment or water column concentrations are not a problem in the shallow south end of Coeur d'Alene lake or the four flood plain Lakes.

Rapid residential and commercial development of the shoreline and intensive recreational use are increasing the potential for nutrient enrichment of the lake. Nutrient loading (nitrogen, phosphorus) in Coeur d'Alene Lake was examined in 1975 as part of a national survey by the EPA. The primary nonpoint sources (in addition to natural, background levels) identified were agriculture (cropland and cattle grazing) and septic tank seepage.

Tables 6 and 7 display the EPA's 1975 total nutrient budget, both point and nonpoint. Additional water quality studies of Lake Creek, Plummer Creek and smaller tributaries along the western Coeur d'Alene lake shore provide more details on nutrient loading

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Average Year

Item	Kg phosphorus per year	Percent of total
1. Inputs		
Source:		
a. Tributaries (nonpoint load)		
C-1 Wolf Lodge Creek	780	0.4
D-1 Coeur d'Alene River	98,085	54.6
E-1 St. Joe River	56,325	31.3
F-1 Benewah Creek	930	0.5
G-1 Plummer Creek	435	0.2
H-1 Lake Creek	980	0.6
b. Minor tributaries and immediate drainage (nonpoint load)	6,185	3.4
c. Known municipal STPs		
South Fork Coeur d'Alene Sewer District	9,615	5.3
St. Maries	3,395	1.9
Plummer	335	0.2
Santa	115	0.1
Harrison	120	0.1
d. Septic tanks[a]	250	0.1
e. Known industrial	None	0.0
f. Direct precipitation[b]	2,265	1.3
Total inputs	179,815	100.0
2. Output: A-1 Spokane River	109,525	
3. Net annual phosphorus accumulation	70,290	

Table 7.

Table Annual Total Nitrogen Loading, Average Year

Item	Kg nitrogen per year	Percent of total
1. Inputs		
Source:		
a. Tributaries (nonpoint load)		
C-1 Wolf Lodge Creek	24,810	0.7
D-1 Coeur d'Alene River	1,492,530	43.9
E-1 St. Joe River	1,483,900	43.7
F-1 Benewah Creek	14,465	0.4
G-1 Plummer Creek	12,285	0.4
H-1 Lake Creek	36,605	1.1
b. Minor tributaries and immediate drainage (nonpoint load)	138,125	4.1
c. Known municiapl STPs		
South Fork Coeur d'Alene Sewer District	30,960	0.9
St. Maries	12,400	0.4
Plummer	575	<0.1
Santa	340	<0.1
Harrison	600	<0.1
d. Septic tanks[a]	9,325	0.3
e. Known industrial	None	0.0
f. Direct precipitation[b]	139,810	4.1
Total inputs	3,396,730	100.0
2. Outputs: A-1 Spokane River	4,354,550	
3. Net annual nitrogen export[c]	957,820	

[a]Estimate based on 875 lakeshore residences, 4 camps, and 1 park.

[b]Estimated. (See NES Working Paper No. 175.)

[c]Export probably due to unknown sources and/or sampling error.

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SOURCE: Meckel et al., 1983 (EPA National Eutrophication study, 1977.)

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from watersheds impacted by cropland, grazing and silicultural practices. Accelerated eutrophication in the bays associated with these watersheds appears linked to elevated phosphorus/nitrogen compounds and sediment eroded into the lake each year. Plummer Creek runoff has a significant effect on Chatcolet Lake water quality, both in terms of nutrients and sediment (IDHW, 1990a).

In Windy Bay, peak concentrations of nitrogen occurred following spring runoff events in Lake Creek; phosphorus loading was generally correlated with sediment deposits. The mean annual total phosphorus concentration in Lake Creek exceeded EPA 0.05 mg/L criteria at all sampling sites except the background station. On one March runoff day, about 190 lbs. of phosphorus were deposited into Windy Bay (IDHW, 1990).

In three small Coeur d'Alene Lake watersheds northeast of Worley, the EPA Region X maximum level of 0.05 - 0.1 mg/L for total phosphorus was exceeded in most samples. Biologically available dissolved ortho-phosphorus alone exceeded these water quality criteria in many of the samples. In spite of the atypical weather and reduced soil erosion during the sample year, nitrogen loading was usually 15-30 times and phosphorus loading 2-3 times higher than EPA recommended in-stream criteria. A normal year would likely produce greater sediment, nitrogen and phosphorus levels into the lake. "Eutrophication has definitely begun in the N.E. Worley bays as well as many other bays on Lake Coeur d'Alene" (DeSmet, 1986). Lake water quality has been demonstrably impacted by agricultural nonpoint pollution.

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A 1974 shoreline survey of individual sewage disposal systems around Coeur d'Alene Lake by the Panhandle Health District included 737 lots and 1127 disposal systems. Of systems surveyed, 45 percent were drywell, cesspool or direct discharge systems that would not meet current standards. About 15 percent of septic-drain field systems did not meet legal standards. Over 80 percent of all system were located 50-120 feet from the lakeshore, with a mean distance of 73 feet. Reports at that time indicated high coliform bacterial concentrations in near-shore areas of developed bays, but nutrient loading did not vary significantly from concentrations in the main lake. A seasonal variation of available nitrates and phosphates was detected, with the lowest (.30 mg/L) in July and the highest level (1.26 mg/L) in April (Panhandle Health District I, 1974). The nutrient input from shoreline development was undetectable by methods used in the 1974 survey. Since this survey an estimated 500-800 additional individual sewer treatment systems have been constructed around the lake (Davis, 1991).

In the past the EPA has identified the Coeur d'Alene River and St. Joe River at St. Maries as "stream segments with significant nonpoint source pollution problems related to forest practices." (Meckel et al., 1983). Most sediment in these larger rivers, regardless of sources, eventually is deposited into Coeur d'Alene Lake. In the two years following ash fallout from Mt. St. Helens, deep water areas of the lake accumulated 0.9 inches (22.2 mm) of sediment. Shallow ares measured in 1983 accumulated 2.75 inches (69.8 mm) in the same time period, indicting a significant contribution from shoreline and/or surface runoff. The deltas of

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the two large rivers accumulated an average of 1.8 inches (46.8 mm) of sediment. The Coeur d'Alene River delta extends one mile up and across the lake where sediments up to 8 inches thick accumulated in two years. The St. Joe delta built up sediment up to 7 inches (180 mm) in this same time period (Skille, 1983).

A maximum annual loading of sediment at the mouth of Plummer Creek has been estimated at 6,171 tons. Near the mouth of the creek in Chatcolet Lake the estimated average yearly sediment accumulation is 0.9 inches (25 mm); agricultural land uses are the primary sources in addition to urban and industrial stormwater runoff (Benewah Soil and Water Conservation District, 1990).

POINT SOURCES

Mining facilities discharging into the South Fork Coeur d'Alene River under current NPDES permits from the EPA include nine facilities and 18 outfalls. Effluent monitored with various discharge limitations or requirements include total flow, suspended solids, pH and various trace or heavy metals. Although trace metal loading from these point sources are significant, Spruill (1990) has concluded that water quality into the South Fork (and likewise in the lower river) is in dissolved form and mostly derived from ground-water discharges in Canyon Creek.

Outfalls from five municipal sewage treatment plants impact the Coeur d'Alene and St. Joe Rivers and eventually Coeur d'Alene Lake and Chatcolet Lake (Plummer via Plummer Creek). Tables 6 and 7 display 1975 EPA estimates of nutrient loads from these upstream

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sources. More recent nutrient loading data for the total lake system are not available.

The City of Coeur d'Alene sewage treatment plant effluent discharges into the Spokane River below the lake's outlet. However, urban storm water from a major portion of the city is piped directly into Coeur d'Alene Lake (or into Fernan Creek a few hundred yards from the lake). These discharges are untreated and deposit unquantified amounts of sediment, nutrients, trace metals and other pollutants into the lake. Several outfalls are located within a few hundred yards of public swimming beaches, boat ramps and resort facilities on the lake's north shore.

MONITORING AND CONTROLS IN PLACE

The state's 1990 Coordinated Nonpoint Source Water Quality Monitoring Program for Idaho lists one "basin trend surface water quality sampling site" on the Coeur d'Alene River (Cataldo), two "watershed trend sampling sites" each for the Coeur d'Alene and St. Joe Rivers and another trend site on the Spokane River 5 miles below the lake outlet. There is no scheduled monitoring of Coeur d'Alene Lake water for sediment, nutrients trace metals or toxic substances.

"Stream segments of concern" (SSC's) approved in 1990 as part of Idaho's Antidegradation Program that drain into Coeur d'Alene Lake include: Tepee Creek and Independence Creeks (upper Coeur d'Alene River); Marie and Wolf Lodge Creeks; Mosquito and Gold Creeks (St. Joe). In addition to these silviculture-related segments, three agricultural-impact streams that flow directly into

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the lake were designated as SSC's - Lake Creek, Plummer Creek and Benewah Creek. These stream segments and their watersheds are to receive special attention and monitoring in an attempt to decrease or minimize suspended sediment loads that enter the lake.

The Panhandle Health District administers tight control over individual shoreline sewage treatment systems. Since the 1974 survey, a number of small, local sewer districts have been formed to prevent or alleviate lakeshore sewage problems.

An Agricultural Pollution Abatement Plan for the Plummer Creek watershed was finalized late in 1990 by the Benewah Soil and Water Conservation District. Goals of this proposal are a reduction of sediment and nutrient flow into the lake and maintenance of soil productivity on 13,000 "critical acres". A similar agricultural pollution effort is underway in the Lake Creek watershed by the Kootenai-Shoshone Soil Conservation District.

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SECTION V: SUMMARY

Coeur d'Alene Lake's designated uses (Table 8) include:

1. domestic water supply
2. agricultural water supply
3. cold water biota
4. salmonid spawning
5. primary contact recreation
6. secondary contact recreation
7. special resource water

Woods (1989) and Rieman (1980) have both reported hypolimnion dissolved oxygen concentrations in Coeur d'Alene Lake below criteria specified for cold water biota. Sampling by Woods showed six sampling stations below the 6 mg/L DO (cold water biota standard) at various depths on six different dates, with one reading as low as 3.7 mg/L. Windy Bay data in 1990 contained one bay sampling station that exceeded the salmonid spawning standard temperature from June-September, and exceeded the DO standard once in September. (IDHW, 1990).

Study of Plummer Creek and Chatcolet Lake (IDHW, 1990a) revealed a significant DO decline in Chatcolet lake's hypolimnion after stratification. Sampling in July, August and September revealed DO levels below 6.0 mg/L in depths from 19-33 feet (6-10 m). Summer water temperatures (July-September) generally exceeded the maximum temperature standard for salmonid spawning.

Bacterial analysis of Lake Chatcolet at 26 sampling sites in 1974 exceeded Idaho standards current at that time. Additional sampling in the northern portion of Coeur d'Alene, including various bays, did not exceed state standards; however, total

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IDAHO WATER QUALITY STANDARDS
COEUR D'ALENE LAKE AND TRIBUTARIES

IDHW/DEQ, 1990

Legend
/ Protected for General Use
* Protected for Future Use
X Use Protected Above Mining Impact Area

DESIGNATED USES

Map Code	Waters	Domestic Water Supply	Agricultural Water Supply	Cold Water Biota	Warm Water Biota	Salmonid Spawning	Primary Contact Recreation	Secondary Contact Recreation	Special Resource Water	
q.	PB-10S	COEUR D'ALENE RIVER - source to S.F. Coeur d'Alene	/	/	/		/	/	/	(1-30-80)
t.	PB-12OS	N.F. COEUR D'ALENE - source to mouth	/	/	/	/	/	/	/	(1-30-80)
u.	PB-13OS	S.F. COEUR D'ALENE - source to Mullan	/	/	/	/	/	/		(3-24-80)L
v.	PB-14OS	S.F.COEUR D'ALENE		/	*		*	/		
bb.	PB-147S	LAKE CREEK-source to mouth	X	/	*X	X	X	/		(3-24-80)L
ee.	PB-20S	COEUR D'ALENE RIVER - S.F. Confluence to mouth (Lake)		/	/	*	/	/		(1-30-80)
ff.	PB-30S	COEUR D'ALENE LAKE	/	/	/	/	/	/	/	(1-30-80)
gg.	PB-31OS	ST.JOE RIVER - source to Calder	/	/	/	/	/	/	/	(1-30-80)
hh.	PB-36OS	WOLF LODGE CREEK -	/	/	/	/	/		/	
ii.	PB-32OS	ST.JOE RIVER-Calder to St.Maries River	/	/	/	/	/	/	/	(1-30-80)
jj.	PB-321S	ST.MARIES RIVER - source to Fernwood	/	/	/	*	/	/	/	(1-30-80)
mm.	PB-33OS	ST.JOE RIVER - St. Maries to mouth		/	/		/	/		(1-30-80)
nn.	PB-34OS	PLUMMER CREEK		/				/		(1-30-80)
oo.	PB-35OS	FERNAN LAKE AND OUTLET to Coeur d'Alene Lake	/	/	/	/	/	/		(1-30-80)
pp.	PB-40S	SPOKANE RIVER - Coeur d'Alene Lake outlet to Ida-Wash border	/	/	/	/	/	/		(10-15-85)

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coliform levels were higher in areas adjacent to shoreline development (Panhandle Area Council, 1979).

Recent data that indicates whether or not water quality standards for other beneficial uses are being achieved is limited to a few individual bays or sampling pints. Swimming and boating use on Coeur d'Alene Lake have not been impacted or restricted by bacteriological or other water quality factors.

Kokanee salmon annually spawn quite successfully in the lake along with various species of warm water fish. All other trout and Chinook salmon depend on inlet streams (or Spokane River) for spawning habitat. In general, cold water biota "are supported in good number" (Horner, 1991). The fishery situation has improved in the past 20 years as trace metals concentrations in the Coeur d'Alene River system have decreased. Cutthroat trout use of the lower river and South Fork Coeur d'Alene is slowly expanding (Horner, 1991).

Heavy metal toxicity in humans has been a concern since the mid-1970's, particularly by the Coeur d'Alene Indian Tribe and others who regularly eat fish and waterfowl from Coeur d'Alene Lake and the lower Coeur d'Alene River, lateral lakes and wetlands. An EPA 1986 study of Chinook and Kokanee salmon revealed lead and cadmium did not accumulate in edible fish tissue (fillets) at levels considered dangerous to sport fishermen. However, high levels of cadmium were found in fish levers and kidneys (Hornig et al., 1988). A 1989 report from the U.S. Department of Health and Human Services concluded that Coeur d'Alene Lake fish consumption resulted in elevated human blood lead and cadmium, but had no known

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clinical significance (Agency for Toxic Substances and Disease Registry, 1989). This human health issue has not been fully resolved. Fish and human sampling in past heavy metal toxicity studies have been critiqued as inadequate; the Coeur d'Alene Indian Tribe and others believe more comprehensive testing and analysis is needed (Scholz and O'Laughlin, 1989).

Currently the primary lake concerns are nutrient loading, eutrophication and trace metal relationships. If Coeur d'Alene's hypolimnion becomes anaerobic because of eutrophication, conditions on the lake bottom could cause large quantities of trace metals and nutrients to be released from bottom sediments. Such a release of metals and nutrients could: (1) accelerate eutrophication and algal production; (2) increase bioaccumulation of trace metals by aquatic organisms; and (3) increase the deep-water dissolved-oxygen deficit (Woods, 1989).

In summary, "there is abundant evidence that things are getting better" in respect to trace metals in the lower Coeur d'Alene River and annual loading of these metals into Coeur d'Alene Lake (Krieger, 1990). This pollution improvement is countered by increasing signs of accelerated eutrophication and nutrient loading, with hypolimnion dissolved-oxygen deficits and heavy sediment deposition. Exploding growth and use on and around the lake - recreational, residential and commercial - will likely add to the nutrient and sediment loads unless substantial land use changes or controls are instituted.

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APPENDIX

Comparison of Primary Coeur d'Alene Lake Water Quality Parameters

Table 9 - Turbidity/Secchi Disc
Table 10 - Water Temperature
Table 11 - Dissolved Oxygen
Table 12 - Conductivity
Table 13 - pH Values

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Table 9.

A comparison of annual average turbidities and Secchi disc transparencies before and after the Mt. St. Helens ash fallout in the Lake Coeur d'Alene area.

	Turbidity (Hach Turbidimeter)		
	1960	1981	1982
1960 (Davis 1961)			
St. Joe River			
Mile 8	2.0	1.5	2.2
Mile 13	1.6	1.6	2.5
Mile 17	1.4	1.1	2.4
Means	1.7	1.4	2.4

	Secchi Disc Transparency (m)		
	1970	1981	1982
1970 (Wissmar 1972)			
Coeur d'Alene River			
Mile 133	2.3	1.9	1.6
Coeur d'Alene			
Delta	2.8	1.8	2.9
St. Joe River			
Mile 8	3.2	2.7	2.3
Means	2.8	2.1	2.3

Table 10.

A comparison of annual average water temperatures before and after the Mt. St. Helens ash fallout in the Lake Coeur d'Alene area.

	Temperature (°C)		
	1960-1972	1981	1982
1960 (Davis 1961)			
St. Joe River			
Mile 8	12.6	17.5	14.3
Mile 13	12.3	16.8	13.9
Mile 17	12.6	17.0	13.9
1970 (Wissmar 1972)			
Coeur d'Alene River			
Mile 133	13.7	17.5	15.6
Coeur d'Alene			
Delta	12.7	18.0	17.2
St. Joe River			
Mile 8	19.3	17.5	14.3
1972 (Winner 1972)			
Lake Chatcolet	13.0	16.5	14.0
Means	13.7	17.3	14.7

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SOURCE: Skille et al., 1983.

Table 11.

A comparison of annual average dissolved oxygen concentrations before and after the Mt. St. Helens ash fallout in the Lake Coeur d'Alene area.

	Dissolved Oxygen (mg/l)		
	1960-1971	1981	1982
1960 (Davis 1961)			
St. Joe River			
Mile 8	11.3	7.9	8.9
Mile 13	11.3	8.0	9.0
Mile 17	11.5	8.5	8.9
1965 (Marcuson 1966)			
Round Lake			
Mid-lake	8.2	9.3	9.4
1970 (Minter 1971)			
Coeur d'Alene River			
Mile 133	9.0	8.6	9.0
Coeur d'Alene			
Delta	9.0	8.4	8.8
1970 (Wissmar 1972)			
Coeur d'Alene River			
Mile 133	8.7	8.6	9.0
Coeur d'Alene			
Delta	8.0	8.4	8.8
St. Joe River			
Mile 8	8.6	7.9	8.9
1971 (Parker 1972)			
Gasser Point	8.0	8.4	8.9
Coeur d'Alene Delta	7.5	8.4	8.5
Brown's Bay	8.5	7.9	8.8
Hidden Lake	8.0	7.9	8.7
Lake Chatcolet	7.5	7.9	8.3
Means	8.9	8.3	8.9

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SOURCE: Skille et al., 1983.

Table 12.

A comparison of annual average conductivities (μ mhos) before and after the Mt. St. Helens ash fallout in the Lake Coeur d'Alene area.

	Conductivity (μ mhos)		
	1970-1971	1981	1982
1970 (Minter 1971)			
Coeur d'Alene River.			
Mile 133	97	84	81
Coeur d'Alene			
Delta	--	84	54
1970 (Wissmar 1972)			
Coeur d'Alene River			
Mile 133	111	84	81
Coeur d'Alene			
Delta	46	84	54
St. Joe River			
Mile 8	<50	49	45
1971 (Parker 1972)			
Gasser Point	60	50	49
Coeur d'Alene Delta	50	84	54
Brown's Bay	55	45	46
Hidden Lake	60	42	42
Lake Chatcolet	60	42	42
Means	65	65	56

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SOURCE: Skille et al., 1983

Table 13.

A comparison of annual average ph values before and after the Mt. St. Helens ash fallout in the Lake Coeur d'Alene area.

	pH Values		
	1960-1971	1981	1982
1960 (Davis 1961)			
St. Joe River			
Mile 8	7.3	6.9	7.0
Mile 13	7.4	6.9	7.0
Mile 17	7.5	7.0	7.1
1965 (Marcuson 1966)			
Round Lake			
Mid-Lake	7.9	8.1	7.5
1970 (Minter 1971)			
Coeur d'Alene River			
Mile 133	6.8	6.9	7.1
Coeur d'Alene			
Delta	7.0	6.9	7.1
1970 (Wissmar 1972)			
Coeur d'Alene River			
Mile 133	6.9	6.9	7.1
Coeur d'Alene			
Delta	7.3	6.9	7.1
St. Joe River			
Mile 8	7.0	6.9	7.0
1971 (Parker 1972)			
Gasser Point	7.3	7.7	7.1
Coeur d'Alene Delta	7.1	6.9	7.1
Brown's Bay	7.2	7.1	7.0
Hidden Lake	7.3	7.2	7.3
Lake Chatcolet	7.4	7.2	7.0
Means	7.2	7.1	7.1

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SURFACE WATER QUALITY DATA COMPILATION AND EVALUATION

FOR THE COEUR D'ALENE BASIN NATURAL RESOURCE DAMAGE ASSESSMENT

RIDOLFI ENGINEERS
and Associates, Inc.

completed 1995

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COEUR D'ALENE BASIN

NATURAL RESOURCE DAMAGE ASSESSMENT

SURFACE WATER QUALITY

DATA COMPILATION AND EVALUATION

Prepared for

The Natural Resource Trustees
Coeur d'Alene Tribe
United States Department of Agriculture
United States Department of the Interior

Prepared by

Ridolfi Engineers and Associates, Inc.
Seattle, Washington

August 1995

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1.0 INTRODUCTION

This report presents the results of the surface water quality data compilation and evaluation for the Coeur d'Alene Basin Natural Resource Damage Assessment (NRDA) in support of the aquatic injury determination. The compilation and evaluation was conducted according to Part 2 Section IIIB: Determination of Injury to Surface Waters of the "Assessment Plan for the Coeur d'Alene Basin Natural Resource Damage Assessment, Phase I" (Ridolfi Engineers, 1993).

Hazardous substances in the form of heavy metals derived from source areas within the Coeur d'Alene Basin have been released and continue to be released to the surface waters of the basin. The evaluation demonstrates that surface water resources in the basin have been injured at many locations and points in time since the initiation of modern surface water quality monitoring in the mid-1960's.

2.0 DEFINITIONS FOR DETERMINATION OF INJURY

2.1 Injury Definition

A regulatory definition of injury to surface water resources is found at 43 CFR § 11.62(b)(1)(iii):

> "An injury to a surface water resource has resulted from the...release of a hazardous substance if...changes in the ...chemical quality of the resource...[results in c]oncentrations and duration of substances in excess of applicable water quality criteria established by section 304(a)(1) of the CWA [Clean Water Act]...The most stringent criterion shall apply..."

2.2 Water Quality Criteria

Under authority of section 304(a) of the Clean Water Act, the U.S. Environmental Protection Agency (EPA) has developed specific criteria to protect aquatic life, generally referred to as ambient water quality criteria (AWQC). In accordance with the injury definition above, injury to surface water resources can be determined by comparing the applicable AWQC to concentrations of hazardous substances, i.e., heavy metals, measured in surface waters of the Coeur d'Alene River basin.

The metals of primary interest to this compilation and evaluation, and for the determination of injury are cadmium, lead, and zinc. Both total recoverable measurements and dissolved measurements for these metals were included in the data compilation. Because the AWQC criteria are based on total recoverable concentrations of metals, only total recoverable measurements have been considered in the determination of injury. However, sufficient data are available for dissolved measurements (Appendix C) for the purpose of injury determination.

The AWQC for the metals of concern are expressed in terms of a criterion maximum concentration (CMC), which is a one-hour average acute limit, and a criterion continuous concentration (CCC), which is a four-day average chronic limit. The CMCs and CCCs for cadmium, lead, and zinc are hardness-dependent, as the toxicity of these metals to aquatic species varies with water hardness. A given concentration of metal is more toxic at low hardness values than at high hardness values. The equations developed to determine criteria for these metals are as follows:

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$$CMC = e^{\{m_A[\ln(\text{hardness})] + b_A\}}$$
$$CCC = e^{\{m_C[\ln(\text{hardness})] + b_C\}}$$

The variables m and b for these equations are given below for cadmium, lead and zinc:

Metal	CMC		CCC	
	m_A	b_A	m_C	b_C
Cadmium	1.128	-3.828	0.7852	-3.490
Lead	1.273	-1.460	1.273	-4.705
Zinc	0.8473	0.8604	0.8473	0.7614

These equations are considered to be valid for hardness values within the range of 25 to 400 mg/L $CaCO_3$ (Federal Register, 1991). Accordingly, hardness values included in the compiled data that are less than 25 mg/L have been substituted with 25 mg/L. No values greater than 400 mg/L were found in the data.

2.3 Injury Determination

The relevant acceptance criterion for injury determination is found at 43 CFR § 11.62(b)(2)(i):

> "The acceptance criterion for injury to the surface water resource is the measurement of concentrations of...a hazardous substance in two samples from the resource. The samples must be one of the following types...: (A) Two water samples from different locations, separated by a...distance of not less than 100 feet; ....or (D) Two water samples from the same location collected at different times."

3.0 WATER QUALITY DATA EVALUATION

3.1 Reach Definitions

To facilitate evaluation of surface water quality, the Coeur d'Alene Basin Assessment Area has been subdivided into reaches, as outlined in Table 3-1 and depicted in Figures 3-1 through 3-3. Each reach is considered separately in the evaluation. The downstream limit of each reach is generally a long-term USGS gage station. The South Fork of the Coeur d'Alene River (SFCDR) has been subdivided into five reaches, plus tributaries; the North Fork of the Coeur d'Alene River (NFCDR) has been divided into two reaches; the Lower Coeur d'Alene River (LCDR) has been subdivided into 3 reaches, plus the lateral lakes; Lake Coeur d'Alene has been evaluated as a whole; and the Spokane River has been subdivided into two reaches extending to below Long Lake Dam, Washington.

3.2 Data Sources

A substantial amount of water quality data has been collected within the Assessment Area since the mid-1960s, when studies concerned with the impact of mining wastes on various natural resources increased in frequency. Most of the known studies with water quality data have been reviewed and are summarized in Appendix A. However, not all of these data sources have been included in the compilation. Instead, data included in the compilation and

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Table 3-1. Reach Definitions for the Surface Water Quality Compilation and Evaluation

Reach Abbreviation	Reach Description[1]	Period of Record[2]
South Fork Coeur d'Alene River		
SFCDR-1	Headwaters upstream of Mullan	1968-1991
SFCDR-2	Near Mullan downstream to Canyon Creek	1971-1991
SFCDR-3	Canyon Creek downstream to Elizabeth Park	1971-1994
Tributaries		
CC-1	Canyon Creek upstream of O'Neill Gulch	
CC-2	Canyon Creek downstream of O'Neill Gulch	1971-1993
NMC	Nine Mile Creek above mouth	1971-1993
PLC	Placer Creek above mouth	1977-1991
LC	Lake Creek above mouth	1970-1991
BC	Big Creek above mouth	1970-1991
SFCDR-4	Elizabeth Park downstream to Pinehurst	1967-1994
Tributaries		
PC	Pine Creek above mouth	1972-1994
SFCDR-5	Pinehurst downstream to NFCDR	1966-1986
North Fork Coeur d'Alene River		
NFCDR-1	Headwaters above Shoshone Creek near Prichard	1992-1994
NFCDR-2	Above Shoshone Creek downstream to Enaville	1966-1994
Lower Coeur d'Alene River		
CDR-1	Confluence of NFCDR /SFCDR downstream to Cataldo	1968-1994
CDR-2	Cataldo downstream to Rose Lake	1968-1994
CDR-3	Rose Lake downstream to Harrison	1966-1994
LL	Lateral Lakes	1983-1993
LCDA	Lake Coeur d'Alene	1971-1992
Spokane River		
SR-1	Mouth of Lake Coeur d'Alene downstream to Post Falls	1973-1994
SR-2	Post Falls downstream to below Long Lake Dam	1970-1982

[1] More detailed descriptions of reaches are given in Appendix A, Table A-1B.

[2] Total recoverable measurements (the period of record is not continuous for any reach).

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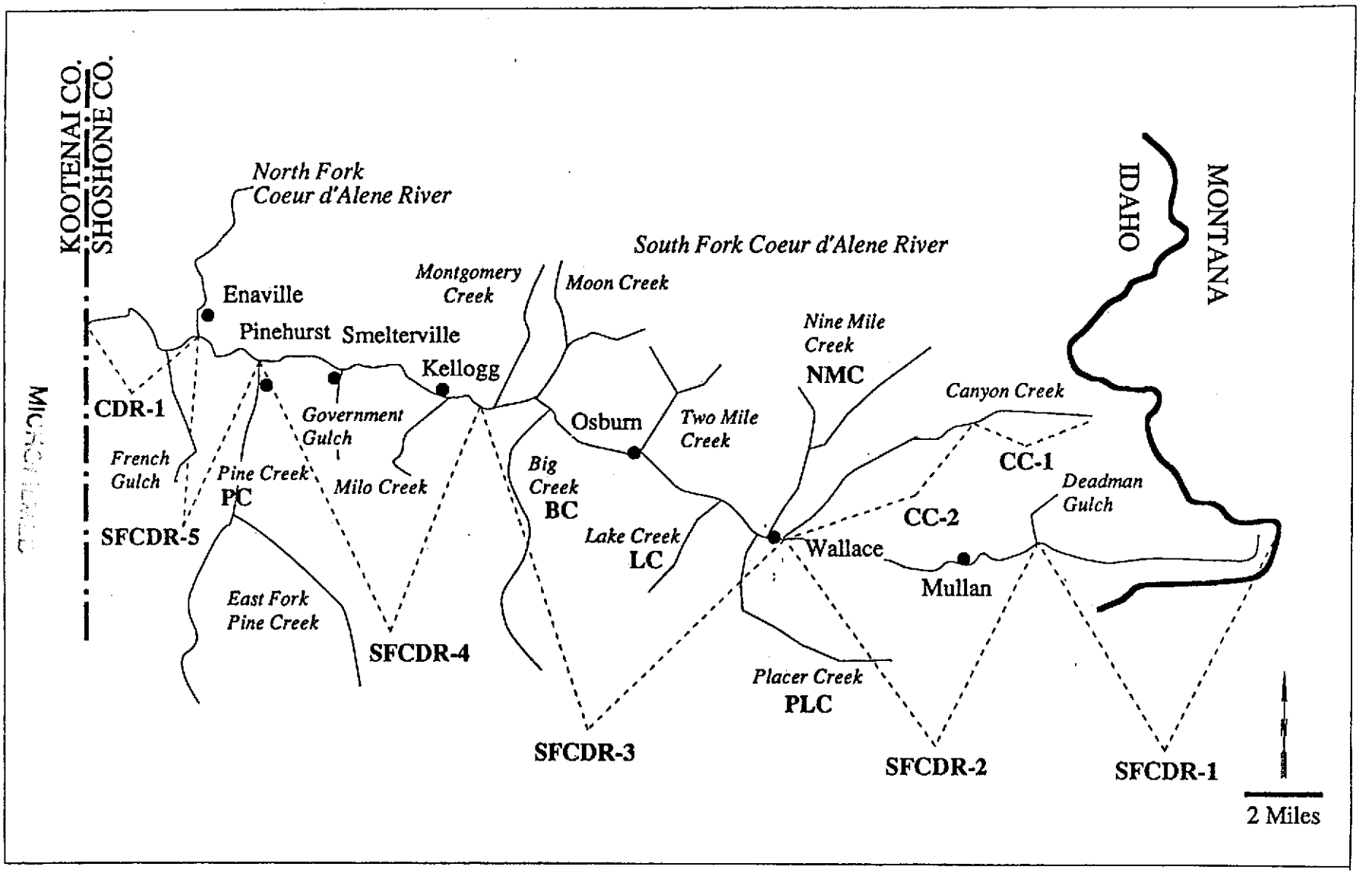


Figure 3-1. Surface Water Reach Locations: South Fork Coeur d'Alene River and Tributaries.

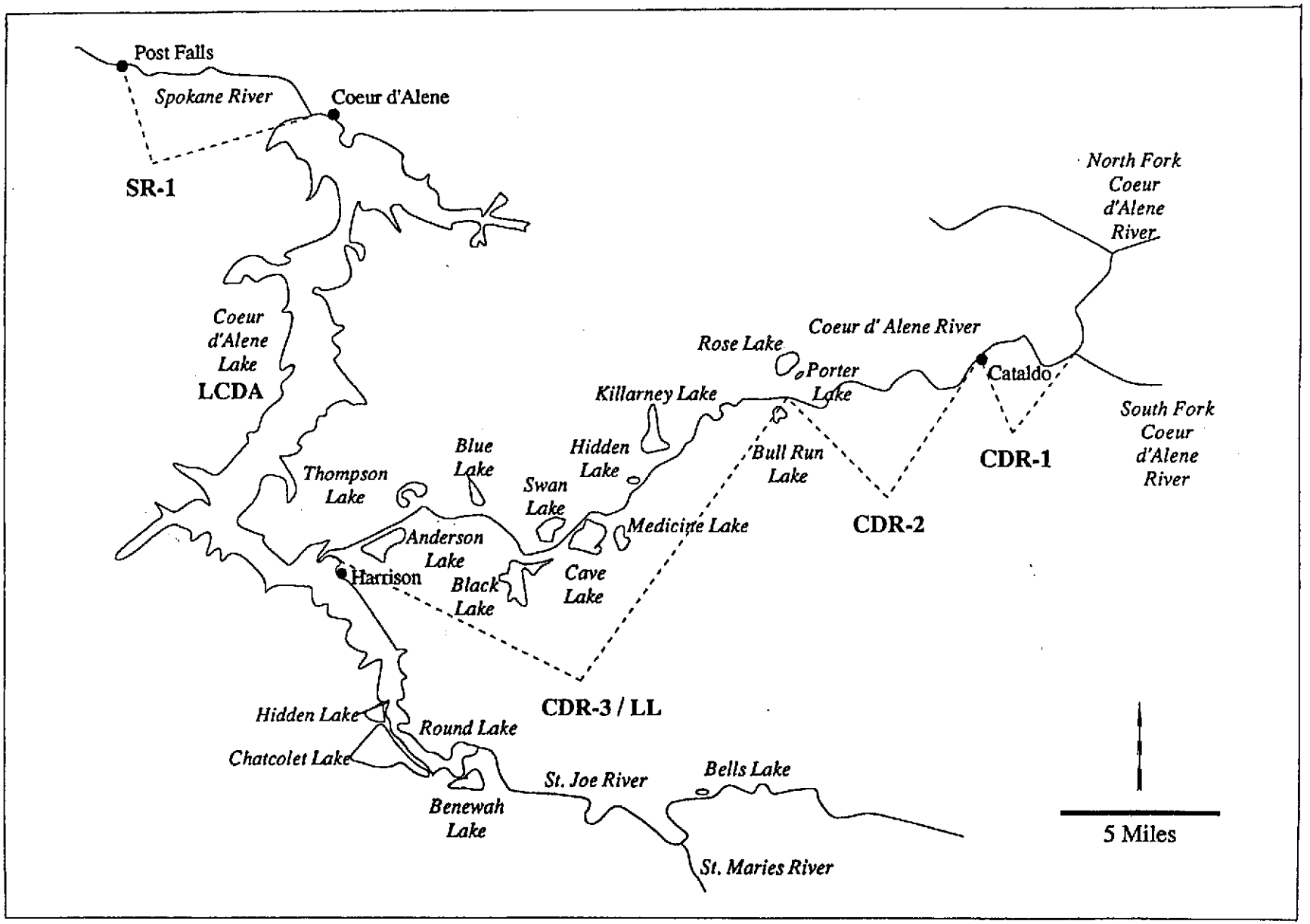


Figure 3-2. Surface Water Reach Locations: Lower Coeur d'Alene River and Lake Coeur d'Alene.

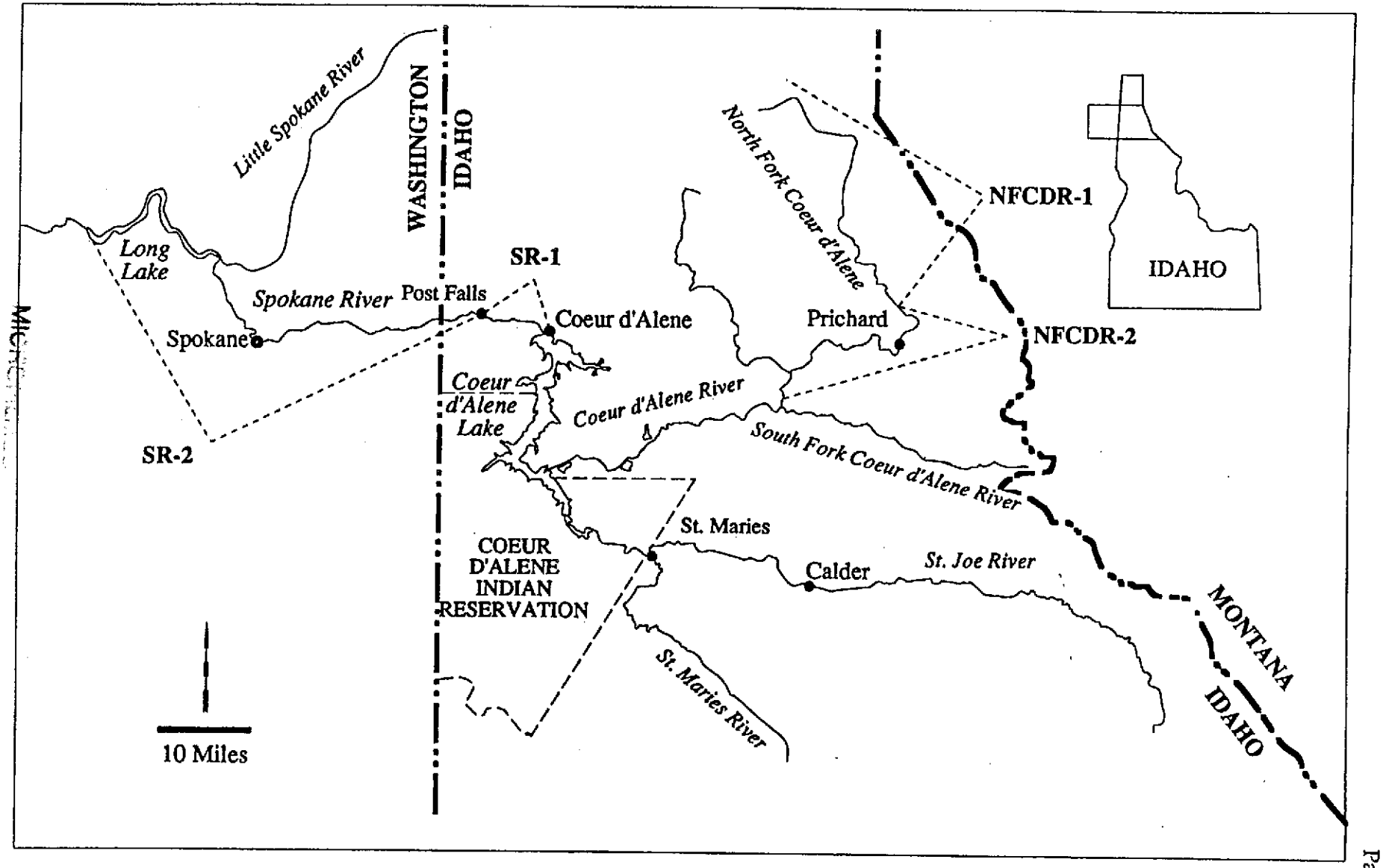


Figure 3-3. Surface Water Reach Locations: Spokane and North Fork Coeur d'Alene Rivers.

evaluation have been selected from studies or data sources that generally have relatively long periods of record, and have been collected and analyzed using standardized methods and QA/QC protocols, ensuring the validity and usability of the data.

Compiled data sources meet the required acceptance criterion, the measurement of hazardous substances in two samples from the resource, either collected from different locations at the same time, or collected from the same location at different times. The following sections briefly discuss the data sources included in the compilation. More detailed discussions of these data sources are included in Appendix A.

3.2.1 EPA STORET Data

The largest single source of available data for the Assessment Area is the EPA STORET database system. The system includes data generated by EPA as well as other agencies, including IDHW-DEQ, USGS, USFS, and others. Most of the STORET data used in the compilation are associated with a long term EPA monitoring program (Hornig et al., 1988) and the Bunker Hill RI/FS (Dames and Moore, 1990).

3.2.1.1 Hornig, Terpening, and Bogue, 1988

This EPA report summarizes the results of a multiyear monitoring program on the Coeur d'Alene River. In all, 26 river stations were sampled for water quality between 1972 and 1986 within reaches on the SFCDR and tributaries, the NFCDR, the LCDR, and Lake Coeur d'Alene. All samples were collected during low flow periods. The report provides an update of conditions as they existed in 1986 and discusses the long term trends documented by the monitoring program. Samples were collected and analyzed according to EPA methods and QA/QC protocols in effect at the time, and are considered usable for the determination of injury.

3.2.1.2 Bunker Hill RI/FS Data

Surface water samples collected during the Bunker Hill RI/FS (1987-1988) included 8 stations on the SFCDR, 3 stations on Pine Creek, and 1 station on the NFCDR (Dames and Moore, 1990). The samples were collected and analyzed, and data were reviewed following QA/QC protocols established by EPA for the RI/FS. The data were considered acceptable for the purposes of the RI/FS, and are considered usable for the determination of injury.

3.2.1.3 Other STORET Data

In certain reaches, additional data from STORET have been included in the evaluation, particularly where other data are lacking. Data sources include IDHW-DEQ and EPA stations, and one USGS station at Long Lake Dam, Washington. Specific studies are not identified for these data in the STORET database. However, the data are assumed to have been acquired in accordance with standard agency protocols in place at the time, and are considered usable for the determination of injury.

3.2.2 USGS WATSTORE Data

A second significant source of available data is the USGS WATSTORE database system. The database includes only data generated by USGS. Data for stations included within the Idaho portion of the Assessment Area are maintained by the Idaho District within their district database. Data from the district database are periodically uploaded to WATSTORE, which is a nation-wide database. Since the Idaho District database is known to be more current, data for the compilation and evaluation have been obtained from the Idaho district database rather

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than WATSTORE. Most of the data used in the compilation are associated with long-term monitoring at gage stations, data collected at gage stations for the Coeur d'Alene Basin NRDA, and two studies of Lake Coeur d'Alene.

3.2.2.1 USGS Monitoring

USGS maintains a system of gage stations within the Assessment Area, many of which have been periodically monitored for water quality. Metals data are available for 23 of these stations from 1967 to 1994. However, the period of record for water quality is not continuous at any one station. All major reaches in the Assessment Area (excluding some tributaries) have at least one USGS gage station with metals data. Water quality monitoring funded in part by the Coeur d'Alene Basin NRDA has been ongoing on a monthly basis at 7 of these stations since 1993. Overall, the data include a mix of total recoverable and dissolved analyses. Data collected since 1993 for the NRDA represent total recoverable analyses. Metals data for the samples were obtained from the Idaho District database.

Water quality samples were collected and analyzed according to USGS standard protocols. The majority of samples were analyzed at the USGS National Water Quality Laboratory in Arvada, Colorado. Data review is conducted by the laboratory before release to the district, and is further reviewed within the district before entry into the district database. Therefore, the data are considered usable for the determination of injury.

3.2.2.2 Woods, 1989

This report summarizes the results of a reconnaissance study of Lake Coeur d'Alene. As part of the study, water quality samples were collected monthly from May through November, 1987 at eight stations located along the lake's thalweg. Two samples were collected at most stations during each sampling event, one within the mid-hypolimnion, and one from 1 meter above the lake bottom. Metals data included dissolved analyses for mid-hypolimnion samples, and dissolved and total recoverable analyses for near bottom samples. Metals data for the samples were obtained from the Idaho District database.

As with stream monitoring samples, the lake samples were collected, analyzed, and the data reviewed according to USGS standard protocols and procedures, and therefore are considered usable for the determination of injury.

3.2.2.3 Woods and Beckwith, 1995

This report (USGS Professional Paper, in press) summarizes a detailed study of Lake Coeur d'Alene that included water quality sampling at 6 limnetic stations, as well as 3 river stations, and 10 lateral lake stations. The limnetic stations were sampled for metals analyses 11 to 13 times during 1991 and 1992. The river stations were also sampled throughout 1991 and 1992. The lateral lake stations were sampled once during a reconnaissance in August 1991. Data for metals analyses are total recoverable concentrations. Metals data for the samples were obtained from the Idaho District database.

As with the previous lake study, samples were collected, analyzed and reviewed according to USGS standard protocols and procedures, and therefore are considered usable for the determination of injury.

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3.2.3 McCulley, Frick & Gilman Data

These data are associated with a surface water quality study conducted by McCulley, Frick & Gilman, Inc. for the State Natural Resource Trustees in 1991 on the SFCDR and tributaries above Elizabeth Park. Samples were collected for the study once during a high flow period (May 1991) and once during a low flow period (October 1991). In all, 56 stations were located on reaches included in the compilation and evaluation. Most of these stations were sampled during both events.

According to the data reports, samples were stored on ice, maintained under chain of custody protocols, and analyzed for metals according to EPA methods. Field QC consisted of duplicate samples, equipment blanks, and trip blanks. Laboratory QC consisted of replicate analyses, laboratory control samples and matrix spike samples. Laboratory data were reviewed and metals results were considered acceptable in accordance with EPA control limits. Therefore, the data are considered usable for the determination of injury.

3.2.4 BLM Data

Surface water quality data for the Assessment Area were obtained from the U.S. Bureau of Land Management (BLM) Coeur d'Alene Office. Data were available for the Lower Coeur d'Alene River (LCDR) and Pine Creek.

3.2.4.1 Lower Coeur d'Alene River

Available data for the LCDR are associated with a river water quality monitoring program (1991 through 1993) and a draft Preliminary Assessment/Site Investigation (PA/SI) conducted during 1992 for BLM by IDHW-DEQ (BLM, undated).

During the period of record for the LCDR water quality monitoring program 6 stations, including 3 river and 3 lateral lake stations, were routinely sampled and analyzed for total recoverable concentrations of metals. The water quality monitoring program was developed according to recommendations provided by Grant, Schreiber, and Associates (1990). QA/QC measures implemented for characterization sampling for the program are indicated as following EPA procedures, including chain of custody and analysis of QC samples. The monitoring program followed the same procedures (D. Fortier, 1995). Therefore, the data are considered usable for the determination of injury.

During the PA/SI, 10 water quality samples were collected from 5 lateral lakes along the LCDR. The samples were analyzed for total recoverable concentrations of metals. The PA/SI report indicates that samples were stored on ice, maintained under chain of custody protocol, and analyzed for metals according to EPA methods. Laboratory QC consisted of a duplicate analysis, a laboratory control sample and a matrix spike sample. Therefore, the data are considered usable for the determination of injury.

3.2.4.2 Pine Creek

Data for Pine Creek are available in a draft PA report prepared for BLM by C.C. Johnson & Malhotra, P.C. (CCJM) in 1994. Surface water samples were collected at 16 locations on Pine Creek during July 1994 and were analyzed for total recoverable concentrations of metals. EPA approved methods and QA/QC protocols for PA/SIs were used (D. Fortier, personal communication 1995), and the data are considered usable for the determination of injury.

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3.3 Data Evaluation

Data from the preceding data sources were compiled by reach into a series of spreadsheets. Most of the data was obtained in electronic digital format from EPA Region 10 (STORET), USGS Idaho District, and BLM Coeur d'Alene. Data associated with the McCulley, Frick, & Gilman study and the BLM PA/SI required data entry from hard copy reports. The acute and chronic AWQC were calculated for each sample for each metal, using available hardness data. A Severity Index (SI) was calculated for each sample and each metal, both acute and chronic. The SI is the measured concentration for a metal divided by the acute or chronic AWQC. The SI is therefore unitless. A SI greater than 1 indicates an exceedance of the criteria The resulting data for total recoverable measurements have been summarized in Tables 4-1 through 4-5, and in a series of graphs in Appendix B (see section 4 for further discussion of results). Dissolved measurements are summarized in Appendix C (Tables C-1 through C-5, and accompanying graphs).

3.3.1 Detection Limits

Analytical detection limits have improved during the time period represented by the data. Detection limits for cadmium and lead associated with older data sets frequently exceed the AWQC. In some cases, detection limits associated with recent data sets also exceed the AWQC for cadmium, both acute and chronic, particularly as the associated hardness decreases. Any sample result reported as a non-detect for a particular metal was not used in the evaluation if the detection limit for that sample exceeded the AWQC, since it is unknown whether the actual concentration for that metal was above or below the AWQC. However, any sample result reported as non-detect for a particular metal that is below the AWQC has been used at the value of the non-detect, since it is known that the actual concentration for the metal is below the AWQC.

3.3.2 Digestion Methods

Sample digestion methods have varied both with time and between agencies. The standard EPA digestion method for aqueous total recoverable metals is SW-846 Method 3005 (EPA, 1987), in which a field-acidified sample is heated and reduced in volume with HNO_3 and HCl. Other agencies may have different operational definitions of total recoverable digestion. For example, USGS uses a warm HNO_3 digestion (M. Hardy, personal communication, 1995). Different digestion methods may affect data comparability. More aggressive digestions than the EPA standard method can extract metals more efficiently, possibly resulting in higher concentrations than would be obtained by the EPA method. Alternatively, a weaker digestion may result in lower concentrations. However, the variability between results obtained from different total recoverable digestion methods is not expected be significant relative to combined sampling and analytical variability, and should not adversely affect overall data comparability.

3.3.3 Hardness Measurements

A hardness value is required to calculate AWQC concentrations for the three metals of concern. However, hardness measurements are not available for all sampling events included in the compilation for which metals measurements are available. If a particular sample had both an associated metal and hardness measurement, that hardness measurement was used in the criteria calculation. However, if no hardness measurement was available for a particular metal measurement, the mean hardness for the reach was substituted in the AWQC calculation. The mean hardness for the reach was determined using all available hardness measurements for a particular reach for the period of record. The mean hardness may underestimate or overestimate the true hardness for a particular measurement; however, use of mean hardness is

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not expected to significantly affect the results of the evaluation. If the measured hardness was below 25 mg/L $CaCO_3$, then the value 25 mg/L $CaCO_3$ was substituted, in accordance with EPA guidelines (Federal Register, 1991).

3.3.4 Data Discontinuities

Although a substantial quantity of surface water quality data are available for the Assessment Area for the past 30 years, data are lacking for certain periods of time in all reaches. Data discontinuities are mostly associated with reaches SFCDR-5 and SFCDR tributary reaches CC-1, PLC, LC, BC, and PC (all metals); NFCDR-1 (all metals), and NFCDR-2 (cadmium); CDR-1, CDR-3, and lateral lakes (all metals); LCDA (lead); and SR-1 and SR-2 (all metals). The reaches with the fewest temporal gaps are SFCDR-1, SFCDR-2, SFCDR-3, SFCDR-4, CDR-2, CC-2, and NMC.

Although data discontinuities do exist for several reaches, sufficient data are available for all reaches for at least one metal to meet the acceptance criterion for injury (Section 2.3).

4.0 AQUATIC WATER QUALITY CRITERIA EXCEEDANCES

Exceedances of acute and chronic AWQC, and thus injury, are illustrated by summary tables and graphical representations. The exceedance summary tables for total recoverable measurements (Tables 4-1 through 4-5) indicate for each reach and each metal (both acute and chronic) the number of samples, the percentage of samples exceeding the criteria, and the range of the exceedances. The measurement of exceedance is the Severity Index, as discussed in Section 3.3.

Graphical representations of exceedances of AWQC for total recoverable measurements are found in Appendix B for each reach and metal, for both acute and chronic criteria. Each graph is a plot of the Severity Index (Y axis) versus year (X axis). Data from EPA, IDHW-DEQ, USGS, BLM, and McCulley, Frick & Gilman are each indicated by a different symbol. For each reach, the period of years represented is the same to facilitate comparison between graphs. The severity index is plotted on a log scale to show the full range of exceedances, which are commonly greater than 100 times the criteria, and to allow visual resolution of data points below a severity index of 1.

Although the following evaluation has been performed using total recoverable measurements, an alternative evaluation using dissolved measurements similarly demonstrates injury (Appendix C). Summary Tables C-1 through C-6 present this evaluation and are organized similarly to those in this section. Graphical representations of exceedances of AWQC for dissolved measurements follow the tables in Appendix C. Although the percentages and the magnitudes of the exceedances are generally lower using dissolved measurements, in many reaches 100% of the samples exceed chronic AWQC at levels that are several orders of magnitude greater than the criterion.

4.1 South Fork Coeur d'Alene River

The SFCDR and its tributaries exhibit significant exceedances of the AWQC over the period of record. Most mining activity in the Assessment Area has been within this watershed. Exceedances for reaches in the SFCDR drainage basin are summarized in Tables 4-1 and 4-2 and depicted in graphically in Appendix B.

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4.1.1 SFCDR

The SFCDR has been subdivided into five reaches for this compilation and evaluation. Exceedances for SFCDR reaches are summarized in Table 4-1. Acute and chronic AWQC are exceeded for all metals in all five reaches. The frequency of AWQC exceedances generally increases downstream on the SFCDR. Additionally, maximum values of AWQC exceedances generally increase downstream.

Reach SFCDR-1 is located in the headwaters of the SFCDR above Mullan. Most of the available data are from stations located below the Lucky Friday #003 Pond discharge. Cadmium shows the greatest impact relative to acute criteria: 27% of the samples collected exceed the criteria, up to a maximum of 500 times the AWQC. Lead shows the greatest impact relative to chronic criteria: 93% of the samples collected exceed the criteria, up to a maximum of 8900 times the AWQC. Reach SFCDR-2 extends from the Mullan area downstream to the confluence with Canyon Creek. Zinc shows the greatest impact relative to acute criteria: 75% of the samples collected exceed the criteria, up to a maximum of 26 times the AWQC. As with SFCDR-1, lead shows the greatest impact relative to chronic criteria: 98% of the samples collected exceed the criteria, up to a maximum of 220 times the AWQC.

Reach SFCDR-3 begins at the confluence with Canyon Creek extending downstream to the USGS gage station at Elizabeth Park. Zinc shows the greatest impact relative to acute criteria: 100% of the samples collected exceed the criteria, up to a maximum of 34 times the AWQC. All metals show significant impact relative to chronic criteria: 100% of the samples collected for each metal exceed the criteria, up to a maximum of 87 times the AWQC for chronic lead.

Reach SFCDR-4 extends from the USGS gage station at Elizabeth Park downstream to the USGS gage at Pinehurst. This reach includes the Bunker Hill complex. Cadmium and zinc show the greatest impact relative to acute criteria: greater than 97% of the samples collected for these two metals exceed the criteria, up to a maximum of 190 times the AWQC for acute zinc. All metals show significant impact relative to chronic criteria: greater than 98% of the samples collected for each metal exceed the criteria, up to a maximum of 910 times the AWQC for chronic lead.

Reach SFCDR-5 begins at the USGS gage at Pinehurst and extends downstream to the confluence with the NFCDR. As with SFCDR-4, cadmium and zinc show the greatest impact relative to acute criteria: greater than 97% of the samples collected for these two metals exceed the criteria, up to a maximum of 630 times the AWQC for acute zinc. All metals show significant impact relative to chronic criteria: greater than 98% of the samples collected for each metal exceed the criteria, up to a maximum of 2100 times the AWQC for chronic lead.

4.1.2 SFCDR Tributaries

Six SFCDR tributaries are included in the evaluation: Canyon Creek (CC-1 and CC-2), Nine Mile Creek (NMC), Placer Creek (PLC), Lake Creek (LC), Big Creek (BC), and Pine Creek (PC). Data availability is best for CC-2, NMC, and PC. Data are limited for CC-1, PLC, LC, and BC. Exceedances for SFCDR tributaries are summarized in Table 4-2. The tributaries are presented in downstream order.

Canyon Creek has been divided into two reaches: CC-1, located above O'Neill Gulch and most of the mining activity in the drainage, and CC-2, which extends downstream from O'Neill Gulch to the confluence with the SFCDR. The limited available data for CC-1 show that impacts relative to AWQC are minor on this reach: No samples collected exceed acute criteria for any

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Table 4-1 - Summary of AWQC Exceedances
Total Concentrations
South Fork Coeur d'Alene River

Criteria	Measure	SFCDR-1	SFCDR-2	SFCDR-3	SFCDR-4	SFCDR-5
Cadmium, acute	Number of samples	44	66	89	191	121
	Percentage exceeding criteria	27%	42%	91%	97%	97%
	Range of severity index (1)					
	Minimum	0.09	0.1	0.7	0.2	0.07
	Maximum	500	13	21	67	100
Cadmium, chronic	Number of samples	23	66	89	191	120
	Percentage exceeding criteria	70%	80%	100%	99%	99%
	Range of severity index					
	Minimum	0.2	0.3	2.2	0.8	0.3
	Maximum	1400	36	67	230	370
Lead, acute	Number of samples	51	68	90	195	107
	Percentage exceeding criteria	14%	25%	21%	36%	67%
	Range of severity index					
	Minimum	0.02	0.01	0.2	0.01	0.06
	Maximum	330	9.0	3.5	36	81
Lead, chronic	Number of samples	27	66	84	187	107
	Percentage exceeding criteria	93%	98%	100%	98%	100%
	Range of severity index					
	Minimum	0.6	0.3	3.9	0.2	1.4
	Maximum	8900	220	87	910	2100
Zinc, acute	Number of samples	78	80	91	195	117
	Percentage exceeding criteria	17%	75%	100%	99%	98%
	Range of severity index					
	Minimum	0.02	0.2	3.9	0.01	0.1
	Maximum	110	26	34	190	630
Zinc, chronic	Number of samples	78	80	91	195	117
	Percentage exceeding criteria	22%	76%	100%	99%	98%
	Range of severity index					
	Minimum	0.02	0.2	4.3	0.01	0.1
	Maximum	120	29	37	200	700

(1) Measured concentrations divided by calculated AWQC.

Table 4-2 - Summary of AWQC Exceedances
Total Concentrations
South Fork Coeur d'Alene River Tributaries

Criteria	Measure	CC-1	CC-2	NMC	PLC	LC	BC	PC
Cadmium, acute	Number of samples	4	101	53	5	8	17	26
	Percentage exceeding criteria	0%	96%	89%	60%	0%	29%	38%
	Range of severity index (1)							
	Minimum	0.1	0.7	0.2	0.2	0.01	0.005	0.1
	Maximum	0.3	75	77	40	0.3	3.6	31
Cadmium, chronic	Number of samples	4	101	53	5	8	17	26
	Percentage exceeding criteria	0%	100%	92%	60%	13%	53%	50%
	Range of severity index							
	Minimum	0.3	1.7	0.4	0.5	0.06	0.01	0.3
	Maximum	0.5	150	200	100	1.2	10	63
Lead, acute	Number of samples	4	107	52	9	10	18	38
	Percentage exceeding criteria	0%	84%	77%	0%	0%	11%	42%
	Range of severity index							
	Minimum	0.07	0.4	0.04	0.06	0.003	0.01	0.04
	Maximum	0.6	190	37	0.6	1.0	4.0	250
Lead, chronic	Number of samples	3	106	50	1	9	9	21
	Percentage exceeding criteria	100%	100%	100%	100%	67%	78%	100%
	Range of severity index							
	Minimum	2	9.1	1.1	14	0.08	0.2	1.9
	Maximum	16	5400	1000	14	25	100	6900
Zinc, acute	Number of samples	21	115	54	13	9	18	46
	Percentage exceeding criteria	0%	100%	96%	0%	11%	11%	89%
	Range of severity index							
	Minimum	0.02	2.0	0.2	0.02	0.04	0.01	0.4
	Maximum	0.6	180	180	0.7	3.7	5.5	76
Zinc, chronic	Number of samples	21	115	54	13	9	18	46
	Percentage exceeding criteria	0%	100%	96%	0%	11%	28%	89%
	Range of severity index							
	Minimum	0.02	2.2	0.3	0.03	0.05	0.01	0.4
	Maximum	0.6	200	200	0.8	4.1	6.1	84

(1) Measured concentrations divided by calculated AWQC.

of the three metals of concern; chronic criteria are exceeded only for lead (100% of the samples collected, up to 16 times the AWQC). Data for reach CC-2 significantly exceed AWQC. All metals show significant impact relative to acute criteria: greater than 84% of the samples collected for each metal exceed the criteria, up to a maximum of 190 times the AWQC for acute lead. All metals show significant impact relative to chronic criteria: 100% of the samples collected for each metal exceed the criteria, up to a maximum of 5400 times the AWQC for chronic lead.

Data for Nine Mile Creek (NMC) include stations on both the main stem and the East Fork. All metals exceed both acute and chronic AWQC on this tributary. All metals show significant impact relative to acute criteria: greater than 77% of the samples collected for each metal exceed the criteria, up to a maximum of 180 times the AWQC for acute zinc. All metals also show significant impact relative to chronic criteria: greater than 92% of the samples collected for each metal exceed the criteria, up to a maximum of 1000 times the AWQC for chronic lead. Data are limited for Placer Creek (PLC). All stations are located close to the mouth of the creek. Acute criteria are exceeded only for cadmium: 60% of the samples collected, up to 40 times the AWQC. Chronic criteria are exceeded for cadmium and lead: 60% and 100% of the samples collected, up to 100 and 14 times the AWQC, respectively; however, only one sample was available for lead.

Data are also limited for Lake Creek (LC). All stations are located close to the mouth of the creek. Acute criteria are exceeded only for zinc: 11% of the samples collected, up to 3.7 times the AWQC. Chronic criteria are exceeded for all three metals. Lead shows the greatest impact relative to chronic criteria: 67% of the samples collected exceed the criteria, up to a maximum of 25 times the AWQC.

Data are also limited for Big Creek (BC). All stations are located close to the mouth of the creek. Cadmium shows the greatest impact relative to acute criteria: 29% of the samples collected exceed the criteria, up to a maximum of 3.6 times the AWQC. Lead shows the greatest impact relative to chronic criteria: 78% of the samples collected exceed the criteria, up to a maximum of 100 times the AWQC.

Data for Pine Creek (PC) include stations on both the main stem and the East Fork. Zinc shows the greatest impact relative to acute criteria: 89% of the samples collected exceed the criteria, up to a maximum of 76 times the AWQC. Lead shows the greatest impact relative to chronic criteria: 100% of the samples collected exceed the criteria, up to a maximum of 6900 times the AWQC.

4.2 North Fork Coeur d'Alene River

The NFCDR has been divided into two reaches, NFCDR-1 and NFCDR-2. Data availability is best for NFCDR-2, although most of the data come from stations located at the downstream end of the reach. Exceedances for NFCDR reaches are summarized in Table 4-3 and depicted in graphically in Appendix B.

Reach NFCDR-1 is located in the headwaters of the NFCDR above the USGS gage station near Shoshone Creek. Availability of data for reach NFCDR-1 is limited to those data collected since 1993 by USGS in conjunction with the NRDA. No hardness data were available for this reach, and the hardness was assumed to be similar to reach NFCDR-2, less than or equal to 25 mg/L $CaCO_3$, which results in minimum criteria concentrations. Detection limits for cadmium in this data set exceed both the acute and chronic AWQC criteria. Since all cadmium results

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Table 4-3 - Summary of AWQC Exceedances
Total Concentrations
North Fork Coeur d'Alene River

Criteria	Measure	NFCDR-1	NFCDR-2
Cadmium, acute	Number of samples	(2)	49
	Percentage exceeding criteria	-	78%
	Range of severity index (1)		
	Minimum	-	0.1
	Maximum	-	180
Cadmium, chronic	Number of samples	(2)	49
	Percentage exceeding criteria	-	84%
	Range of severity index		
	Minimum	-	0.3
	Maximum	-	350
Lead, acute	Number of samples	21	103
	Percentage exceeding criteria	0%	25%
	Range of severity index		
	Minimum	0.07	0.04
	Maximum	0.4	63
Lead, chronic	Number of samples	9	74
	Percentage exceeding criteria	100%	100%
	Range of severity index		
	Minimum	2	2
	Maximum	10	1800
Zinc, acute	Number of samples	21	127
	Percentage exceeding criteria	10%	24%
	Range of severity index		
	Minimum	0.3	0.01
	Maximum	1.1	13
Zinc, chronic	Number of samples	21	127
	Percentage exceeding criteria	10%	27%
	Range of severity index		
	Minimum	0.3	0.02
	Maximum	1.2	14

1) Measured concentrations divided by calculated AWQC. (2) Insufficient data; detection limit exceeded AWQC.

were non-detects, cadmium could not be evaluated. For the other metals, impacts relative to AWQC are minor on this reach. Only zinc exceeds acute criteria: 10% of the samples collected exceed the criteria, up to 1.1 times the AWQC. Lead shows the greatest impact relative to chronic criteria: 100% of the samples collected exceed the criteria, up to a maximum of 10 times the AWQC.

Reach NFCDR-2 extends downstream from the USGS gage station above Shoshone Creek to the USGS gage station at Enaville near the confluence with the SFCDR. All metals exceed the AWQC for reach NFCDR-2. Cadmium shows the greatest impact relative to acute criteria: 78% of the samples collected exceed the criteria, up to a maximum of 180 times the AWQC. Cadmium and lead show the greatest impact relative to chronic criteria: greater than 84% of the samples collected for these two metals exceed the criteria, up to a maximum of 1800 times the AWQC for chronic lead.

4.3 Lower Coeur d'Alene River

Reaches along the LCDR, including the lateral lakes, have received and continue to receive releases of hazardous substances from upstream, and as a result exhibit exceedances of the AWQC over the period of record. Exceedances for reaches along the LCDR are summarized in Table 4-4 and depicted in graphically in Appendix B.

4.3.1 River Reaches of LCDR

The LCDR has been subdivided into three reaches for this compilation and evaluation. More water quality data are available for reach CDR-2 than for the other LCDR reaches. Significant temporal discontinuities in available data exist for reaches CDR-1 and CDR-3. Acute and chronic AWQC are exceeded for all metals in all three reaches.

Reach CDR-1 extends from the NFCDR/SFCDR confluence to the USGS gage station at Cataldo. Zinc shows the greatest impact relative to acute criteria: 98% of the samples collected exceed the criteria, up to a maximum of 51 times the AWQC. All metals show significant impact relative to chronic criteria: greater than 98% of the samples collected for each metal exceed the criteria, up to a maximum of 540 times the AWQC for chronic lead.

Reach CDR-2 extends from the Cataldo gage station to the USGS gage station at Rose Lake. Cadmium and zinc show the greatest impact relative to acute criteria: greater than 91% of the samples collected for these two metals exceed the criteria, up to a maximum of 120 times the AWQC for acute zinc. All metals show significant impact relative to chronic criteria: greater than 99% of the samples collected for each metal exceed the criteria, up to a maximum of 2100 times the AWQC for chronic lead.

Reach CDR-3 extends from Rose Lake gage station to the USGS gage station near Harrison. As with CDR-2, cadmium and zinc show the greatest impact relative to acute criteria: greater than 87% of the samples collected for these two metals exceed the criteria, up to a maximum of 45 times the AWQC for acute zinc. All metals show significant impact relative to chronic criteria: greater than 98% of the samples collected for each metal exceed the criteria, up to a maximum of 670 times the AWQC for chronic lead.

4.3.2 Lateral Lakes

The lateral lakes are located within reach CDR-3. The majority of available data has been

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Table 4-4 - Summary of AWQC Exceedances
Total Concentrations
Lower Coeur d'Alene River and Lateral Lakes

Criteria	Measure	CDR-1	CDR-2	CDR-3	LL
Cadmium, acute	Number of samples	52	181	104	96
	Percentage exceeding criteria	79%	91%	87%	19%
	Range of severity index (1)				
	Minimum	0.5	0.06	0.6	0.3
	Maximum	68	74	22	36
Cadmium, chronic	Number of samples	46	180	103	54
	Percentage exceeding criteria	100%	99%	100%	57%
	Range of severity index				
	Minimum	1.4	0.2	1.7	0.7
	Maximum	190	210	58	83
Lead, acute	Number of samples	52	163	106	85
	Percentage exceeding criteria	31%	56%	47%	56%
	Range of severity index				
	Minimum	0.07	0.03	0.1	0.08
	Maximum	21	79	26	250
Lead, chronic	Number of samples	44	158	105	84
	Percentage exceeding criteria	100%	99%	100%	100%
	Range of severity index				
	Minimum	2.9	0.7	3.3	2
	Maximum	540	2100	670	6400
Zinc, acute	Number of samples	53	227	104	107
	Percentage exceeding criteria	98%	100%	98%	42%
	Range of severity index				
	Minimum	0.9	0.9	0.2	0.02
	Maximum	51	120	45	72
Zinc, chronic	Number of samples	53	227	104	107
	Percentage exceeding criteria	98%	100%	98%	45%
	Range of severity index				
	Minimum	1.0	1.0	0.2	0.02
	Maximum	56	130	49	79

(1) Measured concentrations divided by calculated AWQC.

collected since 1990. Acute and chronic AWQC are exceeded for all metals for the lateral lakes. Lead shows the greatest impact relative to acute criteria: 56% of the samples collected exceed the criteria, up to a maximum of 250 times the AWQC. Lead also shows the greatest impact relative to chronic criteria: 100% of the samples collected exceed the criteria, up to a maximum of 6400 times the AWQC.

4.4 Lake Coeur d'Alene/Spokane River

According to Horowitz, et al. (1995), "an estimated 75 million tonnes of trace element-rich sediments have been deposited on or in the lake bed" of Lake Coeur d'Alene, much of which were derived from the Coeur d'Alene River. The outlet of Lake Coeur d'Alene marks the headwaters of the Spokane River. Exceedances of acute and chronic AWQC for all metals are exhibited for both Lake Coeur d'Alene and the Spokane River as far downstream as Long Lake Dam, Washington. Exceedances for the Lake Coeur d'Alene and the Spokane River are summarized in Tables 4-5, and depicted graphically in Appendix B.

4.4.1 Lake Coeur d'Alene

All available data for Lake Coeur d'Alene have been grouped for the compilation and evaluation. All but 3 of the 34 stations included in the compilation are north of Conkling Point. Surface sediments north of this point are substantially enriched in trace-elements compared to relatively unimpacted sediments to the south of the point (Horowitz, et al., 1992). In general, exceedances of AWQC criteria for the 3 stations south of Conkling Point are somewhat lower in frequency and magnitude, particularly for zinc.

Available data are more limited for cadmium and lead than for zinc, principally because high detection limits associated with older data sets have precluded the use of many non-detects. Cadmium and zinc show the greatest impact relative to acute criteria: greater than 68% of the samples collected for these two metals exceed the criteria, up to a maximum of 48 times the AWQC for acute cadmium. All metals show significant impact relative to chronic criteria: greater than 88% of the samples collected for each metal exceed the criteria, up to a maximum of 240 times the chronic lead AWQC.

4.4.2 Spokane River

Emphasis for the surface water quality data compilation and evaluation has been placed on the uppermost reach of the Spokane River (SR-1), from the outlet of Lake Coeur d'Alene to the USGS gage station below Post Falls Dam. Cadmium and zinc show the greatest impact relative to acute criteria on SR-1: greater than 97% of the samples collected for these two metals exceed the criteria, up to a maximum of 38 times the AWQC for acute cadmium. All metals show significant impact relative to chronic criteria: greater than 98% of the samples collected for each metal exceed the criteria, up to a maximum of 780 times the chronic lead AWQC.

Reach SR-2 extends from the Spokane River below Post Falls to the USGS gage station below Long Lake Dam, Washington. However, the only station included in this compilation and evaluation is the USGS gage station below Long Lake Dam. Zinc shows the greatest impact relative to acute criteria: 61% of the samples collected exceed the criteria, up to a maximum of 19 times the AWQC. Cadmium and lead show the greatest impact relative to chronic criteria: greater than 97% of the samples collected for these two metals exceed the criteria, up to a maximum of 180 times the chronic lead AWQC.

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Table 4-5 - Summary of AWQC Exceedances
Total Concentrations
Lake Coeur d'Alene and Spokane River

Spokane River Reach 1

Criteria	Measure	LAKE CDA	SR-1	SR-2
Cadmium, acute	Number of samples	62	59	12
	Percentage exceeding criteria	68%	97%	25%
	Range of severity index (1)			
	Minimum	0.1	0.4	0.4
	Maximum	48	38	13
Cadmium, chronic	Number of samples	62	58	10
	Percentage exceeding criteria	98%	98%	100%
	Range of severity index			
	Minimum	0.3	0.8	1.1
	Maximum	150	75	33
Lead, acute	Number of samples	243	98	29
	Percentage exceeding criteria	5%	30%	17%
	Range of severity index			
	Minimum	0.04	0.07	0.03
	Maximum	8.6	28	7.0
Lead, chronic	Number of samples	132	97	29
	Percentage exceeding criteria	100%	100%	97%
	Range of severity index			
	Minimum	2	2	0.9
	Maximum	240	780	180
Zinc, acute	Number of samples	296	167	51
	Percentage exceeding criteria	87%	98%	61%
	Range of severity index			
	Minimum	0.03	0.3	0.3
	Maximum	46	23	19
Zinc, chronic	Number of samples	296	167	51
	Percentage exceeding criteria	88%	98%	67%
	Range of severity index			
	Minimum	0.03	0.3	0.3
	Maximum	51	25	21

(1) Measured concentrations divided by calculated AWQC.

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4.5 Conclusions

Surface water resources are determined to have been injured according to regulatory definition whenever one or more metals exceeds the most stringent AWQC at any two locations in the Assessment Area at any point in time, or at any one location at two points in time. Available surface water quality data collected since the mid-1960's show that AWQC are frequently exceeded at many locations and points in time, and thus surface water resources are injured throughout the Assessment Area. The following table (Table 4-6) summarizes information in Tables 4-1 through 4-5. For each reach group, the table shows the ranges of percentages of samples exceeding the most stringent criterion (chronic AWQC) and the ranges of the maximum severity indices:

Table 4-6. Summary of Exceedances of Most Stringent Criterion (Chronic AWQC) Total Recoverable Measurements

Reach Group	Measure	Cadmium	Lead	Zinc
SFCDR Reaches	Range of Percentages[1]	70-100	93-100	22-100
	Range of Maximum SI[2]	36-1400	87-8900	29-700
SFCDR Tributaries	Range of Percentages	0-100	67-100	0-100
	Range of Maximum SI	0.5-200	14-6900	0.6-200
NFCDR Reaches	Range of Percentages	84	100	10-27
	Range of Maximum SI	350	10-1800	1.2-14
Lower CDR Reaches and Lateral Lakes	Range of Percentages	57-100	99-100	45-100
	Range of Maximum SI	58-210	540-6400	49-130
Lake Coeur d'Alene	Range of Percentages	98	100	88
	Range of Maximum SI	150	240	51
Spokane River Reaches	Range of Percentages	98-100	97-100	67-98
	Range of Maximum SI	33-75	180-780	21-25

[1] Percentage of samples exceeding the chronic AWQC.

[2] Maximum severity index (SI) (measured concentration divided by chronic AWQC).

Injury is evident for every reach based on any one of the three metals used in the evaluation. Overall, the Assessment Area has been highly impacted by all three metals: 93% of the 1261 samples included in the total recoverable evaluation for cadmium exceeded the chronic

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cadmium AWQC; 95% of the 1390 samples included for lead exceeded the chronic lead AWQC; and 82% of the 1844 samples included for zinc exceeded the chronic zinc AWQC. Although fewer in number, dissolved measurements show the same pattern: 93% of the 476 samples included in the dissolved evaluation for cadmium exceeded the chronic cadmium AWQC; 85% of the 534 samples included for lead exceeded the chronic lead AWQC; and 81% of the 744 samples included for zinc exceeded the chronic zinc AWQC.

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EFFECT OF MINING AND RELATED ACTIVITIES ON THE SEDIMENT TRACE ELEMENT GEOCHEMISTRY OF LAKE COEUR D'ALENE, IDAHO, USA. PART I: SURFACE SEDIMENTS

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ABSTRACT

During the summer of 1989 surface sediment samples were collected in Lake Coeur d'Alene, the Coeur d'Alene River and the St Joe River, Idaho, at a density of approximately one sample per square kilometre. Additional samples were collected from the banks of the South Fork of the Coeur d'Alene and the Coeur d'Alene Rivers in 1991. All the samples were collected to determine trace element concentrations, partitioning and distribution patterns, and to relate them to mining, mining related and discharge operations that have occurred in the Coeur d'Alene district since the 1880s, some of which are ongoing.

Most of the surface sediments in Lake Coeur d'Alene north of Conkling Point and Carey Bay are substantially enriched in Ag, As, Cu, Cd, Hg, Pb, Sb and Zn relative to unaffected sediments in the southern portion of the lake near the St Joe River. All the trace element enriched sediments are extremely fine grained (mean grain sizes $\ll 63\,\mu m$). Most of the enriched trace elements, based on both the chemical analyses of separated heavy and light mineral fractions and a two step sequential extraction procedure, are associated with an operationally defined Fe oxide phase; much smaller percentages are associated either with operationally defined organics/sulphides or refractory phases.

The presence, concentration and distribution of the Fe oxides and heavy minerals indicates that a substantial portion of the enriched trace elements are probably coming from the Coeur d'Alene River, which is serving as a point source. Within the lake, this relatively simple point source pattern is complicated by a combination of (1) the formation of trace element rich authigenic Fe oxides that appear to have reprecipitated from material solubilized from anoxic bed sediments and (2) physical remobilization by currents and wind driven waves. The processes that have caused the trace element enrichment in the surface sediments of Lake Coeur d'Alene are likely to continue for the foreseeable future.

KEY WORDS Lake sediments Sediment trace element geochemistry Mining impact

INTRODUCTION

By the year 2000, the recovery of metal ores is projected to have directly affected about 240 000 km^2 of the earth's surface, whereas milling and smelting activities currently release between 7 and 70 $\times 10^3$ tonnes of trace elements to the aquatic environment (Moore and Luoma, 1990). A number of areas in the USA, some of which have been designated by the US Environmental Protection Agency as 'superfund sites', such as the Clark Fork River Basin (Montana), the Bunker Hill Complex (Idaho), Whitewood Creek and the Belle Fourche River near Lead (South Dakota), and the Arkansas River and tributaries around Leadville (Colorado), have been affected by current or historic mining and processing activities, or both. A thorough evaluation and understanding of the sources, transport pathways and chemical changes of trace elements

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released to the environment as a result of mining and processing should be viewed as a requisite to developing acceptable remediation measures for affected sites and for designing effective waste management practices to prevent future impacts (Moore and Luoma, 1990).

Lake Coeur d'Alene (CDA) is a natural (submerged river bed) lake in the northern panhandle of Idaho and is about 80 km downstream from the Bunker Hill Complex (Figure 1). The lake lies between the Selkirk and the CDA Mountains and extends northwards from the St Joe River to the headwaters of the Spokane River near the city of CDA (Meckel Engineering *et al.*, 1983; Bender, 1991). The main body of Lake CDA is about 3·2 km wide by 40 km long; however, the southern part is composed of four smaller interconnected lakes that were formed in 1906 when the Post Falls Dam (16 km downstream on the Spokane River) was completed (Meckel Engineering *et al.*, 1983) (Figure 1). The St Joe and CDA Rivers account for 94% ($\approx 4{\cdot}73\ Gm^3\ yr^{-1}$) of the inflow to Lake CDA (Meckel Engineering *et al.*, 1983; Javorka, 1991). Major outflow from the lake occurs at the northern end through the Spokane River. Urban development has increased around Lake CDA and centres on the cities of CDA and Harrison. Much of the shoreline, especially along the bays of the northern part of the lake, supports a substantial year-round residential population. Finally, Lake CDA is a major recreational area for swimming, boating and fishing (Meckel Engineering *et al.*, 1983; Javorka, 1991).

The South Fork of the CDA River begins in the Bitterroot Mountain Range near the Idaho/Montana border and flows slightly north of west through the CDA mining district and the cities of Mullan, Wallace, Kellogg, Smelterville and Pinehurst; it joins the main stem of the CDA River about 4·8 km above Cataldo at Enaville (Figure 1). Between Wallace and Enaville, the South Fork flows rapidly, with a gradient of 5·7 m/km, and little sediment is deposited in the river bed or along its banks and flood plain (Mink, 1971; Norbeck, 1974; Bender, 1991). Below Enaville, the gradient of the CDA River decreases to 0·19 m/km due to backwater from the Post Falls Dam, and substantial amounts of sediment are deposited in the main channel and along the banks and flood plain (Bender, 1991). Annually during high flow (e.g. spring snowmelt and runoff), these sediments are resuspended, transported and redeposited both in the river and in the lake (Bender, 1991).

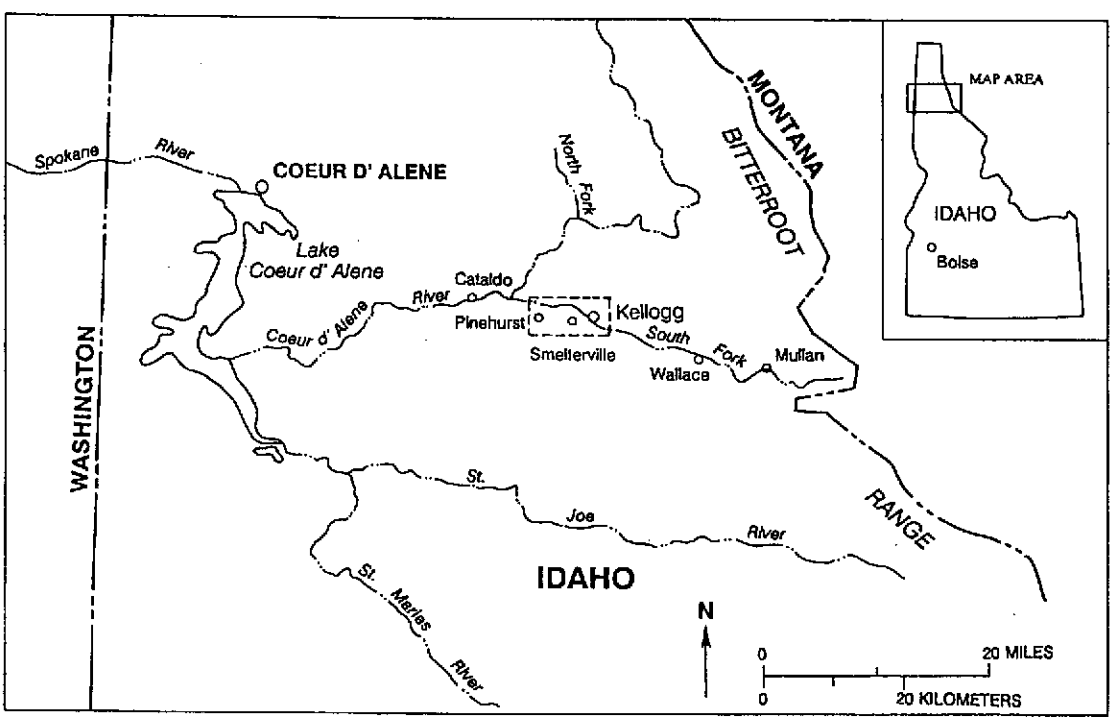


Figure 1. General location map of the South Fork of the Coeur d'Alene River, the St Joe River and Lake Couer d'Alene. The dashed box outlines the location of the 54 km^2 US EPA Bunker Hill Superfund Site

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The South Fork drains a substantial part of the CDA mining district and the so called 'Silver Valley'. The mining district has been in operation since the 1880s and was one of the major sources of Ag, Pb and Zn in the USA (Bender, 1991). Until 1968, when tailings ponds were established to limit sediment transport, most of the mining and ore processing wastes were discharged directly into the South Fork of the CDA River. As late as 1964, additional estimates indicated that about 2200 t d^{-1} of mining and processing wastes still were entering the South Fork (Reece *et al.*, 1978). It has been estimated that during the course of mining, processing and smelting operations in the area, about 115×10^6 tonnes of mine tailings were produced and that over 60% of this material probably entered the South Fork of the CDA and the CDA River system (Javorka, 1991). These materials were highly enriched in Ag, As, Cd, Cu, Fe, Mn, Pb, Sb and Zn (Rabe and Bauer, 1977; Bender, 1991). Specific sources of trace element rich sediments to the South Fork have included: direct discharge of acid mine drainage (until 1965), direct discharge of Pb smelter and Zn plant wastes (until 1974), direct discharge of central impoundment pond and gypsum pond water (until 1974), seepage from the central impoundment area, numerous accidental spills, contaminated overland flow from interaction with airborne deposition and reworking by the river of relatively unconfined mine tailings which had previously been deposited (Woodward-Clyde and Terragraphics, 1986). In 1983, as a result of the increased trace element concentrations of the mining and processing wastes, the US Environmental Protection Agency (EPA) established the Bunker Hill Superfund Site that encompasses 54 km^2 in the Kellogg and Smelterville Flats area (e.g. Bender, 1991; Figure 1).

The St Joe River is south of, and roughly parallels, the South Fork of the CDA and the CDA Rivers (Figure 1). The St Joe River has an average annual discharge slightly higher than that of the CDA River (2·45 Gm^3 yr^{-1} compared with 2·28 Gm^3 yr^{-1}). The river has been used primarily by the logging industry, has supported no major mining activities and has been reported to be relatively uncontaminated with trace elements (Mink, 1971; Rabe and Flaherty, 1974; Bender, 1991).

Between the 1880s (onset of mining operations) and the 1930s, jig tailings containing increased trace element concentrations were left in massive piles along the valley of the South Fork of the CDA River, especially in the Kellogg–Smelterville Flats area (Inoannou, 1979). In the 1930s a dam was constructed downstream from Smelterville to retain the tailings in settling ponds as an aid to secondary ore recovery and to reduce the remobilization and transport of mining and milling wastes (Bender, 1991). In 1968, more than 25 years after Ellis (1940) first recommended it, tailings ponds were constructed to reduce the amount of mining, milling and smelting wastes entering the South Fork of the CDA River. Based on decreases in turbidity, the ponds appeared to reduce the suspended sediment load in the river and lake (Mink, 1971; Ellsworth, 1972). Mining wastes are still actively discharged to the South Fork of the CDA River under a US EPA NPDES permit that allows up to 5 t yr^{-1} of Pb (Neufeld, 1987).

Over the years, numerous environmental studies carried out in the CDA region have indicated that large amounts of mining, milling and ore processing wastes enriched in As, Cu, Cd, Fe, Mn, Pb, Sb and Zn have been deposited throughout the lower CDA River and Lake CDA and have had a substantial effect on the sediment geochemistry, the water quality and the biota of the South Fork of the CDA River, the main stem of the CDA River, Lake CDA and the Spokane River (Ellis, 1940; Galbraith, 1971; Ellsworth, 1972; Funk *et al.*, 1973; Bauer, 1974; Maxfield *et al.*, 1974a; 1974b; Norbeck, 1974; Funk *et al.*, 1975; Sheppard and Funk, 1975; Inoannou, 1979; Wai *et al.*, 1985; Savage, 1986; Neufeld, 1987; Krieger, 1990; Piske, 1990; Bender, 1991). Although natural processes may contribute some trace elements to the drainage basin because there are exposed ore bearing rocks (Fryklund, 1964), most appear to originate from mining and ore processing in the CDA mining district. This view is supported by (1) an evaluation of the chemical data from a series of gravity cores collected in Lake CDA which indicate that enriched trace element levels appear to be confined to the upper 20 cm (recently deposited) of the sediment column (Funk *et al.*, 1975) and (2) estimates that > 90% of the metal loadings in the CDA River at Cataldo are due to inputs from the South Fork of the CDA River which, in turn, is strongly affected by material associated with mining and related activities (Woodward-Clyde and Terragraphics, 1986; Grant, Schreiber & Associates, 1990).

As early as 1923 it was noted that the silt load of the CDA River had increased commensurately with mining operations, and that a substantial sediment plume could be detected far into Lake CDA (Kemmerer

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et al., 1923, cited in Bender, 1991). Maxfield *et al.* (1974a; 1974b) reported highly variable, but increased trace element concentrations in sediments from the CDA River delta; variations were related to sediment grain size, with the highest concentrations being associated with the finer silt and clay fractions. Based on a limited number of core samples, Funk *et al.* (1975) detected increased trace element concentrations in the CDA River delta near Harrison. The increased concentrations could be detected in sediments as far as the northern end of Lake CDA at the headwaters of the Spokane River; however, the thickness of these deposits decreased with proximity to the outlet of the lake (80 cm reducing down to about 5 cm). Finally, substantially increased trace element concentrations have been reported from a variety of sediment samples collected by the US EPA from Lake CDA, and various sections of the CDA River (Hornig *et al.*, 1988).

Although many studies have been carried out in the CDA valley and drainage basin, it is apparent that a detailed and co-ordinated study of the entire lake is overdue. Such a study is necessary to evaluate the potential effects of the inputs of substantial amounts of trace elements into Lake CDA, the effect of increasing nutrient induced eutrophication on these trace element rich sediments, and to establish a management plan to deal with them. As such, in 1990, the Idaho Department of Health and Welfare, Division of Environmental Quality, entered a joint funding agreement with the US Geological Survey to evaluate the water quality of Lake CDA. A major part of this effort was a detailed study of the trace element geochemistry of the bed sediments in the lake. The results from an examination of the surficial sediments of Lake CDA are reported in this paper.

SAMPLE COLLECTION, TREATMENT AND ANALYTICAL METHODS

Sample collection

Surface bed sediment samples were collected in Lake CDA, the CDA River and the St Joe River, Idaho at a density of approximately one sample per square kilometre during one week in August 1989 (Figure 2). Preliminary sampling sites were located, before collection, using 1980 US Geological Survey 7·5 min topographic series maps. During the sampling operation actual sites were located and mapped by taking manual cross-bearings using prominent natural physical or manmade structures, or both. Water depths ranged from < 1 m to slightly over 55 m. Attempts to sample the upper Spokane River failed because the river bottom appeared to be armoured.

Undisturbed (stratified) samples were collected using a stainless-steel Ekmann grab sampler. Subsamples were removed from the grab using polypropylene sample containers. The subsamples were removed from the upper 2 cm of sediment in each grab; care was exercised to ensure that no material was removed from near the metal walls of the sampler. As soon as the subsamples were removed, the containers were capped, labelled and stored on ice at 4°C. The samples were maintained at that temperature during storage, shipped to Atlanta, and kept chilled until they could be processed. Also, a limited group of samples from the river bank were collected by hand, using a plastic trowel, along the lower part of the CDA River. These samples were stored and preserved in the same way as the grab samples. Additional bank samples were collected along the South Fork of the CDA and the CDA Rivers during 1991. These samples were collected and preserved in the same way as those collected during 1989.

Sample pretreatment

Each sample was homogenized with an acid rinsed glass rod and sieved through a 2000 μm polyester screen to remove overly large material (wood chips, leaf litter, etc.). The samples were then freeze dried. Appropriately sized aliquots were removed for specific procedures using an acrylic riffle splitter. Where necessary, aliquots for bulk chemical analyses were ground to < 100 mesh using a sealed ceramic ball mill.

Bulk chemical analysis

Chemical analyses for Fe, Mn, Al, Ti, Cu, Zn, Cd, Pb, Ni, Co, Cr, As, Sb, Se and Hg were made following a slight modification of the procedures of Horowitz *et al.* (1989). For all chemical elements other

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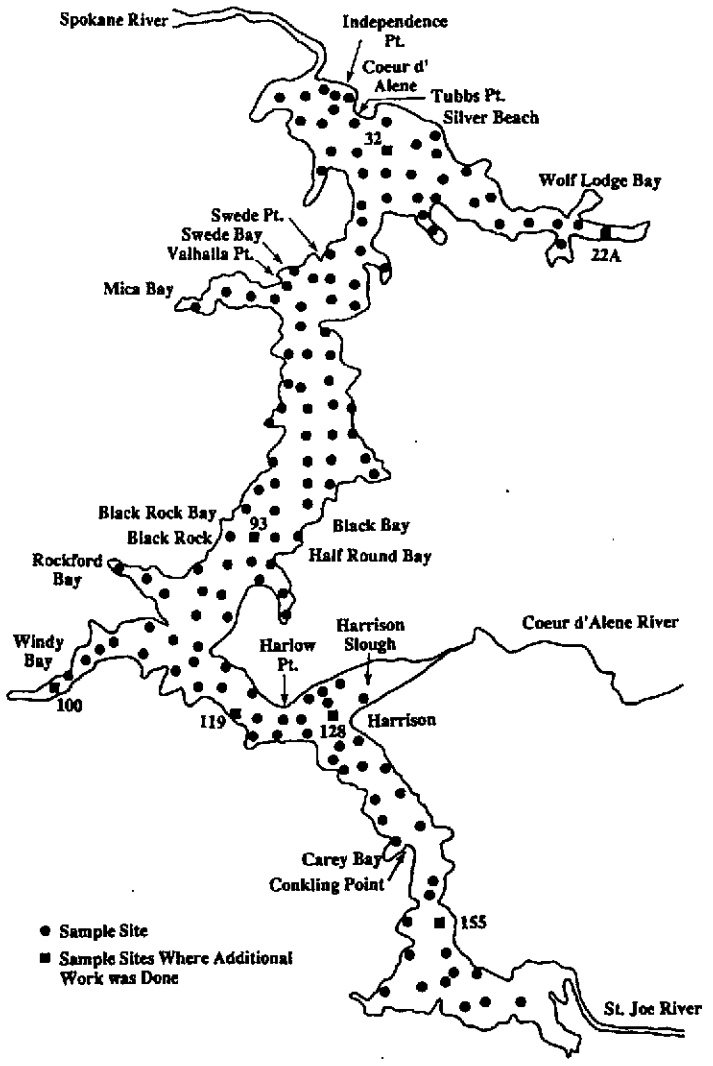


Figure 2. Detailed map of Lake Coeur d'Alene including all sampling locations and cities and features cited in the text

than As, Sb, Se and Hg, 500 mg aliquots were digested with a combination of HF–$HClO_4$–aqua regia in PTFE beakers at 200°C; the resulting salts were dissolved using 50 ml of 2% HCl. Determination was by flame atomic absorption spectrometry (AAS) using mixed salt standards. The same digestion procedure was used for As, Sb and Se, but final solutions were made up in 50% HCl. Selenium was determined in the digestate; As and Sb were determined after the addition of urea and an oxalic acid–hydroxylamine solution and reduction using KI. Determination of all three was by hydride generation AAS. Mercury was determined using 500 mg aliquots digested with LeFort aqua regia at 100°C and a cold vapour technique. Precision and bias (usually better than ±10%) were monitored by replicate analyses of selected samples and by the concomitant digestion and analysis of NIST sediment and US Geological Survey rock and soil standards, and are similar to those reported in Horowitz and Elrick (1985) and Elrick and Horowitz (1985; 1987). Total organic carbon (TOC) was determined on aliquots pretreated with 10% HCl to remove inorganic carbonates, by the evolution of CO_2 using a Leco CR-12 carbon analyser. Precision was better than ±10%; no bias was detected.

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Grain size separations

Grain size separations were made on selected samples for subsequent chemical analyses following the procedures of Horowitz and Elrick (1986; 1988) which consisted of sieving and air elutriation. Unground, freeze dried sample aliquots were placed on an acrylic sieve frame fitted with a 63 μm polyester mesh and wet sieved with deionized water. Material passing through the sieve, and that retained by it, was freeze dried. Material > 63 μm was sized using a stack of acrylic sieves fitted with polyester screens on a shaker table (> 1000, 500–1000, 250–500, 125–250 and 63–125 μm). The material from the pan was added to that which had passed through the 63 μm mesh during the wet sieving, and additional size fractions were separated using air elutriation (32–63, 16–32, 8–16, 4–8, 2–4 and < 2 μm).

Heavy mineral separations

Heavy mineral separations were made on selected samples for subsequent chemical analysis to help partition (determine the phase associations) the trace elements in the Lake CDA samples. Separations were made using a combination of bromoform ($\rho = 2{\cdot}96\,g\,cm^{-3}$) and 100 μl of a surfactant to prevent flocculation. A 10 g sample was floated on 50 ml of the heavy liquid in a 50 ml polypropylene centrifuge tube. The tube was spun at 2000 rev min^{-1} (400 g) for 30 minutes. The heavy mineral fraction which accumulated at the bottom of the centrifuge tube was frozen with liquid nitrogen and the supernatant and light fraction were decanted. The light fraction was washed three separate times with acetone, followed by a single deionized water rinse to remove the bromoform, and oven dried at 105°C before chemical analysis. The frozen heavy mineral fraction was thawed at room temperature and washed and dried in the same manner as the light fraction before chemical analysis.

Geochemical phase determinations

Operationally defined geochemical phase determinations were carried out on dried, unground aliquots using selected procedures from methods developed by Tessier *et al.* (1979) and Chao and Zhou (1983) to partition the trace elements into an Fe oxide phase and an organic/sulphide phase. The Fe oxide procedure used 0·25 M hydroxylamine hydrochloride in 0·25 M HCl heated at 50°C for 30 minutes in a shaking water bath; the organics/sulphide procedure used 30% H_2O_2 adjusted to pH 2 with HNO_3 heated at 85°C for 5 hours followed by treatment with 3·2 M ammonium acetate in 20% v/v HNO_3 shaken at room temperature for 30 minutes. Two 1 g aliquots were sequentially extracted, first for Fe oxide, then for organics/sulphides, in 50 ml centrifuge tubes. Between extractions, the samples were centrifuged at 3000 rpm (895 g), the supernatant decanted and discarded, and the residue washed with deionized water. One residue was retained for subsequent chemical analysis to determine Fe oxide associated trace elements, whereas the other was subjected to the remaining extraction. The second extract was treated in the same way as the first, and the residue was subsequently analysed to determine the organics/sulphide associated trace elements. Chemical analyses of the residues were performed following the same procedures as used for the bulk analyses (see earlier). Precision and bias were monitored by carrying out replicate determinations and by using US Geological Survey MAG-1 and one or two of the GXR-1–GXR-6 standards. Precision and bias were similar to those for the bulk determinations.

Scanning electron microscopy

Some of the heavy/light mineral separates also were subjected to scanning electron microscopy (SEM) linked to an energy dispersive X-ray (EDAX) system to obtain selected chemical data that were used to infer the mineralogy. The heavy mineral separates were mounted on glass slides with an epoxy resin and polished. Before SEM/EDAX analysis the slides were mounted on metal stubs and coated with a carbon film. The treated slides were examined in a backscattering mode at 30 keV to select likely candidates for subsequent EDAX analysis.

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RESULTS AND DISCUSSION

General observations

The August 1989 surface sediment sampling programme took place after an extended period of low flow from both the CDA and St Joe Rivers. Lake CDA therefore contained little suspended sediment and the bottom could be observed to depths of 4–5 m. In the shallow areas around the CDA River delta near Harrison (Figure 2) there were extensive macrophyte beds. Substantial streams of bubbles emanating from irregular sediment mounds indicated active gas production. Based on the 1980 US Geological Survey 7·5 min topographic series maps used for navigation and for locating sample sites, there has been a substantial increase in the size and extent of the macrophyte beds in the shallow areas of Lake CDA. Macrophytes are abundant in areas around the CDA River delta and in and near the mouth of the St Joe River. Although the sampling programme was not designed nor intended to assess the benthic invertebrate population, it appeared that the grab samples from the bed of Lake CDA, outside the areas of the macrophyte beds, contained little or no benthic infauna.

Most of the surface sediment samples collected from the main body of Lake CDA, and from many of the bays (e.g. Wolf Lodge, Mica, Rockford and Windy) north of the CDA River delta, were tan to brown in colour and visually and texturally appeared to be fine to very fine grained ($< 63\,\mu m$). Many of the samples obtained from the main body of Lake CDA had very thin (of the order of a few millimetres) surface veneers of reddish, fine grained material, containing numerous black flecks. Based on an examination of the bank deposits along the CDA River below the area of mining and ore processing operations, this reddish material might be either fine grained mining and ore processing waste or authigenic Fe oxides eroded from the river banks or flood plain of the CDA River. It might also be mineral grains coated with, or individual grains of, authigenic Fe and Mn oxides that were formed from post-depositional dissolution, remobilization and reprecipitation due to anoxic conditions in the sediment column of the lake.

Many of the sediment samples collected in the main body of Lake CDA south of Rockford Bay to the mouth of the St Joe River contained an extremely cohesive, light grey silty clay grain sized layer from 1·5 to 3 cm below the surface. Based on colour and texture, these layers probably represent ash from Mt St Helen's, which blanketed the southern part of Lake CDA after the 1981 eruption. The average depth of this cohesive layer implies a recent sedimentation rate of the order of 0·3 to 0·5 cm yr^{-1}.

All attempts to collect surface sediments from the upper 6 km of the Spokane River failed. The only material recovered was an occasional rounded cobble indicating that this section of the river bottom is armoured. Surface sediments were collected along the lower 6 km and the lower 14 km of the St Joe and the CDA Rivers, respectively. Sediments from the St Joe River were dark olive and substantially coarser (fine to medium sand with some silt) than those found in Lake CDA. The sediments from the CDA River appeared coarser grained than the material collected from the CDA River delta and from the main body of Lake CDA. Most of the CDA River samples contained substantial amounts of reddish black material similar in colour, but finer grained, than that in exposed varves along both banks of the river.

Bulk chemistry

The minimum, maximum, mean and median bulk chemical data for all the Lake CDA surface sediments clearly show that most of the surface sediments are markedly enriched in Ag, As, Cd, Hg, Pb, Sb and Zn, and somewhat enriched in Cu, Fe and Mn (Table I) relative to unaffected fluvial sediments throughout the USA (e.g. Horowitz *et al.*, 1989; Horowitz, 1991). The samples containing increased trace element concentrations also display marked chemical variability over a wide concentration range, in some instances up to three orders of magnitude (e.g. Hg, Pb, Zn; Table I). All enriched samples were collected from the main body of Lake CDA, and all the major and many of the minor bays north of Conkling Point and Carey Bay (near the southern end of Lake CDA, but north of the mouth of the St Joe River; Figure 2). The trace element concentrations in the enriched samples are much higher than those found in some of the most anthropogenically affected rivers in the USA and Europe (e.g. Forstner and Wittmann, 1981). Samples collected from the lake south of Carey Bay and Conkling Point and from the very back of several of the

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Table I. Minimum, maximum, mean and median concentrations for trace and major elements in surface sediments from Lake Coeur d'Alene

Element	Concentration				Unenriched median*
	Minimum	Maximum	Mean	Median	
Ag (ppm)	<0·5	21·0	6·0	4·0	<1
Cu (ppm)	9	215	72	70	25
Pb (ppm)	14	7700	1900	1800	24
Zn (ppm)	63	9100	3600	3500	110
Ni (ppm)	4	36	21	21	16
Co (ppm)	5	43	23	26	12
Cd (ppm)	<0·5	157	62	56	3
Cr (ppm)	<1	63	41	41	41
Hg (ppm)	0·02	4·90	1·80	1·60	0·05
As (ppm)	2·4	660	151	120	5
Sb (ppm)	0·5	96	23	19	1
Se (ppm)	0·1	0·6	0·3	0·2	0·2
Fe (wt %)	1·9	16·4	5·1	4·9	3·0
Mn (wt %)	0·01	2·46	0·67	0·65	0·05
Al (wt %)	2·9	9·0	7·5	8·0	6·8
Ti (wt %)	0·13	0·64	0·34	0·34	0·40
TOC (wt %)	0·3	15·6	2·5	2·2	2·5

* Based on 17 samples from the southern part of Lake Coeur d'Alene and the St Joe River.

northern bays (Wolf Lodge, Rockford and Windy Bays) display trace element concentrations similar to unaffected fluvial sediments throughout the USA (e.g. Horowitz *et al.*, 1989; Horowitz, 1991; Table I).

Initial correlation coefficients were calculated using the data from the trace element enriched samples. The coefficients show strong interrelations among the enriched trace elements. The enriched trace elements also show positive correlations with Fe, and either a slightly negative or no correlation with Ti and TOC. Through a combination of data normalization to Ti/TOC and log transformations, many of the original interrelations were enhanced or clarified, or both (Horowitz *et al.*, 1988; Horowitz, 1991; Table II). The strong correlations between and among the enriched trace elements could imply a similar source or a similar concentrating mechanism, or both. The same could also be said for the correlations between the enriched trace elements and Fe and Al (Table II). Galena (PbS), sphalerite (ZnFeS) and tetrahedrite ($Cu_{12}Sb_4S_{13}$) are the three most common ore minerals in the CDA mining district; the sphalerite also contains substantial amounts of Cd, whereas the tetrahedrite is a major source of Ag and contains substantial amounts of Hg (e.g. Fryklund, 1964; Chan, 1966). The positive correlations between Ag, Cu, Hg, Pb, Sb and Zn in the Lake CDA surface sediments may indicate that the ores or the ore processing waste, or both, from the CDA mining district are a major source for the enriched trace elements. The positive correlations between these elements and Fe could also indicate the same thing as the ores contain substantial amounts of Fe sulphides (e.g. pyrite, pyrrhotite); it may also indicate that the enriched trace elements are associated with or concentrated by Fe oxides.

The distribution patterns for all the surficial samples enriched in trace elements are fairly consistent (e.g. Figure 3 for Pb). Some of the highest concentrations (Ag, As, Cd, Cu, Hg, Pb, Sb and Zn) are found in sediments deposited in and around Harrison Slough (north of the right bank of the CDA River after it enters Lake CDA). Secondary highs were found south of Harlow Point (As, Hg, Pb and Zn); in a deep section of the centre of the main stem of the lake in an area bounded by Black Rock and Black Rock Bay to the west and Half Round and Black Bays to the east (As, Cd, Hg and Zn); in the area of Valhalla Point, Swede Bay and Swede Point near the mouth of Mica Bay (Ag, Cu, Hg, Pb and Sb); near the mouth of Wolf Lodge Bay (Ag, Cu, Cd, Hg, Pb and Zn); and, finally, near Independence Point, Tubbs Point and Silver Beach (Cu, Cd, Hg, Pb and Zn) in and around the corporate limits of the city of CDA (Figure 3). This is not to say that the sediments from others parts of Lake CDA contain normal or near normal concentrations, only that these areas have especially increased concentrations.

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Table II. Correlation coefficients for the enriched elements and some major elements using log transformed normalized (X/Ti/TOC) data. All correlations are significant at the 99% confidence level

	Ag	Cu	Pb	Zn	Cd	Hg	As	Sb	Fe	Mn	Al
Ag	1·00										
Cu	0·94	1·00									
Pb	0·96	0·92	1·00								
Zn	0·85	0·96	0·86	1·00							
Cd	0·69	0·85	0·69	0·91	1·00						
Hg	0·95	0·93	0·92	0·88	0·77	1·00					
As	0·68	0·61	0·65	0·51	0·45	0·64	1·00				
Sb	0·95	0·92	0·96	0·88	0·72	0·96	0·60	1·00			
Fe	0·90	0·91	0·86	0·84	0·65	0·83	0·61	0·85	1·00		
Mn	0·60	0·56	0·56	0·48	0·43	0·57	0·76	0·53	0·64	1·00	
Al	0·68	0·87	0·68	0·90	0·89	0·69	0·44	0·68	0·72	0·39	1·00

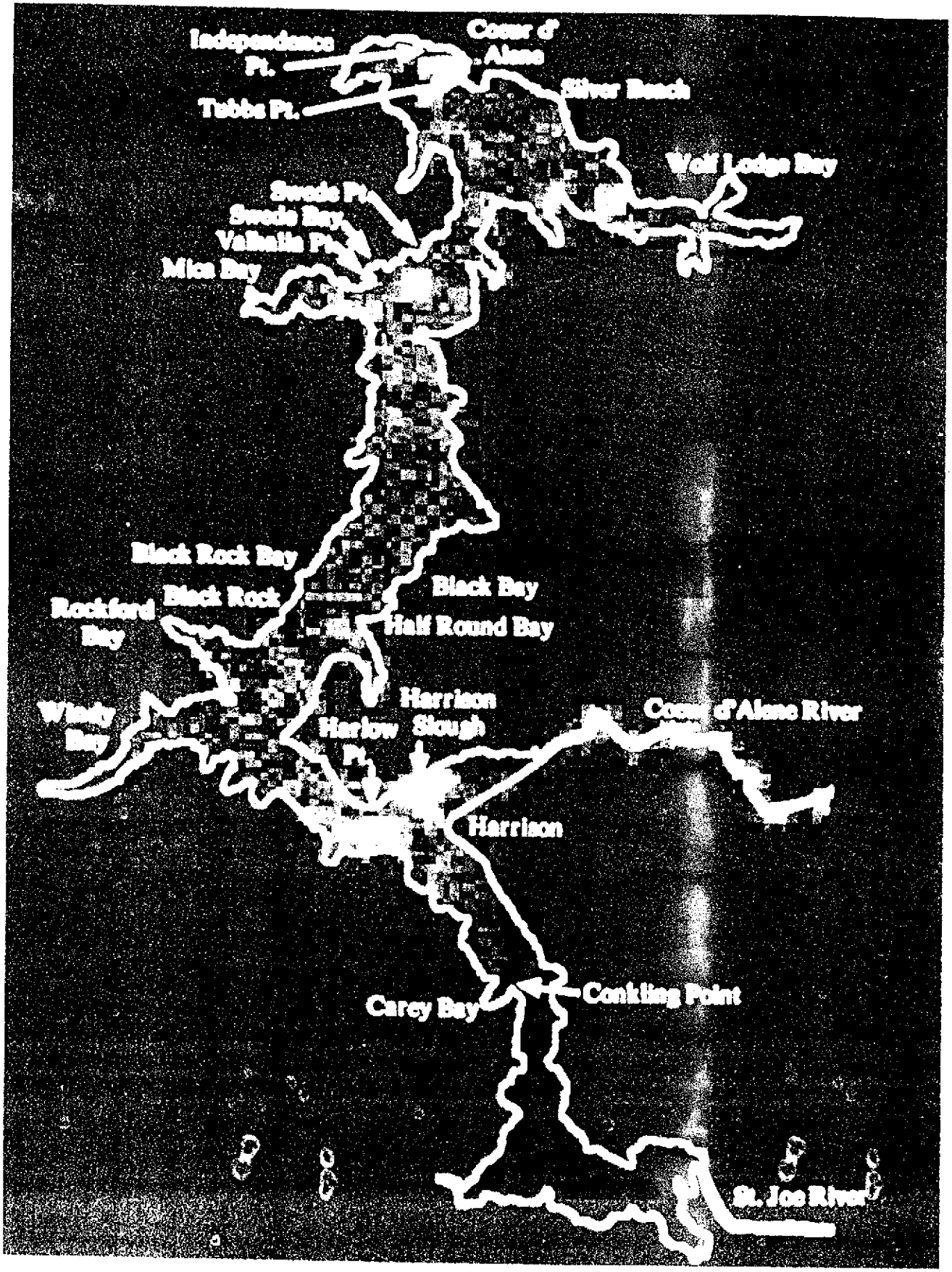
Not unexpectedly, the chemical distribution patterns in Lake CDA surficial sediments appear to be consistent with the CDA River (suspended material from the banks and flood plain, plus ongoing discharges) acting as a major point source for the enriched trace elements. Additionally, the patterns also appear to reflect the velocity and direction of water movement through the system (generally from south to north). For example, some of the highest trace element concentrations in the lake are found just adjacent to the CDA River delta (Harrison Slough). This is consistent with the expected reduction in water velocity when the CDA River enters the lake, causing a concomitant loss in sediment transporting capacity. Further, most of the sites where secondary trace element enrichment maxima occur coincide with locations where the geomorphology of the lake causes a distinct change in current direction and velocity and where a loss in sediment transporting capacity is likely to occur (e.g. Harlow, Valhalla, Swede, Independence and Tubbs Points, Figure 2). These observations are in general agreement with several previous findings (e.g. Funk *et al.*, 1973; 1975). They are also consistent with the enriched trace elements beings transported into the lake by the CDA River.

However, the surficial trace element patterns also appear to indicate that this explanation of the source, movement and redistribution of trace element rich material in Lake CDA is probably an oversimplification. This is because it does not account for the enriched sediment trace element concentrations that occur in surficial sediments collected as far south of the CDA River delta as Conkling Point (notwithstanding the strong northwards current flow due to the influence of the St Joe River; Figure 2). It also does not explain the increased trace element concentrations found well back from the mouths of Windy, Rockford, Mica and Wolf Lodge Bays that are perpendicular to the major current flow in the lake. Further, the trace element distribution patterns do not support the view that the major source of the enriched trace elements in Lake CDA sediments are caused by heavy minerals or coarse grained sediment, or both, carried by the CDA River, because a consistent decrease in enriched trace element concentrations does not occur from south to north. In fact, some of the most increased trace element concentrations occur well away from the mouth of the CDA River (Ag, Cu, Cd and Hg). Therefore, although the trace element patterns in Lake CDA do not preclude the CDA River, nor heavy minerals, from being an important source of the enriched trace elements in the surface sediments, it appears that there may be a secondary source(s) for at least some of the enriched trace elements or physical factors other than just the predominant current direction and velocity (e.g. wind generated wave/current action leading to the physical post-depositional remobilization of the fine grained trace element rich surface sediments; the median depth of the lake is < 22 m) that can affect the surficial trace element distribution patterns.

Chemical variations with sediment grain size

A limited number of samples (seven) from selected sites within Lake CDA, having both high and low bulk trace element concentrations, were separated into standard grain size fractions for subsequent chemi-

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cal analyses as an aid to understanding the trace element distribution and partitioning patterns in the surficial sediments (Figure 2 for locations; Table III). Each of the four trace element enriched samples are extremely fine grained ($M_2 = < 20\,\mu m$), with mean grain sizes well below the sand–silt break. Even the 'coarsest' trace element enriched sample (CDA 128 with a mean grain size of 20 μm) which was collected in the CDA River delta near Harrison is composed of $\geqslant 85\% < 63\,\mu m$ particles (Table III).

The trace element enriched samples all contain increased concentrations of Ag, As, Cu, Cd, Hg, Pb, Sb and Zn (Table III). The highest concentrations of these elements are in the size fractions finer than 16 μm (Table III). The two samples nearest the mouth of the CDA River (CDA 119 and 128) have the highest trace element concentrations in the $< 2\,\mu m$ fraction, whereas the two samples furthest from the mouth of the river generally have the highest concentrations in the 4–8 or the 8–16 μm fractions. This is the reverse of the expected pattern if the CDA River was acting as the single major source of the enriched trace elements or if the major cause of the enriched elements was the presence of sulphide (heavy) minerals, or both. In either instance, the highest concentrations would be expected closest to the mouth of the CDA River, and the size fraction(s) associated with the highest concentrations should decrease with increasing distance from the river.

When the relative contributions of the various size fractions are considered (determined by multiplying the chemical concentration by the percentage the size fraction represents in the sample) rather than just concentration, a slightly different pattern emerges (Table IV). This change is a function of the relative proportions of the various size fractions in conjunction with their respective trace element concentrations. The $< 2\,\mu m$ fractions and occasionally the 8–16 μm fractions contribute the highest concentration of trace elements to the three samples furthest from the mouth (CDA 32, 93 and 119), whereas the 8–16 μm fraction contributes the highest concentration in the sample closest to the mouth (CDA 128) of the CDA River. Secondary highs occur either in the 2–4 μm fraction (CDA 93), the 4–8 μm fraction (CDA 128), or in the 8–16 μm fractions (CDA 32 and 119).

In general, the trace element concentration patterns for the three samples furthest from the mouth of the CDA River tend to be unimodal, whereas the trace element contribution patterns tend to be bimodal for the various size fractions (Tables III and IV). In essence, the differences in trace element concentration between the various size fractions are not sufficiently large to overcome the dominant effect of the relative proportions of the various size fractions (e.g. regardless of the concentration differences between the various fractions, the greatest contributions come from the largest fraction). The bimodal nature of the patterns for these three samples may be indicative of more than a single source for the trace element enriched sediments. On the other hand, the sample closest to the mouth of the CDA River has a unimodal concentration and contribution pattern, with the highest values for both occurring in different fractions. The $< 2\,\mu m$ fraction has the highest concentrations whereas the 8–16 μm fraction has the highest contributions (Tables III and IV). The patterns for the sample closest to the mouth of the CDA River appear more indicative of a single rather than a multiple source for the enriched trace elements. These results both support and contradict some previous findings reported by Maxfield *et al.* (1974a; 1974b) and Funk *et al.* (1975) which indicated that the highest concentrations were associated with the finest size fractions, and that the effect of the CDA River transported trace elements in Lake CDA (based on the decreasing thickness of the enriched layers) decreased from the mouth of the CDA River to the head of the Spokane River (from south to north).

The three samples having normal bulk trace element concentrations that were separated into grain size ranges and chemically analysed come from the back of Wolf Lodge Bay (CDA 22A), the back of Windy Bay (CDA 100) and the southern end of Lake CDA off the right bank of the St Joe River at the boundary between Lake CDA and Round Lake (CDA 155; Figure 2). Generally, all three samples display classic unimodal grain size–trace element patterns of increasing concentration with decreasing grain size (Table III). Contributions for these samples also are unimodal and reflect the

Figure 3. Map of the distribution of Pb in the surface sediments of Lake Coeur d'Alene. Concentration increases from dark to light; therefore the areas of highest concentration appear as white blobs (e.g. near Harrison Slough, Harlow Point, Swede Bay and Tubbs and Independence Points)

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Table III. Size fraction geochemistry of selected Lake Coeur d'Alene surface sediment samples

Sample	Percentage of sample	TOC (wt %)	Concentration (ppm)												Concentration (wt %)			
			Ag	Cu	Pb	Zn	Ni	Co	Cd	Cr	Hg	As	Sb	Se	Fe	Mn	Al	Ti
CDA 32 bulk		2·6	8·0	112	2700	6300	25	30	126	50	2·9	126	39	0·4	5·1	0·28	8·3	0·3
> 63 μm	7	4·3	7·0	106	2500	6200	26	32	161	45	3·6	120	35	0·3	4·8	0·24	8·8	0·3
< 63 μm	93	2·7	9·0	108	2600	6100	27	29	119	52	3·0	125	40	0·4	5·2	0·30	8·5	0·3
Cal. bulk		2·9	8·5	108	2600	6100	27	29	122	51	3·0	125	40	0·4	5·1	0·30	8·5	0·3
> 63 μm %cont		12	7	7	7	7	8	8	10	7	9	7	7	6	7	6	8	7
< 63 μm %cont		97	99	89	90	90	100	90	88	96	95	92	95	93	94	99	94	93
< 2 μm	23	2·8	9·4	149	2700	6400	29	26	119	52	3·0	130	43	0·4	5·0	0·31	7·8	0·3
2–4 μm	14	2·9	9·4	122	2700	6500	29	28	119	53	3·0	125	45	0·4	5·2	0·31	8·1	0·3
4–8 μm	16	3·3	9·4	128	2900	6800	30	30	134	55	3·5	135	46	0·4	5·5	0·34	8·4	0·3
8–16 μm	24	2·9	8·6	123	2800	6700	30	30	134	54	3·3	130	43	0·4	5·4	0·32	8·6	0·4
16–32 μm	8	2·1	6·3	100	2000	4900	27	28	99	47	2·5	95	31	0·3	4·7	0·28	8·5	0·4
32–63 μm	7	1·5	5·7	102	1700	3900	26	27	76	46	1·7	80	26	0·2	4·8	0·24	8·7	0·4
CDA 93 bulk		1·8	9·0	104	2600	4800	27	39	87	54	4·8	400	43	0·5	5·7	0·65	8·4	0·3
> 63 μm	3	2·6	4·0	70	1500	2700	21	33	62	35	9·9	175	39	0·2	4·6	0·50	9·3	0·4
< 63 μm	97	2·2	9·0	99	2700	5000	22	35	86	53	4·4	380	42	0·3	5·7	0·68	8·3	0·3
Cal. bulk		2·2	8·3	97	2600	4800	22	35	84	52	5·0	370	42	0·3	5·6	0·66	8·4	0·3
> 63 μm %cont		4	1	2	1	1	2	3	2	2	5	1	2	1	2	2	3	3
< 63 μm %cont		122	93	93	100	101	80	88	96	96	89	93	95	58	98	101	97	92
< 2 μm	29	2·2	10	121	3100	5100	32	35	90	66	4·4	360	42	0·4	5·5	0·62	9·2	0·4
2–4 μm	23	1·9	9·0	106	2800	4900	26	33	83	62	4·1	330	38	0·3	5·4	0·61	8·9	0·3
4–8 μm	21	1·9	8·0	99	2500	5300	26	35	94	53	4·4	415	38	0·3	5·9	0·70	8·0	0·3
8–16 μm	15	2·2	8·0	102	3000	6200	28	43	119	51	4·8	420	39	0·4	6·1	0·88	7·8	0·3
16–32 μm	5	2·1	6·0	93	2500	4400	28	39	80	52	3·8	355	32	0·3	5·6	0·92	8·4	0·4
32–63 μm	3	1·8	7·0	105	2400	3400	30	37	63	57	0·7	260	29	0·3	5·5	1·02	9·1	0·4
CDA 119 bulk		1·9	8·0	85	2900	2900	19	23	33	41	2·1	660	25	0·2	6·5	1·00	7·6	0·3
> 63 μm	4	3·7	7·0	100	3500	3700	23	31	73	42	2·2	990	26	0·2	6·0	1·40	7·1	0·3
< 63 μm	96	2·0	8·0	80	3100	3000	18	22	33	41	2·0	660	24	0·1	6·3	1·00	7·3	0·3
Cal. bulk		2·1	8·0	81	3100	3100	18	23	35	41	2·0	680	24	0·1	6·3	1·00	7·3	0·3
> 63 μm %cont		8	4	5	5	5	5	6	9	4	4	6	4	4	4	6	4	4
< 63 μm %cont		101	101	90	100	100	91	92	94	96	92	96	92	48	93	96	92	93
< 2 μm	19	2·7	12	122	4300	3900	29	28	45	56	2·6	810	33	0·3	5·8	1·00	8·4	0·3
2–4 μm	15	2·5	10	103	3700	3600	24	25	38	55	2·3	710	29	0·2	5·7	0·95	8·4	0·3
4–8 μm	22	2·3	9·0	84	3200	3100	22	22	32	47	2·1	680	25	0·2	5·9	0·99	7·7	0·3
8–16 μm	29	1·9	7·0	71	2600	2700	19	20	27	38	1·8	600	22	0·1	6·6	1·10	6·5	0·3
16–32 μm	9	1·4	5·0	54	1800	2100	17	15	19	34	1·4	380	17	< 0·1	6·9	1·00	5·7	0·3
32–63 μm	5	1·1	4·0	43	1300	1500	14	12	14	31	1·1	220	14	< 0·1	7·9	0·88	5·0	0·3
CDA 128 bulk		1·9	11	97	3900	3200	13	18	27	35	3·6	480	31	0·1	8·7	0·80	5·8	0·3
> 63 μm	15	2·1	7·0	61	2200	2000	9	9	32	20	4·2	260	24	< 0·1	7·3	0·7	4·1	0·2
< 63 μm	85	2·1	12·0	99	4100	3500	17	15	27	37	3·6	650	37	0·2	9·0	0·79	6·1	0·3
Cal. bulk		2·1	12	96	4000	3400	16	15	27	36	4·0	620	36		8·9	0·78	6·0	0·2

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> 63 μm %cont		16	10	9	8	9	10	7	17	8	17	8	11		12	13	11	10
< 63 μm %cont		91	95	87	90	93	111	71	86	90	85	116	102		88	84	90	85
< 2 μm	8	3·3	17	164	7200	4700	28	27	45	56	4·8	970	52	0·4	7·3	0·59	8·1	0·3
2–4 μm	9	3·2	16	150	6500	4600	26	25	41	55	4·7	910	49	0·3	7·0	0·58	8·2	0·3
4–8 μm	15	2·9	15	127	5700	4100	22	22	35	50	4·6	790	45	0·3	7·2	0·63	7·6	0·3
8–16 μm	25	2·1	14	108	4800	3600	18	20	30	42	4·4	700	42	0·2	8·1	0·75	6·4	0·3
16–32 μm	12	1·3	8·0	64	2300	2300	13	12	16	29	2·5	320	25	< 0·1	10·0	0·86	5·0	0·2
32–63 μm	17	1·7	6·0	49	980	1500	10	8	10	19	1·4	180	19	< 0·1	12·0	1·00	3·8	0·2
CDA 22A bulk		1·1	< 1	9	50	420	14	7	6·0	28	0·3	9·0	1·0	< 0·1	1·9	0·05	5·1	0·4
> 63 μm	68	0·7	0·3	5	27	210	9	5	2·8	23	0·05	2·0	0·9	< 0·1	1·4	0·03	4·1	0·4
< 63 μm	32	2·4	0·4	19	91	800	18	10	9·7	47	0·11	16	2·0	0·1	2·7	0·06	7·6	0·4
Cal. bulk		1·2	0·3	9	47	399	12	7	5·0	31	0·1	6·5	1·3		1·8	0·04	5·2	0·4
> 63 μm %cont		43		38	37	34	44	49	32	56	11	15	61		50	41	55	68
< 63 μm %cont		70		68	58	61	41	46	52	54	89	57	64		45	38	48	32
< 2 μm	2	4·8	0·4	52	233	1490	29	13	22	62	0·55	34	4·0	0·2	3·6	0·09	8·5	0·3
2–4 μm	3	4·2	0·1	38	153	1300	29	12	18	68	0·28	26	2·7	0·2	3·4	0·08	10·3	0·3
4–8 μm	6	3·7	< 0·1	31	125	1140	25	12	15	63	0·18	21	2·2	0·2	3·2	0·07	9·2	0·3
8–16 μm	10	2·7	< 0·1	26	100	890	21	10	11	51	0·13	17	1·8	0·1	2·8	0·07	8·0	0·4
16–32 μm	5	1·3	< 0·1	21	66	530	17	7	5·6	42	0·04	10	1·4	< 0·1	2·2	0·05	6·7	0·4
32–63 μm	6	0·6	< 0·1	11	43	320	16	6	3·4	39	0·11	5·0	1·2	< 0·1	1·8	0·04	5·6	0·5
CDA 100 bulk		1·5	< 1	18	45	230	14	12	1·3	42	0·01	2·4	2·2	0·1	3·1	0·07	7·1	0·6
> 63 μm	15	2·6	0·2	18	41	233	14	14	2·1	35	0·02	3·2	0·5	0·1	3·3	0·07	7·8	0·6
< 63 μm	85	1·4	0·1	16	42	218	15	12	1·4	43	0·05	3·9	0·7	< 0·1	3·1	0·06	7·5	0·6
Cal. bulk		1·6	0·1	16	42	220	15	12	1·5	42	0·10	3·8	0·7	0	3·1	0·06	7·5	0·6
> 63 μm %cont		26		15	14	15	15	18	24	13	8	20	3	15	16	15	16	15
< 63 μm %cont		79		76	79	81	91	85	92	87	106	138	27		85	73	90	85
< 2 μm	3	3·9	2·4	66	128	300	36	20	7·6	72	0·40	14	2·0	0·2	5·3	0·12	9·6	0·7
2–4 μm	4	3·6	1·8	54	104	265	30	18	4·2	66	0·22	11	1·8	< 0·1	5·0	0·11	9·3	0·7
4–8 μm	8	3·0	0·8	39	81	431	25	17	3·2	60	0·13	7·7	1·4	< 0·1	4·1	0·09	8·4	0·6
8–16 μm	25	1·9	0·5	25	53	277	18	12	2·1	47	0·10	5·5	1·0	< 0·1	3·3	0·07	7·7	0·6
16–32 μm	20	0·9	0·5	15	25	133	12	9	0·9	37	0·07	3·1	0·5	< 0·1	2·6	0·05	6·9	0·5
32–63 μm	24	0·4	0·3	9	16	84	10	8	0·5	33	0·03	1·8	0·3	< 0·1	2·5	0·04	6·4	0·6
CDA 155 bulk		3·5	< 1	31	28	133	18	13	< 0·5	46	0·10	4·0	0·7	0·2	3·4	0·05	7·8	0·4
> 63 μm	6	10·0	< 1	40	29	150	18	11	0·4	42	0·11	5·5	1·1	0·5	3·6	0·06	7·3	0·3
< 63 μm	94	3·0	< 1	29	26	130	19	9	< 0·5	35	0·05	4·1	0·9	0·1	3·5	0·05	8·0	0·4
Cal. bulk		3·4		30	26	131	19	9		35	0·10	4·2	0·9	0·1	3·5	0·05	8·0	0·4
> 63 μm %cont		17		8	6	7	6	5		5	13	8	9	15	6	7	6	5
< 63 μm %cont		81		88	87	92	99	65		72	94	96	121	47	97	94	96	94
< 2 μm	8	4·6	< 1	52	47	172	37	11	2·4	51	0·10	3·1	1·6	0·1	3·7	0·05	8·4	0·4
2–4 μm	8	4·7	< 1	46	35	155	25	11	< 0·5	54	0·16	7·1	1·3	0·4	3·6	0·05	8·7	0·4
4–8 μm	18	4·6	< 1	41	29	148	22	11	< 0·5	53	0·10	6·5	1·1	0·4	3·6	0·05	8·6	0·4
8–16 μm	37	4·1	< 1	35	27	140	19	12	< 0·5	46	0·09	5·6	0·9	0·3	3·5	0·05	8·3	0·4
16–32 μm	15	1·6	< 1	28	18	102	15	10	< 0·5	32	0·08	3·5	0·7	0·1	2·9	0·04	7·4	0·4
32–63 μm	8	0·5	< 1	19	16	69	11	7	< 0·5	24	0·04	1·9	0·6	< 0·1	2·2	0·03	6·4	0·4

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Table IV. Chemical contributions for the < 63 μm size fractions of selected surface sediment samples from Lake Coeur d'Alene

Sample	Percentage of sample	Concentration (ppm)							
		Ag	Cu	Pb	Zn	Cd	Hg	As	Sb
CDA 32									
< 2 μm	23	2·2	34	620	1470	27	0·7	30	10
2–4 μm	14	1·3	17	380	910	17	0·4	18	6
4–8 μm	16	1·5	21	460	1090	21	0·6	22	7
8–16 μm	24	2·1	30	670	1610	32	0·8	31	10
16–32 μm	8	0·5	8	160	390	8	0·2	8	3
32–63 μm	7	0·4	7	120	270	5	0·1	6	2
CDA 93									
< 2 μm	29	2·9	35	900	1480	26	1·3	104	12
2–4 μm	23	2·1	24	640	1130	19	0·9	76	9
4–8 μm	21	1·7	21	530	1110	20	0·9	87	8
8–16 μm	15	1·2	15	450	930	18	0·7	63	6
16–32 μm	5	0·3	5	130	220	4	0·2	18	2
32-63 μm	3	0·2	3	70	100	2	0·0	8	1
CDA 119									
< 2 μm	19	2·3	23	820	740	9	0·5	154	6
2–4 μm	15	1·5	15	560	540	6	0·3	107	4
4–8 μm	22	2·0	19	700	680	7	0·5	150	6
8–16 μm	29	2·0	21	750	780	8	0·5	174	6
16–32 μm	9	0·5	5	160	190	2	0·1	34	2
32–63 μm	5	0·2	2	70	80	1	0·1	11	1
CDA 128									
< 2 μm	8	1·4	13	580	380	4	0·4	78	4
2–4 μm	9	1·4	14	590	410	4	0·4	82	4
4–8 μm	15	2·3	19	860	620	5	0·7	119	7
8–16 μm	25	3·5	27	1200	900	8	1·1	175	11
16–32 μm	12	1·0	8	280	280	2	0·3	38	3
32–63 μm	17	1·0	8	170	260	2	0·2	31	3

relative proportions of the various size fractions (e.g. the largest fraction contributes the most trace elements to the sample).

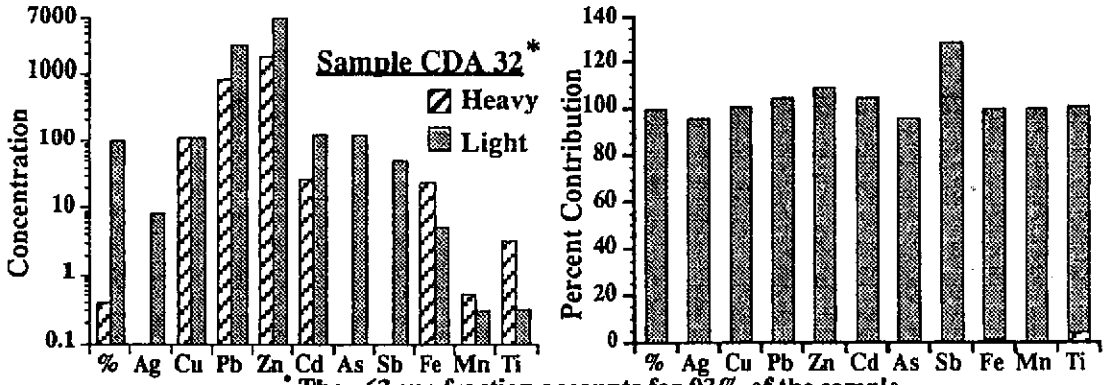
Chemical variations with sediment density

To clarify trace element partitioning and distribution patterns in the lake further, the fine fractions (< 63 μm) of the same four trace element rich samples used in the grain size studies were separated into heavy ($\rho = > 2.96\,g\,cm^{-3}$) and light ($\rho = < 2.96\,g\,cm^{-3}$) fractions. All four samples had relatively small amounts of heavy minerals ranging from as little as 0·4 to 11%, with the heavy fraction increasing in percentage with proximity to the mouth of the CDA River (Figure 4). This distribution pattern is indicative of the CDA River acting as a point source for the heavy fraction.

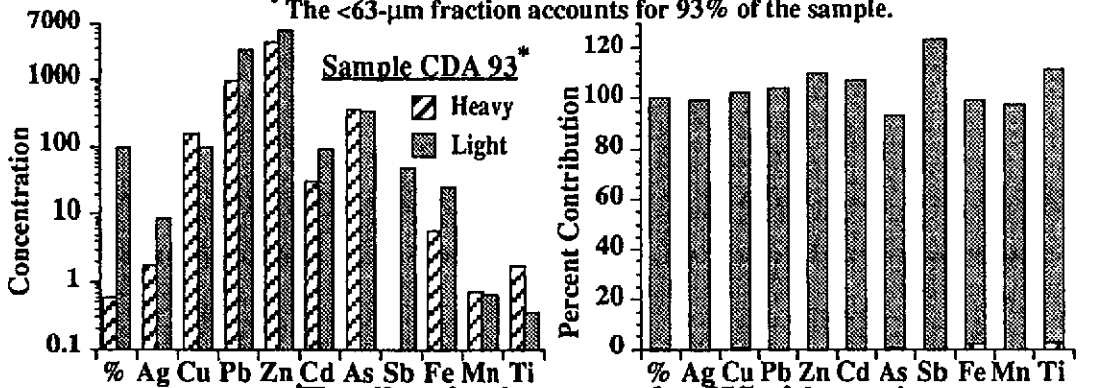
The chemical analyses of both fractions provide additional insights into trace element phase associations and dispersion pattern (Figure 4). The highest trace element concentrations for Ag, Cu, Cd, Sb and Zn shift from the light fraction to the heavy fraction as sample proximity approaches the mouth of the CDA River.

Figure 4. Heavy/light mineral fraction geochemistry of the < 63 μm fraction of selected Lake Couer d'Alene surface sediment samples. The graphs on the left give chemical concentration data for the < 63 μm light and heavy fractions; the graphs on the right give data on the contributions of the light and heavy fractions to the overall chemical concentration of the < 63 μm fraction

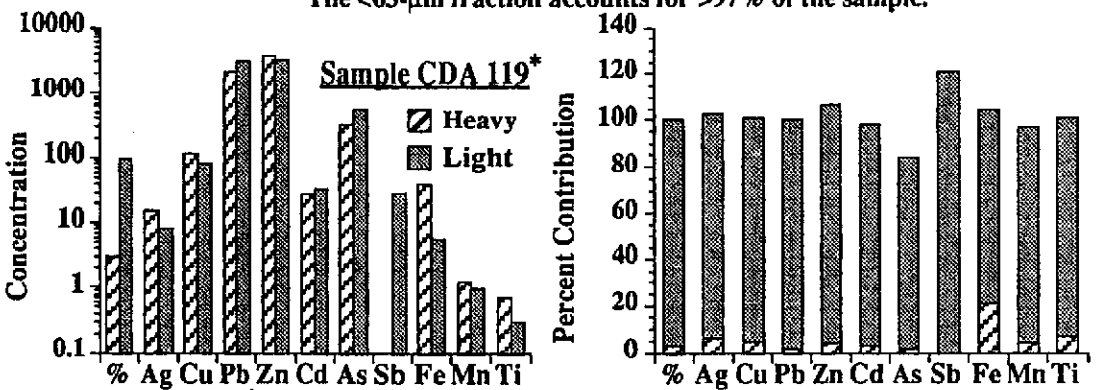
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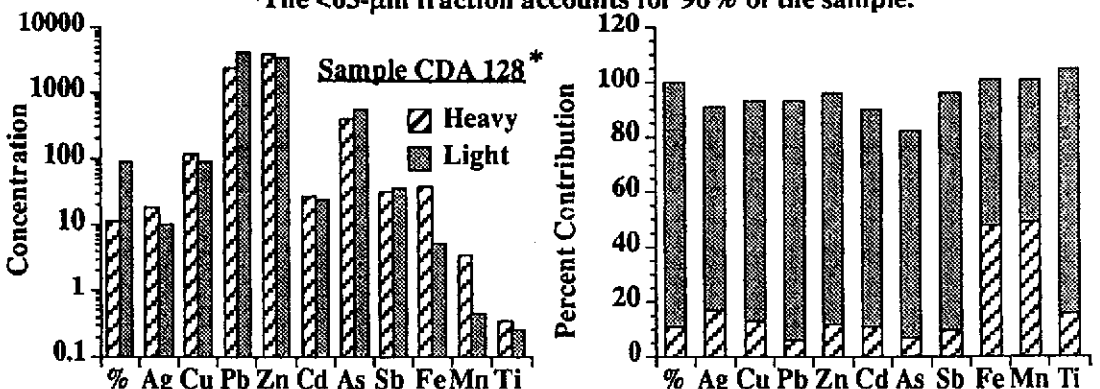
*The <63-μm fraction accounts for 93% of the sample.



*The <63-μm fraction accounts for >97% of the sample.



*The <63-μm fraction accounts for 96% of the sample.



*The <63-μm fraction accounts for 85% of the sample.

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However, Pb is always highest in the light fraction, whereas Fe is always highest in the heavy fraction (Figure 4). Note that the Fe concentration in the heavy fraction increases by over 60% with proximity to the mouth of the CDA River, whereas the Fe concentration in the light fraction remains remarkably consistent (≈ 5%). The Fe contributions also increase with proximity to the CDA River, but these changes are a direct reflection of the relative percentages of the heavy and light fractions. However, in all instances, the light fractions dominate as the source for most of the enriched trace elements because these fractions constitute most of each of the four samples (Figure 4). In fact, with the exception of Fe and Mn in CDA 128, and regardless of the higher trace element concentrations associated with the heavy fractions in the southernmost samples, the heavy fractions rarely contribute more than their percentages in the samples. The relatively small percentage of the heavy fractions in the samples, as well as the relatively small percentage contributions from the heavy fraction to the overall trace element concentrations in the samples, were unexpected, as the cause and provenance for the enriched metals in the lake sediments had always been presumed to be sulphide (heavy) minerals from the CDA mining district (e.g. Bender, 1991; Javorka, 1991).

Subsequent reflected light microscopy and SEM/EDAX examination of the separated heavy fractions indicated the presence of a relatively standard suite of heavy minerals, including sulphides, typical of the region. Galena, sphalerite, Ti oxides, tetrahedrite, monazite, arsenopyrite, chalcopyrite and various Fe sulphides were identified from the EDAX analyses. Many of the heavy minerals were coated by Fe oxide rinds. Of particular interest were the changes in the mean grain sizes of the trace element bearing minerals (e.g. galena, sphalerite, tetrahedrite) with increasing distance from the mouth of the CDA River. It was empirically determined that the mean grain sizes of the heavy mineral suites from each of the four samples decreased with increasing distance from the mouth of the CDA River; those minerals from the sample closest to the river had mean grain sizes of the order of 30–40 μm, whereas those from the sample furthest from the river were of the order of about 5–15 μm. This pattern is consistent with the CDA River acting as a point source for the heavy minerals.

Chemical variations with geochemical phases

A final evaluation of the phase association(s) of the various enriched trace elements was made using a two step sequential extraction procedure designed to segregate elements associated with Fe oxides, organics/sulphides and those in a more resistant (refractory) matrix (Figure 5). The results from these extractions confirmed many of the conclusions already cited based on the physical and chemical results from the grain size, heavy mineral and SEM/EDAX evaluations. Most of the Pb (≈ 95%), Cd (≈ 90%), Zn (≈ 80%), As (≈ 75%) and Cu (≈ 55%) appear to be associated with an operationally defined Fe oxide phase, whereas the remaining percentages appear to be associated with either an operationally defined organics/sulphides phase or are tightly bound in mineral lattices (Figure 5). Silver displays the widest variability, with all of it being associated with organics/sulphides in one sample (100%, CDA 32) and another where most is associated with Fe oxides (≈ 58%, CDA 128). Antimony appears to be associated predominantly with a refractory (lattice held) phase. There do not appear to be any consistent phase association patterns with proximity to the mouth of the CDA River, except for Ag, Cu and Zn. The Fe oxide associated Ag and Cu appear to increase, whereas the Fe oxide associated Zn appears to decrease with proximity to the CDA River.

Based on the results from the chemical extractions, as well as the subsequent chemical analyses and SEM/EDAX and optical examinations of the heavy and light mineral separates, there is little doubt that most of the increased trace elements (As, Cu, Cd, Pb, Zn) in the surface sediments from Lake CDA are associated with Fe oxides either in the form of coatings or separate grains; very limited percentages, with the possible exception of Ag, appear to be associated with sulphide (heavy mineral) phases. Antimony displays the only major exception to this pattern, appearing to be concentrated predominantly in a refractory phase.

The CDA River appears to be the source of the heavy minerals found in the trace element enriched surface sediments of Lake CDA. There also appears to be two sources for the Fe oxides, and the enriched trace elements associated with them, in the same Lake CDA surface sediments: (1) their formation or precipitation, or both, during smelting operations, in the settling ponds near Wallace and Smelterville,

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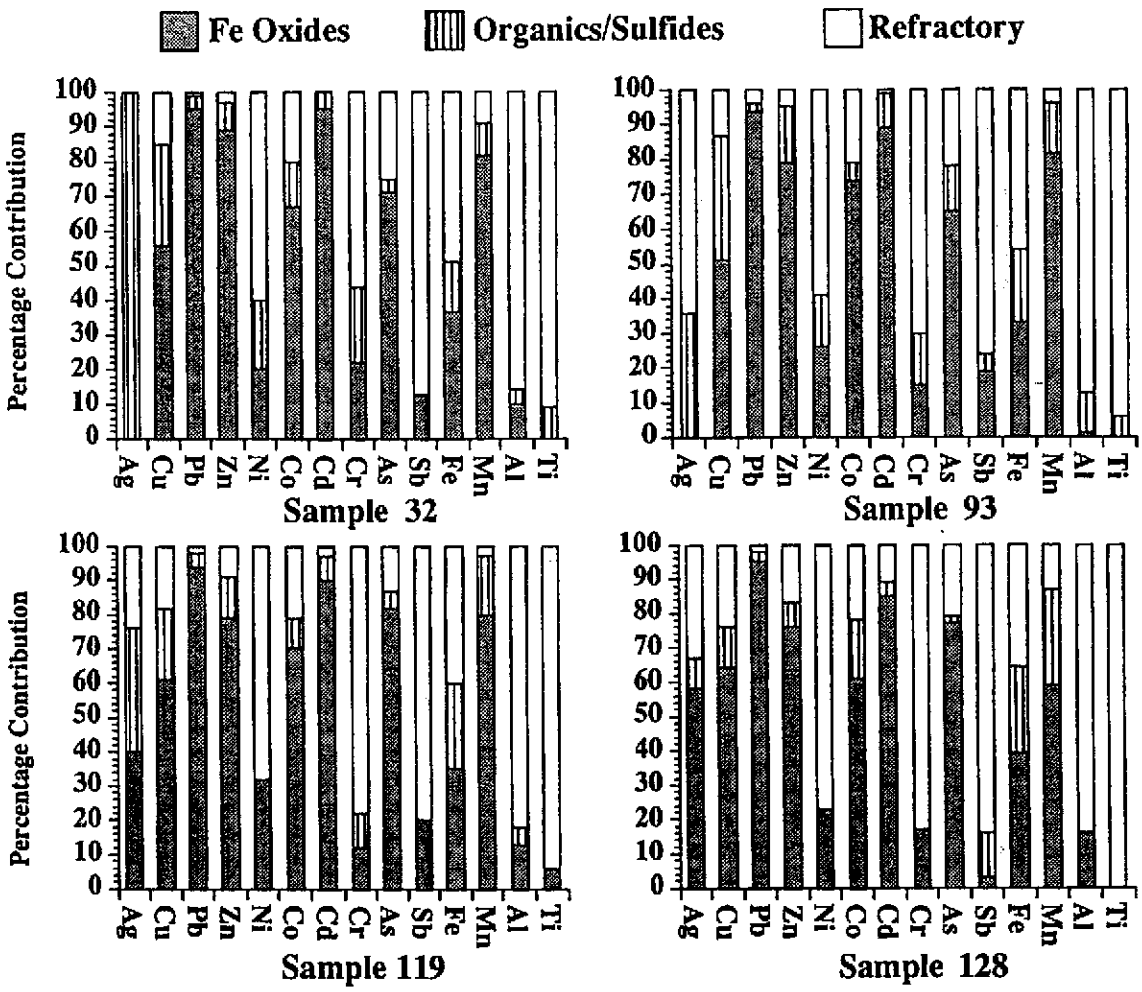


Figure 5. Percentages of various trace elements associated with the oxide, organic/sulphide and refractory fractions in selected Lake Couer d'Alene surface sediment samples. The data are based on sequential partial chemical extractions

or along the channel and banks of the South Fork of the CDA River and the CDA River proper, with subsequent transport into Lake CDA; and/or (2) formation of authigenic Fe oxides within Lake CDA itself. Examination of selected bank deposits from the CDA River reveals substantial amounts of trace elements associated with both heavy minerals and Fe oxides (Table V). Note that the percentage of heavy minerals in the bank deposits decreases markedly between Smelterville ($\approx$ 80%) and the confluence of the North and South Forks of the CDA River and Cataldo Flats ($\approx$ 20%); this percentage decreases even further at the CDA River delta ($\approx$ 11%) and in the main stem of the lake ($<$ 3%). The decrease in the percentage of heavy minerals appears to be indicative of a steady winnowing process, whereby the heavy and light fractions making up the bank and the deltaic deposits are physically separated, with the latter being preferentially transported downstream relative to the former.

Active Fe oxide formation was directly observed in isolated pools (possibly natural seeps or rain puddles) in the Cataldo Flats area during the summer of 1991. The contents of several of these pools were discharging directly into the CDA River. Thus the CDA River can certainly be viewed as a source for at least some of the Fe oxides. In addition, the thin veneer of fine grained Fe oxides found in many of the surface grab samples from the lake could either have been transported from the CDA River, or they could be authigenic. The presence of authigenic Fe oxides in Lake CDA could be due to deposition and burial of detrital

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Table V. Chemical concentrations for the bulk, heavy and light fractions of selected bank samples from the South Fork of the Coeur d'Alene River

Sample	Percentage of sample	Concentration (ppm)								Concentration (wt %)			
		Ag	Cu	Pb	Zn	Cd	Hg	As	Sb	Fe	Mn	Al	Ti
South Fork at Smelterville: right bank													
Bulk		150	590	63 000	12 000	43·5	18·1	90	240	17·1	0·62	3·4	0·13
Light	41	36	150	8100	3700	16·1	3·30	30	130	4·9	0·14	4·2	0·11
Heavy	58	140	730	80 000	16 000	51·0	18·4	120	160	24·3	0·83	3·0	0·14
South Fork at Smelterville I: left bank													
Bulk		173	650	55 000	8800	20·1	21·0	100	340	15·4	0·58	3·9	0·15
Light	40	73	265	21 000	3600	12·8	7·00	40	220	5·4	0·13	4·4	0·11
Heavy	60	178	920	58 000	12 000	24·0	28·6	140	320	24·2	0·90	3·3	0·15
South Fork at Smelterville II: left bank													
Bulk		185	670	71 000	9000	18·9	17·9	96	395	15·1	0·51	4·0	0·15
Light	42	67	240	16 000	3200	7·5	10·0	40	200	5·1	0·13	4·5	0·11
Heavy	58	230	930	76 000	13 000	23·0	27·8	140	300	23·7	0·77	3·4	0·15
Just below confluence with the North Fork of the Coeur d'Alene River													
Bulk		15·5	240	5600	4500	64·0	3·40	170	85	9·2	0·56	4·9	0·24
Light	81	9·7	160	4900	3300	49·4	4·30	100	50	4·1	0·15	5·2	0·17
Heavy	17	42·2	425	7300	7300	56·0	5·70	330	160	38·6	2·60	2·0	0·38
Cataldo Flats: bottom of drop													
Bulk		10·3	76	2800	7700	14·0	0·67	150	48	8·7	0·90	3·2	0·13
Light	78	15·0	47	1400	5100	6·4	0·45	80	35	2·8	0·33	3·6	0·11
Heavy	21	20·4	185	7000	15 000	27·4	1·47	330	70	33·4	3·00	1·9	0·14
Cataldo Flats: mid seep at bottom													
Bulk		11·8	84	2500	6500	8·4	0·72	140	49	7·6	0·85	3·3	0·13
Light	78	5·8	38	1400	3700	3·1	0·33	75	26	2·7	0·30	3·7	0·12
Heavy	21	26·6	220	8600	16 000	34·6	1·38	500	70	38·0	3·25	1·6	0·14
Cataldo Flats: seep solids at river edge													
Bulk		11·6	100	3800	7800	12·9	1·88	160	52	8·8	0·89	3·9	0·17
Light	78	7·4	62	2600	5400	8·1	1·23	80	33	3·8	0·33	4·4	0·15
Heavy	20	25·4	250	8600	14 000	28·8	2·80	420	60	36·8	3·00	1·8	0·16
Cataldo Flats: surface floc of sheep													
Bulk		11·3	89	2000	19 000	9·4	1·57	170	48	14·9	0·85	3·4	0·14
Light	75	9·0	54	2800	17 000	6·1	1·18	100	29	8·4	0·31	3·7	0·11
Heavy	23	20·2	175	6800	27 000	20·4	2·42	430	70	37·2	2·57	1·9	0·16

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Fe oxides in the lake, subsequent remobilization under reducing conditions, upward diffusion in the pore waters and reprecipitation once the waters have passed through the anoxic–oxic boundary. The presence of reducing conditions in the sediment column is supported by some of the trace element patterns (especially for Mn) in analysed core samples reported by Funk *et al.* (1975), and possibly by the direct observation of sediment degassing in shallow portions of the lake (see under *General observations*). Finally, initial chemical analyses of several cores collected during the summer of 1991 clearly indicate the presence of an oxic–anoxic boundary around 10–15 cm into the sediment column (Horowitz *et al.*, in preparation). Trace element remobilization from within the sediment column is likely to continue for the foreseeable future and may be exacerbated by the increased nutrient induced eutrophication that has been reported in the lake [e.g. Meckel Engineering *et al.*, 1983; Javorka, 1991; this study (based on the increased expansion of macrophyte beds)].

It appears that there are at least two source areas for most of the enriched trace elements found in the surface sediments of Lake CDA: (1) heavy minerals (especially sulphides) and Fe oxides which have been transported from and by the CDA River; and (2) the bed sediments in the lake due to post-depositional dissolution, upward migration and subsequent reprecipitation. The heavy mineral dispersion patterns in the surface sediments indicate that the CDA River is acting as a point source for these materials (presumably for at least some of the Fe oxides as well), with decreasing concentrations and grain size occurring as the distance from the river increases northwards in Lake CDA. This pattern is overlain and complicated by the physical remobilization of fine grained sediments by currents and wind driven waves and by the presence of authigenic Fe oxides coming from the bed sediments within the lake.

The major amounts of trace element rich bank and flood plain deposits, in conjunction with post-depositional remobilization and reprecipitation from the sediment column in Lake CDA itself, are likely to ensure continued increased trace element concentrations in the surface sediments of the lake for the foreseeable future, unless active intervention is undertaken. Regardless of the source, most of the enriched trace elements in the surface sediments of Lake CDA appear to be associated with Fe oxides, rather than sulphides; when these surface sediments are buried and subjected to anoxic conditions, the Fe oxides and associated trace elements may be dissolved and made environmentally available and, as such, are in a more environmentally available form than originally thought. More detailed evaluations of the ongoing processes in the sediment column will be carried out on a series of gravity cores collected during the summer of 1991 (Horowitz *et al.*, in preparation) and through detailed studies of pore water dispersion through the upper sediment column and at the sediment–water interface completed during the summer of 1992.

CONCLUSIONS

The overwhelming majority of the surface sediments in Lake CDA north of Carey Bay and Conkling Point are substantially enriched in a variety of trace elements, including Ag, As, Cu, Cd, Hg, Pb, Sb and Zn. All the enriched sediments are extremely fine grained and thus are subject to physical remobilization during periods of high discharge from the CDA or the St Joe Rivers or by wind driven waves and currents, or both. Most of the enriched trace elements are associated with an operationally defined Fe oxide phase; markedly smaller percentages are associated either with operationally defined organics/sulphides or refractory phases. The source of the enriched Fe oxides appears to be a combination of detrital material transported by the CDA River and authigenic deposits reprecipitated from dissolved material within anoxic sediments in the bed of Lake CDA. The association of most of the enriched trace elements with 'Fe oxides' makes them substantially more environmentally available than if they were associated with sulphide minerals. Ultimately, the source for most of the enriched trace elements almost certainly can be ascribed to the mining, ore processing and smelting operations that have occurred since the 1880s in the CDA mining district.

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EFFECT OF MINING AND RELATED ACTIVITIES ON THE SEDIMENT TRACE ELEMENT GEOCHEMISTRY OF LAKE COEUR D'ALENE, IDAHO, USA PART II: SUBSURFACE SEDIMENTS

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ABSTRACT

During the summer of 1990, 12 gravity cores were collected in Lake Coeur d'Alene, Idaho at various depths and in a variety of depositional environments. All core subsamples were analysed to determine the bulk sediment chemistry; selected subsamples were analysed for trace element partitioning and ^{137}Cs activity. The purpose of these analyses was to determine the trace element concentrations and distributions in the sediment column and to try to establish a trace element geochemical history of the lake in relation to mining and mining-related discharge operations in the area.

Substantial portions of the near-surface sediments in Lake Coeur d'Alene are markedly enriched in Ag, As, Cd, Hg, Pb, Sb and Zn, and slightly enriched in Cu, Fe and Mn. Variations in the thickness of the trace element-rich sediments, which range from more than 119 cm to as little as 17 cm, indicate that the source of much of this material is the Coeur d'Alene River. An estimated 75 million tonnes of trace element-rich sediments have been deposited on or in the lake bed. Estimated trace element masses in excess of those considered representative of background conditions range from a high of 468 000 tonnes of Pb to a low of 260 tonnes of Hg.

The similarity between the trace element-rich surface and subsurface sediments with respect to their location, their bulk chemistry, their interelement relations and their trace element partitioning indicate that the sources and/or concentrating mechanisms causing the trace element enrichment in the lake sediments have probably been the same through-out their depositional history. Based on a Mt St Helens' ash layer from the 1980 eruption, ages estimated from ^{137}Cs activity and the presence of 80 discernible and presumably annual layers in a core collected near the Coeur d'Alene River delta indicate that deposition rates for the trace element-rich sediments have ranges from 2·1 to 1·3 cm/year. These data also indicate that the deposition of trace element-rich sediments began, at least in the Coeur d'Alene River delta, some time between 1895 and 1910, dates consistent with the onset of mining and ore processing activities that began in the area in the 1880s.

KEY WORDS Lake sediments Sediment trace element geochemistry Mining impacts

INTRODUCTION

Lake Coeur d'Alene (CDA) is a natural (submerged river bed), as opposed to a man-made lake, in the northern panhandle of Idaho (Figure 1). It was formed about 14 000 BP by glacial meltwaters which overflowed from Lake Missoula (Wyman, 1993). The lake lies between the Selkirk and the CDA Mountains and extends northward from the St Joe River to the headwaters of the Spokane River near the city of CDA

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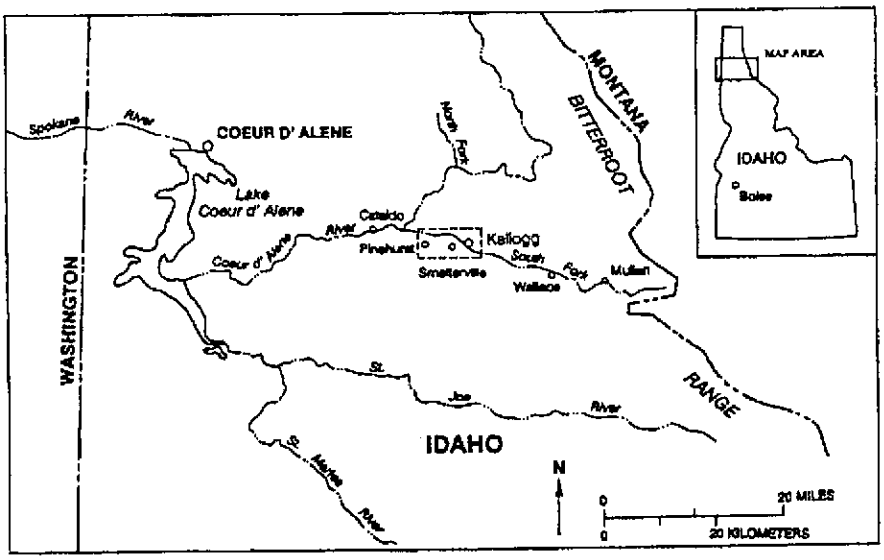


Figure 1. General location map of the South Fork of the Coeur d'Alene River, the St Joe River and Lake Coeur d'Alene. The dashed box outlines the location of the 54 km^2 US EPA Bunker Hill Superfund Site (after Bender, 1991)

(Meckel Engineering *et al.*, 1983; Bender, 1991). The main body of the lake is about 3·2 km wide by 40 km long; however, the southern part is composed of four smaller interconnected lakes that were formed in 1906 when the Post Falls Dam (10 miles downstream on the Spokane River) was completed (Meckel Engineering *et al.*, 1983) (Figure 1). The St Joe and CDA Rivers annually account for 94% ($\approx$ 4·73 Gm^2/yr) of the inflow to Lake CDA (Meckel Engineering *et al.*, 1983; Javorka, 1991). Major outflow from the lake occurs at the northern end through the Spokane River (Figure 1).

The South Fork of the CDA River, which flows into the CDA River, and thence into Lake CDA, drains a substantial part of the CDA mining district and the so-called 'Silver Valley'. The mining district has been in operation since the 1880s and was one of the major sources of Ag, Cu, Pb and Zn in the USA (e.g. Bender, 1991). Until 1968, when ponds were established to trap/retain tailings and limit sediment transport, most of the mining and ore processing wastes were discharged directly into the South Fork of the CDA River. These materials were highly enriched in Ag, As, Cd, Cu, Fe, Mn, Pb, Sb and Zn (Rabe and Bauer, 1977; Bender, 1991). It has been estimated that during the course of mining, processing and smelting operations in the area, about 115 million tonnes of mine tailings were produced and that 60% of this material probably entered the South Fork of the CDA and the CDA River system (Javorka, 1991).

In 1983, as a result of the increased trace element concentrations in the mining and processing wastes, the US Environmental Protection Agency (EPA) established the Bunker Hill Superfund Site that encompasses 54 km^2 in the Kellogg and Smelterville Flats area, about 50 km upstream of Lake CDA. (e.g. Bender, 1991; Figure 1). The Superfund site encompasses the Bunker Mine (Pb and Zn), a milling and concentrating plant, a Pb smelter, a Ag refinery, an electrolytic Zn plant, a phosphoric acid and phosphate fertilizer facility, a sulphuric acid plant, a Cd plant and a 0·65 km^2 mine tailings and waste water disposal area (Woodward-Clyde Consultants and TerraGraphics, 1986). Most of these facilities are no longer active and several have been dismantled.

Over the years environmental studies have indicated that large amounts of mining, milling and ore processing wastes, enriched in a variety of trace elements, have been deposited throughout the lower CDA River and Lake CDA, and have had a substantial effect on the sediment geochemistry, the water quality and the biota of the South Fork of the CDA River, the main stem of the CDA River, Lake CDA and the Spokane River (Ellis, 1940; Galbraith, 1971; Ellsworth, 1972; Funk *et al.*, 1973; 1975; Bauer, 1974; Maxfield *et al.* 1974a; 1974b; Norbeck, 1974; Sheppard and Funk, 1975; Johnson *et al.*,

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1976; Inoannou, 1979; Wai *et al.*, 1985; Savage, 1986; Neufeld, 1987; Woods, 1989; Krieger, 1990; Piske, 1990; Bender, 1991; Horowitz *et al.*, 1993).

A detailed examination of the surficial sediments of Lake CDA was reported previously and showed (Horowitz *et al.*, 1993):

1. Surface sediments in most of Lake CDA ($\approx$ 85%) are substantially enriched in Ag, As, Cu, Cd, Hg, Pb, Sb and Zn relative to sediments in the southern portion of the lake near the St Joe River.
2. Trace element enriched sediments are typically very fine-grained (mean grain sizes $\ll$ 63 μm) and are readily remobilized by currents within the lake.
3. Based on both the chemical analyses of separated heavy and light mineral fractions, and a two-step sequential extraction procedure, most of the enriched trace element concentrations are associated with an operationally defined (by partial chemical extraction) Fe oxide phase; much smaller percentages are associated with operationally defined (by partial chemical extraction) organics/sulphide or refractory phases. The sulphide/heavy mineral phases are almost certainly detrital, coming from the banks and floodplain of the South Fork of the CDA and the CDA Rivers. The Fe oxides seem to be both detrital and authigenic.
4. Within the lake, the presence, concentration and distribution of the enriched trace elements indicate that the CDA River is acting as a source for this material.
5. Within the lake, the point source pattern is complicated by a combination of (a) the formation of trace element-rich authigenic Fe oxides due to remobilization from anoxic bed sediments and (b) physical remobilization by currents and wind-driven waves.

The goal of this study was to examine the subsurface sediments to determine their bulk chemistry, the mass of trace element-rich sediments on or in the lake bed and to establish a sediment geochemical history for the lake. The results of this portion of the study are reported herein.

SAMPLE COLLECTION, TREATMENT AND ANALYTICAL METHODS

Sample collection

Twelve gravity cores were collected in Lake CDA in June 1990. Preliminary sampling sites were identified, before collection, based on the results from the geochemical surface sediment survey carried out in 1989 (Horowitz *et al.*, 1993). Site selection represented an attempt to obtain cores useful in evaluating the vertical and geochemical environments within the lake (e.g. the CDA River delta, the main stem of the lake, the backs of several bays perpendicular to the main stem). During sampling operations, coring sites were located using a portable global positioning system (GPS).

Samples were collected using a 5 cm (2 in) diameter stainless-steel 2·44 m (8 ft) Wildco (the use of brand names is for identification purposes only and does not constitute an endorsement by the US Geological Survey) gravity core with a clear polycarbonate liner and a non-metallic core catcher. On recovery, the liner was removed from the core barrel, kept in a vertical position and capped at both ends. Any water remaining in the liner at the sediment–water interface was removed through a small hole to prevent any additional disturbance of the surface and near-surface sediments. After draining, the liner was trimmed to remove excess material, recapped and the caps taped in place. The cores were stored on ice at 4°C until they could be taken ashore and frozen. The cores remaining frozen during storage, were shipped to a USGS laboratory in Atlanta in that state, and were kept frozen until they could be processed.

Sample pretreatment

Each core was split while frozen; one half was returned to the freezer for archiving whereas the other half was allowed to thaw. Before sampling, each half-core was described, measured and photographed. Subsamples were then removed from the thawed half-core. Wherever feasible (e.g. when sufficient mass could be collected to allow subsequent analyses), individual subsamples were removed from obvious layers, or where significant colour or textural changes could be visually identified. Wherever the core appeared to be homogeneous,

Table I. Location and description of the gravity cores obtained from Lake Coeur d'Alene

Core number	Location	Total length (cm)	Depth/ thickness of layered zone (cm)	Depth/ thickness of ash layer (cm)	Depth/ thickness of trace element maxima (cm)
Core 10	47°37′30″N, 116°40′43″W	130·0	25·0	2·3–2·5	18·0–20·0
Core 13	47°38′08″N, 116°44′27″W	128·5	17·0	N/D*	11·5–14·0
Core 39	47°39′10″N, 116°46′55″W	140·5	23·5	N/D*	7·5–13·5
Core 47	47°36′25″N, 116°48′17″W	128·0	26·0	0·3–0·4	19·0–21·0
Core 71	47°33′17″N, 116°48′00″W	129·0	30·0	0·5–0·7	19·0–21·0
Core 93	47°30′53″N, 116°49′51″W	124·0	31·0	0·5–0·8	23·0–25·5
Core 9	47°28′19″N, 116°55′08″W	122·0	34·0	3·5–3·7	27·0–29·0
Core 6	47°28′05″N, 116°51′08″W	114·5	41·0	5·0–6·5	N/D*
Core 123	47°27′16″N, 116°49′11″W	126·0	119·0	20·5–21·5	102·0–104·5
Core 7	47°27′27″N, 116°48′22″W	97·5	0†	N/D*	N/D*
Core 8	47°26′02″N, 116°46′43″W	105·0	35·0	9·6–9·8	21·0–24·0
Core 146	47°21′39″N, 116°45′06″W	105·0	0‡	N/D*	N/D*

* Not detected, not present, not analysed
† Core does not contain layering, but does display evidence of slumping
‡ Core does not contain layering, basically a solid single colour throughout its length

aliquots from 5 cm intervals were removed. Aliquots were removed using a non-metallic spatula and stored in separately labelled polypropylene vials. The samples, in their vials, were returned to the freezer for storage, until they could be freeze-dried. In all, 442 subsamples were obtained from the 12 cores.

Analytical techniques

All the core samples were analysed for Fe, Mn, Al, Ti, As, Cu, Zn, Cd, Pb, As, Sb, Hg and total organic carbon (TOC). Selected samples were subjected to heavy mineral separations using bromoform ($\rho = 2{\cdot}96$ g/cm^3) followed by total chemical analyses of the light and heavy fractions. Selected heavy and light fractions also were examined and chemically analysed using SEM/EDAX. These techniques were the same as those used on previously collected surface sediment samples from Lake CDA and are described in detail elsewhere (Horowitz *et al.*, 1993). Precision and bias for the chemical analyses were monitored using a variety of standard reference materials and sample duplicates. Precision was better than ±10%; no bias was detected.

Determination of ^{137}Cs

The activity of ^{137}Cs was determined by manually pressing 4·00 ± 0·01 g of dry sediment to a fixed height (4·00 ± 0·05 cm) in standard vials to achieve conditions of constant bulk sediment density and sample shape. Prepared samples were counted using a high resolution solid-state HpGe detector coupled to a multi-channel analyser. System calibration was achieved using sediments doped with NIST-traceable standard solutions of ^{137}Cs. Individual sample sizes were limited as a result of the relatively small diameter of the core (5 cm) and the detailed nature of the sampling (all discernible layers larger than 0·5 cm were excised). Approximately three days of counting time per sample were required to achieve measurement precision between 7 and 20% in the vicinity of maximum activities because of the relatively small sample sizes and/or relatively low activities. For samples in which the ^{137}Cs activities were close to the detection limit, sample size and counting time limitations commonly produced errors as large as 50%.

RESULTS AND DISCUSSION

General observations

The locations and general descriptions of all 12 gravity cores are given in Table I and Figure 2. With the

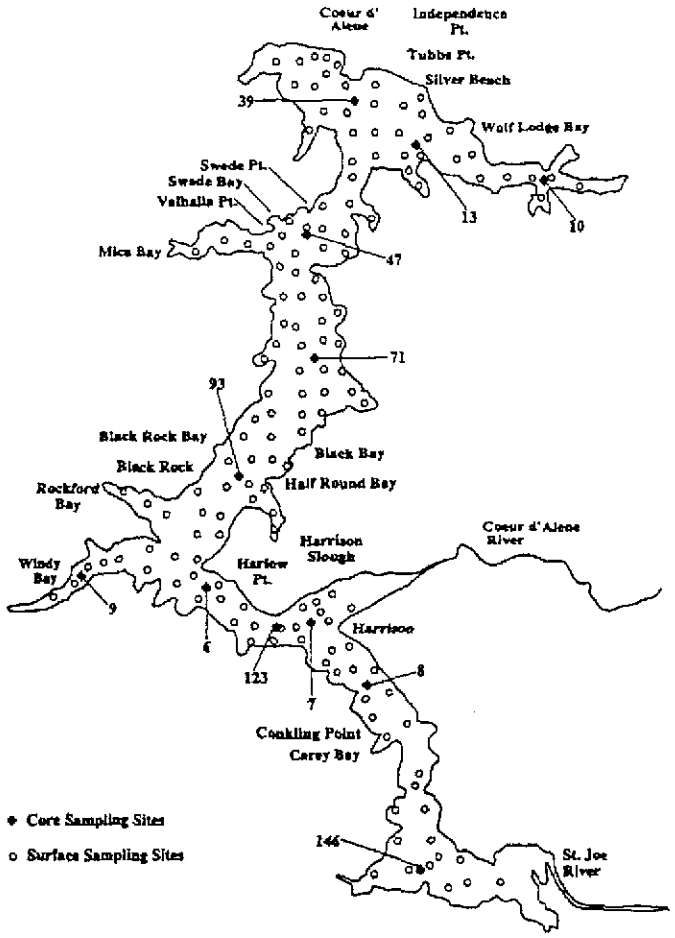


Figure 2 Map of Lake Coeur d'Alene showing all sampling locations, cities and features cited in the text

exception of cores 7 and 146 (to be discussed later), all the cores have similar physical features. Each contains an upper, heavily banded section and a lower, homogeneous section. The banded upper sections tend to be tan to brown and are occasionally interspersed with thin, dark brown to black layers. Where the bands or layers are thick enough, it is possible to observe graded bedding (finer material at the top grading into coarser material towards the bottom). The banded sections of most of the cores also contain a single, distinctive grey/white layer located anywhere from 0·3 to 21·5 cm from their tops (Table I). This singular band is similar in colour and texture to the Mt St Helens' ash layer identified in some of the surface grab samples collected during the previous year, which contained material from the May 1980 eruption (Horowitz *et al.*, 1993). The banded sections range in thickness from 17 to 119 cm (Table I). In several instances, especially where the banded sections are thickest (e.g. cores 123 and 6, Table I), it is possible to identify as many as 80 individual layers. Band thickness varies from as little as 1 or 2 mm to as much as 20 mm. If the bands represent annual runoff events, or periods of annual deposition, then substantial differences in local sedimentation rates occurred through time. The large differences in the thickness of the banded sections, combined with the differences in depth to the ash layer in the various cores, may indicate large variations in sedimentation/deposition rates in different areas of the lake. These differences could also indicate that the material settled, was physically remobilized by currents or wind-driven waves and then settled again, before final deposition on the lake bed. The lower unbanded core sections tend to be dark olive in colour and display no discernible changes in grain size.

Most of the cores contain several disconnected 3–5 cm sections which display large numbers of small (< 0·5 mm) vesicles, probably due to former gas bubbles or gas production; however, there was no detectable odour. As the cores thawed before sampling, the interstitial water on the surface of the split cores, as well as along the edges near the core liners, developed obvious red tinges. This was inferred to be caused by the oxidation of reduced Fe in the interstitial water, and probably indicates that major sections of the sampled sediment column exist in a reducing environment.

In most of the cores, but most notably in cores near the CDA River delta (123, 8 and 9; Figure 2, Table I), the lower sections just below the banded zones contain structures that appear to have been formed by earlier biological activity (e.g. infilled burrows and worm tubes, H. Markewich, personal communication, 1993). The banded zones lacked such structures. Previous sampling indicated little or no benthic biological activity in surface sediments in this area (Horowitz *et al.*, 1993). Thus, the banding may reflect a lack of infauna and associated bioturbation.

Core 146 was collected at the extreme southern end of Lake CDA in Chatcolet Lake (Figure 2). The core contains no banding and is dark olive throughout its length. This colour is identical to that found below the banded sections in all the other cores. Despite the fact that the southern end of Lake CDA was blanketed by Mt St Helens' ash (Sarna-Wojcicki *et al.*, 1981a), core 146 contains no visible ash layer. This could indicate rapid sedimentation rates, high physical energy and/or bioturbation.

Core 7 was collected in relatively shallow water (< 4 m) in the CDA River delta within 0·3 km of the mouth of the river (Figure 2). The sediments in this core are highly disturbed; numerous cross-bedded layers are evident in several discontinuous sections of the core. This cross-bedding, combined with other structures in the core, indicates that the CDA River delta is a high energy zone and/or an area where sediment slumping is taking place. Such sediment instability, along with active erosion, is more likely to occur during periods of high runoff and local turbulence when the inflowing water from the CDA River meets the northward flowing water from the St Joe River (Figure 1). The sediments in core 7 are the coarsest in the collection. The presence of large amounts of coarse-grained material in this part of Lake CDA is not surprising because coarse particles would have been deposited first, as a result of the decrease in energy associated with the transition from the river to lake (the CDA River delta). The grain size distribution in this core mirrors the results from the surface sediments collected in the same area (Horowitz *et al.*, 1993).

Bulk sediment chemistry and vertical trace element distribution patterns

The minimum, maximum, mean and median bulk chemical data for all the core samples clearly show that the upper sediment column in Lake CDA is enriched in Ag, As, Cd, Hg, Pb, Sb and Zn. The cores are less enriched in Cu, Fe and Mn relative to both unenriched fluvial sediments throughout the USA and to unenriched surface and subsurface (e.g. core 146) sediments from within the lake (e.g. Horowitz, 1991; Horowitz *et al.*, 1993; this study, Table II). The highest trace element concentrations in Lake CDA sediments, typically by a factor of two or more, are associated with subsurface rather than surface material (Ag, Cu, Pb, Zn, Hg, As and Sb, the maximum column in Table II); however, this pattern is reversed when the surface and subsurface median concentrations are considered (with the exception of Ag and Sb, the median column in Table II). The highest median concentrations for Cu, Pb, Zn, Cd, Hg and As are found in the surface sediments, whereas the highest median concentration for Ag is found in the subsurface sediments. The median concentration for sediment-associated Sb is almost the same for both. The generally higher median surface sediment concentrations may be the result of post-depositional remobilization, upward diffusion and subsequent reprecipitation caused by reducing conditions in the sediment column which stripped some subsurface trace elements associated with Fe oxides from the sediments.

With the exception of core 7, the increased trace element concentrations in the subsurface sediments occur only in the banded zones in the cores. As pointed out earlier, core 7 is highly disturbed and lacks coherent banding; however, trace element concentrations are increased throughout its length. The trace element-rich banded zones vary in thickness from a low of 17 cm to a high of 119 cm (cores 13 and 123, respectively; Table I). The thickness of the banded zones in the cores increases with proximity to the mouth of the CDA River. This would indicate that, in the past, the CDA River has acted as a point source for the trace element-rich sediments deposited in Lake CDA. The recent geochemical survey of the surface

sediments of Lake CDA also indicated that the CDA River is currently a point source for trace element-rich sediments entering and depositing in the lake (Horowitz *et al.*, 1993).

Individual trace element distribution and concentration patterns within the banded zones of each core display marked variability, in most instances covering at least two orders of magnitude (Table II). Even so, all the concentrations are markedly enriched over background levels (Table II). The downcore trace element distribution patterns for core 123 are fairly typical of all the cores containing both a banded and an unbanded zone (Figure 3).

Cores 8, 9 and 10 (Figure 2) display similar patterns to core 123, but the trace element levels in the upper parts of their banded zones are lower than in the other cores. This is probably caused by the proximity of these sampling sites to inputs of sediments containing background level trace element concentrations. These inputs dilute the trace element-rich sediments found elsewhere in the lake. Cores 9 and 10 were collected at the backs of Windy and Wolf Lodge Bays, respectively (Figure 2), areas subject to the transport and deposition of sediments from small, local streams that drain areas unaffected by mining and ore processing activities. Trace element concentrations in the upper part of core 8 are also reduced, probably because of the transport and deposition of sediments that contain background level trace element concentrations from the St Joe River (Figure 2). This pattern could also have been influenced by currents from the northward

Table II. Minimum, maximum, mean and median concentrations for trace and major elements in surface and subsurface sediments from Lake Coeur d'Alene

Elements*	Minimum	Maximum	Mean	Median	Unenriched median†
Ag (ppm) (S)	<0·5	21·0	6·0	4·0	<1
Ag (ppm) (C)	<0·1	82·5	15·0	15·0	0·5
Cu (ppm) (S)	9	215	72	70	25
Cu (ppm) (C)	20	650	91	60	30
Pb (ppm) (S)	14	7700	1900	1800	24
Pb (ppm) (C)	12	27 500	3200	1250	33
Zn (ppm) (S)	63	9100	3600	3500	110
Zn (ppm) (C)	59	14 000	2400	2100	118
Cd (ppm) (S)	<0·5	157	62	56	2·8
Cd (ppm) (C)	<0·1	137	25	26	0·3
Hg (ppm) (S)	0·02	4·90	1·80	1·60	0·05
Hg (ppm) (C)	<0·01	9·90	1·90	0·95	0·06
As (ppm) (S)	2·4	660	151	120	4·7
As (ppm) (C)	3·5	845	103	30	12
Sb (ppm) (S)	0·5	96	23	19	0·7
Sb (ppm) (C)	<0·1	215	34	18	1·2
Fe (wt.%) (S)	1·9	16·4	5·1	4·9	3·0
Fe (wt.%) (C)	2·6	13·7	6·7	5·7	4·7
Mn (wt.%) (S)	0·01	2·46	0·67	0·65	0·05
Mn (wt.%) (C)	0·01	6·90	0·45	0·26	0·09
Al (wt.%) (S)	2·9	9·0	7·5	8·0	6·8
Al (wt.%) (C)	3·5	11·0	7·6	8·1	8·0
Ti (wt.%) (S)	0·13	0·64	0·34	0·34	0·40
Ti (wt.%) (C)	0·10	0·65	0·32	0·31	0·33
TOC (wt.%) (S)	0·3	15·6	2·5	2·2	2·5
TOC (wt.%) (C)	<0·1	8·9	2·1	2·2	2·5

* (S) Surface samples; (C) core samples

† Unenriched median: (S) based on 17 samples from the southern part of Lake Coeur d'Alene and the St Joe River; (C) based on 189 core sample aliquots

flowing St Joe River, which either physically remobilized trace element-rich sediments deposited from the CDA River, or prevented substantial amounts of CDA River sediments from reaching this site.

Core 146 contains no banded zones nor increased trace element concentrations. The trace element concentrations and distributions for this core mirror those from the surface sediment samples which indicate that there are no trace element-rich sediments south of Carey Bay and Conkling Point (Figure 1; Horowitz *et al.*, 1993). The unbanded zones of all the other cores contain trace element concentrations roughly equivalent to those found in core 146. Therefore, the trace element concentrations for core 146, as well as those for the unbanded zones of all the other cores, probably represent background levels for the area (Table II, 'unenriched median' column).

Surprisingly, despite evidence that reducing conditions exist in portions of the sediment column of Lake CDA (precipitation of Fe oxides when the cores were thawed before sampling, see under *General observations*), the downcore trace element patterns (e.g. Mn and Fe) do not support this observation (Figure 3). In other words, downcore trace element concentrations and distribution patterns indicate that the most of the subsurface sediment-associated trace elements are relatively inert and do not appear to have been substantially affected by post-depositional remobilization. For example, a typical Mn pattern under reducing conditions would show the highest concentrations at or near the surface, a sharp decrease in concentration at the oxic–anoxic boundary, followed by a steady but very low concentration throughout the rest of the core. Such patterns do not appear to any of the Lake CDA cores. It is possible that reducing conditions do not exist in much of the sediment column; however, the precipitation of Fe oxides during thawing and core sampling, plus the high concentrations of trace elements in the surface and near-surface interstitial water and their concentration gradients (N. Simon, personal communication, 1993), all point towards a reducing environment. The only apparent explanation for the lack of typical downcore trace element patterns indicative of reducing conditions appears to be the extremely high trace element concentrations in the sediments — that is, the losses in trace element concentrations that could be attributable to post-depositional solution and remobilization are relatively minor compared with the residual levels. Thus the losses are masked by the very high trace element concentrations themselves. Although post-depositional remobilization does not appear to have a major impact on downcore concentration and distribution patterns, the remobilized (solubilized) trace elements are more bioavailable than their sediment-associated counterparts, and could affect benthic infauna.

Most of the cores contain two distinct trace element stratigraphic markers. The first is a pronounced trace element minimum associated with the Mt St Helens' ash layer. In core 123, for example, this marker

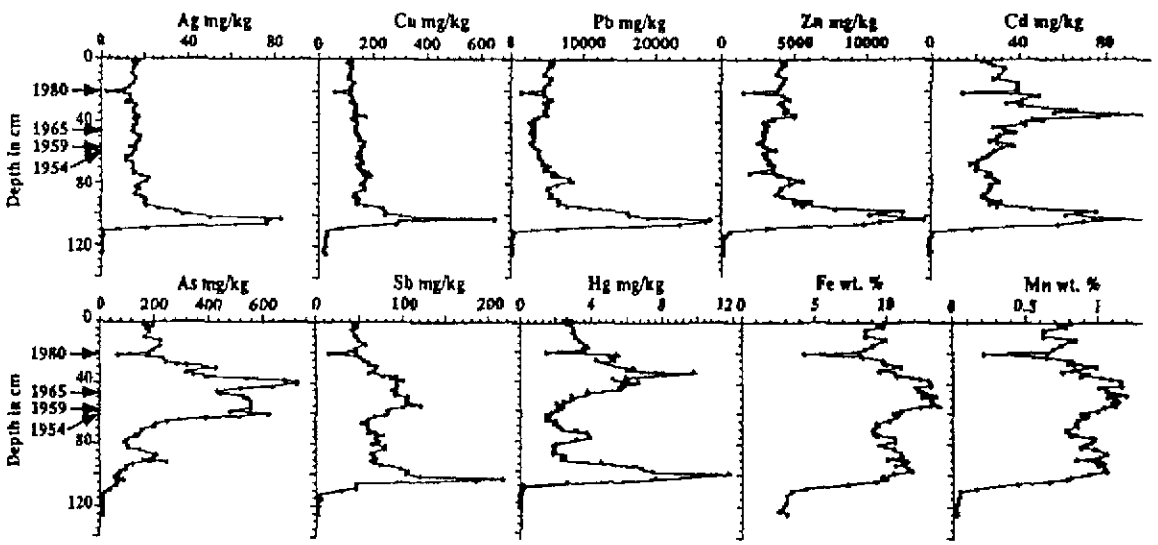


Figure 3. Plots of the vertical distribution patterns for selected trace and major elements in core 123

lies between 20·5 and 21·5 cm (Figure 3). When this same layer is present in the other cores, it is found at various depths ranging from 0·3 to 9·8 cm (Table I). The chemical data for this layer in core 123 indicate that it is by no means pure Mt St Helens' ash, but an admixture of trace element-rich sediment and ash. Based on the chemistry of the ash layer in the core, the reported chemistry of Mt St Helens' ash (Sarna-Wojcicki *et al.*, 1981b) and the chemistry of the layers immediately above and below it, the ash layer appears to be composed of about 65–75% ash and 25–35% trace element-rich sediment.

The other significant stratigraphic marker found in most of the cores is a very distinct trace element maximum. These maxima always occur at or near the base of the banded zones and at depths of 7·5 to 104·5 cm in the sediment column (Table I). In core 123, for example, the maximum occurs between 102 and 104·5 cm (Figure 3, Table I). Based on the location of the maxima in the cores and the extremely elevated trace element concentrations associated with them, they could represent the first substantial discharge of trace element-rich solids to Lake CDA from the drainage basin after the onset of sustained mining and ore-processing activities in the region. This is possible because the initial ore processing procedures used in the area were inefficient and did not improve until the introduction of flotation procedures to preconcentrate the heavy ore minerals before further processing (e.g. Bender, 1991). A similar rationale was proposed by Bender (1991) to explain some trace element-rich bands in cores obtained in nearby Killarney Lake (a lateral lake adjacent to the CDA River). Alternatively, these maxima may represent a period of unusually high mining and ore processing activity, or a period of unusually high discharge in the CDA drainage basin.

It should be noted that all the structures in the cores that appear to be caused by former biological activity (see under *General observations*) are located in the unbanded zones — that is, the disappearance of the structures indicative of former benthic activity seems to coincide with the appearance of increased trace element concentrations. Currently it is impossible to determine if the absence of benthic infauna associated with the trace element-rich banded zones was the result of increased turbidity caused by increasing concentrations of suspended sediments in Lake CDA, increased sedimentation rates associated with the increased turbidity, or to the increased trace element concentrations themselves. All three factors were associated with the inception and continuation of mining and ore processing activities in the CDA mining district. For example, the onset of mining and ore processing in the area caused substantial increases in the turbidity of Lake CDA (e.g. Ellis, 1940; Rabe and Flaherty, 1974). Increased turbidity would almost certainly lead to increased sedimentation rates. Regardless of the specific cause, it seems that the disappearance of at least some portion of the benthic invertebrate community, both in the past as well as in the present, was related to the onset and continuation of mining and ore processing. Currently, turbidity and presumably sedimentation rates are low, and dissolved oxygen levels at the sediment–water interface do not fall below 30% of saturation (P. Woods, personal communication, 1993). On the other hand, the interstitial water at the sediment–water interface contains substantial concentrations of Cu, Pb and Zn (N. Simon, personal communication, 1993). Therefore, although direct evidence is lacking, it appears that a potential cause for at least the current lack of benthic invertebrate activity is related to the increased trace element concentrations in the sediments.

Estimated masses of enriched sediments and associated trace elements

One of the reasons for collecting cores in the lake was to estimate the mass of trace element-rich sediments, as well as the mass of each enriched trace element, currently on or in the bed of Lake CDA. These estimates were calculated on the basis of the following assumptions and procedures (Table III):

1. The lake was divided into 12 separate zones with a near-centrally located core in each zone.
2. The area of each zone was digitized from US Geological Survey 7·5 minute topographic maps.
3. For purposes of this estimate it was assumed that each core represented the thickness and chemical content (median concentration) of the entire zone within which it was located. The thickness of trace element-rich sediments in core 7 had to be estimated as the core never reached background levels. The estimated thickness was 150 cm and was based on the gradient (change in trace element-rich thickness) between cores 6 and 123 and core 8 and 123. Core 6 was never chemically analysed because the liner cracked and the sediment desiccated before sampling. The median chemical concentrations for core 6 were estimated as the average of the median values for cores 123 and 93.

Table III. Calculated estimates of the masses of trace elements associated with enriched sediments in Lake Coeur d'Alene

Element	Total mass in enriched zone (tonnes)	Mass in enriched zone per km^2 (tonnes)	Mass if sediment contained background concentrations (tonnes)	Excess due to presence of enriched sediments (tonnes)
Ag	1350	13	< 38	> 1312
Cu	10 000	99	2600	7400
Pb	470 000	4350	1700	468 000
Zn	240 000	2900	9600	230 000
Cd	3300	31	16	3284
Hg	265	2·4	5·3	260
As	12 000	111	495	11 500
Sb	4650	43	53	4600

Total area of lake 127·8 km^2; area of lake containing enriched sediments 108·2 km^2; percentage of lake containing enriched sediments 85%; weighted average thickness of enriched sediments in enriched zone per km^2 35 cm; and mass of enriched sediments 75·2 Gt

4. The volume of enriched sediment for each zone was then determined by multiplying the area of each zone by the thickness of the trace element-rich section of the appropriate core.
5. The mass of enriched sediment for each zone was subsequently calculated by multiplying the volume of that zone by the estimated bulk density (2·00 g/cm^3) of the sediment (the bulk density was estimated based on measured moisture ranges of < 1–25%, and estimated dry densities ranging from 2·50 to 4·00 g/cm^3; these produced bulk densities ranging from 1·4 to 2·8 g/cm^3).
6. The mass of enriched sediment for the entire lake was determined by summing the results for each of the zones.
7. The mass of each enriched trace element, in each zone, was calculated by multiplying the mass of trace element-rich sediment in that zone by the median trace element concentration ($\mu g/g$) from the appropriate core.
8. The mass of each enriched sediment-associated trace element for the entire lake was determined by summing the results for each of the zones.
9. By substituting unenriched median chemical concentration values obtained from core 146 and the unbanded zones of the other cores in lieu of the enriched median concentrations used in step 7, normal (background) trace element masses were estimated for the same volume of enriched sediments.
10. The excess mass of each sediment-associated trace element was estimated by subtracting the results from step 9 from those calculated from step 8.

The calculated estimates based on the foregoing steps and assumptions indicate that there are about 75×10^6 tonnes of trace element-rich sediments currently blanketing about 85% of the bed of Lake CDA (Table III). The masses of excess trace elements range from about 260 tonnes for Hg to more than 468 000 tonnes for Pb (Table III). With the exception of Cu, the background masses of the other trace elements are essentially inconsequential relative to the enriched masses. The background trace element masses typically represent < 2% of the estimated masses of enriched trace elements (Table III). If the trace element-rich sediments were evenly distributed throughout the area of the lake which currently contains this type of material, they would represent a layer approximately 35 cm thick.

The estimated mass of trace element-rich sediments, as well as the estimated masses of excess trace elements, are a function of the assumptions used in calculating them. If the assumed sediment bulk density was too high, then the calculated masses would decrease (e.g. a bulk density of 1·4 g/cm^3 would reduce the estimated mass of trace element-rich sediments to about 50×10^6 tonnes). Alternatively, if the thicknesses of the trace element-rich sediments determined from each core were not representative of the entire zone within which it was located, then the estimates could increase or decrease. However, seismic reflection surveys indicate that sediment layering and thicknesses are uniform over the entire lake bed; thinning

only appears to occur very close to the shore. Further, errors in the estimates for the median chemical concentrations in core 6 and the thickness of the trace element-rich section of core 7 could increase or decrease the calculated sediment and trace element masses. Regardless of the potential sources of error, alternative calculations indicate that the mass of trace element-rich sediments is still of the order of millions of tonnes.

Trace element interrelations

The enriched trace elements associated with the surface sediments display strong positive interrelations among themselves and with Fe, and either a slightly negative or no correlation with Ti and TOC (Horowitz *et al.*, 1993). The strong correlations between and among the enriched trace elements, and the trace elements with Fe, probably indicate a similar source {the major minerals found in the CDA mining district {[galena (Pb), sphalerite (Zn, Fe), tetrahedrite (Cu, Sb, Ag, Hg), pyrite (Fe) and pyrrhotite (Fe)]} or a similar concentrating mechanism (association with Fe oxides).

Calculated correlation coefficients for the trace element-rich subsurface sediments strongly correspond to those found for the surface sediments. The similarity in the occurrence and strength of the various correlation coefficients for the surface and subsurface sediments is striking and implies that the same sources and/or concentrating mechanisms were active throughout the period of deposition of the trace element-rich sediments in Lake CDA (Table IV). Two major differences in the calculated correlation coefficients for the trace element-rich surface and subsurface (banded zone) sediments are the much stronger correlations between the enriched trace elements and Mn, and between Mn and Fe, for the latter group (Table IV). This difference may be ascribed to reducing conditions in the sediment column that caused a certain amount of 'geochemical smearing' caused by post-depositional solution, remobilization and reprecipitation (when the diffusing pore fluids reached an oxidized zone) of the Fe oxide-associated trace elements and accompanying Mn oxides. After remobilization, the Fe and Mn may have reprecipitated in the same physical phase (Fe/Mn oxyhydroxides), as separate phases in the same physical location, or the Mn on existing Fe sulphide minerals unaffected by the redox potential in the sediment column.

The strong trace element interrelations for all the enriched surface and subsurface sediments, treated as a group, differentiate them from the normal (background) surface and subsurface sediments, treated as a group (Figure 4). In most instances, the strong interelement correlations ($>0{\cdot}70$) observed for the trace elements associated with the enriched sediments do not exist for the normal/background sediments (Figure 4a). In the few instances when strong correlations appear for the two groups (e.g. Pb and Zn, As and Mn), the slopes are typically different (Figure 4b). Further, although the enriched sediments all display strong correlations with Fe, the background group either does not, or, when strong correlations do occur, the slopes differ from the enriched group (Figure 4c). As with the surface sediments this is probably indicative of a similar source (mining and ore processing related discharges) or a similar concentrating mechanism (associated with Fe oxides). One strong correlation (0·90) appears for the background group which did not appear for the enriched group: Fe with Al (Figure 4d). This is probably the result of detrital, lattice-held Fe and Al, eroded from the local rocks and soil.

Trace element partitioning

Phase associations for the trace element-rich surface sediments were determined using heavy mineral separations and partial chemical extractions, with subsequent chemical analyses of the fractions or extracts. A limited number of heavy/light fractions also were examined by SEM/EDAX. These studies indicate that most of the enriched Pb, Cd, Zn, As and Cu are associated with an operationally defined Fe oxide phase, the Ag could be associated with either Fe oxides or sulphides, whereas the Sb is predominantly associated with a refractory phase (Horowitz *et al.*, 1993). Heavy mineral concentrations and associated trace element contributions are limited. The highest concentration of heavy minerals (11%) is within the CDA River delta; this decreases rapidly to $<1\%$ within 2 km of the delta. Heavy mineral-associated trace element contributions are equal to or less than the percentages of the heavy minerals themselves (Horowitz *et al.*, 1993).

Table IV. Correlation coefficients for the enriched elements (surface sediments/subsurface sediments) and some major elements using log-transformed normalized (X/Ti/TOC) data (see Horowitz *et al.*, 1993). All correlations are significant at the 99% confidence level

	Ag	Cu	Pb	Zn	Cd	Hg	As	Sb	Fe	Mn	Al
Ag	1·00/1·00										
Cu	0·94/0·94	1·00/1·00									
Pb	0·96/0·94	0·92/0·89	1·00/1·00								
Zn	0·85/0·86	0·96/0·86	0·86/0·84	1·00/1·00							
Cd	0·69/0·68	0·85/0·72	0·69/0·65	0·91/0·86	1·00/1·00						
Hg	0·95/0·85	0·93/0·87	0·92/0·78	0·88/0·86	0·77/0·82	1·00/1·00					
As	0·68/0·46	0·61/0·54	0·65/0·33	0·51/0·52	0·45/0·59	0·64/0·72	1·00/1·00				
Sb	0·95/0·90	0·92/0·91	0·96/0·82	0·88/0·80	0·72/0·73	0·96/0·89	0·60/0·63	1·00/1·00			
Fe	0·90/0·78	0·91/0·84	0·86/0·68	0·84/0·75	0·65/0·63	0·83/0·84	0·61/0·81	0·85/0·79	1·00/1·00		
Mn	0·60/0·73	0·56/0·80	0·56/0·63	0·48/0·73	0·43/0·70	0·57/0·81	0·76/0·80	0·53/0·78	0·64/0·88	1·00/1·00	
Al	0·68/0·32	0·87/0·34	0·68/0·33	0·90/0·38	0·89/0·31	0·69/0·21	0·44/0·04	0·68/0·19	0·72/0·29	0·39/0·16	1·00/1·00

Similar procedures were used to evaluate the phase associations for the trace element-rich subsurface sediments. However, partial chemical extractions were omitted because there were indications during core thawing and sampling (e.g. the precipitation of reduced Fe as Fe oxide) that at least some of the original sediment–trace element phase associations were altered. As data were already available on the

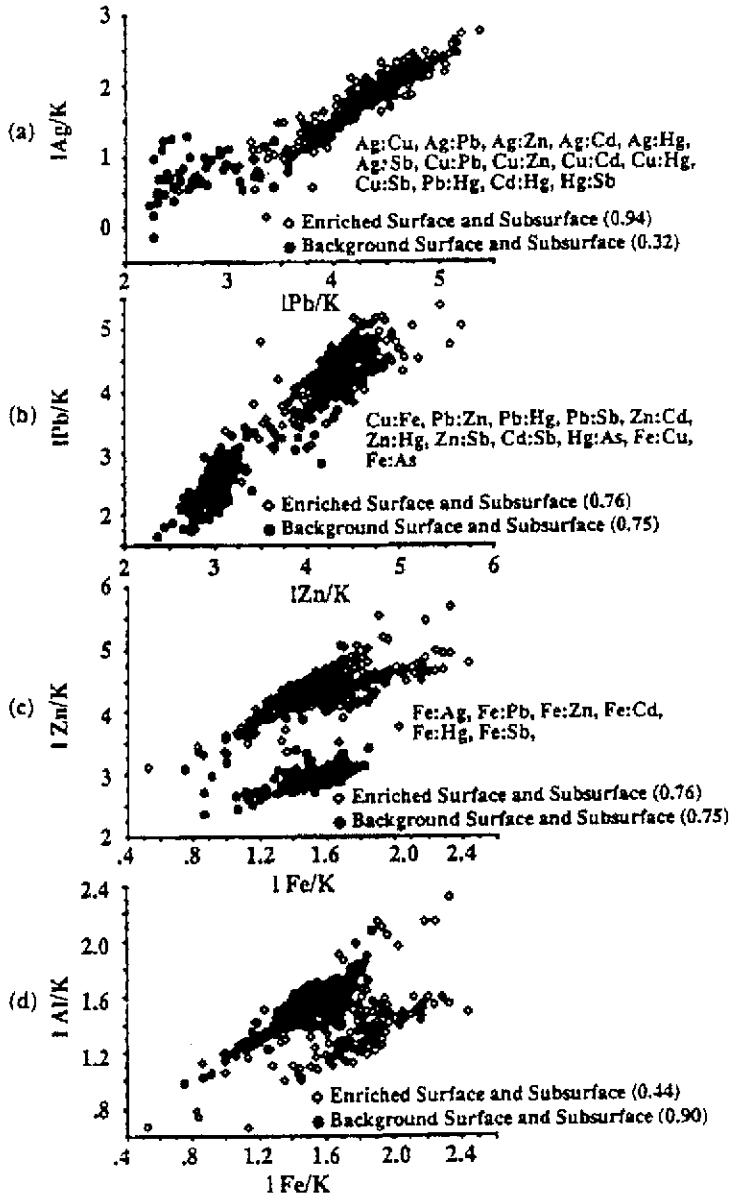


Figure 4. Selected plots of correlation coefficients comparing trace element-rich surface and subsurface samples with those for surface and subsurface background samples. The coefficients were calculated after normalization to Ti/TOC and log transformation (see Horowitz *et al.*, 1993). The element pairs listed adjacent to each graph display similar patterns to those shown in the graph: (a) strong correlation coefficients for the enriched sediments which do not occur for background sediments; (b) strong correlation coefficients for both enriched and background sediments where the slope for each set are different; (c) strong correlation coefficients for the enriched sediment-associated trace elements and Fe which differentiate them from background sediments; and (d) a graph of the correlation coefficients for Fe and Al which differentiates the trace element-rich surface and subsurface samples from those for surface and subsurface background samples

Table V. Heavy/light mineral fraction geochemistry of selected subsurface sediment samples from Lake Coeur d'Alene

Sample	Percentage of sample	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Cd (ppm)	As (ppm)	Sb (ppm)	Hg (ppm)	Fe (wt.%)	Mn (wt.%)	Al (wt.%)	Ti (wt.%)
Core 8: 21–24 cm*													
Bulk		29	220	12000	5800	36	41	63	3·8	7·2	0·50	8·5	0·32
Light fraction	98	26	210	10000	5000	35	41	68	4·0	6·8	0·45	8·5	0·3
Heavy fraction	1	37	300	14000	8000	64	60	90	N/D	14·1	0·95	6·5	1·2
Light contribution		26	206	9800	4900	34	40	67	3·9	6·7	0·44	8·3	0·29
Heavy contribution		0·4	3	140	80	0·6	0·6	0·9	N/D	0·1	0·01	0·1	0·01
Calculated concentration		26	213	10000	5000	35	41	68	3·9	6·8	0·45	8·4	0·3
Core 9: 25–30 cm*													
Bulk		23	179	7900	3200	29	37	67	2·9	7·5	0·43	8·8	0·45
Light fraction	98	22	173	8200	3500	29	31	62	2·7	7·2	0·40	9·0	0·40
Heavy fraction	2	14	153	9900	3300	30	36	55	2·1	8·6	0·50	8·6	1·7
Light contribution		22	170	8000	3400	31	30	61	2·6	7·1	0·39	8·8	0·39
Heavy contribution		0·3	4	220	75	0·7	1	1	0·05	0·3	0·01	0·2	0·04
Calculated concentration		22	174	8200	3500	32	31	62	2·6	7·4	0·40	9·0	0·43
Core 47: 18–22 cm*													
Bulk		35	220	15000	5600	47	35	81	4·5	8·1	0·60	9·4	0·36
Light fraction	99	31	230	14000	5700	45	39	84	4·3	7·8	0·55	9·1	0·32
Heavy fraction	1	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Light contribution		31	228	14000	5600	45	39	83	4·2	7·7	0·54	9·0	0·32
Heavy contribution		N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Calculated concentration		31	228	14000	5600	45	39	83	4·2	7·7	0·54	9·0	0·32
Core 93: 20–27 cm*													
Bulk		42	240	16000	7000	48	53	105	6·0	8·0	0·53	9·6	0·31
Light fraction	99	42	230	15000	6100	48	55	120	6·0	7·5	0·48	9·6	0·28
Heavy fraction	1	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Light contribution		42	228	15000	6000	48	54	118	5·9	7·4	0·48	9·5	0·28
Heavy contribution		N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Calculated concentration		42	228	15000	6000	48	54	118	5·9	7·4	0·48	9·5	0·28
Core 123: 34–38 cm*													
Bulk		16	145	4100	4600	74	530	84	7·9	11·7	1·00	6·1	0·18
Light fraction	77	13	125	3800	2900	75	210	80	7·0	6·4	0·37	5·9	0·17
Heavy fraction	21	28	190	5000	8000	80	1500	110	12·0	31	2·90	2·2	0·2
Light contribution		10	96	2900	2200	58	162	62	5·4	4·9	0·29	4·5	0·13
Heavy contribution		6	40	1100	1700	17	320	23	2·5	6·5	0·61	0·5	0·04
Calculated concentration		16	136	4000	3900	75	482	85	7·9	11·4	0·90	5·0	0·17
Core 123: 75–78 cm*													
Bulk		16	145	8000	5000	30	95	70	3·9	10·5	0·97	5·7	0·15
Light fraction	72	16	145	6000	3000	19	70	55	3·2	5·9	0·40	5·8	0·13
Heavy fraction	26	24	195	10000	7000	46	200	95	6·0	22·7	2·50	5·0	0·18

Light contribution		12	104	4300	2200	14	50	50	2·3	4·3	0·29	4·2	0·09
Heavy contribution		6	51	2600	1800	12	52	25	1·6	5·9	0·65	1·3	0·05
Calculated concentration		18	155	6900	4000	26	102	75	3·9	10·2	0·94	5·5	0·13
Core 123: 102 -103 cm*													
Bulk		63	445	20 000	13 000	103	78	210	10·4	9·5	0·80	6·8	0·20
Light fraction	52	41	270	15 000	6200	46	40	170	6·0	5·5	0·31	7·3	0·18
Heavy fraction	48	105	660	30 000	24 000	150	145	195	20·0	18·2	1·75	5·8	0·24
Light contribution		25	165	9200	3800	28	4	104	3·7	3·4	0·19	4·5	0·11
Heavy contribution		41	260	11 700	9400	59	57	76	7·8	7·1	0·68	2·3	0·09
Calculated concentration		66	425	20 900	13 200	87	81	180	11·5	10·5	0·87	6·8	0·2

N/D = Not determined, insufficient sample
* Similar results also were obtained from core 39: 7·0–13·5 cm and from similarly treated surface sediments (see Horowitz *et al.*, 1993)

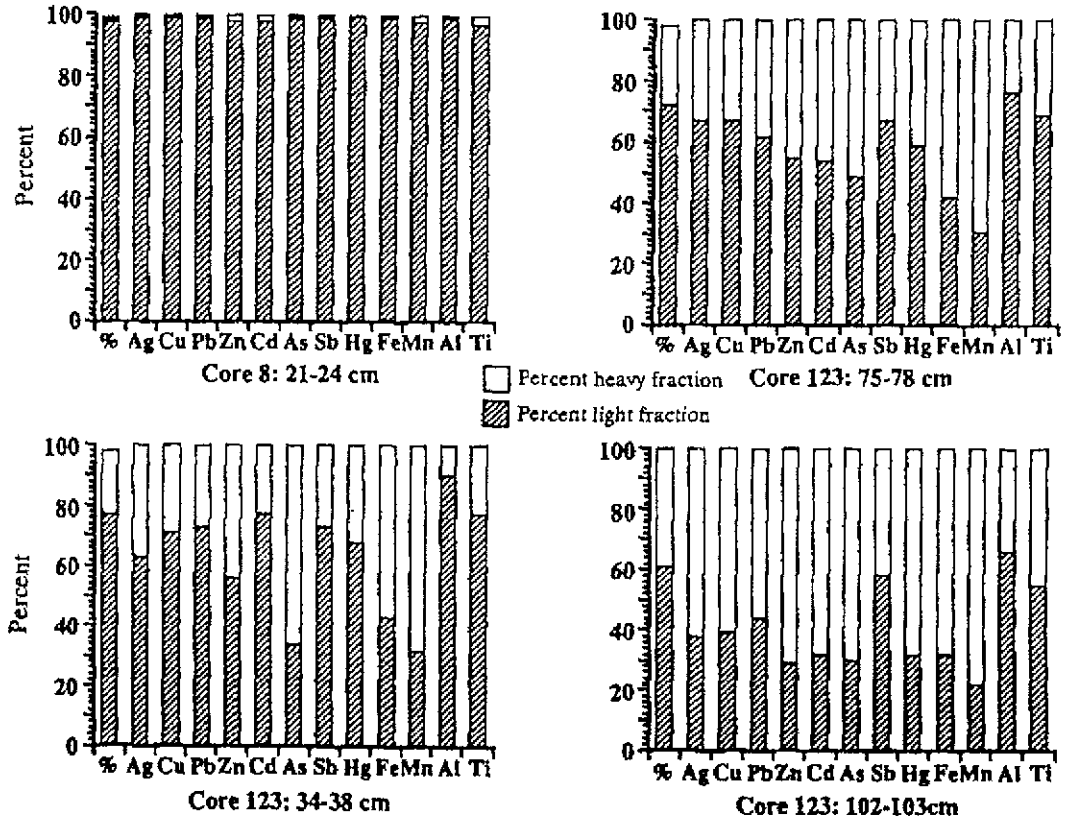


Figure 5. Graphical representation of the trace element contributions (in per cent) from the heavy and light fractions from selected core samples from Lake Coeur d'Alene. The first column, labeled '%', indicates the percentage each fraction represents in the sample. The results for the core 8 sample are similar to those for samples from cores 9, 39, 47 and 93, as well as for similarly treated surface sediments (see Horowitz *et al.*, 1993)

surface sediments, emphasis was placed on evaluating the phase associations of the sediment-associated trace element maxima near the bases of the banded zones.

With the exception of the samples from core 123, the heavy mineral concentrations and associated trace element contributions in the subsurface samples were extremely limited, and similar to the results obtained for the surface sediment samples (generally $< 1\%$, Table V, Figure 5; Horowitz *et al.*, 1993). Because these samples contain substantial amounts of sediment from the layers above and below the maxima, these results may not accurately reflect the phase associations of the specific layer(s) containing the trace element maxima.

The subsamples from core 123 are the only ones that contain large detectable amounts of heavy minerals (21–48%, Table V, Figure 5). The heavy mineral percentages for all three subsamples are markedly higher than for the other core samples, as are the heavy mineral-associated trace element contributions (Table V, Figure 5). The high percentage of heavy minerals could be caused by the proximity of the core 123 site (just outside the delta area) to the CDA River, which is a point source for this material. However, the heavy mineral and heavy mineral-associated trace element contribution percentages are all higher than the highest heavy mineral percentage ($\approx 11\%$) found in a surface sample from the CDA River delta (Horowitz *et al.*, 1993). The largest percentage (48%, Table V, Figure 5) of heavy minerals is associated with the layer containing the trace element maxima for this core. The trace element contributions attributable to the heavy fractions are all much higher than the fractions present in the original samples. This is markedly different from the results from the other cores and from the surface sediments. These differences may be

related to changes in the chemical or mineralogical composition of discharged mining and mining-related material over time and tend to support the view that the trace element maxima near the bases of the banded zones represent the first substantial discharge of trace element-rich solids to Lake CDA from the drainage basin after the onset of sustained mining and ore-processing activities in the region.

Subsequent SEM/EDAX examination of some of the heavy fractions indicated the presence of a suite of heavy minerals, including sulphides, typical of the region and essentially the same as those found in the heavy fractions of the surface sediments (Horowitz *et al.*, 1993). Galena, sphalerite, Ti oxides, tetrahedrite, monazite, chalcopyrite and various Fe oxides were identified from the EDAX analyses. These results could indicate that the trace element maxima near the base of the banded zones are the result of the discharge of inefficiently processed ore material generated before the inception of more efficient milling procedures. The latter procedures retained higher percentages of the ore minerals entrained in the circuit feeding the flotation cells; thus smaller amounts of heavy minerals were discharged as tailings. The similarity in the heavy fraction mineralogy in both the surface and subsurface samples implies that the sources or concentrating mechanisms for the trace element-rich sediments were the same throughout the course of their deposition in Lake CDA. Finally, as with the surface sediments, the mean grain sizes of the heavy minerals decreased with distance from the mouth of the CDA River. This further supports the view that the river is acting as a point source for the heavy minerals and that their current locations are probably the result of physical remobilization (by currents or wind-driven waves) within the lake.

Sediment geochemical history of Lake CDA

One of the major reasons for obtaining cores in Lake CDA was to try to reconstruct the recent geochemical history of the lake from just before the inception of upstream mining and ore processing activities through to the present (a period of about 110 years), This effort was concentrated on core 123 because of: (a) the overall thickness of its banded trace element-rich section (≈ 119 cm); (b) the thickness and number of its readily discernible individual layers (80); (c) the presence of a datable (1980) Mt St Helens' ash layer (20·5–21·5 cm); and (d) the occurrence of background trace element levels at its base, below the banded zone (119–126 cm). Three separate approaches were used to estimate the age of the base of the trace element-rich zone in the core.

An initial estimate of the age of the base of the trace element-rich zone was made by considering the 1990 date the core was obtained, the position and age of the 1980 Mt St Helens' ash layer, and the 10 layers between them. These factors may indicate that the layers are analogous to annual varves along river banks, and that each layer represents annual deposition. If that is the case, and there are 80 layers between the top of the core and the base of the trace element-rich zone, then the deposition of trace element-rich sediments began around 1910.

A trial to test the feasibility of obtaining absolute ages for the upper portion of the core entailed determining the ^{137}Cs activity in four samples. The samples were selected on the assumption that each layer represented annual deposition. Therefore, counting backward from the Mt St Helens' ash layer, samples representing deposition from 1979–80 (21·5–24·5 cm), 1963–4 (48·0–50·0 cm), 1957–8 (56·0–59·0 cm) and 1945–6 (78·5–81·0 cm) were evaluated for ^{137}Cs activity. The activities determined for these samples are consistent with the assigned ages and indicate that each layer could represent annual deposition.

After the trial, ^{137}Cs activity was determined for all the sampled layers in core 123. Often, the resolution of a ^{137}Cs profile is only sufficient to interpret a broad single activity maximum. However, the distribution of ^{137}Cs in core 123 (Figure 6, upper panel) has several features that were used to develop a sediment chronology. The graph shows a strong maximum at about 45 cm and a secondary peak at 55 cm. No ^{137}Cs was detected below 60 cm, nor in the ash layer between 20·5 and 21·5 cm. These features are consistent with the assignment of dates of 1963–4 for the maximum and 1958–9 for the earlier secondary peak. The onset of measurable fallout and sedimentary ^{137}Cs activity occurs around 1954. The assignment of these dates (plus the dated ash layer, 1980), leads to an age–depth model that follows the equation

$$z = (w_0/\beta)[1 - e^{-\beta t}]$$

where w_0 is the linear rate at the surface (cm yr^{-1}) and β describes the degree of non-linearity which is

principally due to compaction effects. Weighted least-squares values of w_0 and β are $2{\cdot}06 \pm 0{\cdot}02$ cm yr^{-1} and $0{\cdot}0133 \pm 0{\cdot}006$ yr^{-1}, respectively. Assignment of ages to each depth interval using this equation allows replotting of the ^{137}Cs activity (broken line) against model year, along with the annually averaged atmospheric fallout rate (solid line), which is arbitrarily normalized to the peak value (Figure 6, lower panel). The plotted atmospheric fallout rate is a representation of the well defined loading function for the Great Lakes region, Lake Superior in particular (Robbins, 1985). Model application produces a predicted age of 1895 for the base of the banded (trace element-rich) zone, although the 95% confidence limits for this date are large.

A notable difference between the core 123 profile and the idealized loading function is the higher ^{137}Cs activity during the 1958–9 period. This variance could be caused by local differences in atmospheric loading, or in-lake transport and deposition processes. Alternatively, the markedly higher ^{137}Cs activities in post-1970 sediments are probably not due to regional differences, and may have resulted from a combination of post-depositional redistribution processes and contributions from long-term ^{137}Cs transport within the lake (e.g. focusing), as well as from ^{137}Cs stores in the catchment. The post-1970 ^{137}Cs activity follows an exponential decay curve with about a 10 year time constant.

By combining (a) the date of collection for the core (1990) with (b) the date for the ash layer (1980) and (c) with the three dates estimated from the ^{137}Cs activity (1965, 1959 and 1954), it is possible to estimate average sedimentation rates for the core site. Without considering the effects of compaction, and assuming constant deposition between the dated points, the average annual rates are as follows: 2·1 cm yr^{-1} (1980–90), 1·7 cm yr^{-1} (1965–80), 1·3 cm yr^{-1} (1959–65) and 1·4 cm yr^{-1} (1954–9). These results indicate that sedimentation reached a constant of 1·3–1·4 cm yr^{-1} for material deposited before 1965. The general decrease in sedimentation rates with increasing depth in the core could be the result of compaction, rather than actual changes in sedimentation rates over time; a view supported by the general decrease in moisture content with increasing depth. The depth of the 1954 layer is 61·0 cm; the depth of the base of the trace element-rich zone is 119·0 cm. Thus the thickness of the undated portion of the trace element-rich zone is 58 cm. If the sedimentation rate for this section of the core is assumed to be 1·35 cm yr^{-1}, then the undated section represents a period of 43 years and the age for the start of trace element-rich sediment deposition is 1911.

The relative consistency of the three estimated dates (1910, 1895 and 1911) for the base of the trace element-rich banded zone in core 123, using three different, albeit not completely independent, approaches, is encouraging. Certainly, the three estimated dates are consistent with the 1880–90 period assigned for the onset of mining and ore processing activities in the CDA mining district (e.g. Bender, 1991). However, final confirmation of the age of the base of the trace element-rich zone requires the use of another radioisotope, probably ^{210}Pb.

CONCLUSIONS

Substantial portions of the subsurface sediments blanketing 85% of the bed of Lake CDA are enriched in Ag, As, Cd, Cu, Hg, Pb, Sb and Zn. The thickness of the enriched sediments ranges from 17 cm to more than 119 cm; the thickness of these deposits increases with proximity to the mouth of the CDA River. The CDA River seems to be the source for most of the trace element-rich sediments in the lake. The similarity in the locations of the trace element-rich surface and subsurface sediments, the trace element concentrations, the correlations between and among the trace elements and the trace element partitioning, all suggest that the sources and concentrating mechanisms causing the trace element enrichment in the lake have probably been much the same throughout the last 100–110 years. An estimated 75×10^6 tonnes of trace element-rich bed sediments have been deposited in Lake CDA. Estimates of enriched trace element masses (masses above calculated background levels) range from 468 000 tonnes for Pb to 260 tonnes for Hg. Core sections containing increased sediment-associated trace element concentrations do not contain any structures indicative of benthic invertebrate activity, whereas such structures were identified in core sections containing background trace element concentrations. Most of the subsurface enriched trace elements are not associated with sulphide minerals; they are probably associated, like their surface sediment counterparts, with an operationally defined Fe oxide phase. Based on the presence of a Mt St Helens' ash layer, three dates based on ^{137}Cs activity, the presence of 80 discernible layers and calculated sedimentation rates for a core from the CDA River delta, the age of the

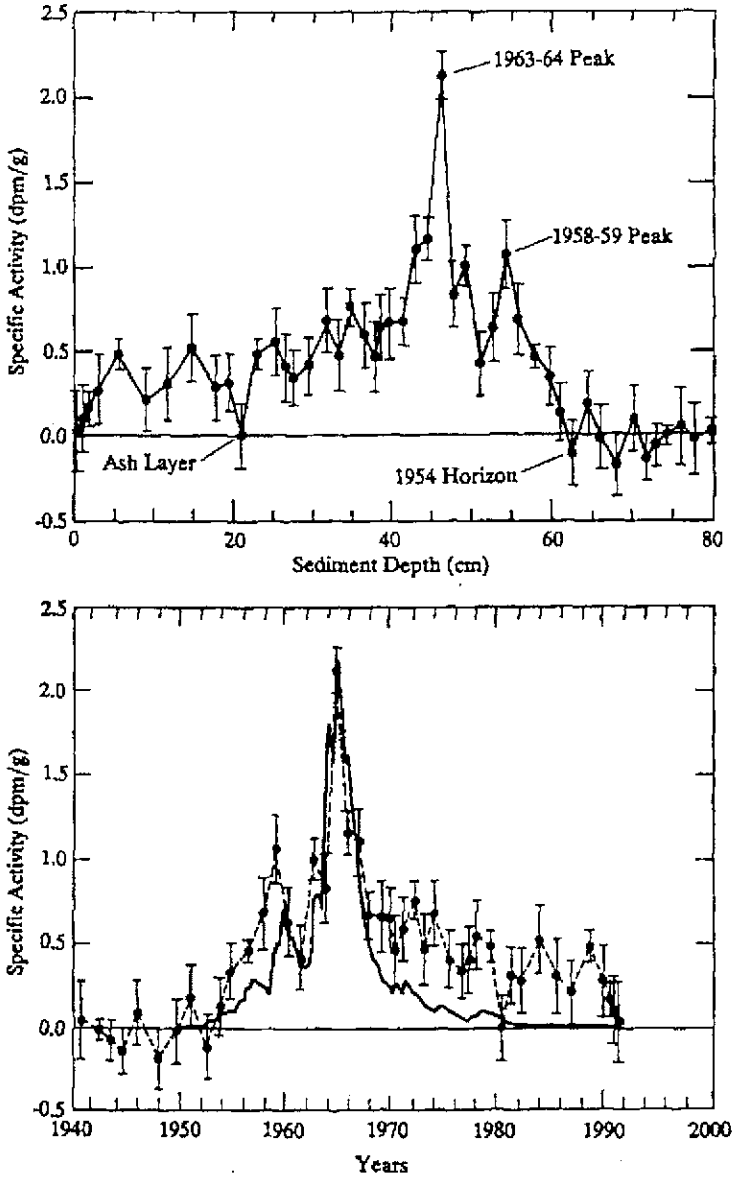


Figure 6. The upper panel is a plot of ^{137}Cs activity (dpm g^{-1}) against sediment depth (cm). The lower panel is a recast of the upper panel and displays ^{137}Cs activity (dpm g^{-1}) against age (broken line). The solid line is a plot of the well-developed loading function for the Great Lakes region (Robbins, 1985)

onset of trace element enrichment in the lake probably falls between 1895 and 1910. These dates are consistent with the onset of mining and ore processing in the CDA mining district, and these activities probably represent the major source of the extreme trace element enrichments in the sediments of Lake CDA.

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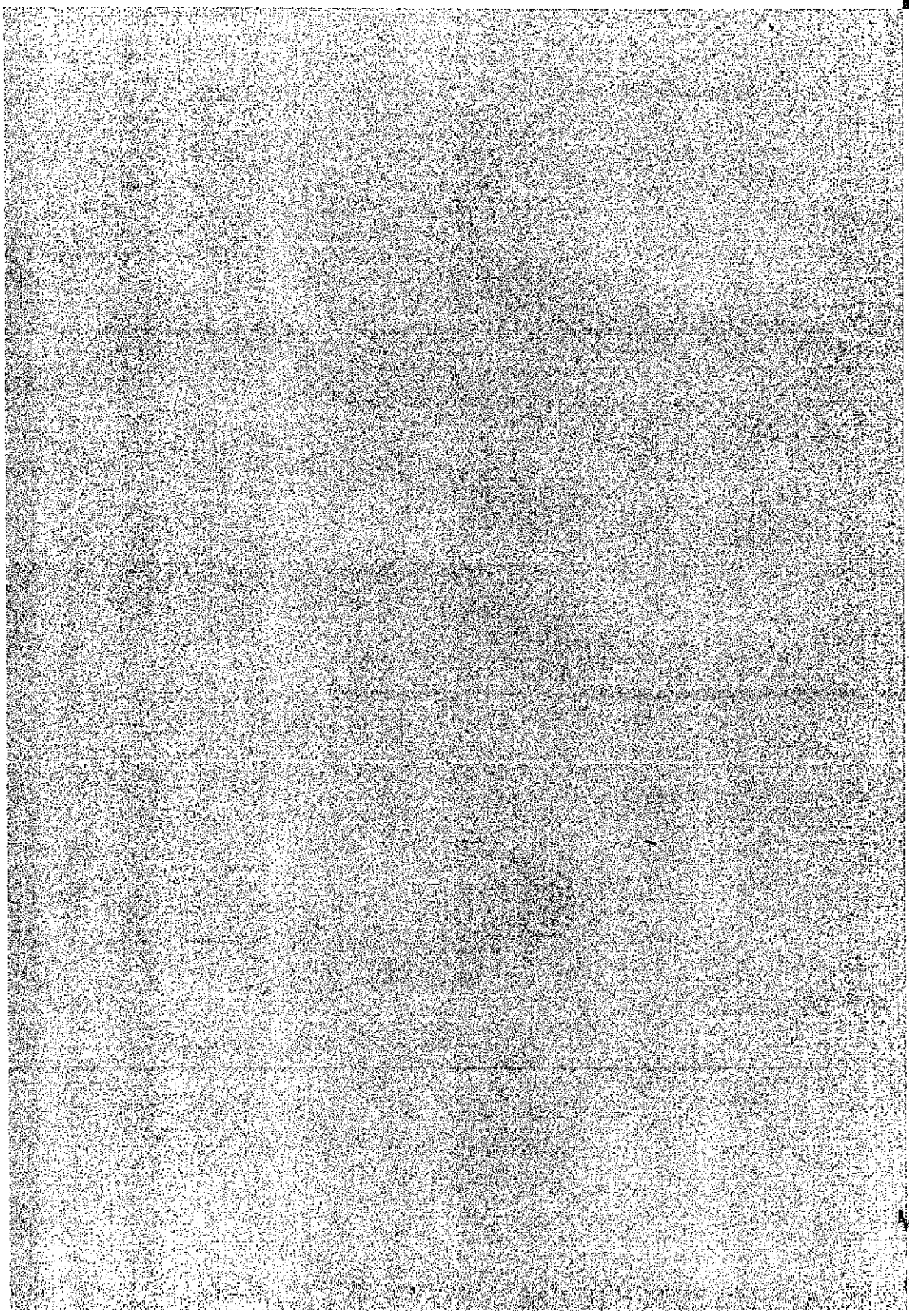
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By PAUL F. WOODS and MICHAEL A. BECKWITH

Prepared in cooperation with the
Idaho Department of Health and Welfare,
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and the Coeur d'Alene Tribe

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
centimeter (cm)	0.3937	inch
cubic centimeter per liter (cm^3/L)	0.2310	cubic inch per gallon
cubic hectometer (hm^3)	810.7	acre-foot
cubic hectometer per square kilometer (hm^3/km^2)	3.281	acre-foot per acre
cubic kilometer (km^3)	0.2399	cubic mile
cubic meter (m^3)	35.31	cubic foot
cubic meter per second (m^3/s)	35.31	cubic foot per second
cubic micrometer per milliliter ($\mu m^3/mL$)	0.00000001059	cubic inch per ounce
hectare (ha)	2.471	acre
kilogram (kg)	2.205	pound
kilogram per hectare (kg/ha)	0.8922	pound per acre
kilogram per square kilometer (kg/km^2)	2,000	ton per acre
kilometer (km)	0.6214	mile
liter (L)	0.2642	gallon
meter (m)	3.281	foot
metric ton	1.102	ton (short)
microgram per liter ($\mu g/L$)	0.00000136	ton per acre-foot
micrometer (μm)	0.00003937	inch
milligram (mg)	0.000002205	pound
milligram per cubic meter per day ($(mg/m^3)/d$)	0.002719	pound per acre-foot per day
milligram per liter (mg/L)	0.00136	ton per acre-foot
milligram per kilogram (mg/kg)	0.002001	pound per ton
milligram per square meter (mg/m^2)	0.008926	pound per acre
milliliter (mL)	0.03381	ounce
millimeter (mm)	0.03937	inch
square kilometer (km^2)	0.3861	square mile
square meter (m^2)	10.76	square foot

To convert °C (degrees Celsius) to °F (degrees Fahrenheit), use the following equation:

$$°F = (1.8°C) + (32)$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units

cells/mL	cells per milliliter
$cells/cm^2$	cells per square centimeter
E	Einstein
E/m^2	Einsteins per square meter
$(\mu E/m^2)/s$	microEinsteins per square meter per second
$\mu S/cm$	microsiemens per centimeter at 25°C
$(mg/m^2)/E$	milligrams per square meter per Einstein

Nutrient and Trace-Element Enrichment of Coeur d'Alene Lake, Idaho

By Paul F. Woods *and* Michael A. Beckwith

Abstract

This study of Coeur d'Alene Lake was undertaken because of concerns over the potential for release of previously deposited nutrients and trace elements from the lakebed if an anoxic hypolimnion were to develop as a consequence of eutrophication. The primary purpose of the study was to determine the lake's assimilative capacity for nutrients. The scope included characterization of water quality in the limnetic and littoral zones of the lake, quantification of hydrologic and nutrient budgets, development of a nutrient load/lake response model, and characterization of trace-element enrichment in surficial and subsurface lakebed sediments.

Coeur d'Alene Lake was classified as oligotrophic during 1991–92, on the basis of annual geometric mean concentrations, in micrograms per liter, of total phosphorus (4.1), total nitrogen (247), and chlorophyll-*a* (0.54). On the basis of nitrogen-to-phosphorus ratios, phosphorus was the nutrient most likely to limit phytoplankton growth. Despite its oligotrophy, Coeur d'Alene Lake developed a substantial hypolimnetic dissolved-oxygen deficit in both years during the late summer. In the deep, northern half of the lake, hypolimnetic dissolved oxygen was reduced to 6.4 milligrams per liter (58 percent saturation). In the lake's shallow, southern end, anoxic conditions developed in the lower water column. A review of historical studies of the lake revealed that substantial hypolimnetic dissolved-oxygen deficits were measured in 1911 and 1975. Historical loads of nutrients and oxygen-demanding substances were estimated to have been much larger than those measured during this study and, thus, capable of producing the earlier deficits.

The lake's current (1992) oligotrophic classification differs from the mesotrophic classification it received in 1975 during the National Eutrophication Survey. The shift in trophic state is consistent with nutrient load reductions in the lake's 9,690-square-kilometer drainage basin since the early 1970's. During 1991, loads of nitrogen and phosphorus to Coeur d'Alene Lake were about half those in 1975. Most of the nutrient load reduction has occurred in the Coeur d'Alene River drainage basin where phosphorus-export coefficients, in kilograms per square kilometer, have declined from 26 in 1975 to 4.5 in 1991.

Approximately 85 percent of the lakebed's surface area was highly enriched in antimony, arsenic, cadmium, copper, lead, mercury, silver, and zinc. Median concentrations of total cadmium, lead, and zinc in the enriched lakebed sediments were 56, 1,800, and 3,500 milligrams per kilogram, respectively. In contrast, median concentrations of cadmium, lead, and zinc in unenriched lakebed sediments in the lake's southern end were 2.8, 24, and 110 milligrams per kilogram, respectively. Most of the trace elements in the surficial and subsurface sediments were associated with ferric oxides, not sulfides, as previously postulated. Under reducing conditions, such as within an anoxic hypolimnion, the ferric oxides would be

readily soluble and the trace elements would be released into the overlying water column. The trace-element enrichment of the lake was largely restricted to the lakebed sediments; however, the median concentration of total recoverable zinc in the water column was 98.6 micrograms per liter. This concentration exceeded the criterion of 32.4 micrograms per liter for protection of freshwater biota in Coeur d'Alene Lake. Phytoplankton bioassays conducted in chemically defined media showed that dissolved, uncomplexed concentrations of zinc typical for much of Coeur d'Alene Lake were strongly inhibitive to growth of three phytoplankton isolates from the lake.

The combined inflows of the Coeur d'Alene and St. Joe Rivers during 1991–92 provided more than 92 percent of the lake's inflow. Streamflow during 1991 in the two rivers was about 130 percent of the long-term mean, whereas in 1992, it was about 60 percent. The residence time of water in the lake was 0.45 year in 1991 and 0.89 year in 1992. During 1991, the lake received 71 and 81 percent, respectively, of its loads of total phosphorus and nitrogen from the combined inflows of the Coeur d'Alene and St. Joe Rivers. The lake retained most of its phosphorus load but very little of its nitrogen load. The Coeur d'Alene River contributed most of the loads of arsenic, cadmium, lead, and zinc. In 1991, the lake retained 85 percent of the 300,000 kilograms of lead it received and 31 percent of the 929,000 kilograms of zinc it received.

The empirical nutrient load/lake response model was used to determine the effect of increased nutrient loads on the hypolimnetic dissolved-oxygen deficit. Modeling results indicated Coeur d'Alene Lake has a large assimilative capacity for nutrients before anoxic conditions could develop in its hypolimnion. The large assimilative capacity and the shift from mesotrophic to oligotrophic have reduced the potential for development of an anoxic hypolimnion and the consequent release of nutrients and trace elements back into the overlying water column.

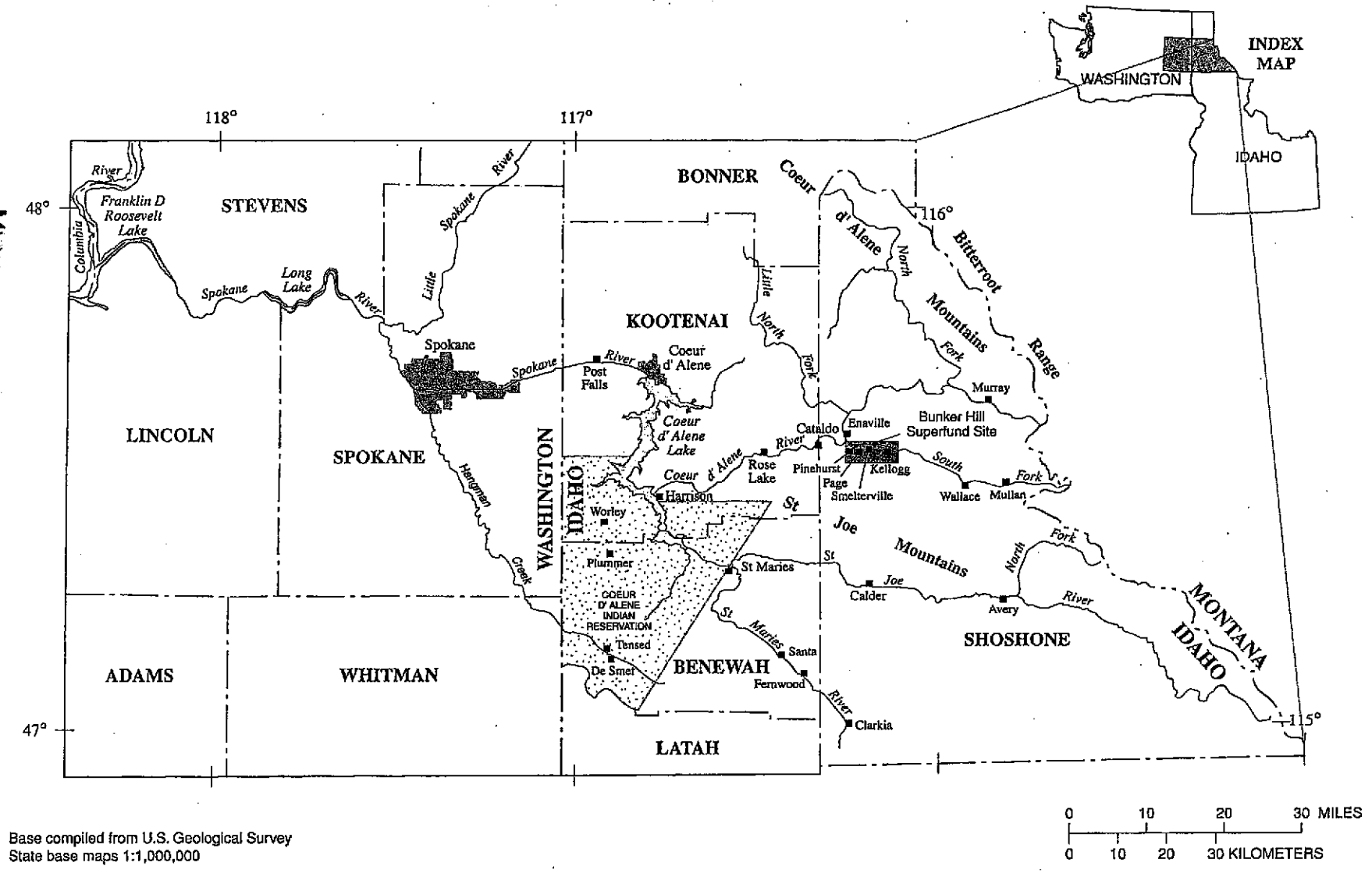
INTRODUCTION

Water-Quality Issues

Coeur d'Alene Lake, Idaho's second largest, is located in northern Idaho within the 17,300-km^2 Spokane River drainage basin (fig. 1). The lake has become a prime recreational site for residents of northern Idaho and eastern Washington because of its beautiful setting and proximity to the cities of Spokane and Coeur d'Alene. Population growth within 80 km of the lake was 24 percent between 1970 and 1980; by 1980, 80 percent of the lake's shoreline had been developed (Milligan and others, 1983). Post-1980 shoreline development includes a $60 million resort complex in the city of Coeur d'Alene that attracts international travelers.

Extensive residential and commercial development of the drainage basin and shoreline, plus intensive recreational use of Coeur d'Alene Lake, has created considerable concern over the potential for nutrient enrichment and subsequent eutrophication of the lake. Although numerous point and nonpoint sources of nutrients exist within the drainage basin, the only nutrient load study of the lake was done in 1975 as part of the National Eutrophication Survey (U.S. Environmental Protection Agency, 1977). As a result of that study, the U.S. Environmental Protection Agency (EPA) classified the lake as mesotrophic, or moderately productive, and recommended that additional studies of the sources and magnitudes of nutrient loads to the lake be done prior to development of management decisions for controlling eutrophication.

Another major water-quality problem for Coeur d'Alene Lake is the massive amount of trace elements that have been introduced into the lake as a consequence of more than 100 years of mining and ore-processing activities in the Coeur d'Alene River drainage basin. Approximately 104 million metric tons of trace-element-enriched tailings have been produced in the drainage basin of the South Fork Coeur d'Alene River; 65.3 million metric tons were discharged directly into the river (Tetra Tech, Inc., and Morrison-Knudsen Engineers, Inc., 1987). Large amounts of trace-element-enriched tailings have been transported downstream and deposited in the lower reaches of the Coeur d'Alene River, as well as in Coeur d'Alene Lake. In the early 1970's, high concentrations of trace elements were measured in lakebed sediments from the northern



Base compiled from U.S. Geological Survey
State base maps 1:1,000,000

Figure 1. Location of study area.

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two-thirds of Coeur d'Alene Lake (Funk and others, 1973, 1975). The EPA obtained nine lakebed sediment cores from Coeur d'Alene Lake in 1986 that contained concentrations of arsenic, cadmium, copper, lead, and zinc far in excess of the upper 95-percent confidence limit for sediments reported nationwide by Lyman and others (1987).

Numerous studies of Coeur d'Alene Lake and River have addressed the environmental effects of long-term mining and ore-processing activities; these studies have been summarized by Wai and others (1985), Savage (1986), and Woodward-Clyde Consultants and Terragraphics (1986). Two significant facts emerge from a review of these studies: (1) Large quantities of trace elements have been deposited in the Coeur d'Alene Lake and River; and (2) trace-element enrichment has been detected in terrestrial and aquatic plants, aquatic invertebrates, fish, and waterfowl. The Coeur d'Alene Indians, whose reservation encompasses the southern part of Coeur d'Alene Lake, are particularly concerned about trace-element enrichment because their diet includes fish, game, plants, and water from Coeur d'Alene Lake and River.

The magnitude of the environmental problems created by these long-term mining activities prompted the EPA to establish, in 1983, the Bunker Hill Superfund site, a 54-km^2 area on the South Fork Coeur d'Alene River (fig. 1). Extensive data have been collected and site remediation is planned for the Superfund site; these activities are described in the Remedial Investigation/Feasibility Study document prepared by Tetra Tech, Inc., and Morrison-Knudsen Engineers, Inc. (1987). Site remediation does not extend beyond the boundaries of the Superfund site, even though prior studies of Coeur d'Alene Lake and River demonstrated that extensive areas upstream and downstream from the Superfund site have been enriched with trace elements.

Eutrophication and deposition of trace elements in Coeur d'Alene Lake may appear to be unrelated water-quality problems; however, large quantities of nutrients and trace elements might be released from lakebed sediments into the overlying water if the lake's hypolimnion becomes anoxic as a result of eutrophication (fig. 2). As anoxic conditions develop in a lake, reductive dissolution of metal oxides, principally iron and manganese, occurs within the lakebed sediments and hypolimnion (Brezonik, 1994). At dissolved-oxygen concentrations less than 1 mg/L, iron oxide-phosphate complexes may become unstable and dissolve, releasing phosphorus from lakebed sediments into the hypolimnion (Jones and Bowser, 1978; Baccini, 1985). In Coeur d'Alene Lake, most of the trace elements such as arsenic, cadmium, copper, lead, and zinc were associated with iron oxides (Horowitz and others, 1993); thus, under anoxic conditions, the reductive dissolution of iron oxides could release trace elements from the lakebed sediments into the hypolimnion. A study of Coeur d'Alene Lake, conducted during 1987 by the U.S. Geological Survey (USGS), showed a substantial dissolved-oxygen deficit; hypolimnetic dissolved-oxygen concentrations as low as 4 mg/L were measured in September (Woods, 1989).

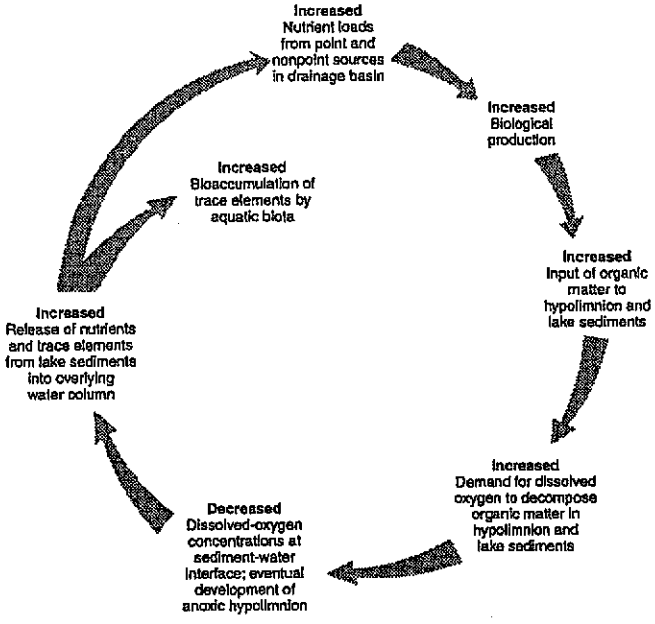


Figure 2. Cyclic relation of the eutrophication process and trace-element enrichment.

The potential release of nutrients and trace elements from lakebed sediments into the water column as a result of eutrophication has several major consequences (fig. 2) for Coeur d'Alene Lake: (1) acceleration of eutrophication as biological production is increased by internally generated nutrients, (2) increased severity of the hypolimnetic dissolved-oxygen deficit as biological production increases, (3) increased environmental availability of trace elements released from lakebed sediments, and (4) increased stress to biota due to the combined effects of enriched trace elements and low dissolved-oxygen concentrations.

Need for Study

The massive amount of trace elements in the lakebed of Coeur d'Alene Lake probably cannot be removed economically. Therefore, an alternative to removal is to keep those trace elements within the lakebed by managing the lake's nutrient income to curtail development of anoxic conditions in the hypolimnion. Lake water-quality models are available for predicting the limnological response of a lake to incremental changes in nutrient loads; however, such models require a data base much more comprehensive than that available for Coeur d'Alene Lake prior to this study.

Idaho's recently enacted Nutrient Management Act mandates that a nutrient management plan be developed for Coeur d'Alene Lake. The Act requires the plan to (1) identify nutrient sources; (2) identify the dynamics of nutrient removal, use, and dispersal; and (3) identify preventive or remedial actions where feasible and necessary to protect surface water. The Idaho Department of Health and Welfare, Division of Environmental Quality (DEQ), has been given responsibility for developing the nutrient management plan for Coeur d'Alene Lake and has requested assistance from the USGS in developing the necessary data base. The Coeur d'Alene Tribe also has requested that the USGS provide information on the status of eutrophication in the southern end of Coeur d'Alene Lake.

Purpose and Scope

The purpose of this cooperative study among the USGS, DEQ, and Coeur d'Alene Tribe was to determine the lake's assimilative capacity for nutrients to assess the potential for development of an anoxic hypolimnion and the consequent release of nutrients and trace elements from the lakebed sediments. Seven major tasks were undertaken: (1) Assess physical, chemical, and biological characteristics in the limnetic and littoral zones of the lake; (2) quantify loads of water, nutrients, and selected trace elements into and out of the lake; (3) develop a nutrient load/lake response model of the lake; (4) using the model, simulate responses of the hypolimnetic dissolved-oxygen deficit to alterations in nutrient loads; (5) analyze lakebed sediments to determine concentration, partitioning, and environmental availability of selected trace elements; (6) characterize land use and land cover throughout the study area by using remote-sensing and geographic information system techniques; and (7) assemble the data base needed for development of a lake management plan.

The 4-year study began in October 1990. The geographic extent of the study was the drainage basin upstream from the USGS streamflow-gaging station on the Spokane River near the Idaho-Washington border (station 12419000).

The DEQ and Coeur d'Alene Tribe intend to use the results of this study in applications to the EPA for grants to implement lake management plan(s) for Coeur d'Alene Lake. The grants are administered under the Clean Lakes Program and consist of Phase I (diagnostic/feasibility) and Phase II (implementation) grants. Applications for Phase II grants require a broad array of limnological and drainage basin data, as well as extensive socioeconomic data (U.S. Environmental Protection Agency, 1980). This report presents most of the information needed for an application for a Phase II grant.

HUMAN EFFECTS ON WATER QUALITY

Early History

By the early 1800's, perhaps 2,000 Native Americans inhabited the Coeur d'Alene Lake watershed (Rabe and Flaherty, 1974). They lived primarily on lakeshores, edges of forests near the marsh areas of the lower Coeur d'Alene and St. Joe Rivers, and the camas grounds around what is now Tensed, Idaho. Fish, game, and edible plants were abundant and easily obtained. The Native Americans were known to have practiced communal hunting drives, occasionally burned areas to improve tribal hunting grounds, built fish weirs, and gathered edible plants from the wetlands.

Among the first settlers to live in the area, Father Nicolas Point noted the abundance of natural resources in the Coeur d'Alene country. Army Capt. John Mullan, while surveying a land route between the Missouri and Columbia Rivers in 1858, described Coeur d'Alene Lake as a "noble sheet of water filled with an abundance of delicious salmon trout" (Rabe and Flaherty, 1974, p. 9). Ruby El Hult, an early settler, recalled the Coeur d'Alene River as "one of the most beautiful streams imaginable ... clear as crystal, deep ... alive with trout and other fish ... they could be seen by the thousands in the clear water" (Rabe and Flaherty, 1974, p. 8). Stands of cottonwood and

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giant cedar, interspersed with fertile grassy meadows, grew along the Coeur d'Alene and St. Joe Rivers. Both drainages also contained some of the largest stands of old-growth white pine on the continent (U.S. Department of Agriculture, 1994a).

Settlement and Development

The original inhabitants were called "Shee-Chu-Umsh" in their native Salish language (Greater Coeur d'Alene Convention and Visitors Bureau, 1993). French-Canadian fur traders in the early 1800's referred to them as having "hearts like the point of an awl," probably in reference to their business manners. Rather than trinkets and beads in exchange for their furs, the Shee-Chu-Umsh demanded practical goods such as iron tools and insisted on conducting trade some distance from their lands and villages (Rabe and Flaherty, 1974). The French name Coeur d'Alene (Coeur - heart; Alene - awl) was applied to the Shee-Chu-Umsh and eventually applied to the area and its features (Greater Coeur d'Alene Convention and Visitors Bureau, 1993).

Early westward exploration and expansion by settlers bypassed the land of the Coeur d'Alene Indians, largely because of its ruggedness and isolation. Lewis and Clark and other early travelers to the Northwest passed to the south, generally following the Snake and Columbia Rivers to the Oregon Territory (Rabe and Flaherty, 1974; Schwantes, 1990). Roman Catholic missionaries were the first nonnatives to live permanently among the Coeur d'Alene Indians. Unlike the earlier fur traders, the Jesuit "Black Robes" were welcomed as a fulfillment of tribal prophesy (Rabe and Flaherty, 1974; Peltier, 1982). Father Nicolas Point founded the Mission of the Sacred Heart among the Coeur d'Alene Indians in late 1842 (Schwantes, 1990). The church, built in 1853 and overlooking the Coeur d'Alene River at Cataldo, is believed to be the oldest standing building in Idaho (Rabe and Flaherty, 1974).

The first serious exploration of the Coeur d'Alene country came with the 1853 search for a railroad route to the Pacific (Schwantes, 1990). Isaac Stevens, first Governor of the Washington Territory, led a reconnaissance party over the Bitterroot Range, down the South Fork Coeur d'Alene River, past the now-thriving Cataldo Mission, and on to Puget Sound (Rabe and Flaherty, 1974; Schwantes, 1990).

Although they were relatively few in number during the early and mid-1800's, settlers quickly brought great changes to the area, such as smallpox and other diseases that decimated the Coeur d'Alene Tribe, reducing them, at one time, to as few as 320 (Rabe and Flaherty, 1974). Their ancestral lands were forcibly opened to settlement (by Governor Stevens and the U.S. Army under Col. George Wright) after a short uprising by regional tribes in 1853 known as the Steptoe War (Peltier, 1982). In 1871, Frederick Post acquired land from Coeur d'Alene Indian Chief Seltice for grist and lumber mills at the falls on the Spokane River to serve growing settlements to the west (Rabe and Flaherty, 1974). In 1873, the Coeur d'Alene Indians were officially restricted to a fraction of their ancestral lands; the reservation did not even include the mission at Cataldo (Coeur d'Alene Tribe, written commun., 1974; Peltier, 1982). In 1877, Gen. William Tecumseh Sherman chose a site for a military outpost that would become the city of Coeur d'Alene (Schwantes, 1990).

Mining

The discovery of precious metals had by far the most profound effect on the Coeur d'Alene country. In the winter of 1883–84, as many as "5,000 men and scores of women stampeded" up the North Fork Coeur d'Alene River in search of gold (Rabe and Flaherty, 1974). In the fall of 1885, Noah Kellogg discovered outcrops of silver ore on the South Fork Coeur d'Alene River. Miners rushed to this new mining district and, by late 1885, all major claims had been staked (Rabe and Flaherty, 1974).

The "boom" was underway in what was to become known as the Fabulous Silver Valley. Steamboats soon plied the waters of Coeur d'Alene Lake and the lower Coeur d'Alene and St. Joe Rivers, transporting passengers and freight (Rabe and Flaherty, 1974). Railroads were built linking the Coeur d'Alene mining district with other population and commerce centers of the rapidly developing West (Schwantes, 1990). Perhaps nowhere in the history of Euro-American settlement of western North America was an area so rapidly and drastically transformed. In an 1888 letter to a friend, General Sherman debated retiring in the vicinity of the fort he founded: "Gold was discovered there, a railroad built, and the beautiful forests are being swept away

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and the virgin lakes and streams robbed of their trout" (Royster, 1991).

By the early 1900's, all major mines in the Silver Valley were producing thousands of tons of silver ore concentrate and, later, lead and zinc. Many more thousands of tons of mine wastes (containing arsenic, cadmium, copper, mercury, zinc, and many other substances) were deposited in or on the banks of the river to be washed downstream toward Coeur d'Alene Lake. Although the hard-rock mining and processing techniques required advanced technologies of the day (as well as a large labor force), little attention was paid to mine waste disposal (Rabe and Flaherty, 1974). The lake's outlet was dammed and its level raised approximately 3.6 m in 1906 to produce hydroelectric power for the booming mines and cities; fertile bottomlands and wetlands were flooded and Benewah, Chatcolet, Hidden, and Round Lakes were created or enlarged near the mouth of the St. Joe River (Rabe and Flaherty, 1974; Coeur d'Alene Tribe, written commun., 1974).

Cities and towns in the Coeur d'Alene mining district and the surrounding area soon resembled those of the industrialized East. The forests around the lake and in the St. Joe and Coeur d'Alene River drainages supplied the growing region with building materials. Farms and ranches in the fertile valleys supplied the growing population with food. The Coeur d'Alene mines soon became the largest producers of silver, lead, and zinc in the Nation. They played a major role in the settlement and economic development of the entire Coeur d'Alene Lake watershed, as well as the Spokane, Wash., area to the west, which served as a major supply point (Schwantes, 1990). As the Silver Valley mines drove the economic, social, and political development of the region, they also profoundly affected its natural environment.

By the early 1900's, the Coeur d'Alene River ran murky with mining wastes and Coeur d'Alene Lake became clouded (Rabe and Flaherty, 1974). The river channel became clogged with sediment. The once-abundant fish disappeared. Riverbank trees and vegetation died. Migratory waterfowl died in the marshes and adjoining lakes. Livestock feeding near the riverbanks sickened and died. Fertile croplands adjacent to the river were contaminated by mine wastes carried by the spring floods (Casner, 1989, 1991). Thousands of acres of forest were killed by toxic smelter fumes (U.S. Department of Agriculture, 1994a).

Bitter social, economic, political, and legal struggles erupted, pitting the mining interests of the Silver Valley against agricultural and other interests downstream. The mining interests generally prevailed (Casner, 1989, 1991). In the early 1930's, the issues entered the political realm when the Idaho Legislature formed a commission to "make a series of investigations of the pollution problems in the Coeur d'Alene District, not only from the standpoint of property damage and alleged injuries to stock and land, but from all angles affecting the State or its assets" (Rabe and Flaherty, 1974).

Dr. M.M. Ellis of the U.S. Bureau of Fisheries conducted the first comprehensive investigations of the Coeur d'Alene Lake and River system in the summer of 1932 (Ellis, 1940). Ellis found "that as far as fisheries are concerned, the mine wastes poured in the South Fork in the Wallace-Kellogg area have reduced the 50 miles [80 km] of the South Fork and Main Coeur d'Alene River from above Wallace to the mouth of the river at Harrison, to a barren stream practically without fish fauna, fish food, or plankton, and with enormous lateral supplies of potentially toxic materials which as they now stand will continue to poison the waters of the Coeur d'Alene River for a considerable period of time."

Other sources of contamination such as raw sewage from the mining settlements and from extensive timber harvest and other land disturbances, as well as human-caused and natural wildfires, undoubtedly contributed significantly to environmental degradation during this period. However, Ellis (1940) concluded, "There is only one complete solution to this [water pollution] problem and that is the exclusion of all mine wastes from the Coeur d'Alene River."

Ellis also investigated a similar mining operation near Kimberly, British Columbia, which employed a system of settling ponds. He found that the water was "so reduced in volume and so purified that within a few yards of the mouth of the outlet ditch ... plankton, algae, aquatic insects and fish were found ..." (Ellis, 1940). He recommended that a similar system be employed in the Coeur d'Alene district. However, such treatment facilities were not installed by the Silver Valley mines until 1968 after much pressure from Federal and State authorities (Rabe and Flaherty, 1974).

Logging

Logging also became a major industry in the region. Initially, timber was harvested near the mines

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and towns or from the lakeshore and riverbanks for easy water transport. As the easily accessible timber was cut, logging crews pushed farther up the Coeur d'Alene and St. Joe River drainages.

Early logging operations often employed extremely damaging methods; frequently, every tree in an entire drainage was cut. Uncontrolled slash burning often resulted in destruction of even more forest. Stream channels were straightened or converted to wooden chutes or flumes down which logs were floated. These flumes often led to temporary lakes formed by earth and log "splash dams." The dams were then periodically opened or blown up, releasing a torrent that carried not only the cut logs, but also sediment and logging slash, downstream. The process sometimes was repeated several times (with devastating results to the stream channel) until the logs reached a sawmill, railhead, or steamship landing. Narrow-gage railroads were built to haul logs, usually at the bottoms of fragile drainages, resulting in further erosion and channel destabilization (Rabe and Flaherty, 1974).

Logging practices common to the late 1800's and early 1900's often resulted in depleted forests, massive soil erosion, and severely destabilized streambanks and channels. Combined with man-caused and natural wildfires and floods, many drainages have yet to recover fully. An example is the Little North Fork Coeur d'Alene River, where flumes were built in almost all side streams and the main channel was repeatedly dammed; splash dams also flushed logs out of Shoshone Creek on the North Fork Coeur d'Alene River (Rabe and Flaherty, 1974). This type of logging peaked in the late 1920's (U.S. Department of Agriculture, 1994a). Similar practices were employed throughout the St. Joe River drainage with similar effects.

Modern logging practices, utilizing extensive road systems and clearcutting, began in the late 1930's and reached peak application in the 1970's. Roads often were built along fragile stream channels and (or) on steep, erodible hillsides (Rabe and Flaherty, 1974). Extensive clearcutting changed the timing and amount of water flowing from heavily logged drainages, further damaging stream and river channels and altering flood patterns (Rabe and Flaherty, 1974).

Agriculture

Agriculture has played a significant role in altering water quality, aquatic ecosystems, and hydrologic conditions in the Coeur d'Alene Lake basin. Extensive dryland agriculture began in the Palouse country to the south around the beginning of the 20th century. Forested areas near the lake were cleared and converted to cropland. Erosion rates from these soils can be among the highest in the Nation, especially if the practice of summer fallowing is employed (Rabe and Flaherty, 1974). Much of the sediment entering the southern end of Coeur d'Alene Lake and the bays on the western lakeshore comes from surrounding farms (Rabe and Flaherty, 1974). Livestock grazing also has contributed to disturbance of tributary riparian areas, resulting in further nutrient and sediment transport.

Human and Animal Waste

Population in the Coeur d'Alene River Basin was probably about 5,000 in the late 1800's (Rabe and Flaherty, 1974; U.S. Department of Agriculture, 1994a). However, because of the transient nature of the logging and mining "boomtowns," the population at times may have been much larger. Old photographs show numerous outhouses and latrines built directly over watercourses. Early sewer systems serving the growing towns and industrial sites also discharged waste directly without treatment (Cornell, Howland, Hayes, and Merryfield, Engineers and Planners, 1964). Wastes from the horses and mules used for transportation at the time undoubtedly entered rivers and streams as well. The Coeur d'Alene River (especially the narrow canyons of the South Fork drainage that confined the Silver Valley mining district) probably carried a substantial load of industrial, human, and animal waste and wastewater, significantly affecting lake and river water quality in the early 1900's.

Wildfires and Floods

Man-caused and natural wildfires burned large parts of the Coeur d'Alene Lake basin on several occasions. The effects of these fires, combined with floods and other land disturbances, contributed significantly to sediment and nutrient loads entering the lake.

Early miners sometimes set fires to expose mineral-bearing rock formations. By the late 1800's, much of the timber along the South Fork Coeur d'Alene River had been burned. Thousands of acres of forest in the upper North Fork basin burned when slash fires from railroad construction spread from the Clark Fork

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River Valley (U.S. Department of Agriculture, 1994a). Construction of railroads across the Bitterroot Mountains and down the St. Joe River caused similar disturbances. Massive fires in 1910, 1919, 1926, and 1931 burned much of the northern part of the basin, along the Bitterroot divide, the upper St. Joe River drainage, and the divide between the South Fork Coeur d'Alene and St. Joe Rivers.

Flooding has occurred frequently in the basin. Major destructive floods were recorded in 1933, 1948, 1956, 1964, and 1974; less severe floods were recorded in 1893, 1904, 1909, 1910, 1913, 1917, 1925, and 1963 (U.S. Department of Agriculture, 1994a).

SOCIOECONOMIC CONDITIONS

Socioeconomic Transition

Until quite recently, the Coeur d'Alene region's economy depended on its abundant natural resources. However, in the early 1980's, the mining industry all but collapsed; the Silver Valley mines were no longer competitive in an increasingly global market due to falling prices of metals and rising costs of production. Trouble in the timber industry soon followed; a national economic slowdown, environmental concerns, dwindling timber supply, and outdated equipment led to the closure of several large mills in the late 1980's (Panhandle Area Council, 1993).

Tourism became a growing component of the region's economy in the 1950's as the scenic beauty, high-quality water resources, and abundant outdoor recreation opportunities drew increasing numbers of visitors (Kootenai County Planning Commission, 1993). As the natural resource industrial base declined, tourism, recreation, and associated services became the region's new growth industries. Tourism could be the region's largest industry by the year 2000 (Panhandle Area Council, 1993).

The population dynamics of north Idaho during 1970 to 1980 were evaluated (Panhandle Area Council, 1993). During that period, north Idaho's population grew 54 percent (82,300 to 126,600); the largest increase was during the 1970's. Bonner and Kootenai Counties gained the most population, whereas Shoshone County lost population, particularly during the 1980's. Projections call for as much as 10-percent growth during the 1990's (Panhandle Area Council, 1993).

Benewah County

Benewah County is the smallest in both area and population of the three counties that compose the Coeur d'Alene Lake basin (table 1). It was part of Kootenai County until 1915. Population increased 27.4 percent from 1970 to 1990 but declined 4.3 percent during the 1980's, possibly as a result of declines in the timber industry (Panhandle Area Council, 1993).

Benewah County contains much of the productive agricultural land in the watershed. Forested areas in the lower St. Joe and St. Maries River Basins support extensive timber harvest and large forest-products processing mills. St. Maries serves as the county seat and as a major transshipment point for logs, many of which are towed down the St. Joe River and onto Coeur d'Alene Lake to mills in Coeur d'Alene. Benewah County contains one of the largest sources of placer-mined industrial and gem-grade garnets in the United States. The county also is becoming a major producer of wild rice grown in wetlands and flooded fields along the lower St. Joe and St. Maries Rivers.

Benewah County contains Heyburn State Park, one of the largest and most heavily used in the State. The county also serves as a gateway for travelers to the St. Joe River and surrounding public lands. However, the recreation/tourism potential of the county remains largely undeveloped (Harris and others, 1989).

Table 1. Population of Benewah, Kootenai, and Shoshone Counties, 1890–1990

Population assessment year	Benewah County	Kootenai County	Shoshone County
1890	(1)	4,108	5,382
1900	(1)	10,216	11,950
1910	(1)	22,247	13,936
1920	6,977	17,878	14,250
1930	6,371	19,469	19,060
1940	7,332	22,283	21,230
1950	6,173	24,947	22,806
1960	6,036	29,556	20,876
1970	6,230	35,332	19,718
1980	8,292	59,770	19,226
1990	7,937	69,795	13,931

[1] Benewah County was combined with Kootenai County until 1915.

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Kootenai County

About 76 percent of the population of the Coeur d'Alene watershed resides in Kootenai County, primarily in the cities of Coeur d'Alene and Post Falls and their immediate vicinities. Kootenai County contains large parts of the forested and agricultural lands in the watershed. The county contains a significant part of the watershed's wetlands, especially at the heads of lake bays, along the Coeur d'Alene River, and around the 10 shallow lakes adjacent to the river's lower reach.

The county's population increased by 136 percent over the last 30 years to 69,795 in 1990. The increase was greatest (69 percent) during the 1970's (table 1). Some current forecasts predict as much as a 20-percent growth in Kootenai County during the 1990's (Kootenai County Planning Commission, 1993; Panhandle Area Council, 1993). Considering tourists in hotels/motels and part-time residents of second homes, the population of Kootenai County may exceed 100,000 in the summer (Kootenai County Planning Commission, 1993).

Much of the direct recreational use of Coeur d'Alene Lake and associated tourist-related business is in Kootenai County. In 1993, total hotel/motel and lodging sales in Kootenai County amounted to more than $27 million, based on stated travel and convention room tax receipts. This figure represents at least a four-fold increase over the last decade (Idaho Department of Commerce, 1992; Idaho Department of Employment, 1993).

The county also contains most of the lakeshore homesites, which are increasingly becoming year-round residences. The total 1991 market value of all property in Kootenai County was estimated to be more than $2.3 billion (Idaho Department of Commerce, 1992), and property on or immediately nearby Coeur d'Alene Lake accounted for more than half that figure (Kootenai County Assessor, written commun., 1993).

Shoshone County

Shoshone County is the largest of the three counties that compose the Coeur d'Alene Lake basin. It contains both rural and mountainous areas, the headwater areas of the Coeur d'Alene and St. Joe Rivers, and the Coeur d'Alene mining district (the Silver Valley). The county's population (about 15.2 percent of the watershed's total) has declined by about 29 percent from 1970 to 1990 (table 1). Shoshone County supports significant timber harvest and some mining activities.

Although Shoshone County's economy has not fully recovered from the collapse of the Silver Valley mining industry, diversification efforts are underway (Panhandle Area Council, 1993). The city of Kellogg is developing a major mountain resort served by the world's longest gondola, which draws increasing numbers of skiers in the winter and sightseers and mountain bikers in the summer. An analytical laboratory, once serving the mining industry almost exclusively, is expanding into the environmental analytical services field. The entire town of Wallace, the county seat, is listed on the National Register of Historic Places, largely because of its unique period architecture and colorful mining past. The town also draws visitors because of its location as a gateway to national forest and other public lands.

Hotel/motel and lodging sales in Shoshone County amounted to $1.8 million in 1991, or about three times those of 1983 (Idaho Department of Commerce, 1992). This trend is expected to continue as plans to develop tourism based on the Silver Valley's mining history and even its environmental damage and cleanup efforts are pursued (Hudson, Jelaco, Welch, and Comer, 1993). Environmental cleanup and mine restoration technology and services also may emerge as viable industries in the future.

The forests of the Coeur d'Alene and St. Joe River drainages are home to large big-game herds, attracting hunters from the region and throughout the Nation. The upper St. Joe River drainage, parts of which are designated as a Wild and Scenic River, contains challenging whitewater runs, a nationally famous wild trout fishery, and some of the most rugged and scenic wildlands in the continental United States. Consequently, outdoor recreation contributes significantly to the county's economy.

Coeur d'Alene Tribe

The 1,400-km^2 Coeur d'Alene Indian Reservation encompasses parts of Benewah and Kootenai Counties. Of the 3,600 km^2 originally included in the reservation at the time of its establishment in 1891, approximately 235 km^2 remains in Indian ownership. The traditional homeland of the Tribe was originally about 16,200 km^2.

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The communities within the reservation boundary include St. Maries, Plummer, Worley, Tensed, and DeSmet. Tribal headquarters are in Plummer. Of about 6,000 residents on the reservation, about 750 are members of the Coeur d'Alene Tribe. Another 550 tribal members reside outside the reservation. The Tribe operates farming, logging, construction, and retail businesses, a school system, and a health-care facility (Coeur d'Alene Tribe, written commun., 1974). Recently, the Tribe opened a bingo hall and is exploring other tourism, recreation, and service enterprises.

About 800 km^2 of the reservation drain into Coeur d'Alene Lake and about a third of the lake lies within the reservation. West and southwest of the lake, the reservation's land use is dominated by agriculture on fertile but highly erodible soils. Land use on the east side of the reservation is devoted largely to timber production.

Lake Uses

Coeur d'Alene Lake is heavily used for recreational boating and fishing. Although Kootenai County contains only 6.9 percent of Idaho's boatable water, 18.5 percent of the State's boats are registered in the county. Boat registration increased by almost 62 percent in the last 5 years, from 12,800 in 1988 to 20,800 in 1992 (Bureau of Land Management, 1993). A large number of Coeur d'Alene Lake boaters are from outside the State. Of the 10,000 out-of-State boats registered in Idaho, a little more than half of the owners declare Benewah and Kootenai Counties as their primary area of use; out-of-State boaters account for about one-fourth of the boats registered in Kootenai County (Idaho Department of Parks, written commun., 1993).

Coeur d'Alene Lake is probably the region's major attraction as a recreation and tourist area. A large lakeshore resort in Coeur d'Alene continues to expand, especially after the addition of a golf course on the site of a former sawmill on the city's eastern edge. Many public and private recreation areas are located on the lake (table 2). A recent Bureau of Land Management recreation management plan describes in greater detail the characteristics and services offered at each site (Bureau of Land Management, 1993). Other large-scale resort/recreation and lodging facilities are planned or are under development.

Table 2. Public and private recreation facilities at Coeur d'Alene Lake

[D, docks; T, toilets; DW, drinking water; BR, boat ramp; C, camping; RS, rental boat slips; data from Bureau of Land Management, 1993]

Facility name	Services available
Public	
North Idaho College beach	D, T, DW
Third Street beach	BR, D, T, DW
Boothes Park	BR, D, T
I–90 boat launch	BR, D
Higgins Point	D
Wolf Lodge Bay	BR, D, T
Squaw Bay	BR, D, T
Turner Point	D, T
Turner Bay	D, T
Carlin Bay	BR, D
Bell Bay	D, T, DW, C
Harlow Point	D
Mowry State Park	D, T, C
Windy Bay	D, T, C
Sun Up Bay	BR, D, T
Rockford Bay	BR, D, T
Loffs Bay	BR, D, T
Mica Bay boat park	D, T, C
Mica Bay	BR, D, T
Goulds Landing	BR, D, T
Rocky Point Marina	D, T, DW, BR, RS
Chatcolet, day use	D, T, BR
Plummer Point	D, T, DW
Hawleys Landing	D, T, DW, C
Private	
Boardwalk Marina	D, RS
Yacht Club Sales	BR, T, DW, RS
Northwest Resort	BR, T, DW, RS
Silver Beach Resort	D, RS
Delevans Marine	RS
Wolf Lodge campground	T, DW, C
Coeur d'Alene Lake Resort	D, T, DW, C
Beauty Bay Resort	D, RS
Squaw Bay Resort	BR, D, T, DW, C, RS
Panhandle Yacht Club	RS
Arrow Point RV Park	T
Arrow Point Resort	D, T, DW
Carlin Bay Resort	D, T, DW, C
Conklin Park Marina	D, T, DW, BR, RS

The cities of Coeur d'Alene, Harrison, Post Falls, and St. Maries operate popular parks offering picnic and (or) camping facilities and water access for boating and (or) swimming. Public beach and picnic areas also are provided along the shoreline property of North Idaho College at the lake's outlet. Many other public outdoor recreation sites are located on the lower Coeur d'Alene River and its lateral lakes, the lower St. Joe River, and throughout the watershed. The historic

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Cataldo Mission along the Coeur d'Alene River also attracts many visitors.

Within an 80-km radius of the city of Coeur d'Alene are numerous lakes that offer recreation opportunities similar to those at Coeur d'Alene Lake (table 3). By far the largest is Lake Pend Oreille, the southern end of which is within the 80-km radius. Most of these lakes are accessible by car; only a few of the lateral lakes adjacent to the Coeur d'Alene River are not.

In 1991, the Idaho Department of Fish and Game conservatively estimated the gross economic value of the Coeur d'Alene Lake fishery to be $6 million. The kokanee fishery contributed almost half, and chinook salmon and spiny rays (which included the "trophy" pike fishery) contributed approximately $225,000 and $330,000, respectively (Coeur d'Alene Tribe, written commun., 1994).

The Coeur d'Alene area's extensive and varied aquatic and terrestrial habitats offer excellent wildlife-viewing and birdwatching opportunities. Migrating bald eagles feed on spawning kokanee salmon during winter months and can be seen easily from vehicles on main roads. Birdwatching is popular in or near the area's extensive wetlands.

Coeur d'Alene Lake is a source of water for agricultural, domestic, and industrial use. At least six public water-supply systems use the lake water; however, the city of Coeur d'Alene recently changed to a ground-water supply. The Idaho Department of Water Resources has recorded 220 water rights filed to withdraw water from Coeur d'Alene Lake (Idaho Department of Water Resources, written commun., 1993). Although environmental and public health agencies advise against using surface water for domestic purposes without extensive treatment, many of these permitted withdrawals serve as drinking-water sources. There are many more unpermitted withdrawals, some of which probably are also used for domestic purposes (Ken Lustig, Panhandle Health District, oral commun., 1993).

Current trends of population growth and transit in an economy based on tourism and associated services (with a significant small manufacturing component) are expected to continue through the 1990's (Kootenai County Planning Commission, 1993; Panhandle Area Council, 1993). The demand for high-quality water also can be expected to increase. Therefore, protection and responsible management of water quality are important economic and environmental issues.

Table 3. Lakes within an 80-kilometer radius of the city of Coeur d'Alene

[km^2, square kilometer; —, no data available]

Lake name	Surface area (km^2)	Lake name	Surface area (km^2)
Idaho lakes		**Idaho lakes—Continued**	
Anderson[1]	1.2	Pend Oreille	330
Black[1]	1.4	Porter	.1
Blue[1]	.8	Rose[1]	1.4
Bull Run[1]	.3	Round	.2
Cave[1]	2.4	Spirit	5.2
Chilco	—	Swan[1]	1.5
Fernan	1.4	Thompson[1]	.8
Granite	.1	Twin	7.8
Hauser	2.4	**Washington lakes**	
Hayden	17		
Kelso	.2	Liberty	2.8
Killarney[1]	1.9	Long Lake	21
Medicine[1]	.7	Newman	4.9

[1]Lateral lakes adjacent to Coeur d'Alene River.

DESCRIPTION OF STUDY AREA

Physical Attributes

The 10,310-km^2 study area is located within Benewah, Kootenai, and Shoshone Counties in northern Idaho and Spokane County in eastern Washington (fig. 1). The Bitterroot Range composes most of the study area and is characterized by high, massive mountains mantled with coniferous forests and deep, intermontane valleys. Elevations range from approximately 610 m above sea level at the Idaho-Washington border to 2,086 m at the Idaho-Montana border. Coeur d'Alene Lake has a surface elevation of 648.7 m at full pool. The lake's two principal tributaries are the Coeur d'Alene and St. Joe Rivers, which drain the Coeur d'Alene and St. Joe Mountains, subsets of the Bitterroot Range. The lake is drained by the Spokane River, a tributary to the Columbia River.

The Coeur d'Alene and St. Joe Mountains are primarily metasedimentary rocks of the Proterozoic Belt Supergroup that have been intruded locally by granitic rocks of Cretaceous age. The lower elevations west of the Coeur d'Alene and St. Joe Mountains are underlain by glaciofluvial deposits and remnants of multiple

basaltic lava flows. An important feature in the northwestern part of the study area is the Rathdrum Prairie, a 1,060-km^2 valley-fill aquifer created during the Pleistocene by repeated outburst floods from glacial Lake Missoula.

A generalized description of the major soil types in the study area was derived from the U.S. Department of Agriculture (1984). Most of the mountainous area east of Coeur d'Alene Lake contains soils formed in volcanic ash and loess over metasedimentary rocks. The mountainous area west of the lake contains soil formed in volcanic ash and loess over granite, gneiss, and schist. Much of the hilly margin of the lake contains two major soil types. The first type is soils on undulating to steep hills, formed in deep loess with some volcanic ash influence. The second type is soils on mountainous slopes and canyon walls associated with hills and plateaus, formed mainly in basalt with a thin loess cover. In the Rathdrum Prairie, soils on glaciated mountainsides, glacial moraines, and associated terraces have formed in volcanic ash overlying glacial drift and in sandy, glacial, lacustrine sediments. The lower valleys of the St. Joe and Coeur d'Alene Rivers contain soils on flood plains and low terraces, formed in silty alluvium.

The study area receives some of the largest amounts of precipitation in Idaho. About 70 percent of the annual precipitation occurs as snow during October to April. The areal distribution of precipitation is influenced by the basin's topography. For example, the climatological station at Coeur d'Alene (elevation 658 m) records a mean annual precipitation of 644 mm, whereas the station at Wallace (elevation 896 m) records 971 mm. Ambient temperature varies throughout the study area, depending on elevation; at Coeur d'Alene, the mean annual temperature is 9.1°C, whereas it is 6.8°C at Wallace. Although winter temperatures at Coeur d'Alene Lake are often below freezing, the lake normally does not freeze except in its shallow southern end.

Coeur d'Alene Lake lies in a naturally dammed river valley, covers 129 km^2, and has a volume of 2.84 km^3. The southern end of the lake contains four shallow lakes, Benewah, Chatcolet, Hidden, and Round, that were flooded in 1906 by impoundment of the Spokane River by Post Falls Dam at Post Falls. The four shallow lakes are contiguous with Coeur d'Alene Lake. The lake's outflow volume is controlled by Post Falls Dam, which provides hydroelectric power, flood control, and irrigation supply. At its outlet, the mouth of the Spokane River, the lake receives surface-water inflow from a 9,690-km^2 drainage area. About 90 percent of the surface-water inflow to the lake is delivered by two rivers, the Coeur d'Alene and the St. Joe.

The Coeur d'Alene River (drainage area, 3,812 km^2) discharges into the lake near Harrison (fig. 1). The river has three major reaches, the North Fork, the South Fork, and the reach downstream from the confluence of the North and South Forks. Land-use activities in the Coeur d'Alene River Basin include recreation, logging, agriculture, and mining and ore processing. Most of the mining and ore-processing activities are in the basin of the South Fork, which contains the Bunker Hill Superfund site.

The St. Joe River (drainage area, 4,520 km^2) discharges into the southern end of the lake (fig. 1). The St. Joe River is joined by the St. Maries River at the town of St. Maries. Recreation and logging are the dominant land uses; little mining activity has occurred in the St. Joe River Basin.

Biological Attributes

Historically, the native fish species abundant in Coeur d'Alene Lake and its tributaries included westslope cutthroat trout, bull trout, mountain whitefish, peamouth, northern squawfish, suckers, and sculpins (Coeur d'Alene Tribe, written commun., 1994). Despite unsubstantiated reports to the contrary, anadromous fish probably did not enter Coeur d'Alene Lake (Coeur d'Alene Tribe, written commun., 1994). Nevertheless, native species provided an abundant subsistence fishery for the area's indigenous people (Rabe and Flaherty, 1974; Peltier, 1982).

In 1937, kokanee salmon were introduced, beginning the lake's transformation into a sportfishery dominated by introduced species. Other introduced species now include chinook salmon, rainbow trout, brook trout, northern pike, tiger muskie, yellow perch, tench, black bullhead, pumpkinseed, largemouth bass, smallmouth bass, and black crappie (Coeur d'Alene Tribe, written commun., 1994).

The extensive forests of the watershed support deer, elk, moose, black bears, coyotes, bobcats, cougars, porcupines, squirrels, martens, badgers, wolverines, beavers, mice, and other small rodents; several species of songbirds, forest grouse, owls, hawks, and other raptors; and many species of amphibians, reptiles, insects, and other invertebrates. The mainly

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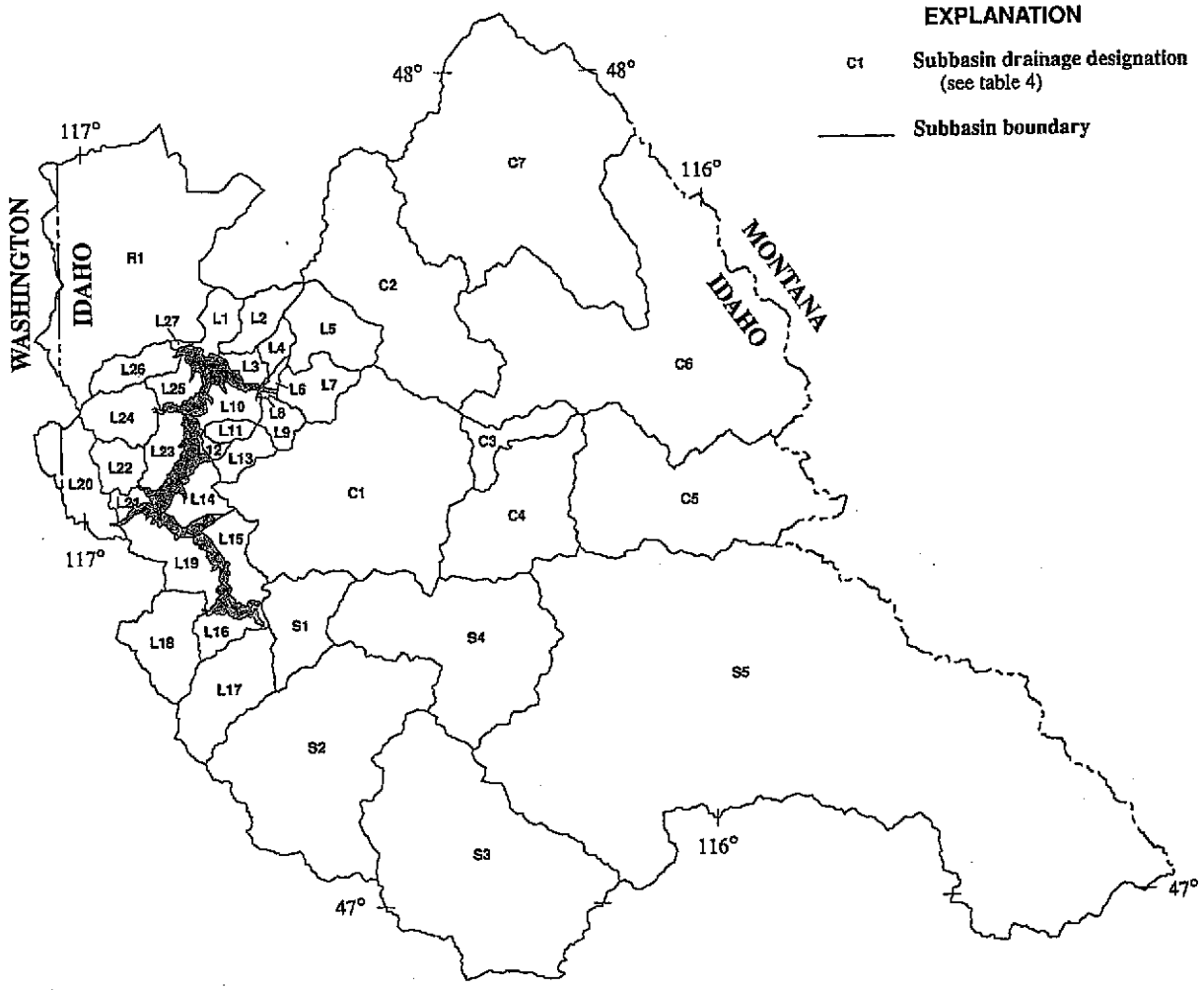


Figure 3. Locations of 40 subbasins within study area

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coniferous forests are composed of fir, pine, hemlock, cedar, and larch. Deciduous trees such as cottonwood and willow grow along lakeshores and streambanks or are interspersed among the conifers, as are isolated stands of aspen and birch. Many species of grasses, mosses, fungi, and deciduous shrubs blanket the forest floor or grow in open areas.

The region's numerous wetlands and nearshore areas also support an abundance of plant, animal, and bird life. Waterfowl are abundant year around, and large numbers pass through the area seasonally during migration. Many species of songbirds, waterbirds, and raptors are plentiful. These areas also support otters, beavers, muskrats, weasels, and other furbearers, as well as numerous species of rodents, amphibians, and reptiles.

CLASSIFICATION OF LAND USE AND LAND COVER

Land use and land cover in the study area were classified using remote-sensing and geographic information system technology. The classification was performed by the Idaho Department of Water Resources under contract with the USGS; their report (Idaho Department of Water Resources, 1993) describes the methods and results and, therefore, will only be summarized here.

Two Landsat scenes were classified; they represented the most current summer scenes with less than 10-percent cloud cover. Scene 42/27 was a full scene acquired on July 21, 1989. Scene 43/27 was a subscene acquired on July 27, 1989. The scenes were geocoded to a UTM projection and mosaicked to produce a single scene. The total root mean square error of the final scene was 16.5 m. An unsupervised classification approach was selected because of the complexity of the study area. Image processing and image interpretation procedures were used to produce the following list of 15 land use and land cover classes:

- dense urban or built-up land
- sparse urban or built-up land
- water
- wetlands
- rangeland
- deciduous forest
- clouds and cloud shadows
- recent clearcuts
- recovering clearcuts
- irrigated agriculture and pasture
- dryland agriculture and pasture
- barren land
- mined land
- coniferous forest
- sparse forest

An accuracy assessment was conducted to determine individual class accuracies and overall accuracy. The overall accuracy for the classifications was 96 percent.

The study area was divided into 40 subbasins (fig. 3 and table 4) to provide detailed information on land use and land cover. Twenty-seven of the subbasins are of small to moderate size and are contiguous to Coeur d'Alene Lake. The Coeur d'Alene River Basin was divided into seven subbasins, whereas the St. Joe River Basin was divided into five subbasins. The remaining subbasin represented the area between the lake outlet and the USGS gaging station near the Idaho-Washington border. The detailed breakdown of land use and land cover for the 40 subbasins is listed in the report by the Idaho Department of Water Resources (1993).

The land use and land cover within the study area (table 5) are dominated by coniferous forest (51.6 percent) and sparse forest (23 percent). The two agriculture classes together represent 5.4 percent of the land use and land cover; recent and recovering clearcuts together represent 6 percent. Mined land represents the smallest amount of land use and land cover, 0.05 percent. Wetlands represent only 0.23 percent of the land use and land cover, but they are significant resources. Within the border of Coeur d'Alene Lake are 11 priority wetland areas (Idaho Department of Parks and Recreation, 1993). Priority wetlands are those that (1) provide a high degree of public benefits, (2) are representative of rare or declining wetland types within an ecoregion, and (3) are subject to an identified threat of loss or degradation.

LIMNOLOGY

Limnological characteristics of Coeur d'Alene Lake were studied to (1) assess spatial and temporal trends in physical, chemical, and biological conditions; (2) characterize the lake's trophic state; and (3) provide limnological data for a nutrient load/lake response model. Numerous limnological variables were monitored to gain an understanding of lake-mixing processes, water-column transparency, nutrient dynamics, dissolved-oxygen deficits, and overall water-quality conditions. The monitoring results also were used to determine whether observed water-quality conditions differed from those reported in earlier studies of Coeur d'Alene Lake.

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Table 4. Subbasins and associated drainage areas in the study area

[km², square kilometer; L, Lake; C, Coeur d'Alene River; S, St. Joe River; R, Spokane River; USGS, U.S. Geological Survey]

Subbasin No. (fig. 3)	Subbasin name	Drainage area (km²)	Subbasin No. (fig. 3)	Subbasin name	Drainage area (km²)
L1	City of Coeur d'Alene	37.1	L27	Cougar Bay, nearshore, northwest	2
L2	Fernan Creek	49.5	C1	Coeur d'Alene River, Harrison to Cataldo gaging stations	652
L3	Bennett Bay, nearshore	18.9	C2	Coeur d'Alene River, Little North Fork	445
L4	Blue Creek	20.5	C3	Coeur d'Alene River, Enaville gaging station	67.
L5	Wolf Lodge Creek	104	C4	Coeur d'Alene River, South Fork, Pinehurst to Elizabeth Park gaging stations	270
L6	Wolf Lodge Bay, nearshore, northeast	5.4	C5	Coeur d'Alene River, South Fork, Elizabeth Park gaging station	482
L7	Cedar Creek	62.5	C6	Coeur d'Alene River, North Fork, Enaville to Prichard gaging stations	1,020
L8	Wolf Lodge Bay, nearshore, southeast	1.7	C7	Coeur d'Alene River, North Fork, upstream from Prichard gaging station	876
L9	Beauty Creek	28.9	S1	St. Joe River, lake to St. Maries gaging station	117
L10	Squaw Bay to Echo Bay, nearshore	34.2	S2	St. Maries River, St. Maries to Santa gaging station	565
L11	Turner Creek	16.5	S3	St. Maries River, upstream from Santa gaging station	713
L12	Carlin Bay, nearshore	7.2	S4	St. Joe River, St. Maries to Calder gaging stations	438
L13	Carlin Creek	31.7	S5	St. Joe River, upstream from Calder gaging station	2,687
L14	Powderhorn Bay, nearshore	44.3	R1	Spokane River, lake outlet to USGS gaging station near State line	624
L15	Harrison to St. Maries, nearshore	54.9			
L16	Chatcolet Lake, nearshore, south	34.3			
L17	Benewah Creek	138			
L18	Plummer Creek	114			
L19	Windy Bay to Chatcolet Lake, nearshore	79.9			
L20	Lake Creek	99.5			
L21	Windy Bay, nearshore, north	14.1			
L22	Fighting Creek	41.6			
L23	Rockford Bay to Mica Bay, nearshore	41.9			
L24	Mica Creek	67.7			
L25	Mica Bay to Cougar Bay, nearshore	29.6			
L26	Cougar Creek	48.5			

Table 5. Land use and land cover in the study area

[km², square kilometers]

Land use and land cover classification	Area (km²)	Percent of total
Coniferous forest	5,260	51.6
Sparse forest	2,350	23.0
Rangeland	688	6.8
Clouds	402	3.9
Recovering clearcut forest	385	3.8
Dryland agriculture and pasture	357	3.5
Recent clearcut forest	227	2.2
Irrigated agriculture and pasture	196	1.9
Water	166	1.6
Dense urban or built-up land	48.9	.48
Cloud shadows	34.6	.34
Sparse urban or built-up land	29.1	.29
Wetland	23.9	.23
Barren land	15.2	.15
Deciduous forest	7	.07
Mined land	4.1	.05
TOTAL (rounded)	10,200	100

Data Collection and Analysis

BATHYMETRY

The bathymetry of the lake was mapped to allow computation of volume, surface area, and a hypsometric curve, three variables required in the nutrient load/lake response model. A calibrated video depth sounder and a global positioning system receiver were used to determine depths at 580 locations throughout the lake. The depths were digitized onto a digital base map; depth contours were drawn manually and digitized to determine the surface area of each depth plane. The volume of the lake was computed with the following equation from Håkanson (1981):

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$$V_p = \sum_{i=0}^{n} \frac{l_c}{3} \left(a_i + a_{i+1} + \sqrt{a_i + a_{i+1}} \right), \qquad (1)$$

where

V_p is the parabolic approximation of the lake volume, in cubic kilometers;

l_c is the contour line interval, in meters; and

a_i is the total surface area within the limits of the contour line l, in square kilometers.

LIMNETIC ZONE

Monitoring of the limnetic zone (open waters, away from shore) began in mid-January 1991 and ended in mid-December 1992. Seven stations were monitored in 1991 and six in 1992 (fig. 4). Each station's latitude, longitude, depth, and official USGS name are listed in table 6. Station selection was based largely upon the results of reconnaissance sampling conducted by the USGS from May through November 1987 (Woods, 1989). Each of the seven limnetic stations represented an important limnological zone. Station 1, south-southeast of Tubbs Hill, monitored the large, deep mass of water in the lake's northern arm. Station 2, in Wolf Lodge Bay, was selected because it was hydrologically isolated from the major northward flow in the lake. Station 3, near Driftwood Point, was in the lake's deepest region. Station 4, near University Point, monitored the water quality of the combined flows of the Coeur d'Alene and St. Joe Rivers after they mixed with lake water. Station 5, near Blue Point, monitored the relatively shallow southern part of the lake that is minimally influenced by the Coeur d'Alene River. Station 6, in Chatcolet Lake, monitored the shallow, macrophyte-dominated southernmost part of the lake. Station 7, near Donavons Point, was selected for special monitoring of near-bottom water quality in log-storage areas within Cougar Bay. This station was discontinued in 1992. Data from several of the stations have been collected by other investigators and can be used for comparative purposes.

Table 6. Locations, depths, and names of limnetic stations in Coeur d'Alene Lake

[m, meters; SE, southeast; SW, southwest; NE, northeast; NW, northwest; mi, miles. To convert miles to kilometers, multiply miles by 1.609]

Limnetic station (fig. 4)	Latitude, longitude	Depth[1] (m)	U.S. Geological Survey name
1	47°39'00", 116°45'30"	42.5	Coeur d'Alene Lake, 1.3 mi SE of Tubbs Hill, near Coeur d'Alene
2	47°37'30", 116°41'00"	29.5	Coeur d'Alene Lake, at Wolf Lodge Bay, near Coeur d'Alene
3	47°35'00", 116°48'20"	52.0	Coeur d'Alene Lake, 0.8 mi SW of Driftwood Point, near Coeur d'Alene
4	47°30'54", 116°50'06"	40.0	Coeur d'Alene Lake, 1.7 mi NE of University Point, near Harrison
5	47°25'00", 116°45'00"	16.5	Coeur d'Alene Lake, NE of Blue Point, near Harrison
6	47°21'20", 116°45'10"	11.0	Chatcolet Lake, 0.4 mi NW of Rocky Point, near Plummer
7	47°40'03", 116°48'27"	4.8	Coeur d'Alene Lake, 0.2 mi NE of Donavons Point, near Coeur d'Alene

[1] Lake surface at full-pool elevation of 648.7 m.

The stations were visited every 3 weeks from May through October and every 4 to 6 weeks during the remaining months. During each monitoring visit, a Hydrolab multiparameter water-quality instrument (model Surveyor II) was used to profile the water column for temperature, specific conductance, pH, dissolved-oxygen concentration, and percent saturation as a means to assess water-column stratification and general water-quality conditions. Vertical profiles of photosynthetically active radiation (PAR) were made with a LiCor integrating quantum radiometer/photometer (model LI–188B) equipped with a LiCor spherical quantum sensor (model LI–193SA) to determine euphotic zone depths and to compute extinction coefficients. The euphotic zone is defined as that part of the water column in which *in situ* PAR is equal to or greater than 1 percent of the PAR incident upon the lake's surface. The equation for computation of an extinction coefficient is as follows:

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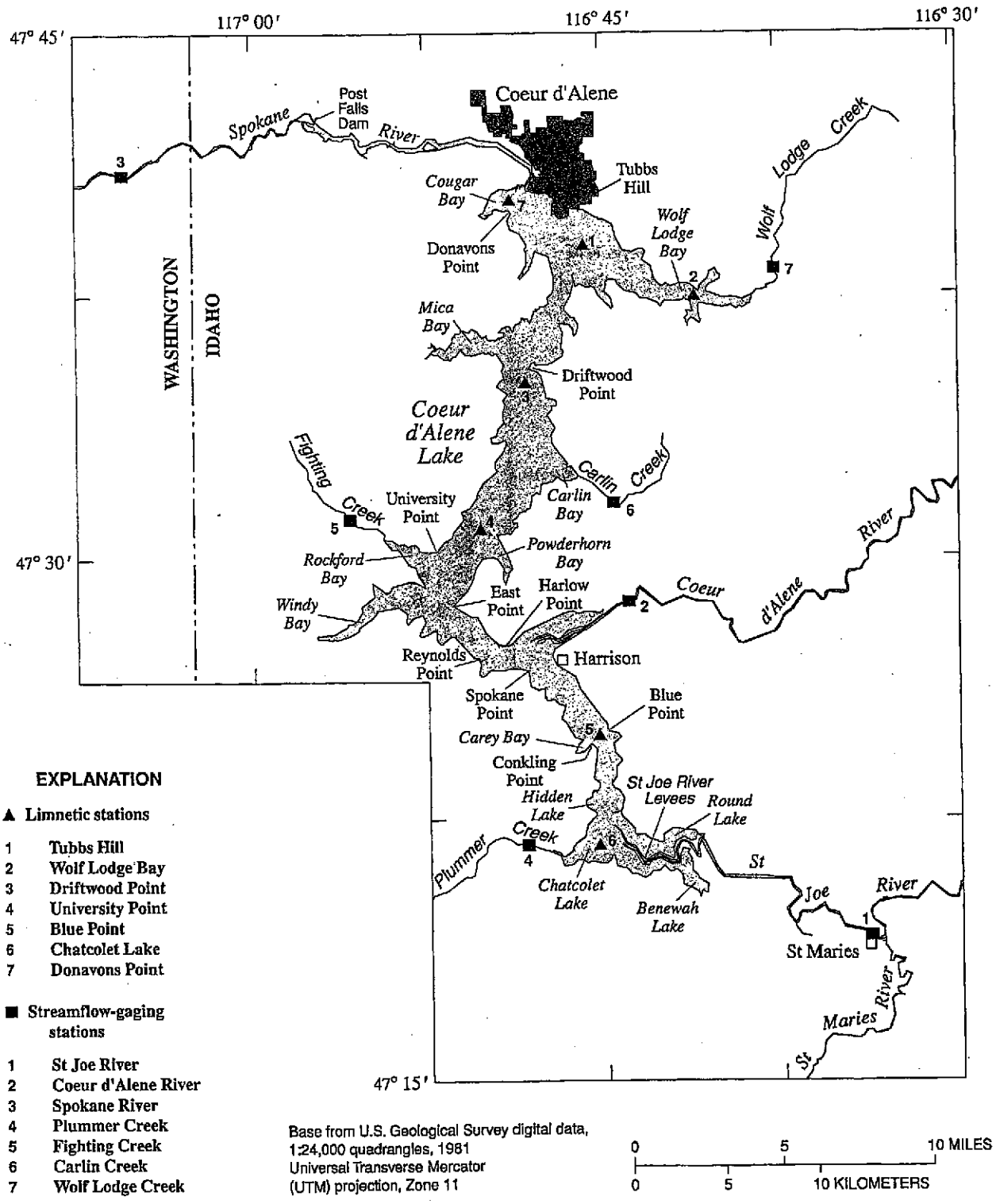


Figure 4. Locations of limnetic sampling and streamflow-gaging stations.

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$$n = \frac{lnI_z - lnI_0}{z}, \quad (2)$$

where

n is extinction coefficient, per meter;
ln is natural logarithm, unitless;
I_z is PAR at depth z, in microEinsteins per square meter per second;
I_0 is PAR immediately above lake surface, in microEinsteins per square meter per second; and
z is depth below lake surface, in meters.

Water-column transparency was measured with a 20-cm-diameter secchi disc. Observations also were recorded for PAR incident upon the lake surface, weather and lake-surface conditions, and any unusual conditions. Water samples were obtained with a nonmetallic Van Dorn bottle. Within the euphotic zone, a depth-weighted composite sample was derived from three point samples. Two additional point samples were taken at mid-depth and 1 m above the lakebed. Because of the shallow depths at stations 5 and 6, mid-depth samples were not taken. At station 7, water samples were obtained only from 0.5 m above the lakebed. At stations 1 through 6, each water sample was analyzed for concentrations of total phosphorus, dissolved orthophosphorus, total organic plus ammonia nitrogen, dissolved ammonia, and dissolved nitrite plus nitrate. The ratio of nitrogen to phosphorus, N:P, was calculated with the following equation:

$$N{:}P = \frac{DIN}{DOP}, \quad (3)$$

where

N:P is the nitrogen-to-phosphorus ratio, unitless;
DIN is the combined concentration of dissolved ammonia, nitrite, and nitrate (as nitrogen), in micrograms per liter; and
DOP is the concentration of dissolved orthophosphorus (as phosphorus), in micrograms per liter.

The euphotic-zone composites from stations 1 through 6 were also analyzed for chlorophyll-*a* and phytoplankton taxonomy. Chlorophyll-*a* samples were field filtered onto glass-fiber filters (Whatman GF/F) and the filters were kept frozen until analyzed. On alternate monitoring visits, the euphotic zone composites and the lower hypolimnion samples from stations 1 through 6 were analyzed for total recoverable concentrations of arsenic, cadmium, copper, lead, mercury, and zinc. The euphotic zone and lower hypolimnion waters of these six stations were also sampled for major and minor cations and anions on a semiannual basis. At station 7, near-bottom water samples were analyzed for dissolved concentrations of orthophosphorus, ammonia, and nitrite plus nitrate. Except for the phytoplankton samples, analyses of the water samples were performed at the USGS's National Water-Quality Laboratory using methods described by Fishman and Friedman (1985) and Britton and Greeson (1987). The phytoplankton analyses were performed under contract by Aquatic Analysts of Portland, Oregon.

Phytoplankton bioassays were conducted to determine whether trace elements in Coeur d'Alene Lake could significantly suppress phytoplankton growth. Dissolved (0.2-micron filter) concentrations of cadmium, copper, iron, zinc, and organic carbon were sampled from 0.5 m beneath the water surface during June and September 1993 and June and August 1994 at the following six locations: St. Joe River about 6.6 km upstream from Chatcolet Lake, Coeur d'Alene River about 4 km upstream from Coeur d'Alene Lake, Mica Bay, and limnetic stations 1, 4, and 6 (fig. 4). Additionally, phytoplankton samples were collected at the six locations to identify and isolate species for culturing and use in the bioassays.

Trace-element concentrations were determined by Zeeman-corrected atomic absorption spectroscopy in conjunction with ultraclean methods. Dissolved organic carbon concentrations were determined by oxygen/ultraviolet/persulfate oxidation as described by Hunter and Kuwabara (1994). The trace-element and dissolved organic carbon data were combined with data on major and minor cations and anions measured in the lake during this study to compute chemical speciation with the geochemical modeling program HYDRAQL (Papelis and others, 1988).

The chemically defined phytoplankton bioassays were conducted using the methods reported by Kuwabara (1985). Three treatments were devised on the basis of the geochemical modeling. Each treatment was conducted in triplicate using three phytoplankton genera isolated from Coeur d'Alene Lake. The number of cells and biomass were monitored with a particle-size analyzer (model Multisizer 2E, Coulter Instruments) until the stationary growth phase was attained.

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LITTORAL ZONE

A comparison of water-quality conditions among limnetic and littoral stations (shoreline waters) was made by analyzing data collected concurrently at those stations during September 1991 and August 1992. In 1991, water-quality samples were collected at limnetic stations 1 through 6 and 20 littoral stations (table 7) during September 16 to 18. The sampling protocol for the limnetic stations was employed at the 20 littoral stations, except that phytoplankton and trace elements were not sampled. In 1992, water-quality samples were collected at limnetic stations 1 through 6 and 15 shallow littoral stations (table 8) during August 10 to 13. At the littoral stations, a 1-m-deep discrete sample was retrieved for analysis of the same constituents sampled at the limnetic stations, except for extinction coefficient and phytoplankton.

Periphyton samples collected from artificial substrates at the 15 shallow littoral stations listed in table 8 were used to assess periphyton production in relation to various levels of nearshore development. Artificial substrates were chosen, instead of natural substrates, to reduce the number of environmental variables used for the statistical assessment. Artificial substrates were placed at the 15 littoral stations during July 21 to 22, 1992, and were incubated *in situ* for about 30 days. The substrates were retrieved during August 17 to 19 for analysis of biomass accrual, quantified as chlorophyll-*a*. The substrates at stations C, D, L, M, and O were vandalized so were unusable for analysis.

Each artificial substrate consisted of a 5-cm-diameter unglazed ceramic ball affixed with silicone adhesive to a 1-m-long rigid plastic shaft. At each station, five substrates were held vertically by a concrete-filled, plastic bucket. The bucket was placed on the lakebed such that the ceramic balls were about 1 m beneath the lake surface and about 1 m above the lake bed. The design and placement of the artificial substrates reduced the potential losses of periphyton due t benthic-invertebrate grazing and wave-induced sloug ing. The amount of PAR received by each station's art ficial substrates during the incubation was computed s periphyton growth rates could be normalized to PAR. A LiCor solar monitor (model LI–1776) located on th northern shore of Coeur d'Alene Lake recorded the hourly input of PAR during the incubation period. At each station, an extinction coefficient was computed from depth profiles of PAR. The amount of shading t the horizon and nearby structures and vegetation was quantified at each site using a solar pathfinder. This allowed adjustment of incubation PAR data to accou for differences in incident PAR at each station. Finall the PAR received during incubation at each station's substrates was computed with the following equatio

Table 7. Locations, depths, and names of littoral stations in Coeur d'Alene Lake sampled during September 1991

[m, meters]

Littoral station (fig. 20)	Latitude, longitude	Depth[1] (m)	U.S. Geological Survey name
1	47°38'43", 116°47'52"	9.8	Kid Island Bay
2	47°40'00", 116°46'03"	14.0	Sanders Beach
3	47°38'43", 116°43'06"	12.8	Bennett Bay
4	47°37'51", 116°40'26"	16.2	Blue Creek Bay
5	47°36'59", 116°41'04"	22.2	Beauty Bay
6	47°37'30", 116°44'49"	9.8	Squaw Bay
7	47°36'40", 116°48'08"	11.9	Echo Bay
8	47°36'15", 116°51'00"	11.6	Mica Bay
9	47°35'33", 116°47'22"	15.2	Driftwood Bay
10	47°34'24", 116°46'59"	13.4	Turner Bay
11	47°33'23", 116°49'18"	12.2	Loffs Bay
12	47°32'20", 116°46'26"	12.5	Carlin Bay
13	47°29'41", 116°48'57"	16.5	Powderhorn Bay
14	47°30'18", 116°53'18"	15.5	Rockford Bay
15	47°28'46", 116°54'55"	14.9	Windy Bay
16	47°28'16", 116°53'12"	12.5	16 to 1 Bay
17	47°27'56", 116°52'36"	14.0	Aberdeen Lodge Bay
18	47°26'49", 116°50'04"	12.8	Cottonwood Bay
19	47°26'02", 116°47'22"	12.8	Fullers Bay
20	47°24'35", 116°45'44"	11.8	Carey Bay

[1] Lake surface at full-pool elevation of 648.7 m.

Table 8. Locations, depths, and names of littoral stations in Coeur d'Alene Lake sampled during August 1992

[m, meters]

Littoral station (fig. 20)	Latitude, longitude	Depth[1] (m)	U.S. Geological Survey name
A	47°38'26", 116°47'57"	1.8	Kid Island Bay
B	47°38'49", 116°43'08"	1.8	Bennett Bay
C	47°37'35", 116°40'54"	1.8	Wolf Lodge Bay
D	47°36'42", 116°46'00"	1.8	Echo Bay
E	47°36'28", 116°50'42"	2.4	Mica Bay
F	47°34'15", 116°46'23"	1.8	Turner Bay
G	47°33'30", 116°49'17"	1.8	Loffs Bay
H	47°32'35", 116°46'25"	1.8	Carlin Bay
I	47°29'50", 116°48'55"	1.8	Powderhorn Bay
J	47°30'25", 116°53'27"	1.8	Rockford Bay
K	47°28'40", 116°55'11"	1.8	Windy Bay
L	47°28'19", 116°53'18"	1.8	16 to 1 Bay
M	47°28'02", 116°52'41"	1.8	Cave Bay
N	47°26'06", 116°47'28"	1.8	Fullers Bay
O	47°24'37", 116°46'08"	1.8	Carey Bay

[1] Lake surface at full-pool elevation of 648.7 m.

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$$PAR_z = PAR_i \ (e^{-nz}) \ PS, \qquad (4)$$

where

PAR_z is PAR input to artificial substrate during incubation, in Einsteins per square meter;

PAR_i is PAR input to lake surface during incubation, in Einsteins per square meter;

e is base of natural logarithms, unitless;

n is extinction coefficient, per meter;

z is depth of artificial substrate, in meters; and

PS is decimal percent of station unshaded.

When each artificial substrate was retrieved, the periphyton attached to the ceramic ball were brushed gently into a 500-mL plastic jar containing 250 mL of filtered lake water. The 250-mL sample was homogenized for 1 minute, then three subsamples were withdrawn and each was filtered through a Whatman GF/F glass-fiber filter. The filters were frozen until subsequent analysis for chlorophyll-*a*. The chlorophyll-*a* analyses were performed by the authors using a Turner Designs fluorometer (model 10-005R) and the methods described by Koenings and others (1987). Two replicate analyses were run on the supernatant derived from the acetone extraction of each chlorophyll-bearing filter. The amount of chlorophyll-*a* associated with the periphyton on each ceramic ball was computed with the following equation:

$$B_{chl} = \frac{(C) \ (V_e) \left(\frac{V_t}{V_f}\right) (CF)}{A}, \qquad (5)$$

where

B_{chl} is periphyton biomass, as chlorophyll-*a*, on artificial substrate, in milligrams per square meter;

C is concentration of chlorophyll-*a* in extract, in micrograms per liter;

V_e is volume of extract, in liters;

V_t is volume of periphyton sample, in liters;

V_f is volume of periphyton sample filtered, in liters;

CF is factor to convert micrograms to milligrams; and

A is area of artificial substrate, in square meters.

The distribution, relative abundance, and taxonomic composition of aquatic macrophytes were determined in August 1993. Sixty-three sites throughout the lake, mostly in bays, were sampled (fig. 5). Divers sampled macrophytes along transects from the shoreline to the maximum depth of macrophyte occurrence. Representative specimens were taxonomically identified onsite by a Bureau of Land Management botanist.

Bathymetry

At its normal full-pool elevation of 648.7 m above NGVD, Coeur d'Alene Lake covers 129 km^2 and contains 2.84 km^3 of water (table 9). At full pool, the lake's mean depth is 22.0 m and its maximum depth is 63.7 m. When the lake level is reduced to an elevation of 646.2 m, the limit of available drawdown, the surface area is reduced to 122 km^2 and the volume to 2.60 km^3. The relation of depth to lake surface area and volume is illustrated in figure 6. The variation in lake surface elevation during 1991–92 is shown in figure 7. A bathymetric map of Coeur d'Alene Lake (Woods and Berenbrock, 1994) is shown in figure 8.

Limnetic Zone

WATER TEMPERATURE

The maximum water temperature measured at the six limnetic stations during 1991 was 23.4°C at station 6 and, during 1992, 23.1°C at station 4 (fig. 9). During 1991, water temperature at the six stations reached a maximum in early August. The date of the maximum was more variable in 1992, occurring between mid-July and mid-August. Minimum water temperatures reached 0°C at station 6 in January 1991 and December

Table 9. Morphometric data for Coeur d'Alene Lake at full-pool elevation of 648.7 meters

[km^2, square kilometers; km^3, cubic kilometers; m, meters]

Surface area, in km^2	129
Volume, in km^3	2.84
Shoreline length, in km	243
Maximum depth, in m	63.7
Mean depth, in m	22.0

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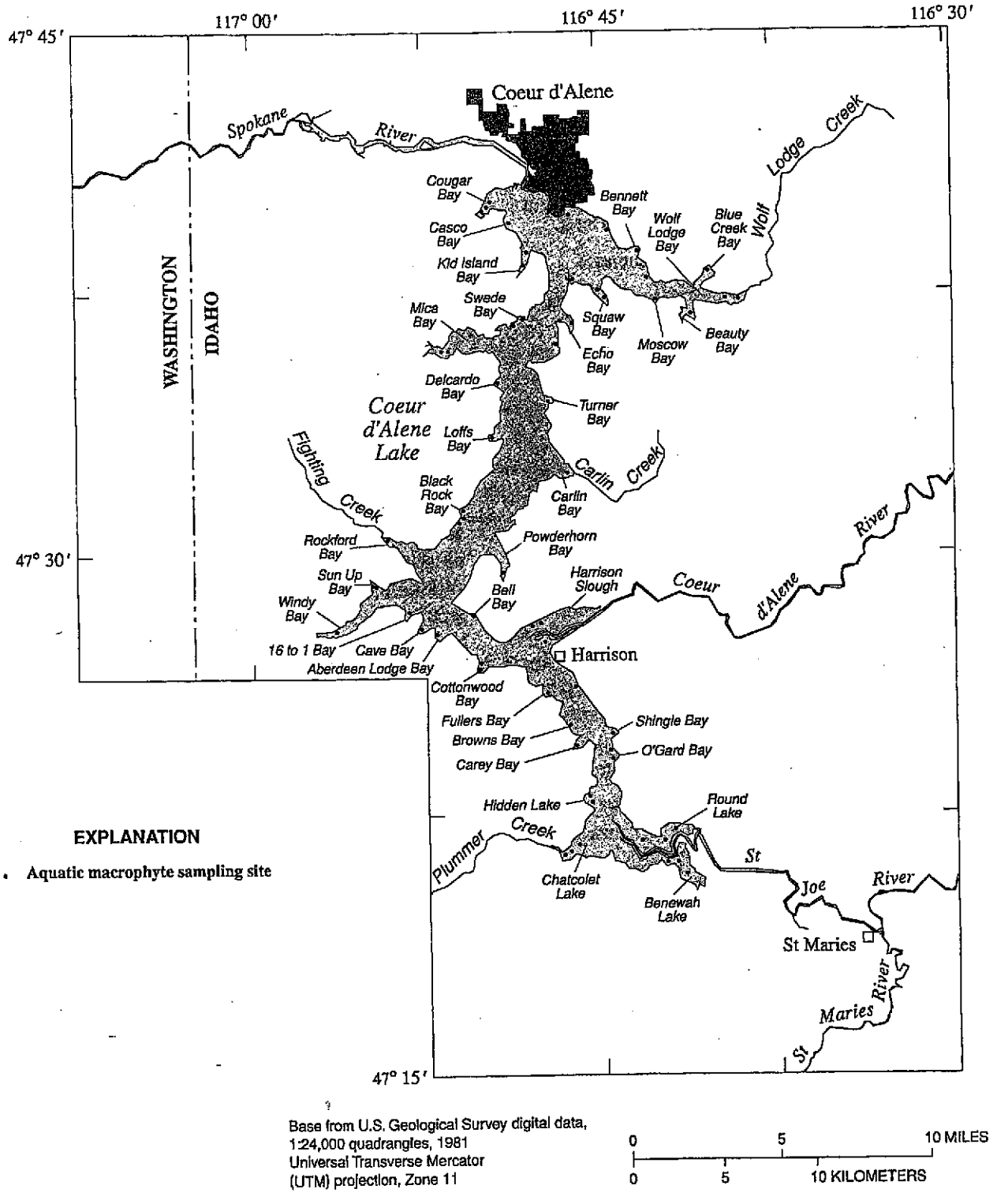


Figure 5. Locations of aquatic macrophyte sampling sites.

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1992 when ice covered the lake at that station. Minimum water temperatures at the other five stations were about 2°C during January 1991, whereas the minimums were slightly warmer, 4 to 5°C, during January and February 1992.

Thermal stratification developed at the six stations during both years but varied in duration and depth (fig. 9). If thermal stratification develops to the point that the decrease in water temperature with depth exceeds 1°C per meter, then a thermocline has developed (Lind, 1979). During 1991, a thermocline generally developed by mid-July and ended by early October. In 1992, development of the thermocline began in June and ended in mid-October, except at station 6, where it ended in early September. The deepest thermocline in 1991 was 16.5 m at station 1, whereas in 1992, it was 21.5 m at stations 1 and 2. Thermocline depth at station 6, the shallowest, was atypical, ranging from 4.5 to 8.5 m; at the other stations, thermocline depth ranged from 7.5 to 21.5 m.

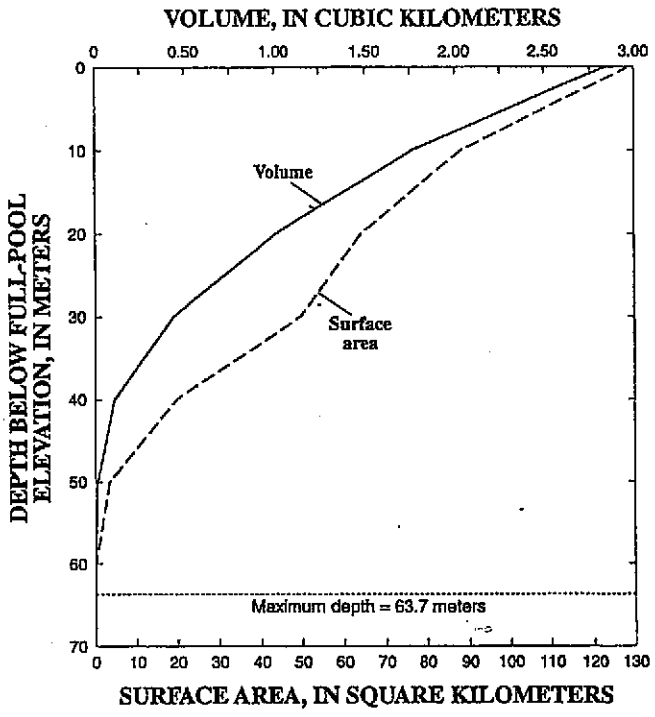


Figure 6. Relation of depth to lake surface area and volume for Coeur d'Alene Lake.

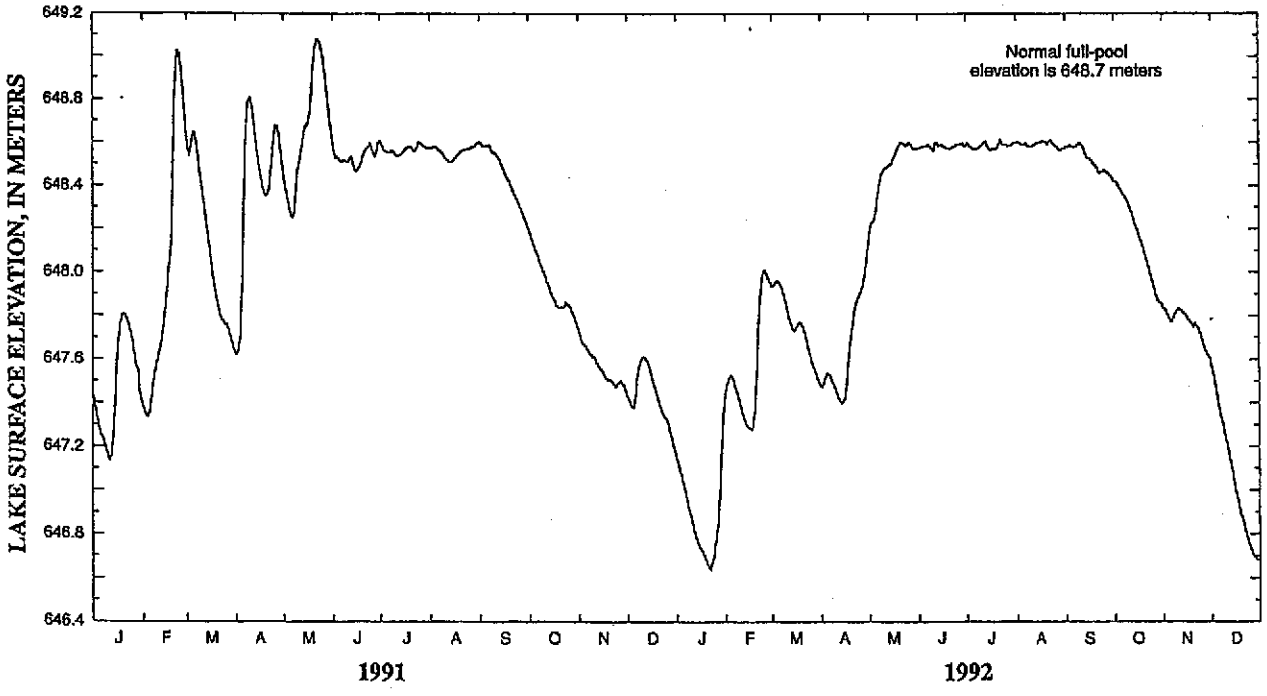


Figure 7. Variation in lake surface elevation of Coeur d'Alene Lake during 1991–92.

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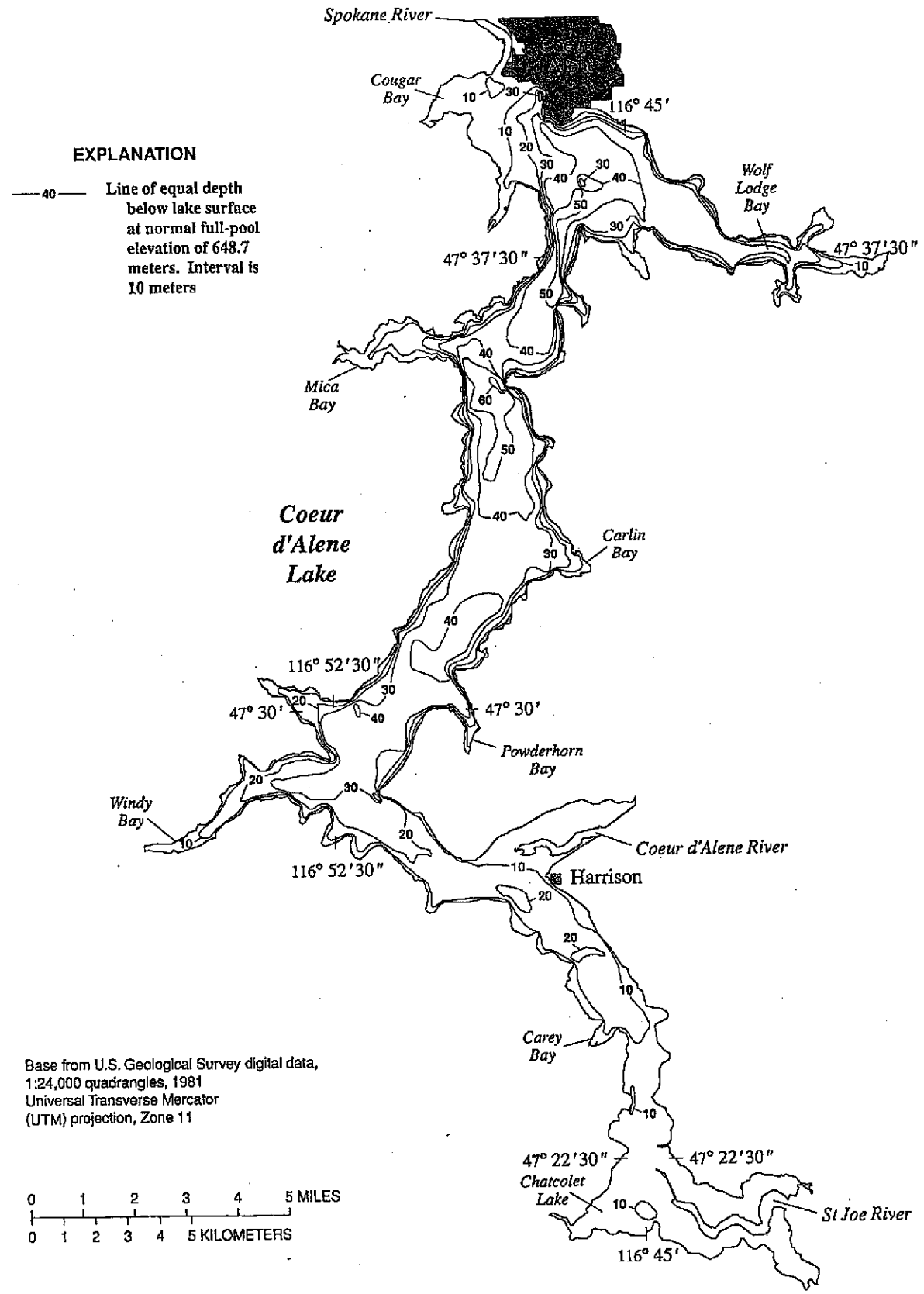


Figure 8. Bathymetric map of Coeur d'Alene Lake.

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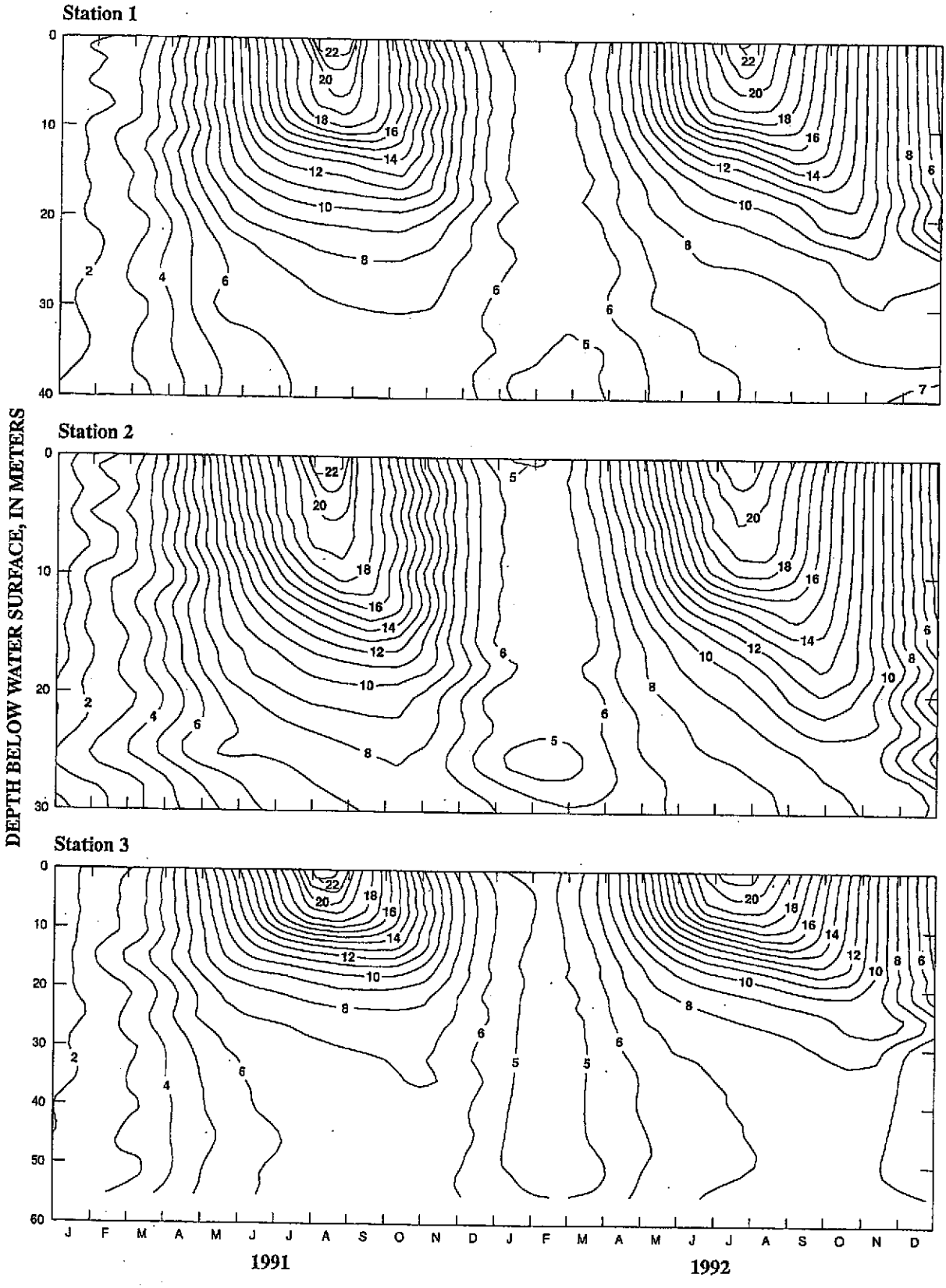
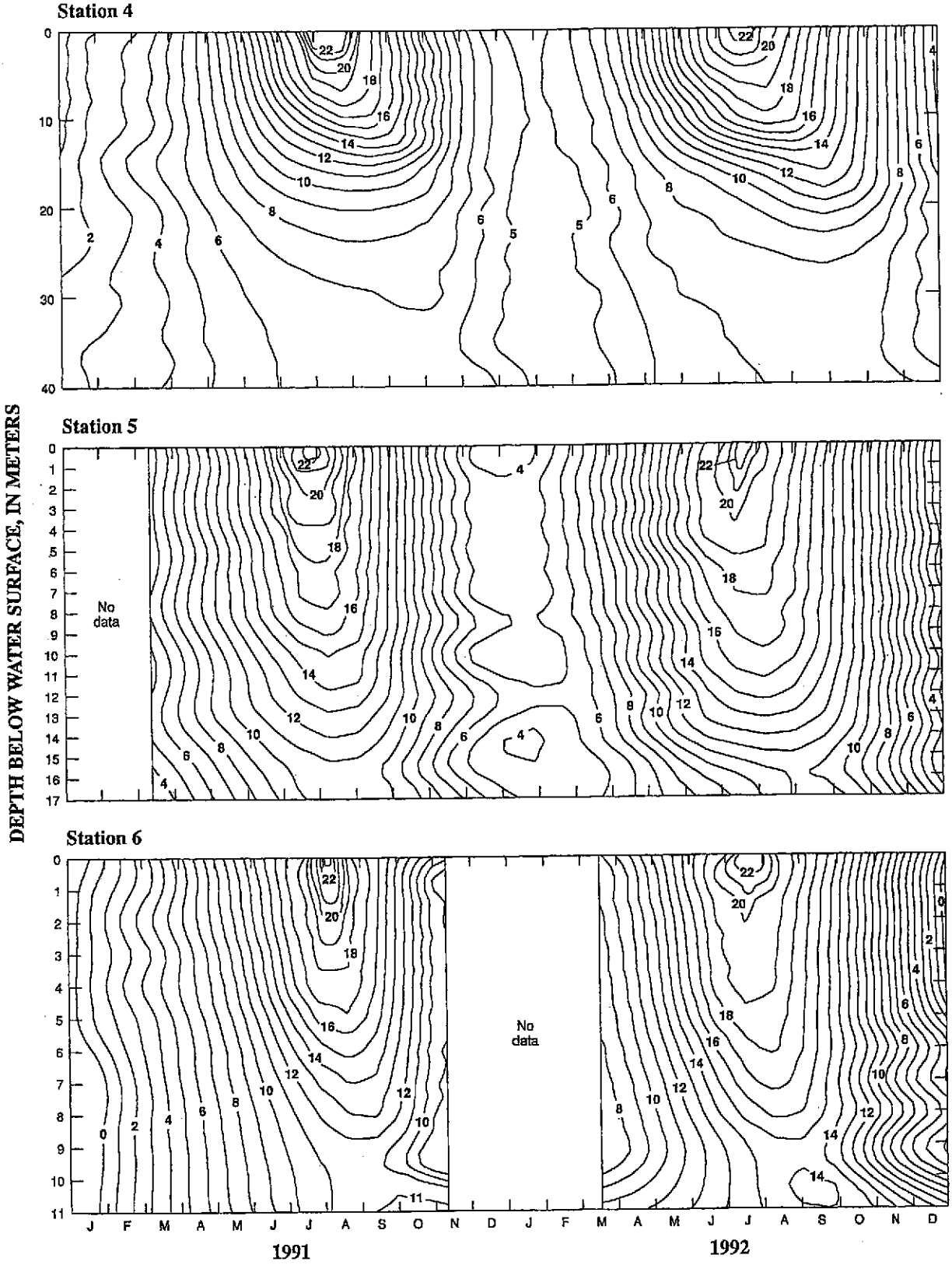


Figure 9. Lines of equal water temperature, in degrees Celsius, at stations 1–6 during 1991–92.

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Figure 9. Lines of equal water temperature, in degrees Celsius, at stations 1–6 during 1991–92—Continued.

WATER-COLUMN TRANSPARENCY

Secchi-disc transparency and euphotic-zone depth had a strong positive correlation ($r=0.92$, $p<0.00001$, $n=130$). The smallest values for both variables (fig. 10) were recorded during late winter and spring when snowmelt runoff had increased turbidity in the lake. The largest values generally were recorded during late summer and autumn after the sediments input by runoff had settled out of the water column. The area-weighted lakewide mean for secchi-disc transparency was 4.9 m (n=76) in 1991 and 6.9 m (n=75) in 1992. The overall range in secchi-disc transparency in 1991 was 0.7 to 9.5 m, whereas the range in 1992 was 1.7 to 11.1 m. The larger mean secchi-disc transparency in 1992 was likely due to a substantially reduced volume of snowmelt runoff into the lake in 1992.

During both years, the smallest values for secchi-disc transparency were measured at stations 5 and 6. Other studies of Coeur d'Alene Lake have reported that secchi-disc transparency was less in the shallow, southern end of the lake than in the deeper, northern end (Kemmerer and others, 1923; Rieman, 1980; Woods, 1989). The consistently smaller values for secchi-disc transparency in the lake's southern end are due largely to its proximity to the mouths of the two major inflows, the St. Joe and Coeur d'Alene Rivers; the shallow depths, which permit resuspension of bottom sediments by wind-induced turbulence; and increased biological production.

Typically, the euphotic zone was deeper than the thermocline at stations 1 through 4 (fig. 10). Under that condition, the phytoplankton circulating within the epilimnion (mixing zone), above the thermocline, remain exposed to amounts of PAR sufficient for photosynthetic production of carbon in excess of respiratory demands.

SPECIFIC CONDUCTANCE

Specific conductance is a measure of the ability of water to conduct electricity and is typically proportional to the water's dissolved-solids concentration. The mean ratio of dissolved-solids concentration (in milligrams per liter) to specific conductance (in microsiemens per centimeter) in Coeur d'Alene Lake during 1991–92 was 0.70, which is within the range of most natural waters (Hem, 1985).

All specific conductance measurements in Coeur d'Alene Lake (fig. 11) were less than 100 µS/cm, which is low compared with measurements in other natural waters (Hem, 1985). The variation in specific conductance over depth and time at stations 1 through 4 was similar and ranged from 42 to 59 µS/cm. Specific conductance at stations 5 and 6 ranged from 38 to 63 µS/cm and from 30 to 95 µS/cm, respectively. Some minor stratification with depth developed at each station. Stratification was most pronounced at station 6 where steep gradients developed within 2 m above the lakebed in conjunction with severe depletion of dissolved oxygen in the lower water column. The smallest values for specific conductance were measured at all stations during May through July 1991. These minima represented the dilutional effects of snowmelt runoff from the St. Joe and Coeur d'Alene Rivers. Similar dilution did not occur in 1992 because snowmelt runoff was substantially below normal.

pH

The water-quality variable pH represents the negative base-10 logarithm of the hydrogen ion activity in moles per liter (Hem, 1985). The overall range of pH for dilute solutions is 0 to 14; values above 7 are considered basic and those below 7 are considered acidic. pH in most open-water lakes in which bicarbonate is the dominant anion ranges from 6 to 9 (Wetzel, 1975).

The overall range in pH lakewide was 6.6 to 8.2 (fig. 12). The minimum values were measured near the bottom of station 6 during October 1991, whereas the maximum values were measured within the euphotic zone of station 5 during June and July 1992. The general trend in pH was larger values in the euphotic zone during late summer and smaller values in the hypolimnion during late summer and autumn. The overall pattern in pH fits that described for many lakes. In the summer, pH in the euphotic zone increased in response to photosynthetic utilization of carbon dioxide, whereas pH in the hypolimnion decreased as carbon dioxide was added by decomposition of organic matter.

DISSOLVED OXYGEN

In natural freshwater, the concentration of dissolved oxygen is affected by temperature, barometric pressure, production of oxygen by photosynthesis, consumption of oxygen by respiration and decomposition, and mixing. The ratio (expressed as a percent) of measured dissolved-oxygen concentrations to those that would exist under saturated conditions at the same tem-

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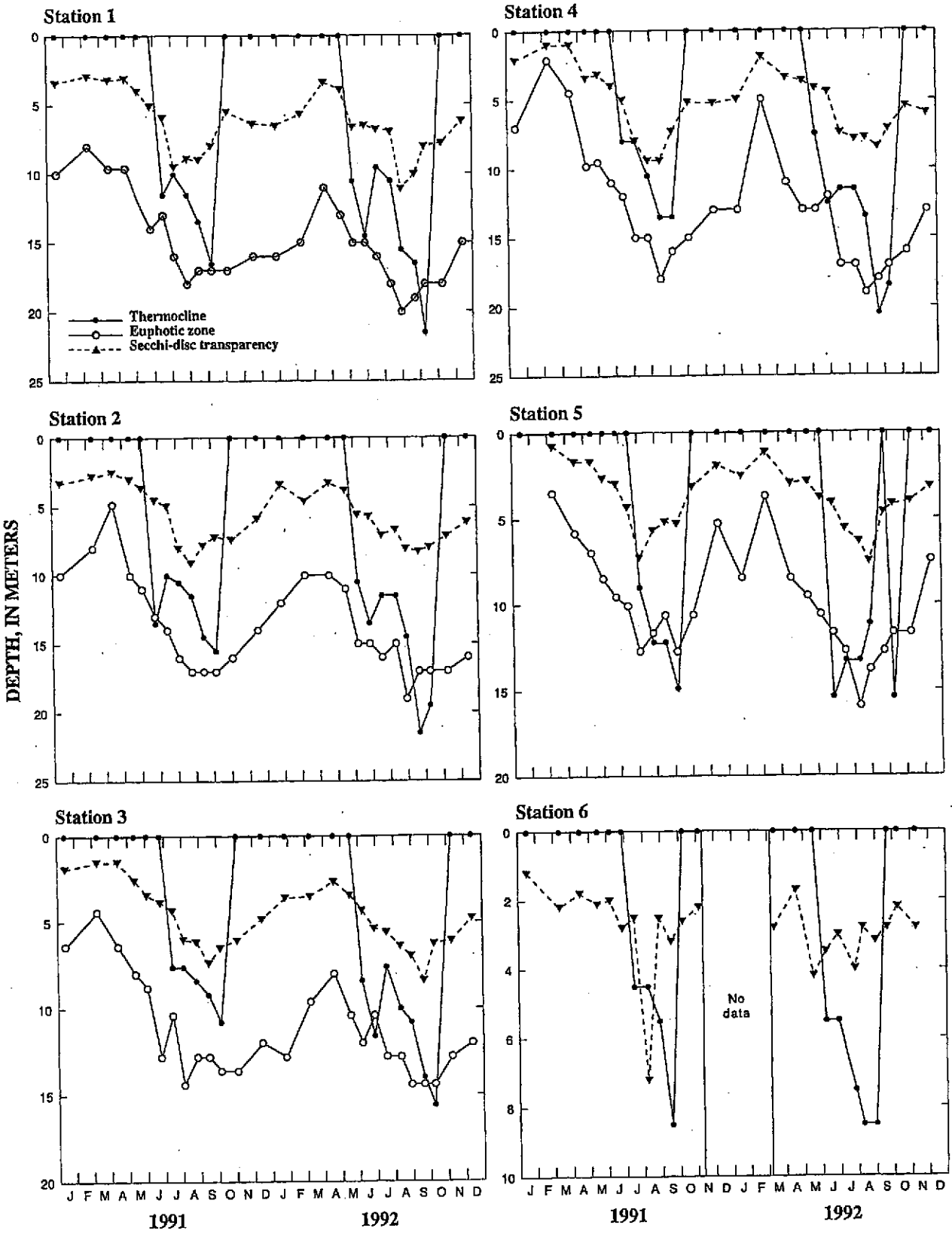


Figure 10. Depths of thermocline, euphotic zone, and secchi-disc transparency at stations 1–6 during 1991–92.

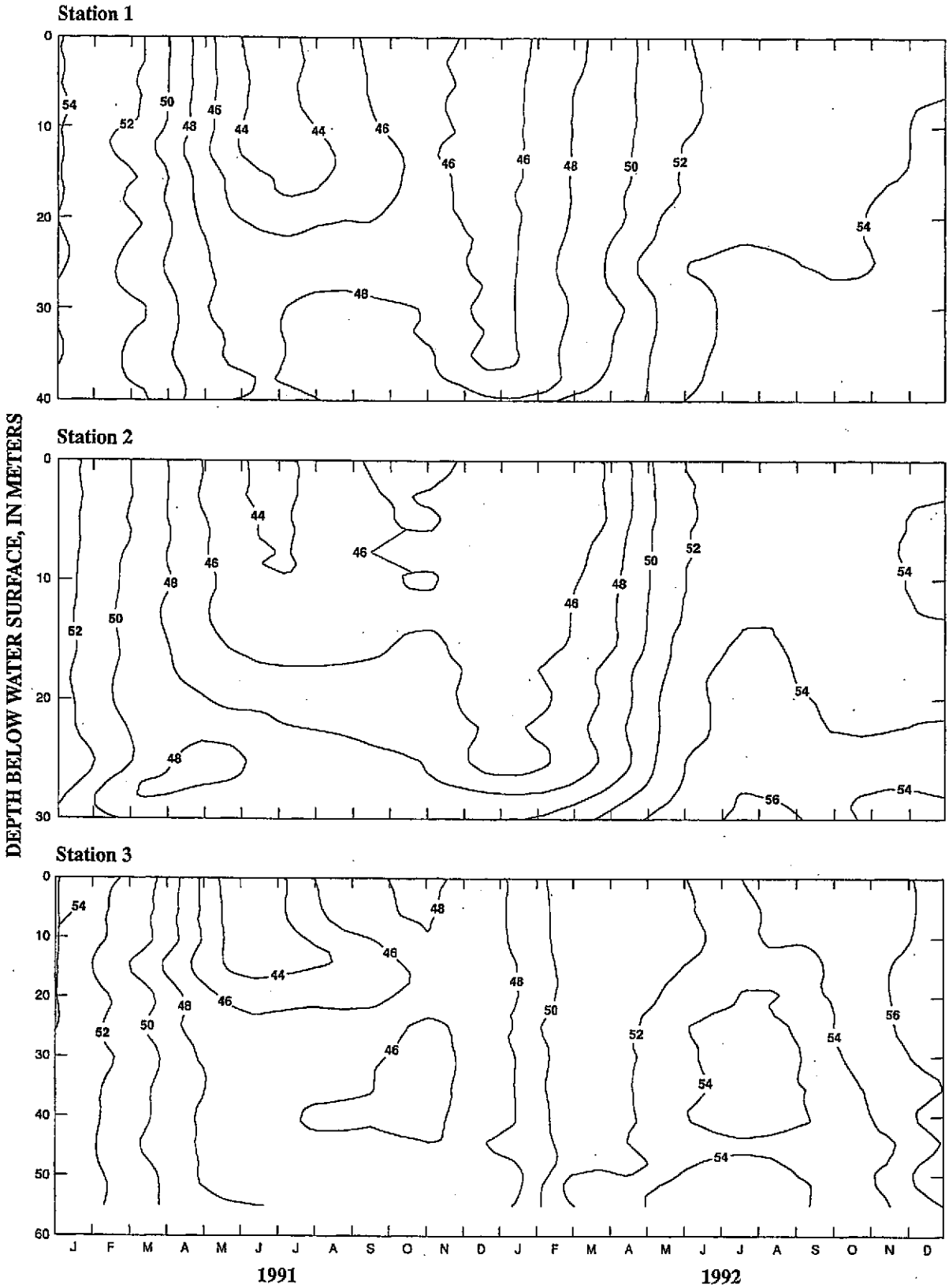


Figure 11. Lines of equal specific conductance, in microsiemens per centimeter, at stations 1–6 during 1991–92.

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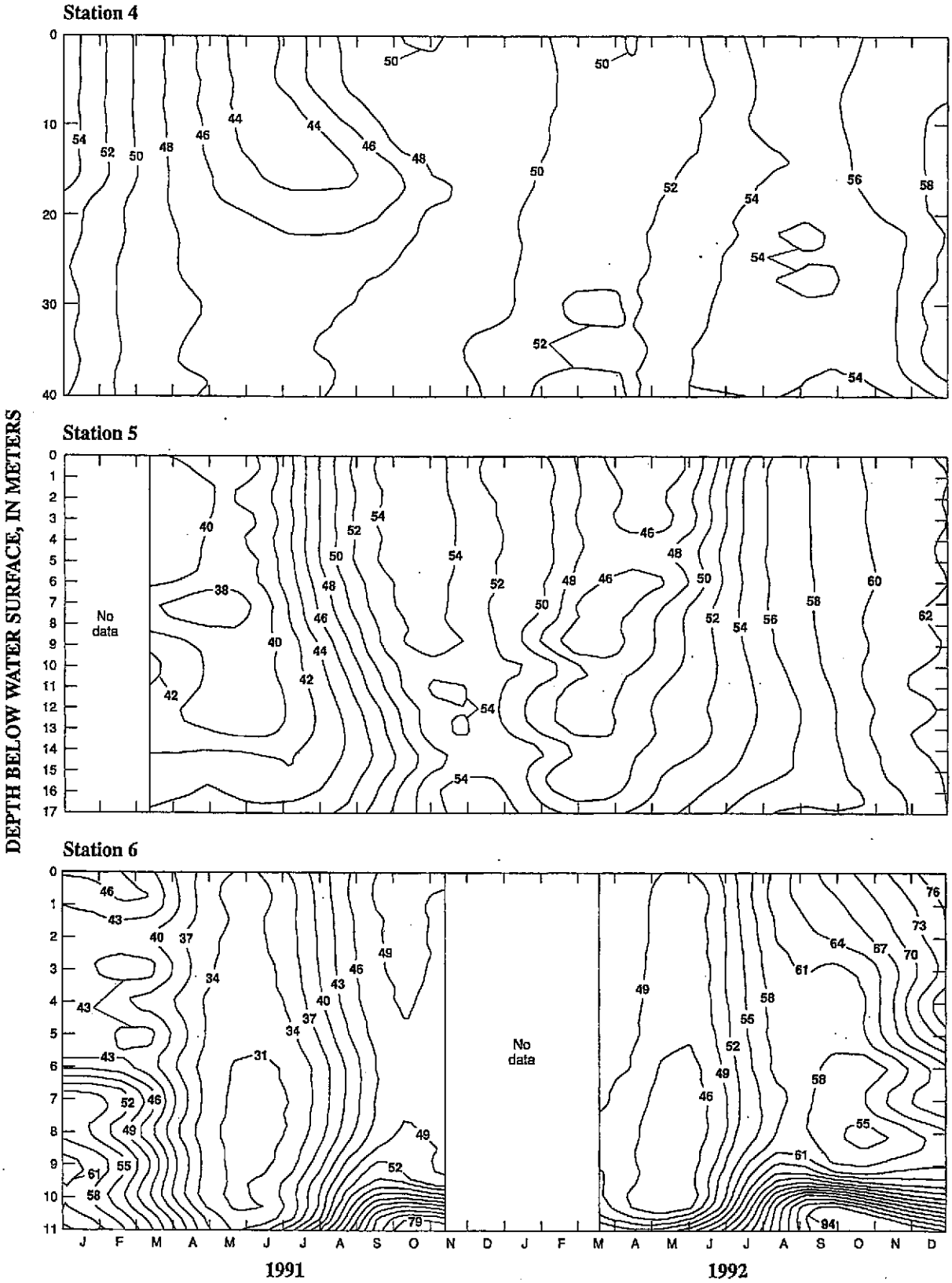


Figure 11. Lines of equal specific conductance, in microsiemens per centimeter, at stations 1–6 during 1991–92—Continued.

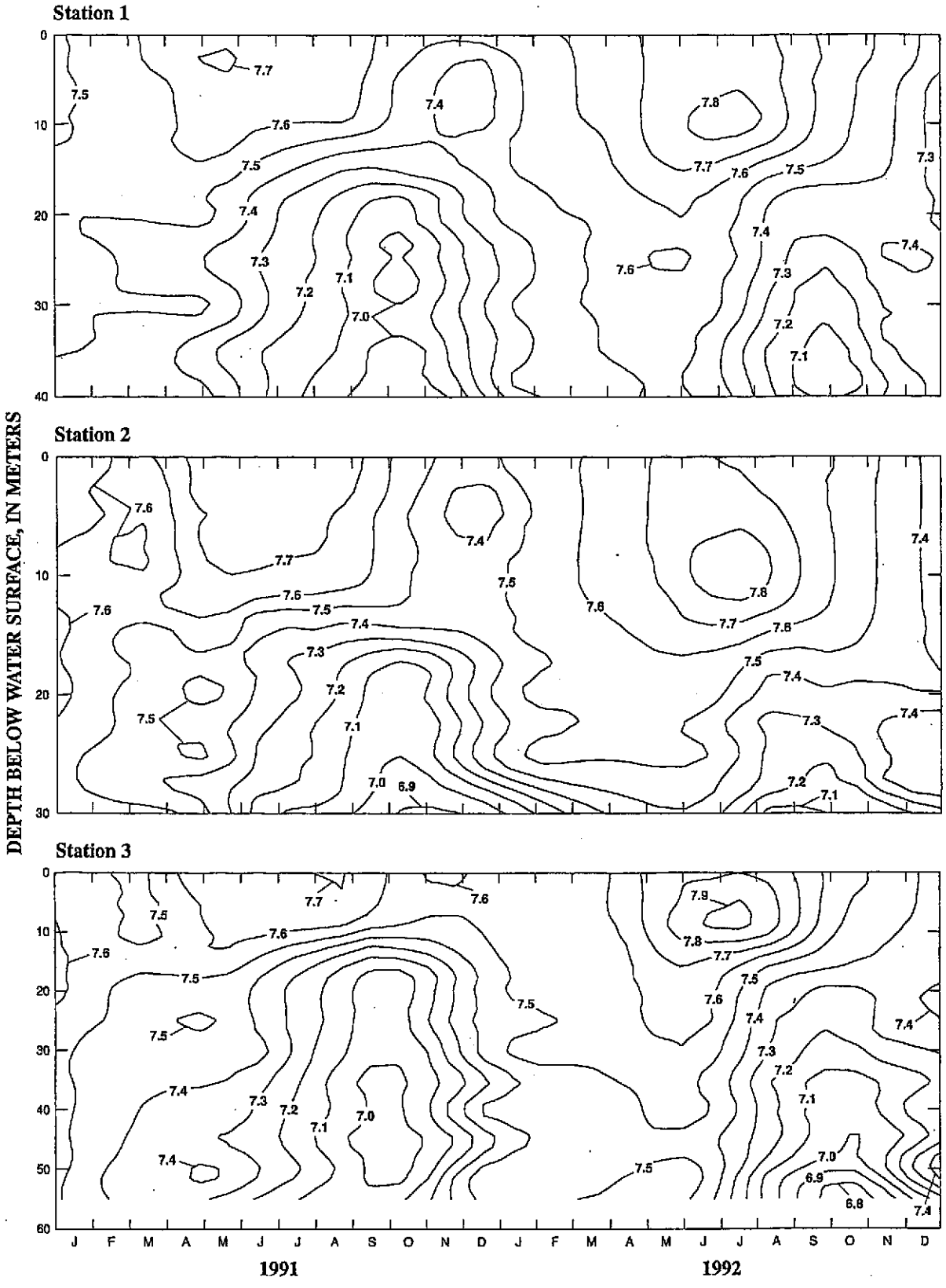


Figure 12. Lines of equal pH, in standard units, at stations 1–6 during 1991–92.

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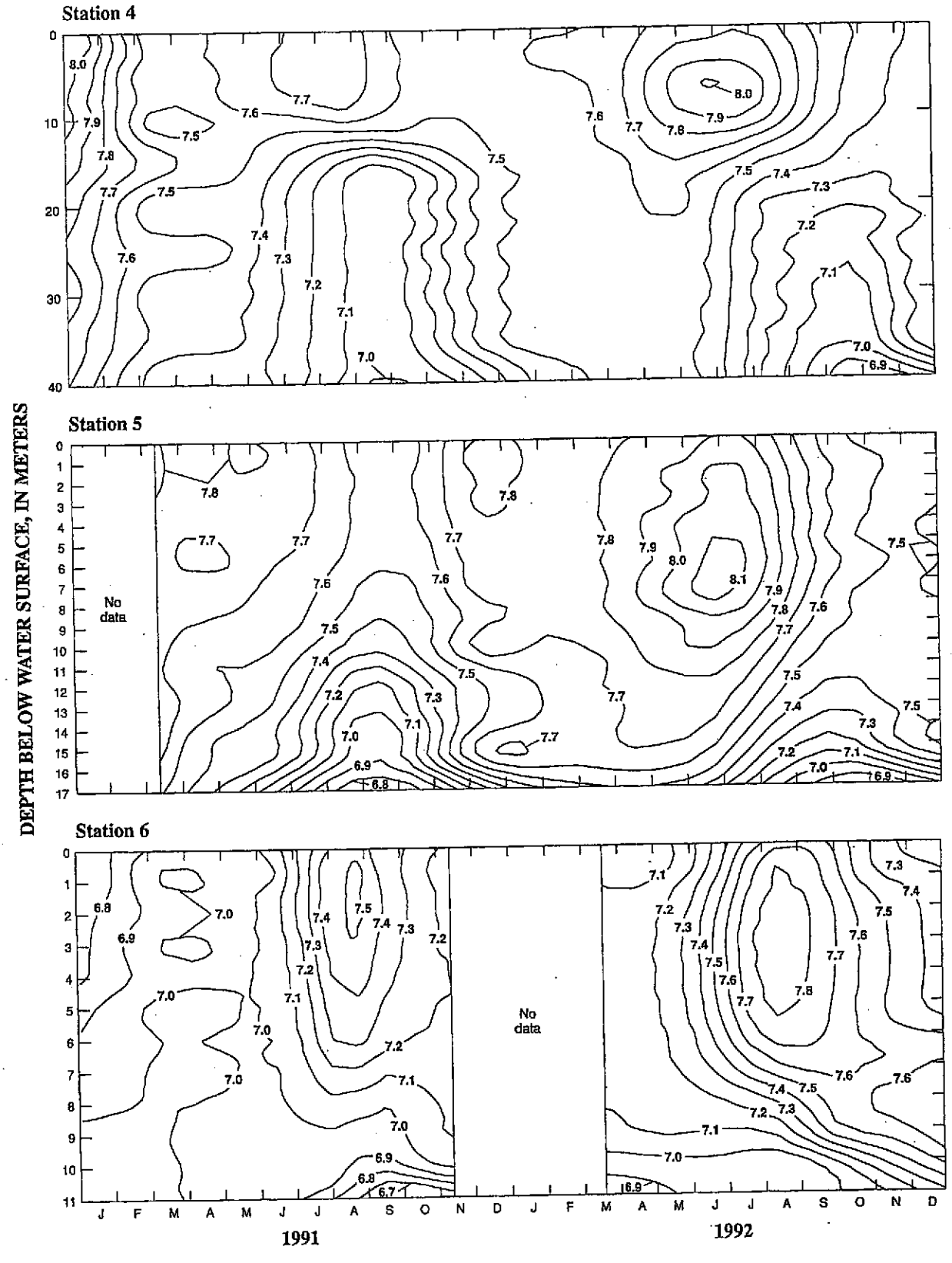


Figure 12. Lines of equal pH, in standard units, at stations 1–6 during 1991–92—Continued.

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perature and pressure is useful for comparing dissolved oxygen when significant variations in temperature and pressure exist, such as comparisons spanning time or depth.

The overall range in dissolved-oxygen concentration over depth and time at the six stations (fig. 13) was 0 to 13.6 mg/L; both extremes were measured at station 6. At each station, the highest concentrations were measured in the winter in association with minimum water temperatures; this conforms to the inverse relation between dissolved oxygen and temperature. The minimum dissolved-oxygen concentrations at each station were measured in the hypolimnion during late summer or autumn. The dissolved-oxygen minima resulted when thermal stratification reduced mixing of the oxygenated epilimnion with the hypolimnion. The minimum concentration ranged from 6.4 to 6.5 mg/L at stations 1 through 4, was 2.8 mg/L at station 5, and declined to anoxia at station 6.

The variation in percent saturation of dissolved oxygen over depth and time (fig. 14) was similar in both years at each of the stations, but the overall maximum values were measured in 1992. Saturation greater than 100 percent was measured in the euphotic zone of each station during the summer months when photosynthetic production of oxygen exceeded oxygen consumption by respiration and decomposition. The maximum saturation at stations 1 through 4 ranged from 113 to 117 percent and was 120 percent at station 5. At station 6, dense beds of aquatic macrophytes and associated periphyton augmented phytoplanktonic oxygen production and yielded saturation as high as 133 percent during August 1992. The minimum percent saturations were measured in the hypolimnion during late summer or autumn and corresponded with minimum dissolved-oxygen concentrations. The minimum saturation at stations 1 through 4 ranged from 58 to 60 percent, was 28 percent at station 5, and was 0 at station 6.

Several previous studies, one done as early as 1911, reported dissolved-oxygen data for Coeur d'Alene Lake. Among these earlier studies is a comparable time period, July through September, and a comparable location, near limnetic station 3 of the current study. Most of these earlier studies did not report percent saturation; using reported water temperatures and an assumed barometric pressure of 700 mm of mercury, saturation was calculated for the dissolved-oxygen concentrations. Kemmerer and others (1923) conducted biological and chemical studies of numerous northwestern lakes to assess their potential for fish production. For Coeur d'Alene Lake, they measured a dissolved-oxygen concentration on July 15, 1911, as low as 7.8 mg/L (5.4 cm^3/L) at the 50-m depth. The water temperature at that depth was 6.9°C; therefore, the saturation was 63 percent. Ellis (1940) studied Coeur d'Alene Lake in 1932 to assess pollution from mine wastes. He reported that at the 60-m depth (near-bottom) on July 15, 1932, the dissolved-oxygen concentration was 8.4 mg/L and saturation was 80.3 percent. During July 1971, Winner (1972) reported that the lower 35 m of a 50-m-deep water column contained a dissolved-oxygen concentration of about 4 mg/L. The water temperature in the lowermost 10 m was 5°C, which yielded a saturation of 30 percent. The EPA (1977) studied Coeur d'Alene Lake during 1975 as part of its National Eutrophication Survey. On September 9, the EPA measured a dissolved-oxygen concentration of 7.0 mg/L at a depth of 43 m (station depth of 56 m). The associated water temperature was 7.2°C, which yielded a saturation of 57 percent. The USGS studied the lake during 1987 (Woods, 1989). On September 22, 1987, the dissolved-oxygen concentration and saturation in the metalimnion were 5.6 mg/L and 54 percent, respectively.

Dissolved-oxygen concentrations in the southern end of Coeur d'Alene Lake, represented by limnetic station 6, also have been studied previously. Data for July 10, 1932, showed dissolved-oxygen concentration and saturation down to 2.7 mg/L and 28.2 percent, respectively, near the lake bottom (Ellis, 1940). Winner (1972) measured a dissolved-oxygen concentration of 1 mg/L in a near-bottom water sample in July 1971. That value represented a saturation of 7 percent at a water temperature of 6°C. The EPA (1977) reported a dissolved-oxygen concentration of 2.8 mg/L near the lake bottom on September 9, 1975. That value equated to a saturation of 28.2 percent, given a water temperature of 13.3°C.

MAJOR CATIONS AND ANIONS

Concentrations of major cations (Ca^{2+}, K^+, Mg^{2+}, Na^+) and anions (Cl^-, HCO_3^-, SO_4^{2-}) at the six stations were determined from near-surface and near-bottom samples obtained in January and July 1991 and March and September 1992. The ranges in concentrations, in milligrams per liter, were as follows: Ca^{2+}, 5.2 to 6.4; K^+, 0.5 to 1.1; Mg^{2+}, 1.2 to 1.9; Na^+, 1.2 to 2.1; Cl^-, 0.1 to 0.8; HCO_3^-, 22 to 40; and SO_4^{2-}, 1 to 6.6. Alkalinity ranged from 19 to 33 mg/L as $CaCO_3$, whereas hard-

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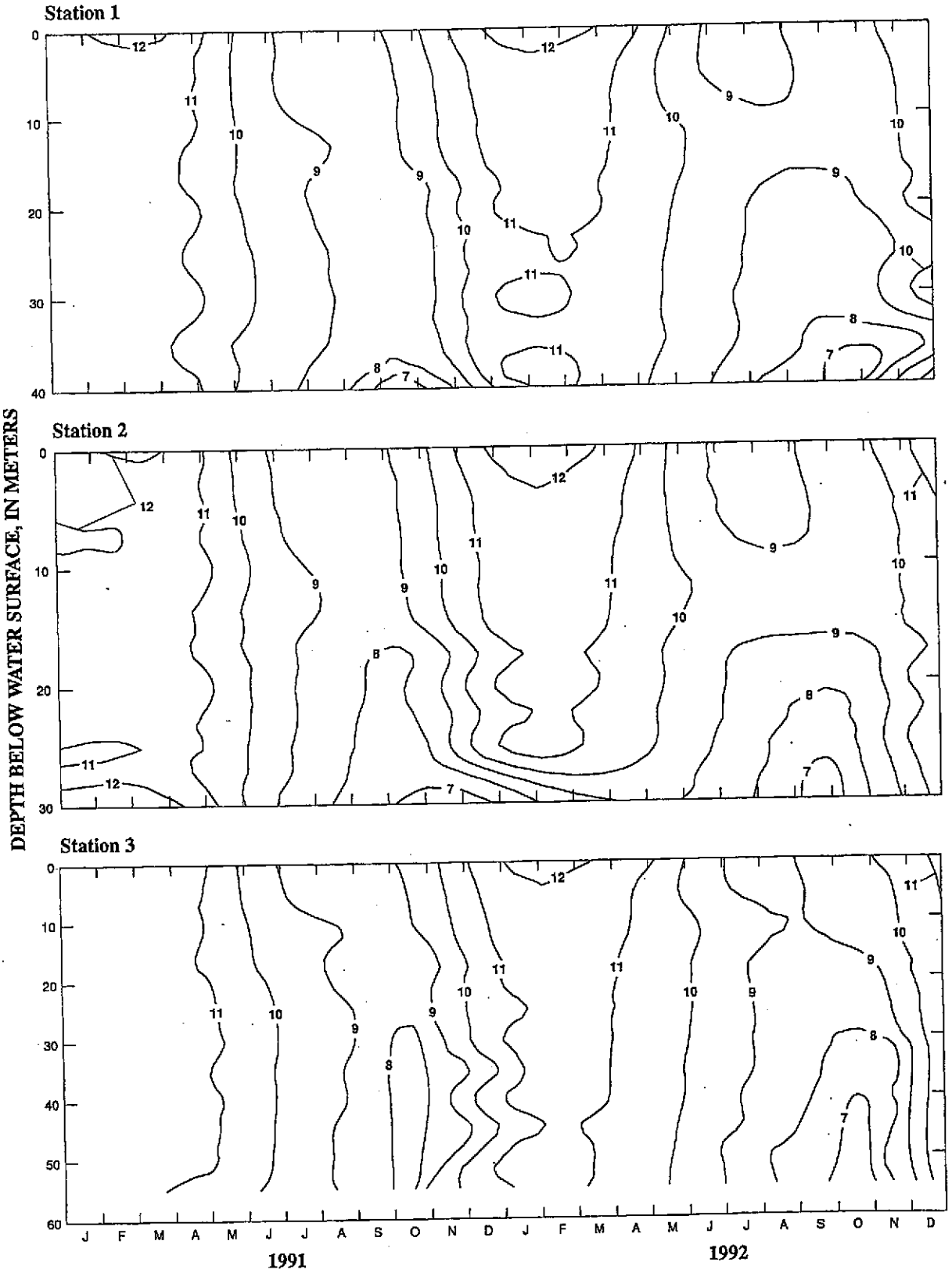


Figure 13. Lines of equal dissolved-oxygen concentration, in milligrams per liter, at stations 1–6 during 1991–92.

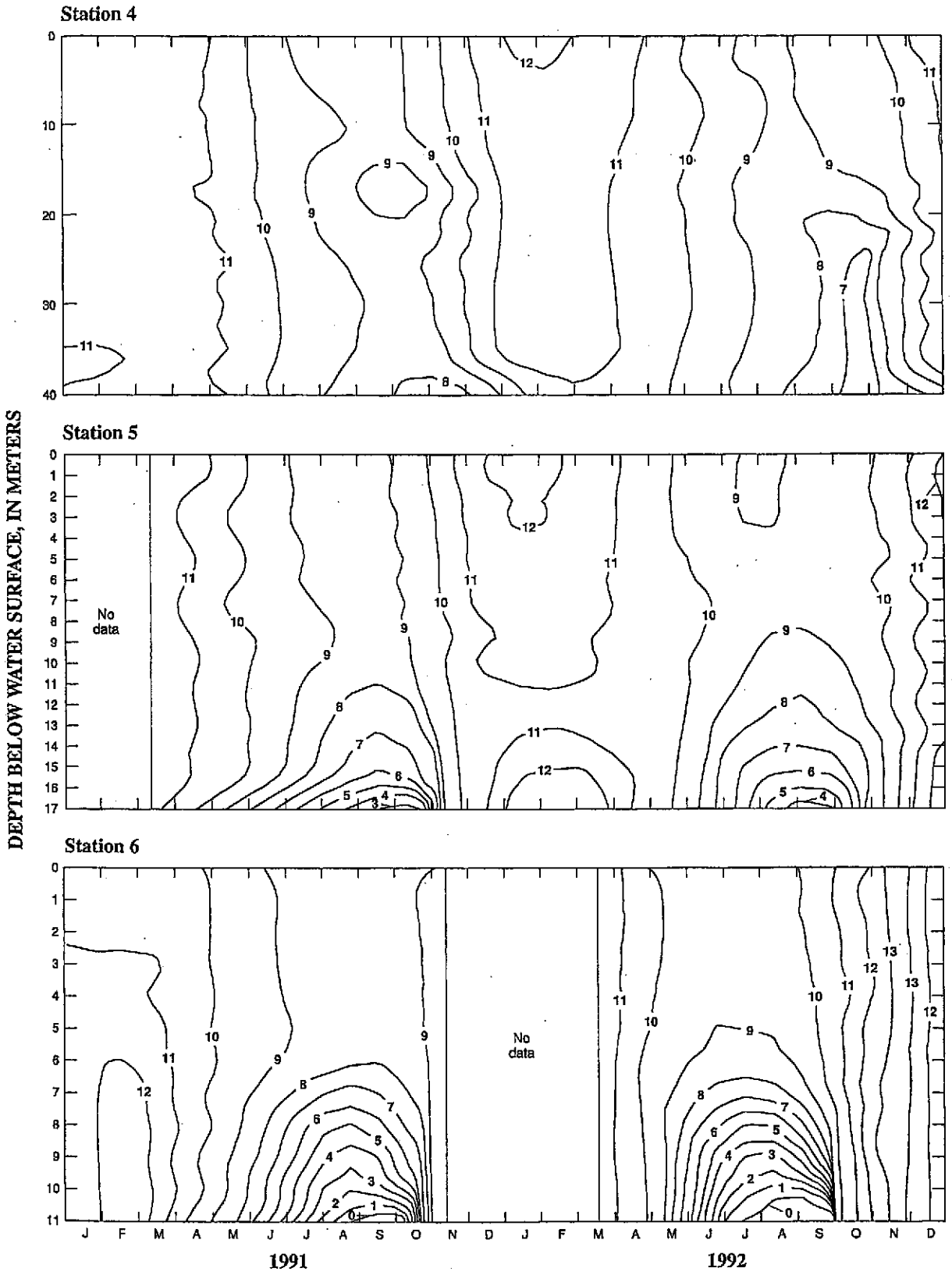


Figure 13. Lines of equal dissolved-oxygen concentration, in milligrams per liter, at stations 1–6 during 1991–92—Continued.

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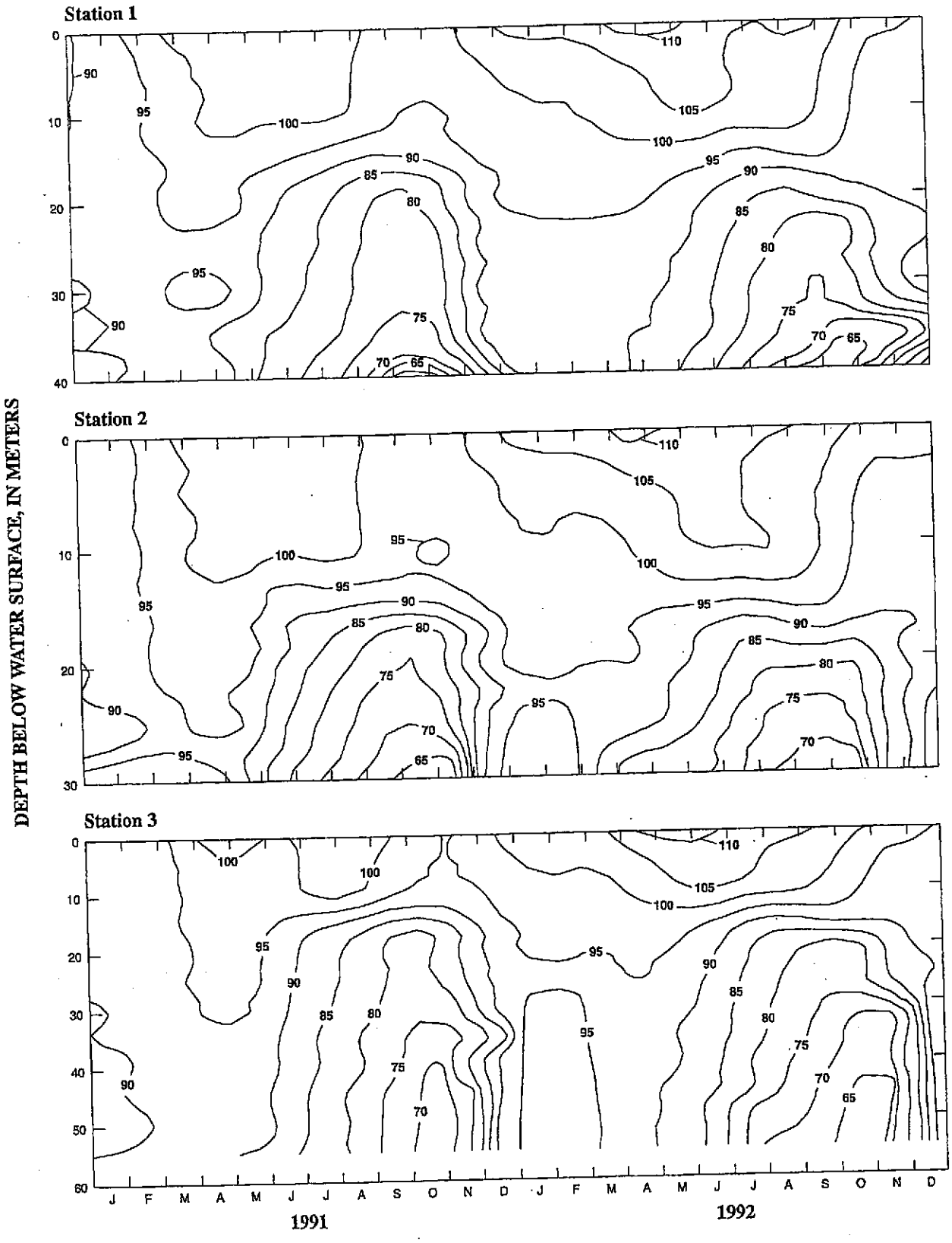


Figure 14. Lines of equal percent saturation of dissolved oxygen at stations 1–6 during 1991–92.

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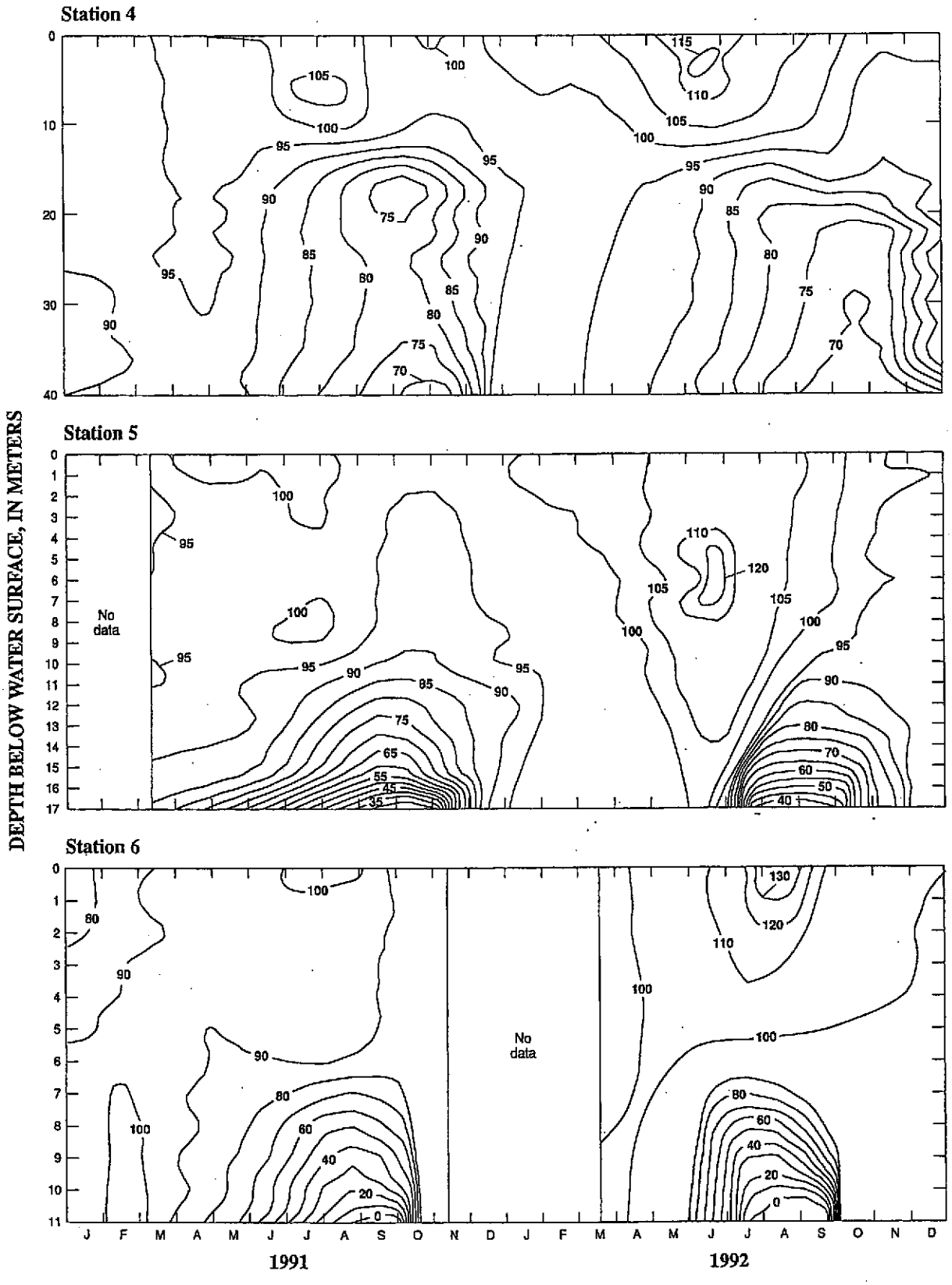


Figure 14. Lines of equal percent saturation of dissolved oxygen at stations 1–6 during 1991–92—Continued.

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Table 10. Lakewide concentrations of six trace elements in samples from the euphotic zone and lower hypolimnion, Coeur d'Alene Lake, 1991–92

[µg/L, micrograms per liter; <, less than]

Trace element	Concentration (µg/L) Range	Median	Percent of samples below detection limit	No. of samples
Arsenic, total	<1–1	<1	94.5	145
Cadmium, total recoverable	<1–2	<1	97.3	146
Copper, total recoverable	<1–15	1.6	40.0	136
Lead, total recoverable	<1–41	3.3	26.7	146
Mercury, total recoverable	<0.1–1.8	<.1	79.3	145
Zinc, total recoverable	<10–390	98.6	11.0	146

ness ranged from 16 to 28 mg/L as $CaCO_3$. Differences in concentrations in near-surface and near-bottom samples were minor. The concentrations of the cations and anions were converted to milliequivalents to determine the percentage contribution of each constituent. On the average, calcium represented 67 percent of the major cations and bicarbonate represented 82 percent of the major anions. Therefore, water in Coeur d'Alene Lake is a calcium bicarbonate type.

TRACE ELEMENTS

Six trace elements were analyzed in samples from the euphotic zone and lower hypolimnion of the six stations. Concentrations of arsenic, cadmium, and mercury were below their detection limits in at least 75 percent of the samples (table 10). Copper was above the detection limit (1 µg/L) in 80 percent of the samples and the median concentration was 1.6 µg/L. Lead was above the detection limit (1 µg/L) in about three-fourths of the samples and the median concentration was 3.3 µg/L. Zinc was above the detection limit (10 µg/L) in 89 percent of the samples and the median concentration was 98.6 µg/L. Nearly all the lead and zinc samples with concentrations below their detection limits were from station 6. Lakewide, concentrations of arsenic, cadmium, copper, and mercury in the euphotic zone were comparable to those in the lower hypolimnion. Median concentrations of lead in the euphotic zone and lower hypolimnion were 2.4 and 4.4 µg/L, respectively. Similarly, the median concentration of zinc in the euphotic zone was 81.8 µg/L and, in the lower hypolimnion, was 115.3 µg/L.

Wissmar (1972) sampled trace elements in Coeur d'Alene Lake during May 1969 to November 1970 to investigate the effects of mine drainage on primary production. Trace-element samples were collected from the euphotic zone from Spokane Point to near East Point (fig. 4). The mean and range of concentrations, in micrograms per liter, and the number of samples for Wissmar's trace-element data were as follows: copper, 100, <10 to 400, 28; cadmium, 10, <10 to 20, 18; lead, 200, <10 to 1,700, 32; and zinc, 400, <10 to 1,000, 32. Wissmar's samples were collected near the mouth of the Coeur d'Alene River and may therefore be positively biased if compared with samples collected lakewide.

The USGS sampled trace elements in the lake's lower hypolimnion at eight stations (lakewide) from May to November 1987 (Woods, 1989). Concentrations of total recoverable cadmium, lead, and zinc ranged from <1 to 1, <5 to 29, and 50 to 210 µg/L, respectively; these concentrations are comparable to those measured during the present study.

PHOSPHORUS

Phosphorus is one of several essential nutrients in the metabolism of aquatic plants. Eutrophication research has focused heavily on phosphorus because it is the nutrient typically found to have the smallest supply-to-demand ratio for aquatic plant growth (Ryding and Rast, 1989).

Phosphorus concentrations for this study are reported as total phosphorus and dissolved orthophosphorus. Total phosphorus represents the phosphorus in solution and contained in or attached to biotic and abiotic particulate material. Dissolved orthophosphorus is determined from the filtrate that passes through a filter with a nominal pore size of 0.45 µm. The orthophosphate ion, PO_4^{3-}, is the most important form of phosphorus because it is directly available for metabolic use by aquatic plants.

Total phosphorus concentrations at the six stations ranged from <1 to 192 µg/L during 1991 and from <1 to 25 µg/L during 1992 (table 11). Dissolved orthophosphorus concentrations ranged from <1 to 100 µg/L during 1991 and from <1 to 8 µg/L during 1992 (table 11). Mean concentrations of the two constituents in the euphotic zone (fig. 15) and lower hypolimnion (fig. 16) from stations 5 and 6 were higher than those from stations 1 through 4 during both years. Lakewide, concentrations of the two constituents were slightly less in the euphotic zone than in the lower hypolimnion.

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Table 11. Means and ranges of concentrations of total phosphorus and dissolved orthophosphorus in samples from the euphotic zone and lower hypolimnion at six limnetic stations and lakewide, Coeur d'Alene Lake, 1991–92

[µg/L, micrograms per liter; n, number of samples; <, less than]

Limnetic station (fig. 4)	Total phosphorus (µg/L)						Dissolved orthophosphorus (µg/L)					
	Euphotic zone			Lower hypolimnion			Euphotic zone			Lower hypolimnion		
	Mean[1]	Range	n	Mean[1]	Range	n	Mean[1]	Range	n	Mean[1]	Range	n
						1991						
1	5.2	1–16	13	4.9	<1–12	13	1	<1–1	13	2	<1–5	12
2	4.4	2–10	13	4.9	<1–8	12	1.2	<1–3	13	1.6	<1–4	12
3	4.6	1–6	13	4.8	2–6	13	1	<1–2	12	1.3	<1–3	13
4	5.6	<1–9	13	6.2	3–10	13	1.2	<1–2	13	1.5	<1–3	13
5	8.8	4–17	12	10.1	<1–21	12	2.3	<1–7	11	2.3	<1–7	12
6	14.2	7–41	12	42.1	12–192	8	2.7	<1–11	12	13.6	<1–100	9
Lakewide	6.5	1–41	76	8.1	<1–192	71	1.4	<1–11	74	2.4	<1–100	71
						1992						
1	2.4	<1–6	13	2.5	<1–4	13	1	<1–1	13	1.1	<1–2	12
2	3.8	<1–10	12	4.8	<1–25	13	1.1	<1–2	12	1.6	<1–8	13
3	2.9	<1–13	13	2.8	<1–8	13	1.4	<1–6	13	1.1	<1–2	13
4	4.2	<1–8	13	3.7	<1–8	13	1	<1–1	12	1.4	<1–4	13
5	5.0	<1–13	12	5.8	<1–15	12	1.4	<1–5	12	1.9	<1–7	12
6	5.2	<1–8	9	10.0	7–17	8	1	<1–3	9	2.1	<1–4	8
Lakewide	3.7	<1–13	72	3.8	<1–25	72	1.2	<1–6	71	1.3	<1–8	71

[1]Mean computed by assigning detection limit value to less-than values.

Mean concentrations of dissolved orthophosphorus during 1991 and 1992 were similar, differing by 0.2 µg/L. However, the mean concentration of total phosphorus in 1992 was much lower than in 1991 and may reflect a reduced influx of phosphorus-bearing suspended sediment as a consequence of below-normal streamflow in 1992.

Maximum concentrations of total phosphorus and dissolved orthophosphorus were measured in the lower hypolimnion during September 1991 at station 6 (fig. 16), where the lower hypolimnion was anoxic periodically during both years. Under anoxic conditions, constituents such as phosphorus, ammonia, iron, and manganese in the lakebed sediments are redissolved and released into the hypolimnion (Stumm and Morgan, 1970).

Uptake of orthophosphorus by phytoplankton during the summer growing season often is revealed by distinct declines in dissolved orthophosphorus and concomitant increases in total phosphorus as dissolved phosphorus is converted to particulate phosphorus within the phytoplankton population. On the basis of temporal patterns illustrated in figure 15, increases in total phosphorus were not correlated with declines in dissolved orthophosphorus. The conversion of dissolved orthophosphorus to total phosphorus in Coeur d'Alene Lake was masked because concentrations of dissolved orthophosphorus were frequently at or below the detection limit of 1 µg/L.

During 1975, phosphorus data were collected by the National Eutrophication Survey (U.S. Environmental Protection Agency, 1977). During April, July, and September 1975, the reported lakewide mean concentration of total phosphorus in the upper water column was 22.1 µg/L and the range was 8 to 53 µg/L; in the hypolimnion, the mean was 29.8 µg/L and the range was 10 to 108 µg/L. The mean concentration of dissolved orthophosphorus in the upper water column was 5.5 µg/L and the range was 1 to 12 µg/L; in the hypolimnion, the mean was 7.5 µg/L and the range was 1 to 20 µg/L. Mean concentrations measured during the National Eutrophication Survey were substantially higher than those measured during this study and did not include samples from the vicinity of station 6, where mean concentrations were highest during this study.

NITROGEN

Nitrogen, like phosphorus, is essential to aquatic biota. Nitrogen's supply-to-demand ratio is small; thus, nitrogen may limit the growth of aquatic plants as

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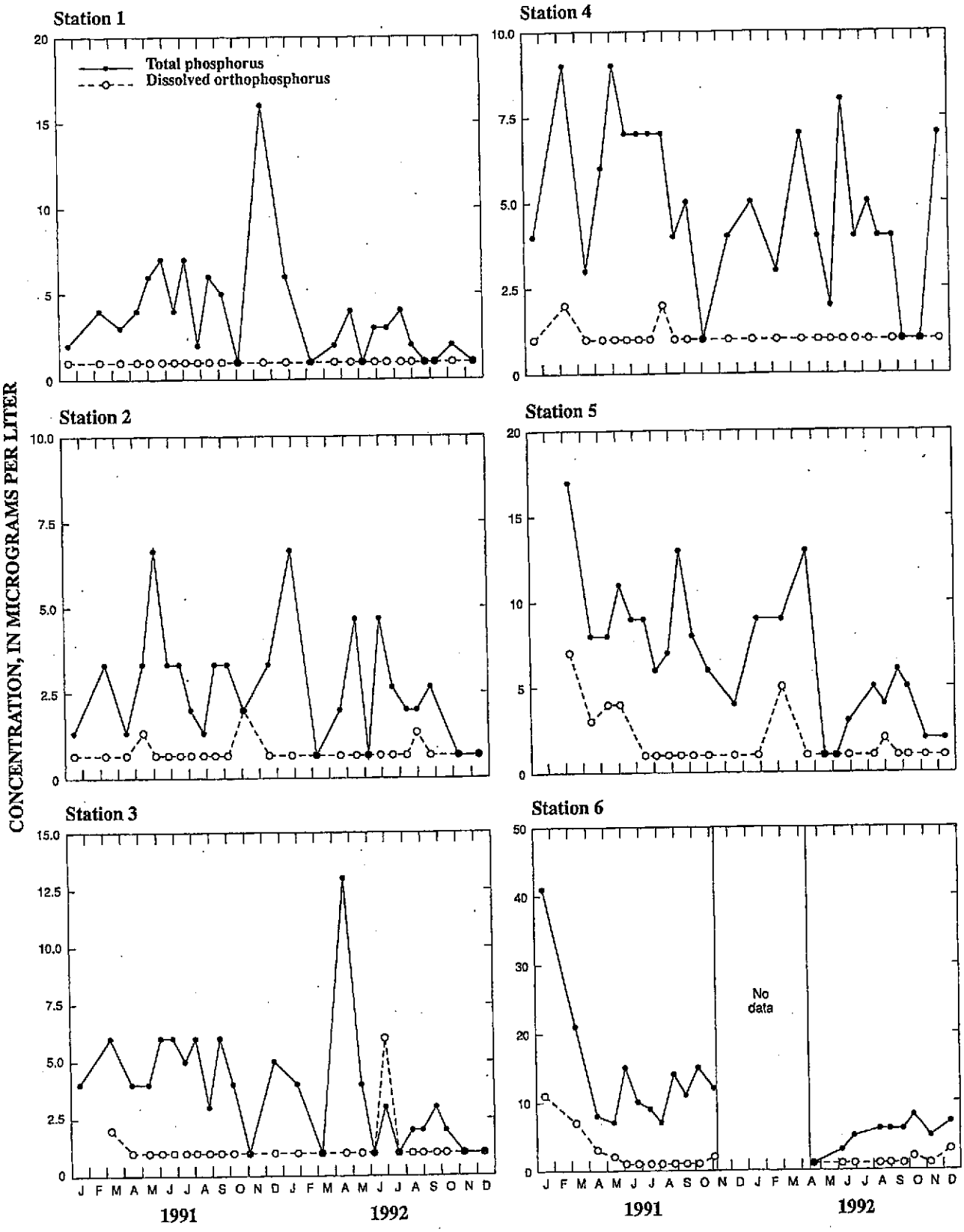


Figure 15. Concentrations of total phosphorus and dissolved orthophosphorus within the euphotic zone of stations 1–6 during 1991–92. (Values less than detection limit represented at detection limit value)

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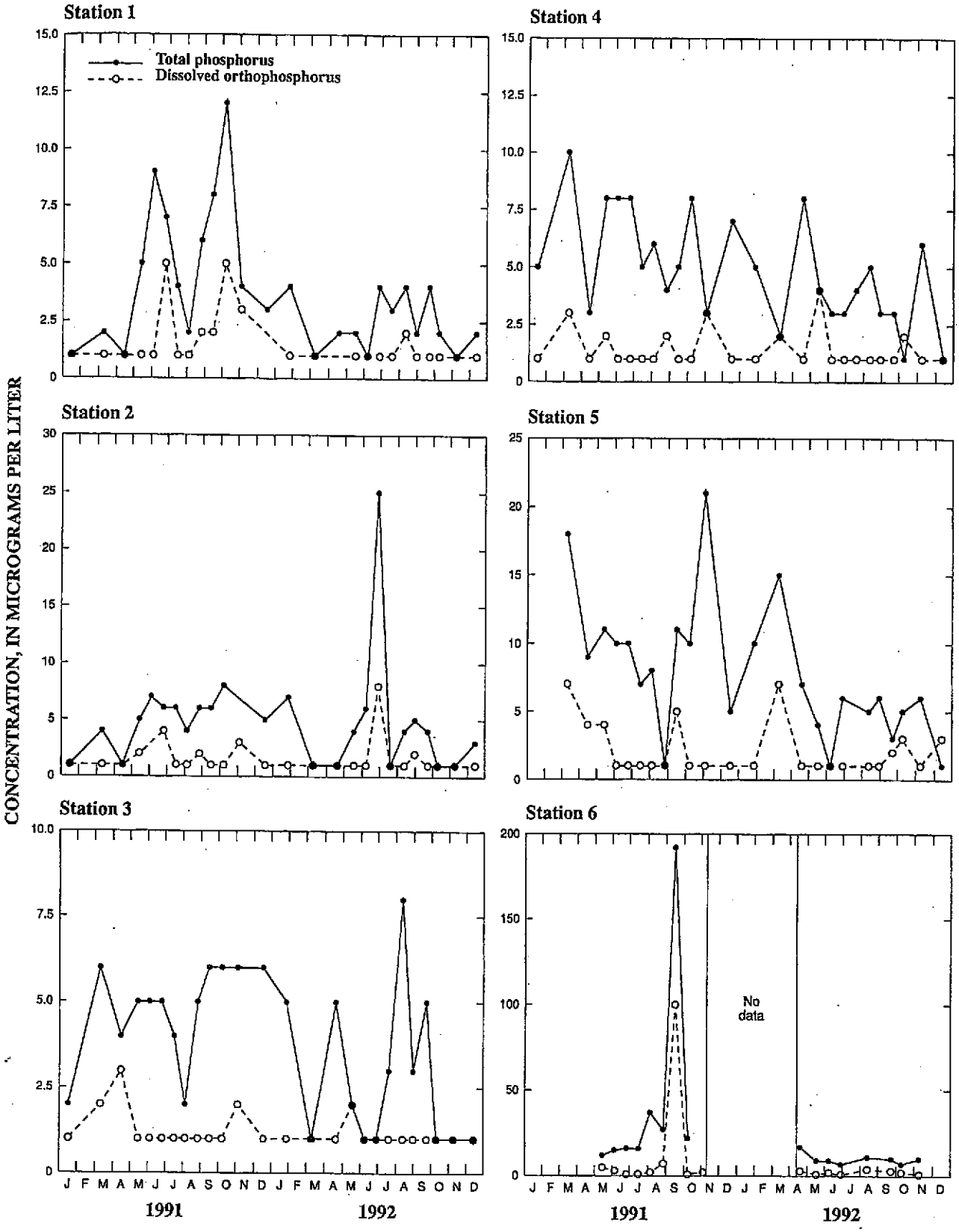


Figure 16. Concentrations of total phosphorus and dissolved orthophosphorus in the lower hypolimnion at stations 1–6 during 1991–92. (Values less than detection limit represented at detection limit value)

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phosphorus does. The cycle of nitrogen in aquatic ecosystems is complex because most processes involving nitrogen are biologically mediated. In aquatic ecosystems, nitrogen commonly exists in the following forms: dissolved molecular nitrogen (N_2), nitrogen-containing organic compounds, ammonia (NH_3), ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-).

Nitrogen concentrations for this study are reported as total ammonia plus organic nitrogen (commonly called kjeldahl nitrogen), dissolved ammonia, and dissolved nitrite plus nitrate. Total ammonia plus organic nitrogen represents the ammonia, ammonium, and organic nitrogen compounds in solution and associated with biotic and abiotic particulate material. The dissolved concentrations represent the ammonia (includes ammonium) or nitrite plus nitrate in filtrate that passes through a 0.45-µm filter. The following discussion is for total nitrogen (the sum of total ammonia plus organic nitrogen and dissolved nitrite plus nitrate as nitrogen) and dissolved inorganic nitrogen (the sum of dissolved ammonia and dissolved nitrite plus nitrate as nitrogen).

Total nitrogen concentrations in 1991 ranged from <205 to 902 µg/L; in 1992, the range was smaller, <205 to 607 µg/L (table 12 and figs. 17 and 18). Dissolved inorganic nitrogen concentrations ranged from <7 to 332 µg/L in 1991 and from <6 to 153 µg/L in 1992. The maximum concentration of total nitrogen was from a lower hypolimnion sample measured at station 3 in May 1991. The maximum concentration of dissolved inorganic nitrogen was from a lower hypolimnion sample measured at station 6 in September 1991 during a period of anoxia. Lakewide mean concentrations of these two constituents were lower in 1992 than in 1991 (table 12). In general, lower hypolimnion concentrations of total nitrogen were slightly higher than those in the euphotic zone. This differenc was more pronounced for dissolved inorganic nitroge the difference was about two to three times higher in most of the comparisons. Increased dissolved inorgani nitrogen concentrations in lower hypolimnion sample reflect, in part, the process of nitrification, during which organic and ammonia nitrogen is converted int nitrite and then nitrate under aerobic conditions. Dissolved inorganic nitrogen concentrations in the euphotic zone were generally lowest during the summe and indicate phytoplanktonic uptake of that nutrient. Concomitant increases in total nitrogen, associated with phytoplankton, were not evident, however.

The National Eutrophication Survey (U.S. Envi ronmental Protection Agency, 1977) was a source of comparative data for nitrogen. The reported lakewide mean concentration of total nitrogen in the upp water column was 309 µg/L and the range was 220 t

Table 12. Means and ranges of concentrations of total nitrogen and dissolved inorganic nitrogen in samples from the eupho zone and lower hypolimnion at six limnetic stations and lakewide, Coeur d'Alene Lake, 1991–92

[µg/L, micrograms per liter; n, number of samples; <, less than; LW, lakewide]

Limnetic station (fig. 4)	Total nitrogen (µg/L)						Dissolved inorganic nitrogen (µg/L)				
	Euphotic zone			Lower hypolimnion			Euphotic zone			Lower hypolimnion	
	Mean[1]	Range	n	Mean[1]	Range	n	Mean[1]	Range	n	Mean[1]	Range
					1991						
1	289	<205–427	13	349	244–631	11	38.3	<7–161	13	102	43–141
2	267	<205–409	13	309	229–481	13	32.8	<7–101	13	87.2	35–229
3	292	<205–616	13	375	249–902	13	42.2	9–117	13	94.4	30–137
4	309	<205–805	13	337	241–887	13	43.3	<7–104	13	102	43–131
5	329	<205–808	12	279	<205–459	12	36.6	11–117	12	54.8	14–137
6	365	<205–821	12	402	<205–833	8	45.8	8–234	12	84.6	<7–332
LW	307	<205–821	76	290	<205–902	70	41.9	<7–234	76	70.8	<7–332
					1992						
1	211	<205–221	13	265	222–340	13	19.7	<7–58	13	74.6	28–144
2	212	<205–239	12	240	<205–281	13	20.4	<7–47	12	48.7	<6–86
3	216	<205–257	13	274	224–316	13	23.2	<7–66	13	84.9	27–123
4	220	<205–270	13	273	<205–333	13	27.9	9–76	13	81.7	19–141
5	219	<205–287	12	238	<205–334	12	28.0	<7–98	12	50.2	16–153
6	206	<205–216	9	258	<205–607	8	15.0	<7–31	9	21.8	<7–48
LW	216	<205–287	72	256	<205–607	72	23.8	<7–98	72	56.7	<6–153

[1]Mean computed by assigning detection limit value to less-than values.

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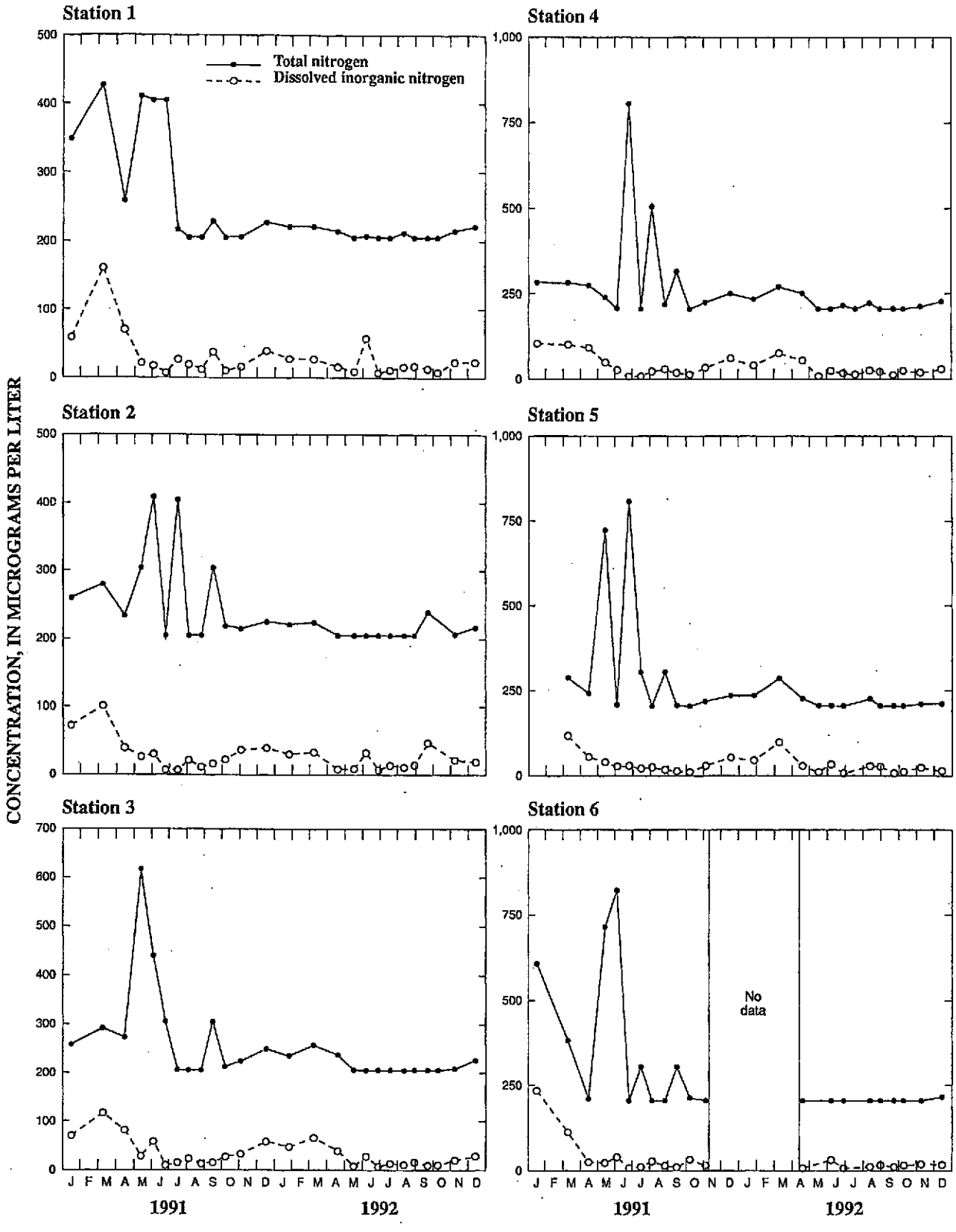


Figure 17. Concentrations of total nitrogen and dissolved inorganic nitrogen within the euphotic zone of stations 1–6 during 1991–92. (Values less than detection limit represented at detection limit value)

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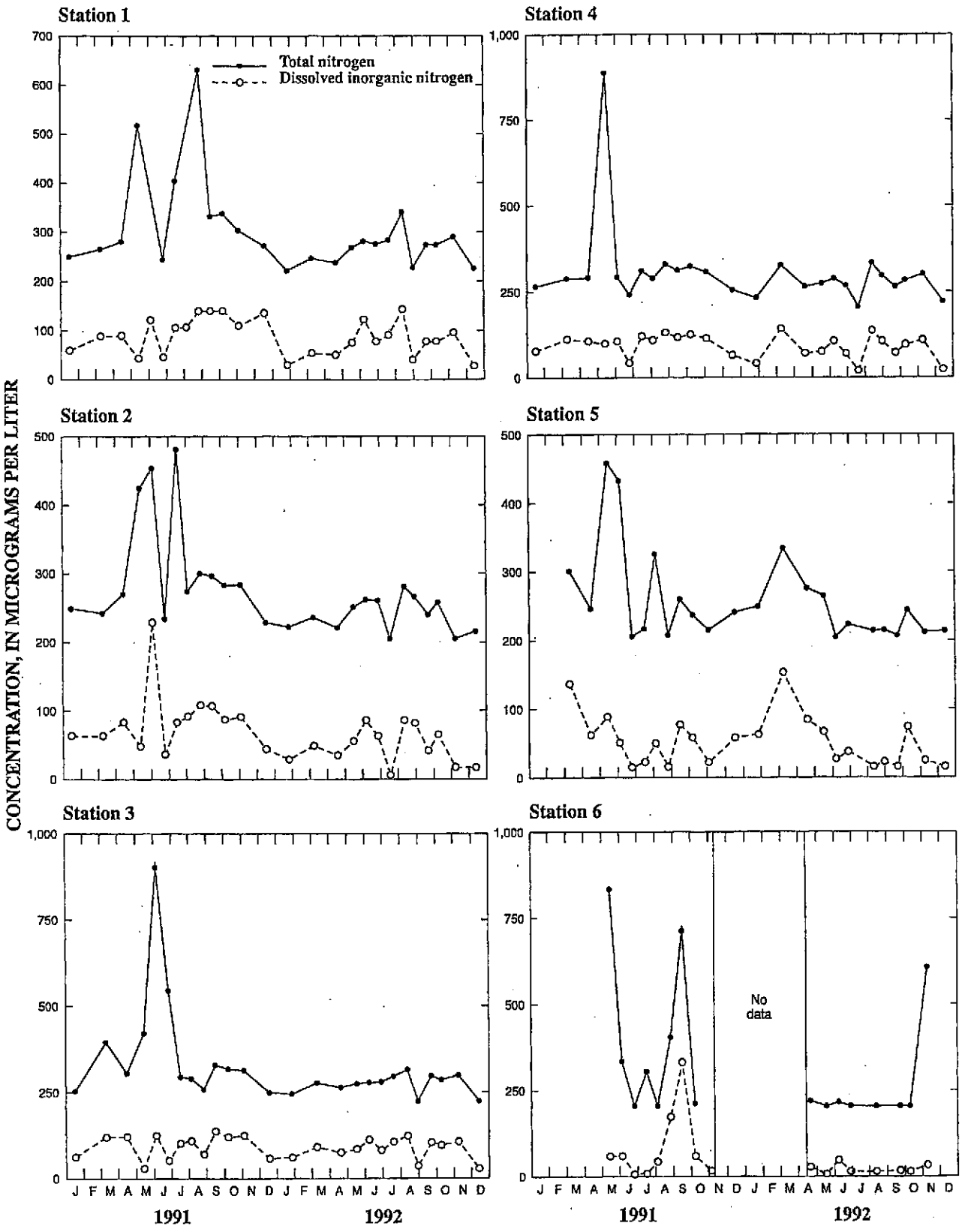


Figure 18. Concentrations of total nitrogen and dissolved inorganic nitrogen in the lower hypolimnion at stations 1–6 during 1991–92. (Values less than detection limit represented at detection limit value)

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660 µg/L; in lower hypolimnion samples, the mean was 335 µg/L and the range was 225 to 730 µg/L. The mean concentration of dissolved inorganic nitrogen in the upper water column was 72 µg/L and the range was 20 to 360 µg/L; in lower hypolimnion samples, the mean was 105 µg/L and the range was 25 to 430 µg/L. Total nitrogen concentrations measured during the 1975 National Eutrophication Survey were slightly higher than those measured during this study. Mean dissolved inorganic nitrogen concentrations measured during 1975 exceeded those measured during this study by a factor of 2 to 3 for upper water-column samples and a factor of 1.5 to 2 for lower hypolimnion samples.

LIMITING NUTRIENT

The limiting nutrient concept of Liebig (Welch, 1980) states that the ultimate yield of a crop will be limited by the essential nutrient that is most scarce relative to the specific needs of the crop. This concept, in concert with the stoichiometry of the photosynthesis equation, led to formulation of nitrogen-to-phosphorus ratios (N:P). These ratios have been used extensively in eutrophication studies to determine whether nitrogen or phosphorus was the nutrient most likely to limit phytoplankton growth. The atomic ratio of nitrogen to phosphorus, 16N:1P, in the photosynthesis equation corresponds to a mass ratio of 7.2N:1P. Typically, N:P values are calculated using the biologically available forms of these two nutrients. If N:P (by weight) is less than 7.2, then nitrogen may be limiting, whereas if N:P exceeds 7.2, then phosphorus may be limiting (Ryding and Rast, 1989).

The mean N:P values in table 13 indicate a strong tendency toward phosphorus limitation of phytoplankton growth in Coeur d'Alene Lake. Except for the instance of an N:P of 1 at station 3 in 1992, the minimum N:P values at all stations were at or above the phosphorus-limitation threshold of 7.2. The lowest mean N:P in both years was at station 6, whereas the highest mean N:P in both years was at station 4. The mean N:P values in 1992 were lower than in 1991, except at station 5, where they were nearly equal. The difference in values between the 2 years resulted from the lower concentrations of dissolved inorganic nitrogen that were measured in 1992; dissolved orthophosphorus concentrations during these 2 years were nearly equal (tables 11 and 12).

Table 13. Means and ranges of ratios of dissolved inorganic nitrogen to dissolved orthophosphorus in samples from the euphotic zone at six limnetic stations and lakewide, Coeur d'Alene Lake, 1991–92

[LW, area-weighted lakewide value]

Limnetic station (fig. 4)	Ratio		No. of samples
	Mean	Range	
	1991		
1	38.3	7–161	13
2	30	7–101	13
3	35	9–81	12
4	38.3	7–104	13
5	20.3	7–54	11
6	17.1	8–39	12
LW	34.4	7–161	74
	1992		
1	19.7	7–58	13
2	19.8	7–47	12
3	22.8	1–66	13
4	28.5	9–76	12
5	20.4	7–45	12
6	12.8	6–31	9
LW	22.7	1–76	71

CHLOROPHYLL-*a*

Chlorophyll-*a* is the primary photosynthetic pigment of phytoplankton and, as such, is used as an estimator of phytoplanktonic biomass. Chlorophyll-*a* concentrations in Coeur d'Alene Lake during 1991–92 ranged from <0.1 to 2.6 µg/L; the highest concentrations were measured at station 6 in both years (table 14). Within each year, the highest concentrations were measured during March-April, August, or November (fig. 19). The mean concentration at each station was slightly higher in 1992; this increase may be attributable to the substantial reduction in 1992 inflows, which yielded a longer-than-normal water residence time for the lake in 1992. The increased residence time may have reduced flushing of phytoplankton out the lake's outlet and also allowed more time for phytoplankton populations to develop prior to being flushed.

Two studies of Coeur d'Alene Lake conducted in the 1970's provided comparative chlorophyll-*a* data. The chlorophyll-*a* data collected as part of the National Eutrophication Survey (U.S. Environmental Protection Agency, 1977) were obtained at eight stations during April, July, and September 1975. The April samples contained higher chlorophyll-*a* concentrations than did

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Table 14. Means and ranges of chlorophyll-*a* concentrations in samples from the euphotic zone at six limnetic stations and lakewide, Coeur d'Alene Lake, 1991–92

[µg/L, micrograms per liter; <, less than; LW, area-weighted lakewide value]

Limnetic station (fig. 4)	Chlorophyll-*a* (µg/L)		No. of samples
	Mean[1]	Range	
	1991		
1	0.5	0.1–1	13
2	.5	.2–1.1	13
3	.4	.3–1	13
4	.5	<.1–1	13
5	.6	.3–1.4	12
6	.8	.1–2	11
LW	.5	<.1–2	75
	1992		
1	.6	<.1–1.3	12
2	.8	.4–1.4	11
3	.7	.2–1.2	13
4	.7	.2–1.5	13
5	.9	.2–1.7	13
6	1.1	.1–2.6	11
LW	.8	<.1–2.6	73

[1]Mean computed by assigning detection limit to less-than values.

samples collected during the other months. In April, the lakewide mean concentration was 17.3 µg/L and the range was 1.9 to 32.1 µg/L; in July and September, the means were 3.3 and 11.4 µg/L and the ranges were 2.3 to 4.2 and 4.1 to 29.3 µg/L, respectively. Rieman (1980) determined chlorophyll-*a* from composite samples of the upper 12 m of the water column at three stations on Coeur d'Alene Lake during April to November 1979. The overall range in the 33 samples was 1 to 22 µg/L and the lakewide mean concentration was 4.0 µg/L.

The two studies conducted in the 1970's reported a substantially wider range in chlorophyll-*a* concentrations than did this study. Part of this difference may be methodological. The USGS National Water Quality Laboratory used high-performance liquid chromatography to determine chlorophyll-*a* in samples collected during 1991–92. The National Eutrophication Survey used fluorometric procedures to determine chlorophyll-*a* in the 1975 samples (U.S. Environmental Protection Agency, 1975). Rieman's samples were analyzed using the spectrophotometric method (U.S. Environmental Protection Agency, 1973).

Regardless of methodological differences among the three studies, chlorophyll-*a* concentrations in Coeur d'Alene Lake declined substantially from the 1970's to the early 1990's. The substantially lower concentrations measured during this study were corroborated recently by chlorophyll-*a* analyses conducted by personnel at the Coeur d'Alene wastewater-treatment plant (H. Sid Fredrickson, City of Coeur d'Alene, written commun., 1993). Fredrickson's samples were collected approximately 0.2 km downstream from the outlet of Coeur d'Alene Lake. Chlorophyll-*a* concentrations in the five samples collected in May, June, August, and September 1993 were <1 µg/L, on the basis of spectrophotometric methods.

PHYTOPLANKTON

The taxonomic composition of phytoplankton at the six limnetic stations in Coeur d'Alene Lake comprised 65 genera during 1991–92 (table 15). The following six phyla were represented: Chlorophyta, or green algae; Chrysophyta, or yellow-brown algae; Cryptophyta, or cryptomonads; Cyanophyta, or blue-green algae; Euglenophyta, or euglenoids; and Pyrrhophyta, or dinoflagellates.

The lakewide median density and biovolume of phytoplankton was 400 cells/mL and 174,000 µm^3/mL, respectively (table 16). The lakewide range in density and biovolume for the 151 samples was 28 to 7,100 cells/mL and 6,100 to 1,500,000 µm^3/mL, respectively. The maximum density was at station 6 in November 1992, whereas the maximum biovolume was at station 2 in May 1991. The dominant algal genera, based on density, were *Asterionella* and *Synedra* at stations 1 through 5 and *Cyclotella* at station 6. These three genera are members of subphylum Bacillariophyceae, or diatoms, of the phylum Chrysophyta. The Cyanophyta were incidental or absent at stations 1 through 5. At station 6, the Cyanophyta constituted at least 10 percent of the phytoplankton density during the summer months of 1991 and 1992. The blue-green alga, *Anabaena flos-aquae*, numerically dominated the phytoplankton at station 6 during June and July 1992.

Two studies conducted in the 1970's provided comparative data on the presence of Cyanophyta in Coeur d'Alene Lake. Parker (1972) sampled phytoplankton from 12 stations (lakewide) during July to November 1971. He determined that, on the basis of density, the Cyanophyta composed 10 percent of the phytoplankton population and were dominant in August at one-half of the stations. *Aphanizomenon* was most frequently observed; *Nostoc* and *Anabaena* were

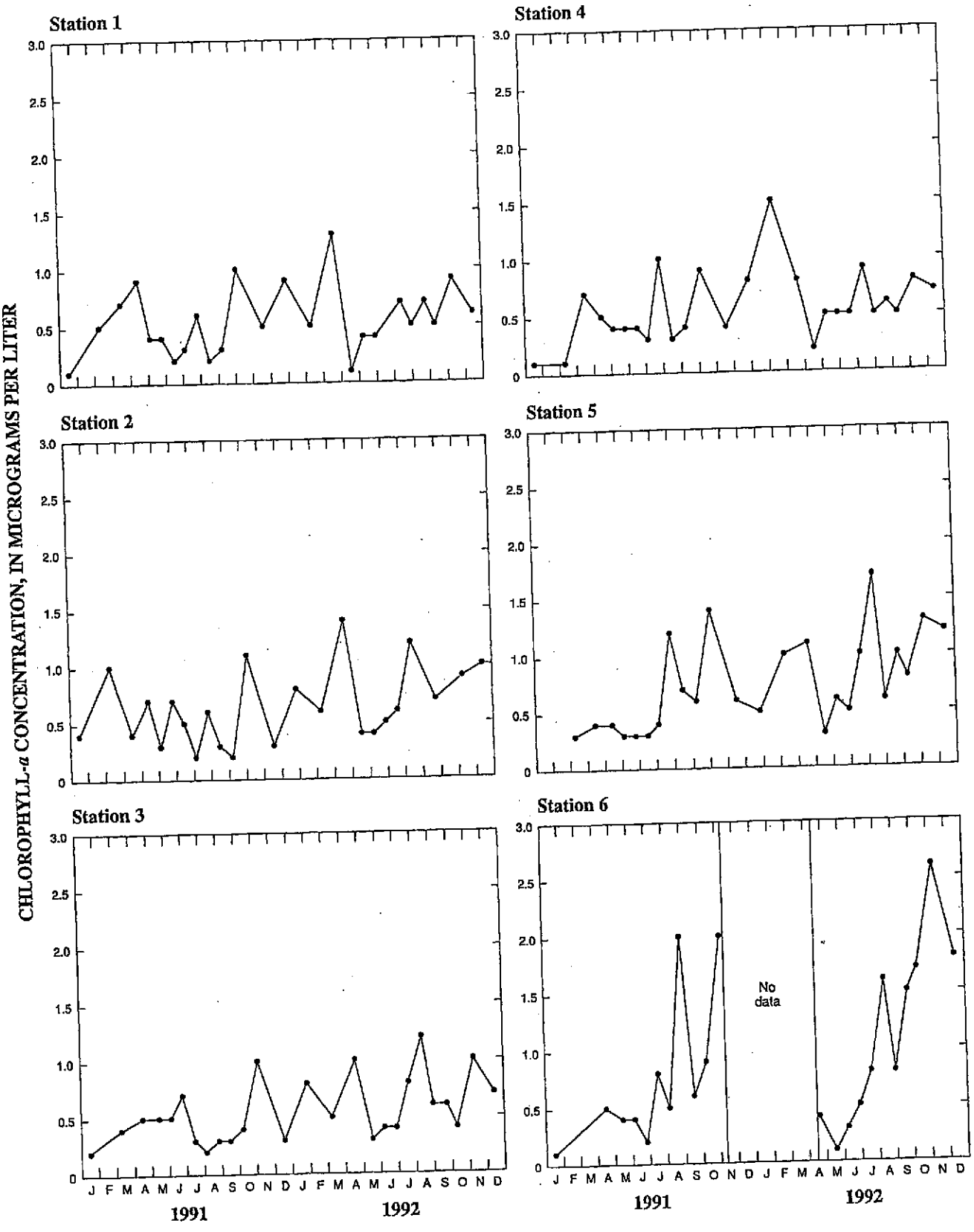


Figure 19. Chlorophyll-*a* concentrations at stations 1–6 during 1991–92. (Values less than detection limit represented at detection limit value)

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Table 15. Phytoplankton taxa at six limnetic stations, Coeur d'Alene Lake, 1991–92

Phytoplankton taxa[1]
Phylum Chlorophyta
Subphylum Chlorophyceae
Order Chlorococcales
Family Chlorococcaceae
Tetraedron sp. (6)
Family Coccomyxaceae
Elakatothrix gelatinosa (1,2,3,4,5,6)
Family Dictyosphaeriaceae
Botryococcus braunii (1,2,3,4)
Family Hydrodictyaceae
Pediastrum boryanum (5,6)
P. duplex (5,6)
Family Oocystaceae
Ankistrodesmus falcatus (1,2,3,4,5,6)
Chodatella wratislawiensis (3,4)
Nephrocytium sp. (1,2,3,4,6)
Oocystis lacustris (1,2,4,5,6)
O. pusilla (1,2,3,4,5,6)
Quadrigula closterioides (4,6)
Selenastrum minutum (1,3,4,5,6)
Family Palmellaceae
Sphaerocystis schroeteri (1,2,3,4,5)
Family Scenedesmaceae
Crucigenia quadrata (6)
C. tetrapedia (1)
Scenedesmus denticulatus (1,3,4,5)
S. quadricauda (1,3,4,5,6)
Tetrastrum staurogeniaeforme (6)
Order Tetrasporales
Family Gloeocystaceae
Gloeocystis sp. (1,2,3,4,5,6)
Order Ulotrichales
Family Ulotrichaceae
Ulothrix sp. (3,5)
Order Volvocales
Family Chlamydomonadaceae
Chlamydomonas (1,2,3,4,5,6)
Order Zygnematales
Family Desmidiaceae
Cosmarium sp. (6)
Staurastrum sp. (4)
S. gracile (4,5)
Family Zygnemataceae
Mougeotia sp. (2,3,4,5)
Phylum Chrysophyta
Subphylum Bacillariophyceae
Order Centrales
Family Coscinodiscaceae
Cyclotella sp. (2)
C. atomus (1,4,5,6)
C. kutzingiana (3,5,6)
C. meneghiniana (4,5,6)
C. stelligera (1,2,3,4,5,6)
Melosira sp. (3,6)
M. ambigua (2,5,6)
M. distans (1,2,3,4,5,6)
M. granulata (4,5,6)
M. granulata var. *angustissima* (4,5,6)
M. italica (1,2,3,4,5,6)
M. varians (2)
Family Coscinodiscaceae (Continued)
Stephanodiscus astraea (5,6)
S. astraea var. *minutula* (1,2,3,4,5)
S. hantzschii (1,2,3,4,5)
S. subsalsus (6)
Family Rhizosoleniaceae
Rhizosolenia eriensis (1,2,3,4,5)
Order Pennales
Family Achnanthaceae
Achnanthes sp. (6)
A. clevei (5,6)
A. exigua (5,6)
A. hauckiana (5)
A. lanceolata (1,2,3,4,5,6)
A. lewisiana (2,3,5,6)
A. linearis (2,4,5,6)
A. marginulata (6)
A. microcephala (2)
A. minutissima (1,2,3,4,5,6)
A. peragalli (6)
Cocconeis placentula (2,4,5,6)
Rhoicosphenia curvata (5,6)
Family Cymbellaceae
Amphora ovalis (5,6)
A. perpusilla (5,6)
Cymbella affinis (6)
C. lunata (6)
C. microcephala (4)
C. minuta (1,2,3,4,5,6)
C. sinuta (4,5,6)
C. tumida (6)
Family Epithemiaceae
Epithemia sorex (5,6)
E. turgida (1,6)
Rhopalodia gibba (6)
Family Eunotiaceae
Eunotia pectinalis (2,4,6)
Family Fragilariaceae
Asterionella formosa (1,2,3,4,5,6)
Diatoma hiemale var. *mesodon* (5,6)
Fragilaria sp. (1,5)
F. brevistriata (1,2,5,6)
F. capucina (2,5)
F. capucina var. *mesolepta* (5,6)
F. construens (1,2,4,5,6)
F. construens var. *venter* (1,2,3,4,5,6)
F. crotonensis (1,2,3,4,5,6)
F. leptostauron (4,6)
F. pinnata (1,2,3,5,6)
F. vaucheriae (1,2,3,4,5,6)
Hannaea arcus (1,2,3,5,6)
Meridion circulare (2,3,5)
Synedra sp. (1,2,3,4)
S. delicatissima (3)
S. mazamaensis (5)
S. parasitica (5)
S. radians (1,2,3,4,5)
S. rumpens (1,2,3,4,5)
S. socia (1,2,3,4,5)
S. ulna (2,5)

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Table 15. Phytoplankton taxa at six limnetic stations, Coeur d'Alene Lake, 1991–92—Continued

Phytoplankton taxa[1]
Family Fragilariacea (Continued)
Tabellaria fenestrata (1,2,3,4,5,6)
T. flocculosa (1,2,3,4,5)
Family Gomphonemaceae
Gomphonema sp. (3,5,6)
G. acuminatum (6)
G. angustatum (1,2,3,4,5,6)
G. clevei (5,6)
G. gracile (6)
G. olivaceum (5,6)
G. subclavatum (4,5,6)
G. tenellum (3,5,6)
G. ventricosum (6)
Family Naviculaceae
Caloneis sp. (2,5,6)
C. placentula (6)
C. ventricosa var. *minuta* (6)
Diploneis elliptica (4,5,6)
D. puella (5)
D. smithii (6)
Navicula sp. (1,2,3,4,5,6)
N. anglica (6)
N. capitata (5,6)
N. cascadensis (6)
N. contenta var. *biceps* (6)
N. cryptocephala (2,4,5,6)
N. cryptocephala var. *veneta* (5,6)
N. decussis (3,5,6)
N. graciloides (6)
N. gregaria (5)
N. minima (1,2,3,4,5,6)
N. minuscula (5)
N. mournei (3)
N. mutica (3,5)
N. pelliculosa (2)
N. pseudoscutiformis (5,6)
N. pupula (1,2,3,4,5,6)
N. radiosa (6)
N. rhynchocephala (4,5,6)
N. scutiformis (6)
N. seminulum (6)
Neidium sp. (4,6)
Pinnularia sp. (1,2,3,5,6)
Stauroneis sp. (2)
Family Nitzschiaceae
Nitzschia sp. (1,2,4,5,6)
N. acicularis (1,2,3,4,5,6)
N. amphibia (6)
N. capitellata (2,6)
N. communis (5)
N. dissipata (4,5,6)
N. epiphytica (1)
N. fonticola (1,2,3)
N. frustulum (3,4,5,6)
N. linearis (3)
N. palea (3,5,6)
N. paleacea (1,2,4,5,6)
Subphylum Chrysophyceae
Order Chromulinales
Family Chromulinaceae
Chromulina sp. (1,2,3,4,6)
Kephyrion sp. (1,2,3,4,6)
K. obliquum (1,2,3,4)
K. spirale (4)
Family Chrysococcaceae
Chrysococcus rufescens (1,2,3,4,5,6)
Family Pedinellaceae
Pseudopedinella sp. (1,2,4,5)
Order Ochromonadales
Family Dinobryaceae
Dinobryon sp. (1,2,4,5,6)
D. bavaricum (1,2,3,4)
D. sertularia (1,2,3,4,5,6)
Family Ochromonadaceae
Ochromonas sp. (3,6)
Family Synuraceae
Mallomonas sp. (1,2,3,4,5,6)
Order Prymnesiales
Family Prymnesiaceae
Chrysochromulina sp. (1,2,3,4,6)
Phylum Cryptophyta
Family Cryptochrysidaceae
Rhodomonas minuta (1,2,3,4,5,6)
Family Cryptomonadaceae
Cryptomonas sp. (1,2,3,4,6)
C. erosa (1,2,3,4,5,6)
Phylum Cyanophyta
Order Chroococcales
Family Chroococcaceae
Anacystis sp. (6)
Chroococcus sp. (3,4,5,6)
Order Nostocales
Family Nostocaceae
Anabaena sp. (5)
A. circinalis (5,6)
A. flos-aquae (1,5,6)
A. planctonica (5,6)
Aphanizomenon flos-aquae (6)
Phylum Euglenophyta
Order Euglenales
Family Euglenaceae
Trachelomonas sp. (5,6)
T. hispida (5,6)
T. pulchella (6)
T. robusta (5,6)
T. volvocina (4,5,6)
Phylum Pyrrhophyta
Class Dinophyceae
Order Dinokontae
Family Ceratiaceae
Ceratium hirundinella (6)
Family Glenodiniaceae
Glenodinium sp. (1)

[1] Taxonomy based on Prescott (1970).

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Table 16. Median density and biovolume of phytoplankton at six limnetic stations and lakewide, Coeur d'Alene Lake, 1991–92

[cells/mL, cells per milliliter; $\mu m^3/mL$, cubic micrometers per milliliter; LW, lakewide]

Limnetic station (fig. 4)	Density (cells/mL)	Biovolume ($\mu m^3/mL$)	No. of samples
1	490	172,000	26
2	450	220,000	25
3	370	172,000	26
4	450	221,000	26
5	440	238,000	25
6	210	150,000	23
LW	400	174,000	151

rarely observed. The National Eutrophication Survey of Coeur d'Alene Lake (U.S. Environmental Protection Agency, 1977) reported a range of phytoplankton density of 1,250 cells/mL in September to 10,651 cells/mL in April 1975 but provided no information on the spatial distribution of the phytoplankton genera. During July, *Aphanizomenon* and *Anabaena* composed 18 and 15 percent, respectively, of the phytoplankton population. During September, *Aphanizomenon* codominated with the diatom *Tabellaria* at 37.7 percent each. On the basis of this study and the two conducted in the 1970's, the presence of Cyanophyta in Coeur d'Alene Lake has declined substantially since the 1970's.

TROPHIC STATE

The term "trophic state" refers to the biological productivity of a water body. For ease of categorization, three trophic states commonly are defined: oligotrophic, or low productivity; eutrophic, or high productivity; and mesotrophic, a middle ground between oligotrophic and eutrophic. Numerous variables have been employed as the basis for trophic-state classification. Although no classification system is universally accepted, variables such as total phosphorus, total nitrogen, chlorophyll-*a*, and secchi-disc transparency frequently have been used to classify trophic state.

A system developed by the United Nation's Organization for Economic Cooperation and Development (Ryding and Rast, 1989) was used to classify the trophic state of Coeur d'Alene Lake. Total phosphorus, total nitrogen, chlorophyll-*a*, and secchi-disc transparency (table 17) were analyzed statistically and an open-boundary trophic-state classification system was developed. This approach compensates for the overlap in classification that commonly occurs with fixed-boundary systems. Under the open-boundary system, a water body is considered to be classified correctly if three of the four variables are within two standard deviations of their geometric mean for the same trophic state.

Annual geometric mean values for total phosphorus, total nitrogen, chlorophyll-*a*, and secchi-disc transparency during 1991–92 were computed for limnetic stations 1 through 6 and lakewide (table 18). These values were compared with those shown in table 17 to determine the lake's trophic state. On the basis of concentrations of total phosphorus, total nitrogen, and chlorophyll-*a*, all stations were oligotrophic in both years. However, on the basis of secchi-disc transparency, five of the six stations were mesotrophic in both years. At station 6, secchi-disc transparencies fell into both the mesotrophic and eutrophic categories.

Several studies conducted during the 1970's classified the trophic state of Coeur d'Alene Lake. Parker (1972) used the results of carbon-14 primary productivity measurements to delineate three lake areas of different trophic states. Parker classified the lake area north of Rockford Bay as oligotrophic, the area south of Rockford Bay to Conkling Point as mesotrophic, and the Chatcolet Lake area as strongly mesotrophic. The National Eutrophication Survey classified the lake as mesotrophic on the basis of nutrient and chlorophyll-*a* concentrations (U.S. Environmental Protection Agency, 1977). The Idaho Department of Fish and

Table 17. Trophic-state classification based on open-boundary values for four limnological variables

[Modified from Ryding and Rast (1989); µg/L, micrograms per liter; m, meters]

Limnological variable[1]		Oligotrophic	Mesotrophic	Eutrophic
Total phosphorus (µg/L)	$\bar{x}$	8.0	26.7	84.4
	$\bar{x} \pm 1$ SD	4.8–13.3	14.5–49.0	48.0–189.0
	$\bar{x} \pm 2$ SD	2.9–22.1	7.9–90.8	16.8–424.0
Total nitrogen (µg/L)	$\bar{x}$	661	753	1,875
	$\bar{x} \pm 1$ SD	371–1,180	485–1,170	861–4,081
	$\bar{x} \pm 2$ SD	208–2,103	313–1,816	395–8,913
Chlorophyll-*a* (µg/L)	$\bar{x}$	1.7	4.7	14.3
	$\bar{x} \pm 1$ SD	0.8–3.4	3.0–7.4	6.7–31.0
	$\bar{x} \pm 2$ SD	0.4–7.1	1.9–11.6	3.1–66.0
Secchi-disc transparency	$\bar{x}$	9.9	4.2	2.4
	$\bar{x} \pm 1$ SD	5.9–16.5	2.4–7.4	1.5–4.0
	$\bar{x} \pm 2$ SD	3.6–27.5	1.4–13.0	0.9–6.7

[1] Annual geometric mean values and standard deviations.

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Table 18. Trophic state of Coeur d'Alene Lake at six limnetic stations and lakewide during 1991–92 based on annual mean values for four limnological variables

[µg/L, micrograms per liter; m, meters; TS, trophic state; O, oligotrophic; M, mesotrophic; E, eutrophic; LW, area-weighted lakewide value]

Limnetic station (fig. 4)	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-*a* (µg/L)		Secchi-disc transparency (m)	
	[1]$\bar{x}$	TS	[1]$\bar{x}$	TS	[1]$\bar{x}$	TS	[2]$\bar{x}$	TS
				1991				
1	4.2	O	275	O	0.39	O	5.3	M
2	3.9	O	259	O	.45	O	4.9	M
3	4.3	O	276	O	.39	O	4.7	M
4	5.0	O	282	O	.38	O	4.0	M
5	8.3	O	290	O	.52	O	3.1	M
6	12.4	O	316	O	.55	O	2.4	M/E
LW	5.6	O	282	O	.43	O	4.0	M
				1992				
1	2.0	O	211	O	.54	O	6.6	M
2	2.8	O	212	O	.71	O	5.6	M
3	2.1	O	215	O	.62	O	6.2	M
4	3.6	O	219	O	.62	O	5.2	M
5	3.7	O	218	O	.81	O	4.6	M
6	4.6	O	206	O	.79	O	2.9	M/E
LW	2.9	O	214	O	.67	O	5.1	M
				1991–92				
LW	4.1	O	247	O	.54	O	4.5	M

[1] Annual geometric mean concentration within euphotic zone.
[2] Annual geometric mean value.

Game classified the lake as mesotrophic on the basis of chlorophyll-*a* concentrations in samples collected from three stations during April to November 1979 (Rieman, 1980).

Of these three studies, the National Eutrophication Survey data base was most comparable to that of the present study. The open-boundary trophic-state classification listed in table 17 was compared with geometric mean values computed from the National Eutrophication Survey data. The comparison data were upper water-column samples obtained from eight stations during April, July, and September 1975. The geometric mean value for total nitrogen, 292 µg/L, resulted in an oligotrophic classification, whereas the geometric mean values for total phosphorus (19.1 µg/L), chlorophyll-*a* (7.2 µg/L), and secchi-disc transparency (2.7 m) resulted in a mesotrophic classification. Nutrient and biological productivity (chlorophyll-*a* and primary productivity) data from the three earlier studies resulted in a mesotrophic classification; however, the data from the present study, except for secchi-disc transparency, resulted in an oligotrophic classification.

WATER QUALITY AT LIMNETIC STATION 7

Water quality at limnetic station 7 was assessed during 1991 to determine whether log-storage wastes created sufficient biochemical oxygen demand to reduce dissolved-oxygen concentrations to anoxic levels. Dissolved-oxygen concentrations ranged from 6.6 to 12 mg/L (saturation ranged from 83 to 105 percent); the minimum concentrations were measured near the lake bottom, at a depth of 4 m, in early August.

Sampling results failed to show any significant adverse water-quality effects attributable to log wastes at limnetic station 7. However, the superintendent of the Coeur d'Alene wastewater-treatment plant supplied data indicative of substantial dissolved-oxygen depletion at their lake sampling station about 0.2 km north of limnetic station 7 and situated over a 20-m-deep depression near the lake's outlet (H. Sid Fredrickson, City of Coeur d'Alene, written commun., 1993). Fredrickson's data showed dissolved-oxygen concentrations as low as 1 mg/L and saturations as low as 10 percent in the lower half of the water column on August 19 and September 15, 1993. Apparently, the cumulative effects that were measured at Fredrickson's sampling station were not detected at limnetic station 7 because it was situated at the "upstream" side of the log-storage areas.

PHYTOPLANKTON BIOASSAYS

A topical review of environmental studies of the Coeur d'Alene area (Savage, 1986) concluded that most studies of the effects of trace elements on the lake's biota dealt with fish and invertebrates. Only two studies dealt with phytoplankton, even though photosynthetic production of organic matter by phytoplankton is the basis of the food web in most lakes. The two phytoplankton studies were done in the early 1970's and used a bioassay approach to test the inhibitory effects of cadmium, copper, and zinc (Wissmar, 1972; Bartlett and others, 1974).

The present study demonstrated that concentrations of total recoverable cadmium, copper, and zinc have declined since Wissmar (1972) measured them (see "Trace Elements" section). Of the three, only zinc remains well above its detection limit. Therefore, only zinc was used in the 1994 bioassays to assess inhibition of phytoplankton growth in Coeur d'Alene Lake.

The two earlier phytoplankton bioassay studies arrived at different conclusions regarding the inhibitory

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effects of zinc on phytoplankton. Wissmar (1972) did not observe significant inhibition; Bartlett and others (1974) did. The discrepancy in the results is due, in part, to interpretive limitations associated with the two different approaches. Wissmar measured the primary productivity of nanoplankton from Coeur d'Alene Lake in a series of short-term (hours) bioassays conducted in a laboratory incubation system. Bartlett and others measured biomass changes in the green alga *Selenastrum* in a series of long-term (days) bioassays using algal-assay bottle-test procedures (U.S. Environmental Protection Agency, 1971). Both studies reported total concentrations of zinc and, therefore, did not consider speciation and bioavailability of zinc.

The question of zinc inhibition of phytoplankton growth in Coeur d'Alene Lake remained important in the early 1990's; however, the methodological differences and inconclusive results of the two 1970's bioassays left the question unresolved. Therefore, current-technology bioassays were conducted in 1994 using phytoplankton isolated from the lake and chemically defined media. The media was formulated on the basis of geochemical data from Coeur d'Alene Lake. This approach accounted for speciation and bioavailability of zinc to phytoplankton that were adapted to the chemical conditions in Coeur d'Alene Lake.

Table 19. Bioassays showing effects of dissolved, uncomplexed zinc on cell number, biomass, and doubling rate of three phytoplankton isolates from Coeur d'Alene Lake, 1994

[µg/L, micrograms per liter; Kcells/mL, thousand cells per milliliter; mg/L, milligrams per liter; 1/d, number per day; ND, no discernible growth detected]

Bioassay number, culturing period, and phytoplankton isolate	Treatment	Dissolved bioavailable zinc concentration (µg/L)	Phytoplankton conditions at end of bioassay		
			Mean cell concentration (Kcells/mL)	Biomass, dry weight (mg/L)	Doubling rate (1/d)
1					
5/24–6/7	Basal	0.5	4,481	45.7	0.87
Achnanthes minutissima	Mid	19.6	17.7	.16	ND
	Station 4	39.2	20.4	.18	ND
2					
6/14–21	Basal	.5	48.9	31.9	.55
Cyclotella stelligera[1]	Mid	19.6	11.0	6.3	ND
	Station 4	39.2	8.1	4.5	ND
3					
9/2–9	Basal	.5	48.6	29.8	.52
Cyclotella stelligera[2]	Mid	19.6	15.0	9.8	.23
	Station 4	39.2	12.1	8.1	.19

[1] From limnetic station 6.
[2] From limnetic station 4.

Table 20. Concentrations of dissolved zinc and organic carbon in samples of near-surface water from Coeur d'Alene Lake and the St. Joe and Coeur d'Alene Rivers, 1993–94

[Zn, dissolved zinc concentration, in micrograms per liter; DOC, dissolved organic carbon concentration, in milligrams per liter; NS, not sampled]

Sampling station (fig. 4)	Constituent	Sample month and year				Median concentration
		6/93	9/93	6/94	8/94	
Limnetic station 1	Zn	33.1	64.5	63.3	44.7	54.0
	DOC	1.39	1.36	1.48	1.17	1.38
Limnetic station 4	Zn	40.1	66.0	57.6	45.4	51.5
	DOC	1.23	1.25	1.32	1.33	1.29
Limnetic station 6	Zn	.55	.16	.73	.40	.48
	DOC	1.20	1.53	1.47	1.82	1.50
Mica Bay	Zn	40.1	NS	63.0	44.5	44.5
	DOC	1.34	NS	1.40	1.24	1.34
St. Joe River	Zn	NS	.26	1.18	.49	.49
	DOC	NS	1.14	1.29	1.28	1.28
Coeur d'Alene River	Zn	NS	400.0	69.6	202.5	202.5
	DOC	NS	.66	.86	.81	.81

The three bioassays conducted in 1994 (table 19) showed that phytoplankton growth was strongly inhibited by zinc concentrations greater than the basal media treatment (Kuwabara and others, 1994). In each bioassay, the mean cell concentrations, biomasses, and doubling rates of the mid and station 4 media treatments were much lower than those of the basal media treatment. Inhibition was particularly evident for *Achnanthes minutissima*, a pennate diatom known to be intolerant of elevated trace-element concentrations. Inhibition in the three bioassays occurred at dissolved zinc concentrations >0.5 µg/L, the basal treatment, and <19.6 µg/L, the mid treatment. This concentration range lies well below the median concentrations of dissolved zinc measured in Coeur d'Alene Lake during 1993–94, except for limnetic station 6 and the St. Joe River (table 20). Concentrations of dissolved organic carbon, concurrently measured with zinc, were consistently low in the lake (table 20). The low concentrations enhanced the bioavailability of zinc to phytoplankton because dissolved organic carbon compounds represent an important source of ligands for chemically binding (complexing) with trace elements such as zinc (J.S. Kuwabara, U.S. Geological Survey, written commun., 1994).

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Littoral Zone

COMPARISONS TO LIMNETIC ZONE

Water quality at 20 littoral stations (fig. 20) was assessed during mid-September 1991 to compare littoral and limnetic water quality and to identify potential sites for a 1992 assessment of littoral periphyton production. No major differences were detected in water quality, based on concentrations of total phosphorus, dissolved orthophosphorus, and chlorophyll-*a*, between littoral and limnetic stations (table 21). Some differences were detected in dissolved-oxygen concentrations, percent saturations, and dissolved inorganic nitrogen (table 21). The differences in dissolved oxygen were largely attributable to the anoxic conditions at limnetic station 6 and the substantial oxygen depletion at limnetic station 5. None of the 26 stations exhibited supersaturated oxygen concentrations. Dissolved inorganic nitrogen at the littoral stations ranged from <8 to 93 µg/L and, at the limnetic stations, from <10 to 38 µg/L. The median and 75th-percentile concentrations of dissolved inorganic nitrogen at the littoral stations were 12 and 15 µg/L, respectively. Concentrations in excess of 15 µg/L were measured at littoral stations 1, 2, 4, 6, and 13. Of these five, four were in bays where beds of aquatic macrophytes were extensive. The fifth station, Sanders Beach, was adjacent to the mouth of Fernan Creek, the outlet for Fernan Lake, a mesotrophic lake 0.3 km north of Coeur d'Alene Lake. Mossier (1993) reported that summer concentrations of total inorganic nitrogen in Fernan Lake ranged from 50 to 60 µg/L; these concentrations were similar to the concentration of 65 µg/L measured at littoral station 2.

Table 21. Water-quality data for 20 littoral and 6 limnetic stations, Coeur d'Alene Lake, mid-September 1991

[µg/L, micrograms per liter; mg/L, milligrams per liter; <, less than; —, missing value]

Station No.	Station name	Dissolved inorganic nitrogen (µg/L)	Total phosphorus (µg/L)	Dissolved ortho-phosphorus (µg/L)	Chloro-phyll-*a* (µg/L)	Dissolved oxygen	
						Concentration (mg/L)	Percent saturation
			Littoral stations[1] (fig. 20)				
1	Kid Island Bay	28	5	<1	0.2	8.1–8.4	94–99
2	Sanders Beach	65	—	9	.2	8.2–8.3	95–100
3	Bennett Bay	<12	5	<1	.1	8.3–8.6	96–101
4	Blue Creek Bay	19	6	<1	.2	8.0–8.4	91–97
5	Beauty Bay	<12	5	<1	.2	7.7–8.3	72–97
6	Squaw Bay	93	5	—	.2	8.2–8.4	95–100
7	Echo Bay	14	4	<1	.2	8.4–8.6	96–100
8	Mica Bay	13	4	<1	.2	8.4–8.5	96–98
9	Driftwood Bay	<11	13	<1	.2	8.4–8.6	87–99
10	Turner Bay	<11	4	<1	.2	8.2–8.6	89–99
11	Loffs Bay	<10	4	<1	.1	8.5–8.6	98–99
12	Carlin Bay	10	8	<1	.4	8.2–8.7	93–100
13	Powderhorn Bay	55	7	<1	.4	7.2–8.7	82–100
14	Rockford Bay	<12	4	<1	.2	7.6–8.6	83–99
15	Windy Bay	<9	6	<1	.3	7.9–8.6	88–99
16	16 to 1 Bay	13	5	<1	.2	8.3–8.6	94–99
17	Cave Bay	<8	6	2	.2	8.2–8.6	91–99
18	Cottonwood Bay	14	8	<1	.4	8.3–8.7	94–100
19	Fullers Bay	9	7	<1	.3	7.2–8.4	74–96
20	Carey Bay	15	10	<1	.5	7.7–8.1	86–92
			Limnetic stations[2] (fig. 4)				
1	St. Joe River	38	6	<1	.2	8.4–8.5	84–98
2	Coeur d'Alene Lake	16	5	<1	.3	8.2–8.4	88–97
3	Spokane River	<16	6	<1	.3	8.4–8.6	84–100
4	Plummer Creek	18	4	<1	.3	7.6–8.5	77–98
5	Fighting Creek	14	13	<1	.7	5.4–8.4	52–96
6	Carlin Creek	<10	11	<1	.6	0–7.8	0–88

[1] Dissolved inorganic nitrogen, total phosphorus, dissolved orthophosphorus, and chlorophyll-*a* data from 1-meter-depth samples.

[2] Data from euphotic zone samples.

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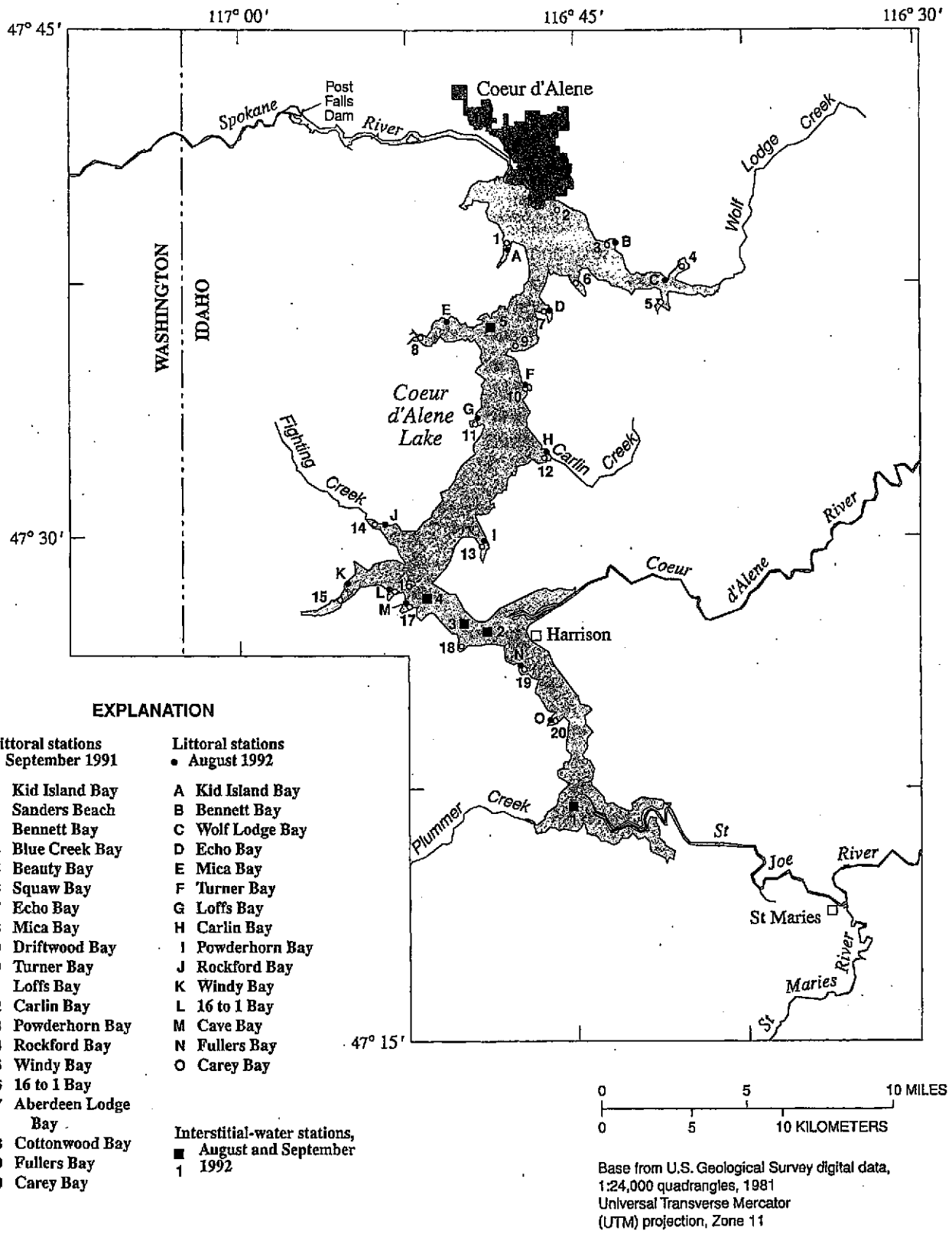


Figure 20. Locations of littoral sampling stations, September 1991 and August 1992, and interstitial-water sampling stations, August and September 1992.

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Water quality among 15 littoral and 6 limnetic stations also was compared during mid-August 1992 (table 22). Unlike the 1991 comparison of euphotic-zone composites, the 1992 comparison was based on 1-m-deep samples because the littoral stations were used for an assessment of periphyton production. Minor differences in concentrations of total phosphorus, dissolved orthophosphorus, chlorophyll-*a*, and percent saturation of dissolved oxygen were detected. Unlike the 1991 comparison, the range in dissolved inorganic nitrogen was larger at the limnetic stations; however, the median concentrations were comparable. Zinc concentrations at the limnetic stations had a wider range (10 to 90 µg/L) than at the littoral stations (40 to 70 µg/L). The median concentration of zinc at the limnetic stations was 90 µg/L, whereas at the littoral stations, it was 60 µg/L. The other five trace elements that were analyzed (arsenic, cadmium, copper, mercury, and lead) were at or below detection limits at the 21 stations.

AQUATIC MACROPHYTES

Coeur d'Alene Lake contained 22 genera of aquatic macrophytes on the basis of sampling at 63 stations (table 23). Four of the genera were observed rarely. *Nymphaea* was observed only in Hidden Lake, and the only specimens of *Brasenia*, *Spirodela*, and *Utricularia* were observed in Bell Bay. Seven genera—*Equisetum*, *Fontinalis*, *Myriophyllum*, *Nuphar*, *Sagittaria*, *Typha*, and *Zizania*—were observed infrequently. The remaining 11 genera were observed at most of the stations. The genus *Potamogeton* was the most common aquatic macrophyte at most of the stations. The aquatic macrophytes were observed only at water depths less than 6 m.

The southern end of the lake contained the most abundant beds of aquatic macrophytes, although Cougar Bay at the lake's northern end also was heavily populated. Most of the bays with extensive sedimentary deltas contained abundant beds of aquatic macrophytes. Those bays were Carey, Carlin, Kid Island,

Table 22. Water-quality data for 15 littoral and 6 limnetic stations, Coeur d'Alene Lake, mid-August 1992

[µg/L, micrograms per liter; mg/L, milligrams per liter; <, less than]

Station No.	Station name	Dissolved inorganic nitrogen (µg/L)	Total phosphorus (µg/L)	Dissolved ortho-phosphorus (µg/L)	Chloro-phyll-*a* (µg/L)	Dissolved oxygen		Zinc, total recoverable (µg/L)
						Concentration (mg/L)	Percent saturation	
				Littoral stations[1] (fig. 20)				
A	Kid Island Bay	21	16	1	1.7	9.0	105	40
B	Bennett Bay	44	4	<1	.8	8.8	111	50
C	Wolf Lodge Bay	18	4	<1	.7	8.4	105	60
D	Echo Bay	44	3	<1	.8	8.6	107	60
E	Mica Bay	19	3	<1	.8	8.8	107	50
F	Turner Bay	32	3	1	1.0	8.7	107	50
G	Loffs Bay	34	2	<1	1.0	8.9	109	60
H	Carlin Bay	42	4	<1	.9	8.7	106	60
I	Powderhorn Bay	44	4	<1	1.0	8.9	110	60
J	Rockford Bay	33	2	<1	1.1	8.8	107	60
K	Windy Bay	25	3	<1	1.0	9.1	111	60
L	16 to 1 Bay	15	4	<1	.9	9.0	111	60
M	Cave Bay	16	2	1	1.3	9.0	108	70
N	Fullers Bay	21	5	1	.9	8.7	105	60
O	Carey Bay	23	6	<1	1.0	9.0	108	50
				Limnetic stations[1] (fig. 4)				
1	St. Joe River	16	4	1	.7	8.4	104	90
2	Coeur d'Alene Lake	86	3	<1	1.2	8.4	104	90
3	Spokane River	11	2	1	1.2	8.8	108	90
4	Plummer Creek	25	5	1	.9	8.6	107	90
5	Fighting Creek	26	5	<1	1.7	8.5	106	70
6	Carlin Creek	<11	6	<1	1.6	7.9	98	10

[1]Data from 1-meter-depth samples.

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Loffs, Mica, Powderhorn, Rockford, 16 to 1, Windy, and the eastern end of Wolf Lodge (fig. 5). Beds of aquatic macrophytes were abundant in Harrison Slough, north of the mouth of the Coeur d'Alene River; were moderate in Bennett, Echo, Fullers, and Turner Bays; and were sparse to very sparse at the remaining stations.

PERIPHYTON PRODUCTION

Limnological studies of eutrophication traditionally have focused on the limnetic zone. However, recent studies of several large lakes have detected eutrophication much earlier in the littoral zone than in the limnetic zone (Loeb, 1986; Aloi and others, 1988; Kann and Falter, 1989; Jacoby and others, 1991). The additional influx of nutrients caused by disturbance of the lake's shoreline can stimulate periphyton production on natural substrates as well as constructed substrates such as docks and pilings.

Periphyton production in the littoral zone of Coeur d'Alene Lake during July and August 1992 was assessed to determine whether a statistical relation existed between periphyton production and various indices of nearshore and watershed development. Comparison of periphyton production in Coeur d'Alene Lake with that of other lakes was not a goal because such studies are not standardized. After evaluating numerous studies of periphyton production, Morin and Cattaneo (1992) concluded that the ability to detect patterns in periphyton ecology was limited because numerous environmental factors affect sampling variability. Periphyton production also is known to exhibit large temporal and spatial variations, such as those observed at Lake Tahoe, Nev. (Aloi and others, 1988).

In Coeur d'Alene Lake, periphyton production, as chlorophyll-*a*, at 10 littoral stations ranged from 0.32 to 3.92 mg/m^2, a difference of 12.2 times (table 24). When normalized to PAR input, the production ranged from 0.00036 to 0.014 (mg/m^2)/E, a difference of 38.9 times. For both comparisons, production was lowest at station G and highest at station A.

The relation of PAR-normalized periphyton production to nearshore and watershed development was investigated with multiple linear regression using procedures described by Helsel and Hirsch (1992). The periphyton production rates were normalized to PAR input to remove the influence of that variable from the predictive equations. For each littoral station, the following variables were tested as predictors of periphy-

Table 23. Aquatic macrophyte taxa, Coeur d'Alene Lake, 1993

Aquatic macrophyte taxa[1]	Aquatic macrophyte taxa[1]	Aquatic macrophyte taxa[1]
Phylum Bryophyta	Class Angiospermae (Continued)	Class Angiospermae (Continued)
Class Musci	Family Callitrichaceae	Family Naiadaceae
Family Fontinalaceae	*Callitriche hermaphroditica*	*Potamogeton amplifolius*
Fontinalis sp.	*C. heterophylla*	*P. epihydrus*
Phylum Chlorophyta	Family Ceratophyllaceae	*P. foliosus*
Family Characeae	*Ceratophyllum demersum*	*P. praelongus*
Nitella sp.	Family Elatinaceae	*P. richardsonii*
Phylum Pteridophyta	*Elatine triandra*	*P. robbinsii*
Family Equisetaceaesp	Family Gramineae	Family Nymphaeaceae
Equisetum fluviatile	*Zizania aquatica*	*Brasenia schreberi*
Family Isoetaceaesp	Family Haloragaceae	*Nuphar polysepalum*
Isoetes sp.	*Myriophyllum spicatum* var. *exalbescens*	*Nymphaea odorata*
Phylum Spermatophyta	Family Hydrocharitaceae	Family Ranunculaceae
Class Angiospermae	*Elodea canadensis*	*Ranunculus aquatilis*
Family Alismaceae	Family Lemnaceae	Family Sparganiaceae
Alisma gramineus	*Lemna minor*	*Sparganium eurycarpum*
A. plantago-aquatica	*Spirodela polyrhiza*	Family Typhaceae
Sagittaria cuneata	Family Lentibulariaceae	*Typha latifolia*
S. latifolia	*Utricularia vulgaris*	

[1]Taxonomy based on Prescott (1969) and Steward and others (1963).

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ton production: concentration of total phosphorus in the littoral zone, percentage of agricultural land use in the contributing watershed, number of nearshore homes using septic tanks, and degree of nearshore development (low, moderate, and high). The relation of the individual predictor variables to the response variable was examined with scatter plots, whereas a correlation matrix was used to test for multicollinearity among the variables. Initial analyses indicated that station A (Kid Island Bay) unduly influenced the regression models; station A was deemed an outlier and was removed from the data set. For the remaining nine stations, PAR-normalized periphyton production was best predicted by the following equation:

$$PP = 0.000045 + 0.00015\,(TP) + 0.000006\,(PA)\,, \quad (6)$$

where

PP is periphyton production, as chlorophyll-*a*, in milligrams per square meter per Einstein;

TP is concentration of total phosphorus in the littoral zone, in micrograms per liter; and

PA is decimal percent of agricultural land in the contributing watershed.

This two-variable regression model explained 88.4 percent of the variation in PAR-normalized periphyton production and was highly significant with a probability of 0.0016. The regression coefficients for *TP* and *PA* were significantly different from 0 and probabilities were <0.01; the intercept coefficient was not significantly different from 0. The residuals were plotted and were deemed satisfactory. The positive sign for the regression coefficients indicates that as total phosphorus concentrations and percentage of agricultural land use increase, so does periphyton production.

The excluded variables, number of nearshore homes using septic tanks and degree of nearshore development, appeared to be reasonable for inclusion in the regression models; additional examination, however, revealed reasons why they were poor predictors. The efficiency of wastewater treatment by septic tanks may be quite variable and often is a function of age. Gilliom (1983) reported that older septic-tank systems contributed more phosphorus to Puget Sound region lakes than did newer systems. Gilliom also noted that long lag times are possible between installation of a septic-tank system and detection of its effects on phosphorus concentrations in a lake. Around Coeur d'Alene Lake, a wide disparity exists for the installation dates and adequacy of maintenance for septic-tank systems. The degree of nearshore development was a qualitative variable and did not adequately differentiate among the numerous factors that can affect periphyton production in the littoral zone.

Table 24. Periphyton production, as chlorophyll-*a*, at 10 littoral stations, Coeur d'Alene Lake, July and August 1992

[PAR, photosynthetically active radiation; E, Einstein; mg/m^2, milligrams per square meter; (mg/m^2)/E, milligrams per square meter per Einstein]

Littoral station (fig. 20)	Station name	PAR input (E)[1]	Periphyton production (mg/m^2)	Periphyton production normalized to PAR [(mg/m^2)/E]
A	Kid Island Bay	278	3.92	0.014
B	Bennett Bay	945	.66	.00070
E	Mica Bay	944	.44	.00047
F	Turner Bay	914	.59	.00064
G	Loffs Bay	892	.32	.00036
H	Carlin Bay	971	.61	.00063
I	Powderhorn Bay	856	.70	.00082
J	Rockford Bay	924	.56	.00061
K	Windy Bay	888	.72	.00081
N	Fullers Bay	896	.96	.00110

[1]Quantity of photon flux, as Einsteins (1 E=1 mole of photons), input to periphyton during incubation period.

The taxonomic composition of periphyton grown on the artificial substrates was assessed for seven of the littoral stations. The number of algal species at each station ranged from 19 to 32; the mean density was 50,400 cells/cm^2 and the range was 25,400 to 75,900. *Fragilaria construens* and *F. crotonensis* composed more than 50 percent of the density at stations B, I, J, K, and N (fig. 20). *F. crotonensis*, *F. vaucheriae*, *Cymbella microcephala*, *Achnanthes minutissima*, and *Mougeotia* sp. composed more than 50 percent of the density at stations F and H. One species, *Rhopalodia gibba*, composed between 32 and 76 percent of the biovolume at each littoral station. Of the algal genera just discussed, all are diatoms except *Mougeotia*, which is a filamentous green alga.

LAKEBED SEDIMENT GEOCHEMISTRY

Several studies of Coeur d'Alene Lake have reported concentrations of trace elements in the lakebed sediments (Funk and others, 1973, 1975; Maxfield and others, 1974a, 1974b; Hornig and others, 1988);

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however, these studies have not assessed potential environmental availability of trace elements. As part of this study, an intensive geochemical analysis of lakebed sediments was conducted to determine concentration, partitioning, and environmental availability of selected trace elements. The trace-element analysis was conducted in three phases: (1) surficial lakebed sediments, (2) lakebed sediment cores, and (3) interstitial water. Concentrations of total phosphorus and nitrogen in the surficial lakebed sediments also were determined.

Data Collection and Analysis

Surficial samples of the lakebed sediments were collected in August 1989 at 172 stations, at a density of one per square kilometer, in the lake and the lower reaches of the Coeur d'Alene and St. Joe Rivers. Samples were collected with a stainless-steel Ekman dredge. Subsamples of the upper 2 cm of sediment in the dredge were collected for trace-element analyses. A detailed description of the sampling locations and analytical methods is presented in a report by Horowitz and others (1993) and is only summarized here. Bulk sediment samples were analyzed for concentrations of total aluminum, antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, titanium, zinc, and total organic carbon. Selected samples were separated according to grain size and the resulting size fractions were analyzed for the same chemical constituents as were the bulk samples. Selected samples were separated into heavy and light mineral fractions to help determine phase association. Selected heavy/light mineral separates were subjected to scanning-electron microscopy linked to an energy-dispersive X-ray system to help infer mineralogy.

During June 1992, 12 lakebed sediment cores were obtained using a 2.4-m, stainless-steel, Wildco gravity corer equipped with a clear polycarbonate liner and nonmetallic core catcher. Coring locations were based on results of the surficial lakebed sediment samples. The sampling locations and analytical procedures used for the cores are described in detail in a report by Horowitz and others (1995). The same chemical constituents were analyzed as for the surficial lakebed sediments. A core near the mouth of the Coeur d'Alene River was evaluated for cesium-137 activity to help estimate the ages of various layers in that core.

Interstitial water in lakebed sediments at five stations (fig. 20) was sampled using diffusion-controlled equilibrator samplers, or "peepers"; the samplers and their operation are described in a report by Simon and others (1985). The samplers were placed in the lakebed by scuba divers in late August 1992 and were retrieved after a 30-day incubation. The samplers obtained interstitial water at 1-cm intervals within the upper 20 cm of the lakebed sediments. All analytical work was performed in a nitrogen atmosphere to prevent redox changes by the introduction of oxygen. The interstitial water samples were analyzed for concentrations of dissolved copper, lead, and zinc, as well as calcium and magnesium, for calculation of hardness.

Twenty stations were sampled for lakebed sediment nutrients in late June 1992. Samples were collected with a stainless-steel Ponar dredge. A subsample, taken from the centroid of the dredged sample, was analyzed for total phosphorus and total nitrogen using methods described by Fishman and Friedman (1985).

Sediment Trace Elements

Results from the geochemical study of lakebed sediments in Coeur d'Alene Lake were reported in detail by Horowitz and others (1993, 1995); they are summarized briefly here. The surficial and subsurface sediments over about 85 percent of the lakebed's surface area were highly enriched in antimony, arsenic, cadmium, copper, lead, mercury, silver, and zinc. Concentrations of selected trace elements were highest in the subsurface sediments; however, median concentrations in the surficial sediments exceeded the median concentrations in the subsurface sediments (table 25). The higher medians in the surficial sediments may have resulted from post-depositional remobilization, upward diffusion, and reprecipitation caused by reducing conditions in the sediment column beneath the oxidized surficial zone. Remobilization is likely to have occurred because most of the trace elements are associated with an operationally defined ferric oxide phase. The ferric oxide can redissolve under reducing conditions present in the sediment column. Most of the trace elements in the lakebed were associated with ferric oxides; only near the mouth of the Coeur d'Alene River were the trace elements strongly associated with sulfide minerals.

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Table 25. Statistical summary of selected trace elements in surficial and subsurface lakebed sediments in enriched and unenriched areas, Coeur d'Alene Lake

[mg/kg, milligrams per kilogram; S, surficial sample; C, subsurface sample; <, less than; data from Horowitz and others (1993, 1995)]

Trace element	Sample type	Concentration for enriched area (mg/kg)				Median concentration for unenriched area[1] (mg/kg)
		Minimum	Maximum	Mean	Median	
Arsenic	S	2.4	660	151	120	4.7
	C	3.5	845	103	30	12
Cadmium	S	<.5	157	62	56	2.8
	C	<.1	137	25	26	.3
Copper	S	9	215	72	70	25
	C	20	650	91	60	30
Lead	S	14	7,700	1,900	1,800	24
	C	12	27,500	3,200	1,250	33
Mercury	S	.02	4.9	1.8	1.6	.05
	C	<.01	9.9	1.9	.95	.06
Zinc	S	63	9,100	3,600	3,500	110
	C	59	14,000	2,400	2,100	118

[1]Unenriched area median concentration for sample type S based on 17 samples from southern area of Coeur d'Alene Lake and lower reach of St. Joe River. Unenriched area median concentration for sample type C based on 189 sample aliquots from cores beneath enriched area.

The trace-element-enriched sediments extended northward from about Conkling Point (fig. 4) and varied in thickness from 17 to 119 cm; the thickest layer was near the mouth of the Coeur d'Alene River. The chemical distribution pattern indicates the Coeur d'Alene River as the source of the trace elements. Some of the highest concentrations were measured near the river mouth. Other high concentrations were measured in the lake's northern end and reflected the advective transport of extremely fine-grained sediments from the mouth of the Coeur d'Alene River toward the lake's outlet to the Spokane River.

The recent geochemical history of the lakebed sediments was determined from a core taken north of the mouth of the Coeur d'Alene River. This core was chosen because it had readily discernible varves, the Mt. St. Helens, Wash., ash layer was present, the trace-element-enriched section was about 119 cm in length, and the interface between background and highly enriched trace-element layers was definitive. The age of the interface was determined by three different methods, which yielded dates of 1895, 1910, and 1911. These dates roughly coincide with the onset of mining in the Coeur d'Alene River Basin, which began around 1885.

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Interstitial-Water Trace Elements

The highly enriched trace-element concentrations in the lakebed sediments of Coeur d'Alene Lake (Horowitz and others, 1993, 1995) represented total concentrations determined from only the solid phase; dissolved trace-element concentrations in interstitial water in the lakebed sediments were not included. The amount of biologically available trace elements in lakebed sediments is more realistically evaluated using dissolved trace-element concentrations in interstitial water (Ankley and others, 1994).

The concentrations of dissolved copper, lead, and zinc in interstitial water (table 26) were substantially lower than the total concentrations in the surficial and subsurface lakebed sediments (table 25). Median concentrations of dissolved copper in interstitial water sampled at the five stations were similar, ranging from 2 to 3 µg/L. The spatial variation of interstitial-water concentrations of lead and zinc was different from that of copper. The lowest median concentrations of lead and zinc were measured at station 1, in Chatcolet Lake; the highest median concentrations were measured at station 2, within the delta of the Coeur d'Alene River.

Table 26. Statistical summary of concentrations of dissolved copper, lead, and zinc in interstitial water, August and September 1992

[µg/L, micrograms per liter; Min., minimum; Max., maximum; <, less than]

Interstitial water sampling station (fig. 20)	Latitude, longitude	Copper (µg/L)			Lead (µg/L)			Zinc (µg/L)		
		Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.
[1]	47°21'43" 116°45'03"	3	2	15	<6	<6	14	<20	<20	26
[2]	47°27'15" 116°48'47"	2.5	2	4	205	85	562	287	212	451
[3]	47°27'13" 116°49'27"	2	2	10	70	6	236	106	35	342
[4]	47°28'06" 116°51'24"	3	2	8	26	6	134	133	68	319
[5]	47°36'26" 116°48'38"	2	2	5	11	6	73	108	20	251

[1] Number of samples was 24.
[2] Number of samples was 12.

Sediment Nutrients

Total phosphorus concentrations in lakebed sediments at 20 stations on Coeur d'Alene Lake ranged from 500 to 1,600 mg/kg, whereas total nitrogen concentrations ranged from 860 to 3,900 mg/kg (table 27). The mean concentration of total phosphorus was 940 mg/kg and, of total nitrogen, was 2,100 mg/kg.

The smallest concentration of total phosphorus (500 mg/kg) was measured at limnetic station 5, where the lakebed is subject to erosion because it is 5.6 km from the mouth of the St. Joe River. The largest concentration of total phosphorus (1,600 mg/kg) was measured at limnetic station 1, in the deep northern end of the lake, where deposition predominates.

The smallest and largest concentrations of total nitrogen were measured in Rockford and Windy Bays, respectively. Analogous to concentrations of total phosphorus, the smallest concentration of total nitrogen among limnetic stations 1 through 6 was at limnetic station 5; the largest concentration was at limnetic station 1.

The sediment nutrient data for Coeur d'Alene Lake were compared with data for several northwestern United States lakes and reservoirs that drain to the Columbia River, as does Coeur d'Alene Lake. Lake Koocanusa in northwestern Montana is a large, oligotrophic reservoir created by Libby Dam in 1972. Iskander and Shukla (1981) analyzed 20 surficial lakebed sediment samples from Lake Koocanusa and reported a range in total phosphorus from 750 to 1,500 mg/kg. Lake Chelan in central Washington is a large, oligotrophic lake that was studied by Patmont and others (1989). On the basis of surficial lakebed sediment samples from four limnetic stations, they reported that total phosphorus and total nitrogen in Lake Chelan ranged from 300 to 1,100 mg/kg and from 470 to 1,830 mg/kg, respectively. Long Lake is a reservoir on the Spokane River downstream from Coeur d'Alene Lake. In 1974, when Long Lake was classified as eutrophic, Thomas and Soltero (1977) determined total phosphorus and nitrogen concentrations in a single core. For the surficial part of that core, total phosphorus ranged from 1,400 to 3,500 mg/kg, whereas total nitrogen ranged from 1,800 to 6,500 mg/kg. The range of total phosphorus concentrations in surficial sediments of the two oligotrophic water bodies was comparable to the range in Coeur d'Alene Lake, whereas the range of total phosphorus concentrations in Long Lake was much higher. The range of total nitrogen concentrations in surficial sediments of Coeur d'Alene Lake was higher than the range in Lake

Table 27. Concentrations of total phosphorus and total nitrogen in lakebed sediments at 20 stations, Coeur d'Alene Lake, June 1992

[m, meters; mg/kg, milligrams per kilogram]

Station name[1] (figs. 4, 5)	Water depth (m)	Concentration (mg/kg)	
		Total phosphorus	Total nitrogen
Limnetic station 1	42.7	1,600	2,900
Limnetic station 2	29.9	940	2,600
Limnetic station 3	53.0	1,500	2,600
Limnetic station 4	41.1	1,300	2,000
Limnetic station 5	17.7	500	1,100
Limnetic station 6	11.3	840	1,700
Between Harlow and Reynolds Points	18.0	730	1,300
Coeur d'Alene River delta	5.0	920	1,900
Cave Bay	19.8	830	1,400
16 to 1 Bay	18.6	590	1,100
Between East and Rockford Points	31.7	1,200	1,900
Windy Bay	29.6	1,000	3,900
Powderhorn Bay	29.3	900	1,600
Rockford Bay	19.2	920	860
Carlin Bay	15.8	920	1,900
Mica Bay	14.9	1,000	2,200
Squaw Bay	11.9	610	3,600
Bennett Bay	29.3	880	2,000
Casco Bay	11.3	580	3,200
Near Tubbs Hill	28.7	1,100	2,900

[1] Latitude and longitude reported by Harenberg and others (1993).

Chelan but was comparable to the low part of the range measured in Long Lake.

WATER-QUALITY STANDARDS AND CRITERIA AND SEDIMENT-QUALITY GUIDELINES

The Idaho water-quality standards (Idaho Department of Health and Welfare, 1985) designate the appropriate beneficial uses of Idaho's water and list general and specific criteria to determine whether beneficial uses are supported by the water-quality conditions of a particular water body. Idaho defines a beneficial use as the reasonable and appropriate use of water for a purpose consistent with Idaho State laws and the best interest of the people. The beneficial uses for Coeur d'Alene Lake are designated in the Idaho water-quality standards and include the following: domestic water supply, agricultural water supply, primary contact recreation, secondary contact recreation, cold water biota, and salmonid spawning. The 1992 Idaho Water Quality Status Report concluded that the designated beneficial uses for Coeur d'Alene Lake were fully supported but were threatened by nutrients, sediment, low dissolved oxygen, pathogens, metals, and "other" causes (Idaho Department of Health and Welfare, 1992).

The EPA (1986) has established water-quality criteria for assessing the potential toxicity of many water-quality constituents, including trace elements, to freshwater biota. The criteria are listed for continuous (chronic) and maximum (acute) concentrations. The toxicity criteria for the six trace elements sampled in Coeur d'Alene Lake are listed for total recoverable and dissolved concentrations (table 28). The original criteria were developed with total recoverable concentrations, but criteria for dissolved concentrations can be estimated as a percentage of the total recoverable concentration (M.G. Prothro, U.S. Environmental Protection Agency, written commun., 1993). The median concentrations for the six trace elements sampled in Coeur d'Alene Lake (table 10) were used to assess potential toxicity on the basis of toxicity criteria listed in table 28. The potential toxicity of cadmium and mercury could not be determined because their analytical detection limits exceeded the criteria. Arsenic concentrations did not exceed the criteria. Concentrations of total recoverable and dissolved (estimated) copper and lead exceeded the continuous concentration criteria. Concentrations of total recoverable and dissolved (estimated) zinc exceeded the continuous and maximum concentration criteria. On the basis of these comparisons, copper and lead were considered chronically toxic to freshwater biota in Coeur d'Alene Lake, whereas zinc was considered chronically and acutely toxic.

Table 28. Concentrations of selected trace elements considered acutely or chronically toxic to freshwater biota based on hardness-dependent criteria

[µg/L, micrograms per liter; CMC, criterion maximum concentration; CCC, criterion continuous concentration; e, base of natural logarithms; ln, natural logarithm; H, hardness, in milligrams per liter as $CaCO_3$; —, data not available; mg/L, milligrams per liter]

Trace element	Criteria	Toxicity equation[1,2]	Concentration (µg/L)	
			Total recoverable	Dissolved
Arsenic.....	CMC	None	360	342
	CCC	None	190	180
Cadmium....	CMC	$e^{[1.128(\ln H)-3.878]}$	.71	.60
	CCC	$e^{[0.7852(\ln H)-3.49]}$	.35	.30
Copper.....	CMC	$e^{[0.9422(\ln H)-1.464]}$	4.3	3.7
	CCC	$e^{[0.8545(\ln H)-1.465]}$	.16	.14
Lead.....	CMC	$e^{[1.273(\ln H)-1.46]}$	11.9	6.0
	CCC	$e^{[1.273(\ln H)-4.705]}$	.5	.12
Mercury.....	CMC	None	2.4	2.0
	CCC	None	.012	—
Zinc	CMC	$e^{[0.8473(\ln H)+0.8604]}$	32.4	27.5
	CCC	$e^{[0.8473(\ln H)+0.7614]}$	29.4	25.0

[1] From U.S. Environmental Protection Agency (1986).
[2] Hardness is median value for Coeur d'Alene Lake, 1991–92, 22 mg/L as $CaCO_3$.

The concentrations of dissolved copper, lead, and zinc in interstitial water (table 26) were compared with the water-quality criteria for potential toxicity to freshwater biota (table 28). Criteria in table 28 are hardness-dependent and, thus, were computed with a hardness of 22 mg/L as $CaCO_3$. The hardness of the interstitial water was lower, about 5 mg/L as $CaCO_3$, on the basis of measured concentrations of calcium and magnesium. The decrease in hardness effectively lowered the concentrations at which copper, lead, and zinc would be considered chronically or acutely toxic. The adjusted acute (CMC) criteria for dissolved concentrations of the three trace elements are as follows: copper, 0.9 µg/L; lead, 0.9 µg/L; and zinc, 7.8 µg/L. The median concentrations of copper (3 µg/L), lead (26 µg/L), and zinc (108 µg/L) in interstitial water in Coeur d'Alene Lake are substantially higher than the criteria concentrations considered acutely toxic to freshwater biota.

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Table 29. Median concentrations of selected trace elements in surficial lakebed sediments in Coeur d'Alene Lake related to aquatic sediment-quality guidelines

[mg/kg, milligrams per kilogram]

Trace element	Guideline concentration[1] (mg/kg)		Median concentration in surficial sediments (mg/kg)	
	Lowest effect level	Severe effect level	Unenriched	Enriched
Arsenic.....	6	33	4.7	120
Cadmium ..	.6	10	2.8	56
Copper	16	110	25	70
Lead	31	250	24	1,800
Mercury	.2	2	.05	1.6
Zinc.....	120	820	110	3,500

[1] From Persaud and others (1993).

The Ontario Ministry of Environment published guidelines for aquatic sediment quality for numerous elements and compounds, including trace elements and nutrients (Persaud and others, 1993). The guidelines include three levels: no effect, lowest effect, and severe effect. The lowest effect level signifies sediment contamination that can be tolerated by most benthic organisms. The severe effect level signifies severely polluted sediment that will significantly affect benthic organisms. The lowest effect and severe effect levels for arsenic, cadmium, copper, lead, mercury, and zinc are listed in table 29, as are the median concentrations of these six trace elements in unenriched and enriched surficial sediments in Coeur d'Alene Lake. Median concentrations of arsenic, lead, mercury, and zinc in unenriched sediments were less than the lowest effect level guidelines; median concentrations of cadmium and copper were slightly above those guidelines but were less than the severe effect level guidelines. Median concentrations of arsenic, cadmium, lead, and zinc in enriched sediments exceeded the severe effect level guidelines; median concentrations of copper and mercury did not. On the basis of these comparisons, the concentrations of arsenic, cadmium, lead, and zinc indicate severely polluted sediment that can significantly affect benthic organisms. The Ontario Ministry guidelines for nutrients are as follows: lowest effect level for total phosphorus, 600 mg/kg, and for total nitrogen, 550 mg/kg; severe effect level for total phosphorus, 2,000 mg/kg, and for total nitrogen, 4,800 mg/kg. The mean concentration of total phosphorus in the lakebed sediments of Coeur d'Alene Lake was 940 mg/kg, which is slightly higher than the lowest effect level guideline and much less than the severe effect level guideline. The mean concentration of total nitrogen was 2,100 mg/kg, which is about midway between the lowest effect level and severe effect level guidelines.

HYDROLOGIC BUDGETS

Hydrologic budgets for Coeur d'Alene Lake were determined for calendar years 1991 and 1992. The budgets accounted for the mass of water entering and leaving the lake via pathways such as streamflow, precipitation, and evaporation. Such data were important components of the nutrient load/lake response model and were used to compute budgets for nutrients and trace elements entering and leaving the lake.

Data Collection and Analysis

The hydrologic budgets included a 28.6-km reach of the Spokane River from the outlet of Coeur d'Alene Lake to the USGS gaging station near the Idaho-Washington border. Inclusion of this station provided the most accurate method for measuring surface-water outflow from the lake and also permitted calculation of the residual between inflow and outflow quantities. Hydrologic budgets for 1991 and 1992 were computed using the following equation (quantities in cubic hectometers):

$$R = SWGI + SWUI + WWI + P - E - GWRP - SWGO - CS, \quad (7)$$

where

R is the residual;
$SWGI$ is gaged surface-water inflow;
$SWUI$ is ungaged surface-water inflow;
WWI is wastewater inflow;
P is precipitation to the lake and river surface;
E is evaporation from the lake and river surface;
$GWRP$ is ground-water outflow to the Rathdrum-Prairie aquifer;
$SWGO$ is gaged surface-water outflow; and
CS is change in lake storage.

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Gaged surface-water inflow to the lake was determined at six USGS gaging stations; gaged surface-water outflow from the lake was determined at a USGS gaging station on the Spokane River 28.6 km downstream from the lake's outlet (fig. 4 and table 30). Discharge at the seven gaging stations was determined from continuous monitoring of stage (water-surface elevation) and periodic measurements of streamflow using standard USGS methods. Streamflow measurements were made weekly during March through May and biweekly otherwise at the St. Joe, Coeur d'Alene, and Spokane River gaging stations. The remaining four gaging stations were measured biweekly during March through May and monthly otherwise.

Daily discharges at the St. Joe River at St. Maries gaging station and the Coeur d'Alene River near Harrison gaging station were computed with a hydraulic model because backwater conditions created by Coeur d'Alene Lake negated the correlation between streamflow and stage that commonly is used to compute discharge. The hydraulic model is a USGS-developed branch-network flow model, referred to as BRANCH, and is based on one-dimensional, partial-differential equations of continuity and momentum that govern unsteady flow (Schaffranek and others, 1981). The model is applied by continuously measuring stage at two or more gaging stations in a low-gradient reach of stream. Multiple channel cross sections in the reach are input to the model to quantify channel capacity. For the St. Joe River application, the upstream and downstream stage-measurement stations were St. Joe River at St. Maries (gaging station 1) and St. Joe River near Chatcolet (USGS gaging station 12415140), respectively. For the Coeur d'Alene River application, the upstream and downstream stage-measurement stations were Coeur d'Alene River near Cataldo (USGS gaging station 12413500) and Coeur d'Alene River near Harrison (gaging station 2), respectively.

Ungaged surface-water inflows were estimated by multiplying drainage basin areas by unit-runoff coefficients. Unit-runoff coefficients for the gaged surface-water inflow at Carlin, Fighting, Plummer, and Wolf Lodge Creeks were determined using the following equation:

$$RO = \frac{Q}{A}, \tag{8}$$

where

RO is a unit-runoff coefficient, in cubic hectometers per square kilometer per year;
Q is annual discharge, in cubic hectometers; and
A is drainage area, in square kilometers.

Each of 23 ungaged surface-water inflows was assigned a unit-runoff coefficient on the basis of factors such as similar land use and land cover characteristics and proximity to a particular gaged surface-water station.

Precipitation to the lake and river was determined by multiplying surface area by the precipitation recorded at the National Weather Service station in Coeur d'Alene. Precipitation during 1991 and 1992 at Coeur d'Alene was 0.50 and 0.58 m, respectively. Long-term average annual precipitation is 0.66 m (Woods, 1989). Precipitation was 76 percent of normal in 1991 and 89 percent of normal in 1992. Evaporation from the lake and river was estimated by multiplying the surface area by an evaporation rate of 0.76 m. The evaporation rate was derived from a map of annual free-water-surface evaporation in Idaho (Myron Molnau and K.C.S. Kpordze, University of Idaho, written commun., 1992).

The change in lake storage for 1991 and 1992 was reported in USGS annual reports of water resources data for Idaho (Harenberg and others, 1992, 1993, 1994). These reports contain tables of lake capacity and stage for numerous Idaho lakes and reservoirs. The change in lake storage represents the difference in

Table 30. Gaging stations used to calculate inflow to and outflow from Coeur d'Alene Lake

[km^2, square kilometer]

Gaging station name (fig. 4)	Gaging station No.	Drainage area (km^2)	Period of record
St. Joe River at St. Maries	12415075	4,400	1991–92
Plummer Creek near Plummer	12415250	114	1991–92
Coeur d'Alene River near Harrison	12413860	3,812	1991–92
Fighting Creek near Rockford Bay	12415285	41.6	1991–92
Carlin Creek near Harrison	12415290	31.7	1991–92
Wolf Lodge Creek near Coeur d'Alene	12415350	104	1985–Present
Spokane River near Post Falls	12419000	10,313	1912–Present

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contents between January 1 and December 31 in a given year.

An evaluation of ground-water flux to Coeur d'Alene Lake was beyond the scope of this study. However, Wyman (1993) reported that ground-water outflow from Coeur d'Alene Lake to the Rathdrum Prairie aquifer was 205 hm^3 per year; this value was assigned as an outflow quantity for the 1991 and 1992 hydrologic budgets. The remaining ground-water flux was assigned to the residual.

The volume of wastewater inflow to the lake was a summation of discharges from municipal wastewater-treatment plants and wastewater-disposal systems in the nearshore area of Coeur d'Alene Lake. The municipal wastewater-treatment plants serving Coeur d'Alene and Post Falls reported their annual discharge of effluent on the basis of frequent measurements during 1991 and 1992. During 1992, the small municipal wastewater-treatment plants serving Clarkia, Harrison, Mullan, Page, Plummer, Santa/Fernwood, Smelterville, and St. Maries measured their effluent discharge on an approximate biweekly basis to quantify their annual discharge. The 1992 discharge value was used as an estimate for the 1991 hydrologic budget. Several of the small municipal wastewater-treatment plants are upstream from gaged surface-water inflows; thus, their effluents are part of the gaged inflow. The Coeur d'Alene River at Harrison receives effluent from Mullan, Smelterville, and Page. The St. Joe River at St. Maries receives effluent from Santa/Fernwood and Clarkia. Plummer Creek receives effluent from Plummer. The effluent contribution from the nearshore area was determined differently because inflows could not be measured. In 1993, the Panhandle Health District, under contract to the USGS, conducted a survey of private and community wastewater-disposal systems and the associated user population within 150 m of Coeur d'Alene Lake (Hale, 1993). The population data were reported as full-time and part-time residency. The population data were converted to an equivalent full-time residency and then were multiplied by a yearly per capita effluent production rate of 55,000 L, which was based on a daily per capita rate of 150 L reported by Canter and Knox (1985). The 1993 survey also reported the volume of wastewater generated annually by nearshore commercial and camp facilities.

The residual for the hydrologic budget was computed as the difference between gaged surface-water outflow and the algebraic sum of inflow and outflow components upstream from the Spokane River gaging station near the Idaho-Washington border. The residual includes the errors associated with all budget components and unmeasured components such as ground-water flux, bank-storage flux, and urban runoff.

The error associated with the hydrologic budgets was computed with methods described by Winter (1981) and Brown (1987). The error associated with each budget component was computed with the following equation (Brown, 1987):

$$E = \sqrt{(P)^2 (C)^2}, \tag{9}$$

where

E is total standard error associated with budget component C,

P is percent error used to determine budget component C, and

C is value of the budget component.

Percent error for each budget component was adapted from Winter (1981). Assignment of percent error to each budget component was as follows: St. Joe River, Coeur d'Alene River, and precipitation, 15 percent; Carlin, Fighting, Plummer, and Wolf Lodge Creeks, lake storage change, and Spokane River, 7.5 percent; and ungaged surface-water inflow, wastewater, evaporation, and ground-water outflow, 25 percent. The propagation of error for the hydrologic budgets was computed with the following equation (Brown, 1987):

$$OE = \sqrt{(E_1)^2 + (E_2)^2 + \ldots + (E_n)^2}, \tag{10}$$

where

OE is overall standard error associated with hydrologic budget, in cubic hectometers; and

E_n is total standard error associated with each budget component.

The residence time of water in Coeur d'Alene Lake was computed with the following equation:

$$RT = \frac{V}{Q}, \tag{11}$$

where

RT is residence time, in years;

V is lake volume, in cubic hectometers; and

Q is total inflow, in cubic hectometers per year.

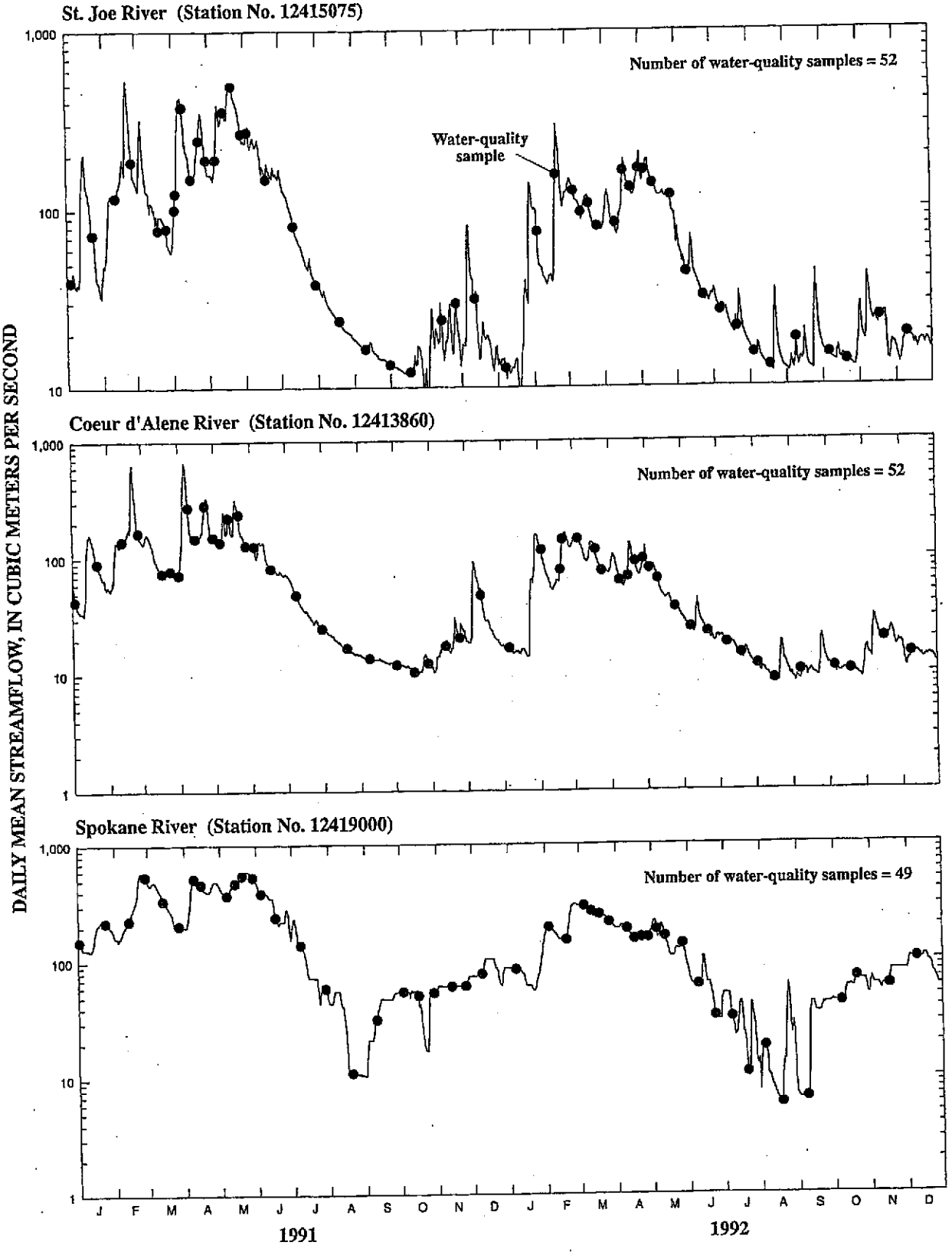


Figure 21. Daily mean streamflow and timing of water-quality samples at seven gaging stations during 1991–92.

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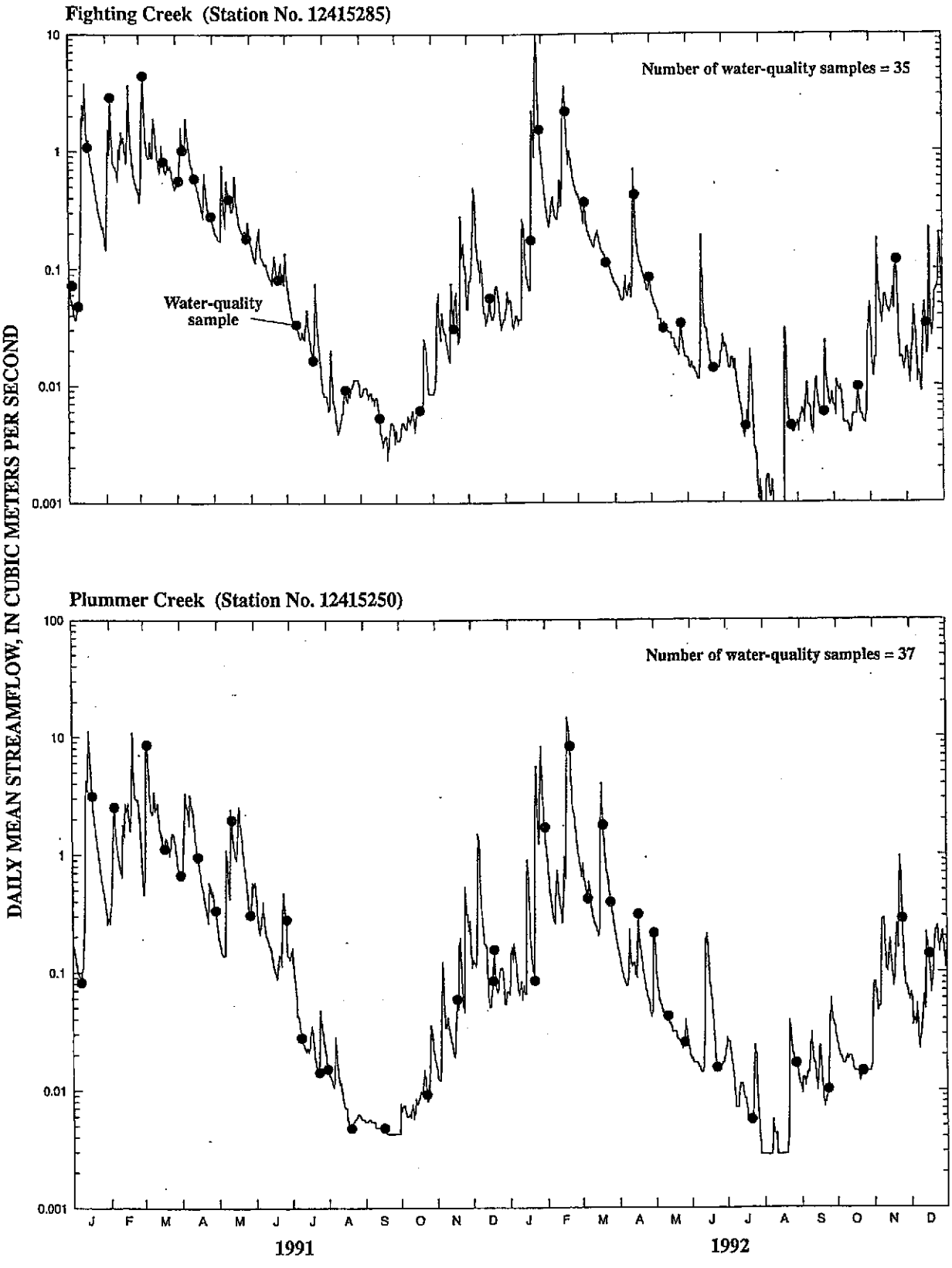


Figure 21. Daily mean streamflow and timing of water-quality samples at seven gaging stations during 1991–92.—Continued.

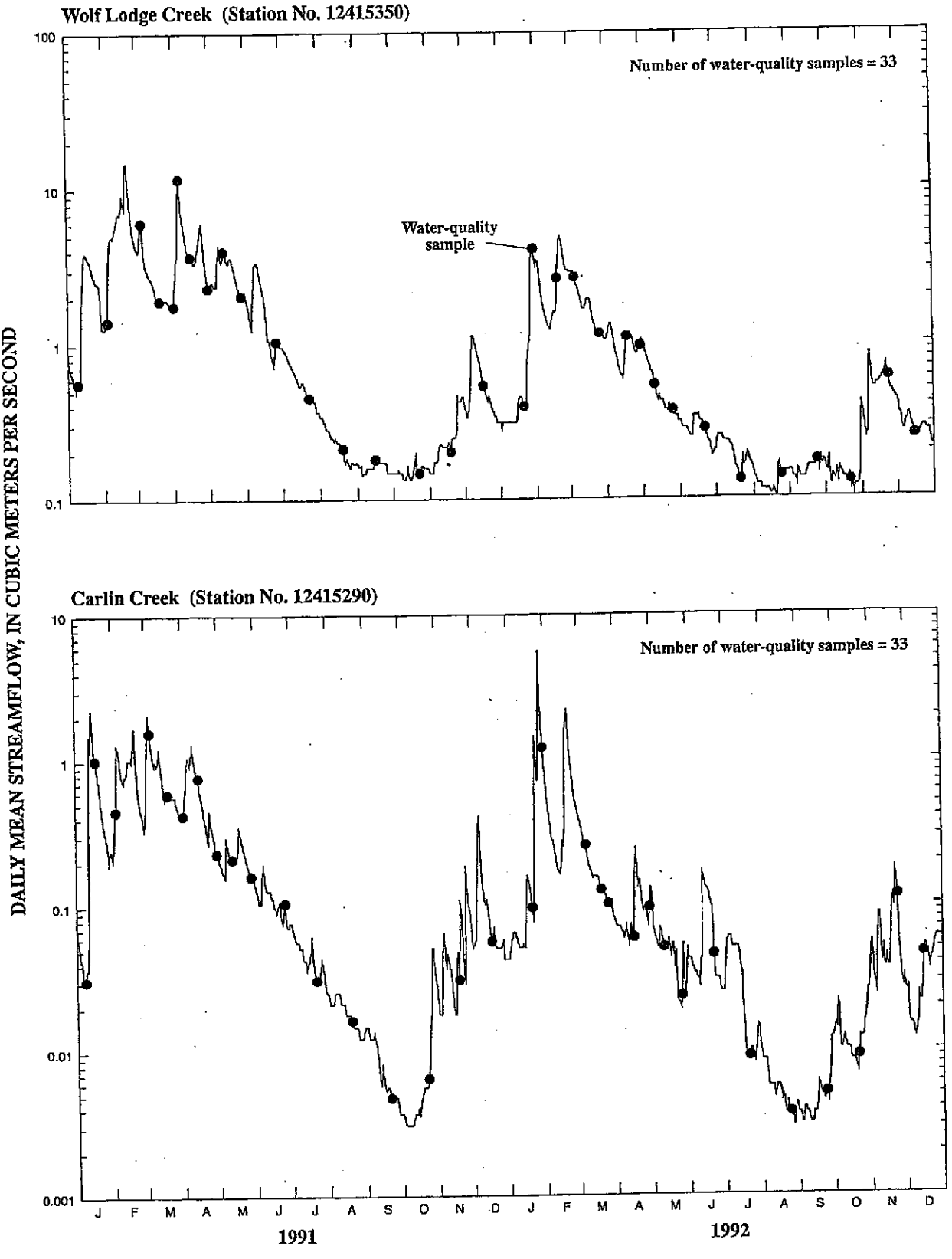


Figure 21. Daily mean streamflow and timing of water-quality samples at seven gaging stations during 1991–92—Continued.

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Streamflow, 1991 and 1992

Daily mean streamflows at the seven gaging stations varied widely (fig. 21). Maximum streamflows at the two primary inflow stations at the St. Joe and Coeur d'Alene Rivers were between February and May. Maximum streamflows at the four secondary inflow stations were earlier, from January to March, because these stations do not record drainage from upper-elevation areas as do the two primary inflow stations. The variability in the streamflow record at the outlet station, Spokane River, was somewhat muted because of regulation by Post Falls Dam.

Statistical summaries of streamflow at USGS gaging stations in Idaho were presented by Harenberg and others (1993); however, the summaries were computed for water years, not calendar years, as used in this study. The 1991 and 1992 streamflows, based on water years, at three stations in the study area were compared with long-term mean annual streamflows (table 31). Streamflow during the 1991 water year was about 130 percent of the long-term mean and, during the 1992 water year, was about 56 to 60 percent of the mean.

Unit-runoff coefficients for gaged and ungaged surface-water inflows for 1991 (0.10 to 0.74 hm^3/km^2) were about twice as large as those determined for 1992 (0.05 to 0.37 hm^3/km^2) (table 32). The largest coefficient in each year was for the St. Joe River at St. Maries; the coefficient for the Coeur d'Alene River near Harrison was slightly smaller. These two gaging stations record drainage from the highest elevation areas in the study area. Conversely, the smallest coefficients were for low-elevation, nearshore areas around Coeur d'Alene Lake.

Hydrologic Budgets, 1991 and 1992

Inflows from the St. Joe and Coeur d'Alene Rivers during 1991 accounted for 93.2 percent of the total inflow to Coeur d'Alene Lake (table 33). Gaged inflows from Plummer, Fighting, Carlin, and Wolf Lodge Creeks accounted for only 1.6 percent of the total, whereas the 23 ungaged surface-water inflows accounted for 4.1 percent. The smallest inflow contribution, 0.1 percent, was from wastewater. The outflows

Table 31. Long-term mean annual streamflow in relation to streamflow during 1991 and 1992 measured at three gaging stations near Coeur d'Alene Lake

[m^3/s, cubic meters per second; period of record in water years]

Gaging station name (fig. 4)	Gaging station No.	Mean annual streamflow (m^3/s)		Streamflow (m^3/s)		Percent of long-term mean	
		Long-term	Period of record	1991	1992	1991	1992
St. Joe River at Calder	12414500	66.4	1911–92	85.6	40.2	129	60.5
Coeur d'Alene River at Cataldo	12413500	71.6	1911–92	92.9	40.1	130	56.0
Spokane River near Post Falls	12419000	175	1912–92	227	97.8	130	55.9

Table 32. Unit runoff coefficients for surface-water inflow to Coeur d'Alene Lake, 1991–92

[km^2, square kilometer; hm^3/km^2, cubic hectometer per square kilometer; SA, study area; USGS, U.S. Geological Survey]

Subbasin No. (fig. 3)	Subbasin name (table 4)	Drainage area (km^2)	Unit runoff (hm^3/km^2)	
			1991	1992
L1	City of Coeur d'Alene	[1]34.9	0.55	0.21
L2	Fernan Creek	49.5	.55	.21
L3	Bennett Bay, nearshore	18.9	.13	.07
L4	Blue Creek	20.5	.27	.14
L5	Wolf Lodge Creek	104	.55	.21
L6	Wolf Lodge Bay, nearshore, northeast	5.4	.13	.07
L7	Cedar Creek	62.5	.55	.21
L8	Wolf Lodge Bay, nearshore, southeast	1.7	.13	.07
L9	Beauty Creek	28.9	.27	.14
L10	Squaw Bay to Echo Bay, nearshore	34.2	.27	.14
L11	Turner Creek	16.5	.27	.14
L12	Carlin Bay, nearshore	7.2	.14	.07
L13	Carlin Creek	31.7	.27	.14
L14	Powderhorn Bay, nearshore	44.3	.27	.14
L15	Harrison to St. Maries, nearshore	54.9	.19	.10
L16	Chatcolet Lake, nearshore, south	34.3	.10	.05
L17	Benewah Creek	138	.17	.10
L18	Plummer Creek	114	.19	.10
L19	Windy Bay to Chatcolet Lake, nearshore	79.9	.19	.10
L20	Lake Creek	99.5	.25	.13
L21	Windy Bay, nearshore, north	14.1	.13	.06
L22	Fighting Creek	41.6	.25	.13
L23	Rockford Bay to Mica Bay, nearshore	41.9	.12	.06
L24	Mica Creek	67.7	.25	.13
L25	Mica Bay to Cougar Bay, nearshore	29.6	.25	.13
L26	Cougar Creek	48.5	.25	.13
L27	Cougar Bay, nearshore, northwest	2	.15	.06
R1	Spokane River, lake outlet to USGS gaging station near State line	624	.27	.14
C1–C7	Coeur d'Alene River upstream from Harrison	3,812	.68	.34
S1–S5	St. Joe River upstream from St. Maries	4,520	.74	.37
SA	Spokane River upstream from USGS gaging station	10,313	.61	.30

[1] Drainage area of 37.1 km^2 (table 4) reduced to 34.9 km^2 by subtraction of 2.2 km^2 area serviced by stormwater drainage system.

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were dominated by the Spokane River at 94.8 percent. The residual of the total outflow of 6,610 hm^3 minus the total inflow of 6,390 hm^3 was 220 hm^3, which represented 3.4 percent of the total inflow. The overall error in the budget was 796 hm^3; thus, the residual was accounted for by the overall error.

During 1992, inflows from the St. Joe and Coeur d'Alene Rivers again dominated at 92.1 percent of the total (table 34). The relative magnitude of the other inflow sources was similar to that in the 1991 budget. The Spokane River accounted for 89.8 percent of the total outflow. The overall error in the 1992 budget was 436 hm^3 and encompassed the residual of 310 hm^3. The residual represented 9.7 percent of the total inflow for 1992.

The residence time of water in Coeur d'Alene Lake was different for each year because of the large differences in inflow. In 1991, the inflow of 6,390 hm^3 was delivered into a lake volume of 2,840 hm^3 and yielded a residence time of 0.45 year. In 1992, the smaller inflow of 3,190 hm^3 yielded a residence time of 0.89 year, nearly twice that of 1991.

Table 33. Hydrologic budget and errors associated with each budget component, Coeur d'Alene Lake, 1991

[Volumes and errors are in cubic hectometers]

Budget component	Inflow or outflow		Error
	Volume	Percent of total	
Inflow			
St. Joe River	3,350	52.4	502
Coeur d'Alene River	2,610	40.8	391
Plummer Creek	22	.3	1.6
Fighting Creek	10.5	.2	.8
Carlin Creek	8.5	.2	.6
Wolf Lodge Creek	57	.9	4.3
Ungaged surface-water inflow	260	4.1	68
Wastewater	6.2	.1	1.5
Precipitation	64.6	1.0	9.7
Outflow			
Evaporation	98.3	1.5	24.6
Ground-water outflow to Rathdrum Prairie	205	3.1	51.2
Lake storage change	33.6	.06	2.5
Spokane River	6,270	94.8	470
Summary			
Total inflow	6,390		
Total outflow	6,610		
Residual (outflow - inflow)	220		
Overall error	796		

Table 34. Hydrologic budget and errors associated with each budget component, Coeur d'Alene Lake, 1992

[Volumes and errors are in cubic hectometers]

Budget component	Inflow or outflow		Error
	Volume	Percent of total	
Inflow			
St. Joe River	1,660	52.0	300
Coeur d'Alene River	1,280	40.1	200
Plummer Creek	11.4	.4	.9
Fighting Creek	5.5	.2	.4
Carlin Creek	4.5	.1	.3
Wolf Lodge Creek	21.9	.7	1.6
Ungaged surface-water inflow	125	3.9	34
Wastewater	5.5	.2	1.4
Precipitation	75	2.4	11
Outflow			
Evaporation	98.3	2.8	24.6
Ground-water outflow to Rathdrum Prairie	205	5.8	51.2
Lake storage change	54.3	1.6	4.1
Spokane River	3,140	89.8	236
Summary			
Total inflow	3,190		
Total outflow	3,500		
Residual (outflow - inflow)	310		
Overall error	436		

NUTRIENT BUDGETS

Nutrient budgets for Coeur d'Alene Lake were determined for calendar years 1991 and 1992. The budgets accounted for the mass of total phosphorus and total nitrogen entering and leaving the lake via pathways such as gaged and ungaged streamflow, precipitation, and wastewater from point and nonpoint sources. The nutrient budgets were calculated from the hydrologic budgets and nutrient concentration data from several sources.

Data Collection and Analysis

Nutrient data for gaged inflows and the outflow at seven gaging stations (table 30) were collected using standard USGS cross-sectional and depth-integrating

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methods (Edwards and Glysson, 1988). The frequency of sampling is illustrated in figure 21. During 1991–92, each gaging station was sampled between 33 and 52 times; the gaging stations on the Coeur d'Alene, St. Joe, and Spokane Rivers were sampled the most frequently. Nutrient samples were analyzed for concentrations of total phosphorus, orthophosphorus, organic plus ammonia nitrogen, ammonia, and nitrite plus nitrate at the USGS National Water Quality Laboratory using methods described by Fishman and Friedman (1985).

Annual loads of nutrients at the seven gaging stations were computed with methods presented by Walker (1987). Walker developed a computer program (FLUX) that stratifies streamflow and nutrient concentration data to reduce error. The stratified data sets then are used to compute load with five equations: direct load averaging, flow-weighted concentration, modified flow-weighted concentration, first-order regression, and second-order regression. The equation and stratification method that yields the smallest coefficient of variation is considered the best estimate of load. The program provides several diagnostic tools for assessing the results; these include plots of residuals and hypothesis tests for the various model parameters.

Annual loads of nutrients from ungaged surface-water inflows were computed with the following equation:

$$L = (A)\ (N), \qquad (12)$$

where

L is annual nutrient load, in kilograms;
A is drainage basin area, in square kilometers; and
N is nutrient export coefficient, in kilograms per square kilometer.

The nutrient export coefficients were computed for the gaged inflows from Plummer, Fighting, Carlin, and Wolf Lodge Creeks. A coefficient is computed by dividing the annual nutrient load, in kilograms, by the drainage basin area, in square kilometers. The application of a specific nutrient export coefficient to an ungaged inflow was based on similarities in hydrology and land use and land cover characteristics.

Annual loads of nutrients from atmospheric sources were estimated with data presented by Stanford and others (1983), Hallock and Falter (1987), and National Atmospheric Deposition Program (1991). The annual areal deposition rates, in kilograms per square kilometer, were multiplied by lake surface area, in square kilometers, to determine the annual load to the lake.

Annual loads of nutrients from municipal wastewater-treatment plants were computed by multiplying their annual effluent volume, in cubic hectometers, by the mean nutrient concentration of their effluent, in micrograms per liter. Private and community wastewater-treatment systems in the nearshore area of the lake also contribute nutrient loads to the lake. Their annual effluent volumes, in cubic meters, computed for the hydrologic budgets, were multiplied by nutrient concentrations, in milligrams per liter, to compute annual loads. The nutrient concentrations in septic-tank effluents were estimated to be 15 mg/L for total phosphorus and 38 mg/L for total nitrogen (Canter and Knox, 1985). Nutrients leached from septic tanks are partially retained by soil; therefore, the nutrient loads were adjusted by applying a soil retention coefficient: 0.9 for total phosphorus and 0.5 for total nitrogen (Soltero and others, 1993).

The annual loads of nutrients leaving Coeur d'Alene Lake in ground-water outflow to the Rathdrum Prairie aquifer were computed by multiplying the outflow volume, in cubic hectometers, by the mean nutrient concentration, in micrograms per liter, in the hypolimnion of the northern end of Coeur d'Alene Lake. Similarly, the mean annual concentration of nutrients, in micrograms per liter, in the epilimnion of the northern end of the lake was multiplied by the annual change in lake volume, in cubic hectometers, to compute the annual nutrient load associated with this budget component.

The residual for each nutrient budget was computed as the difference between the nutrient load discharged from the outflow station, Spokane River, and the algebraic sum of nutrient loads (inflow and outflow) upstream from the outflow station. The residual contains the errors associated with measured and unmeasured budget components. Residuals of these nutrient budgets cannot be used to assess the adequacy of the load computations because nutrients in Coeur d'Alene Lake are not conservative and are affected by physical, chemical, and biological processes.

Errors associated with each component of the nutrient budgets were computed using errors in the hydrologic budgets and errors in the collection and analysis of nutrient concentration data. Assignment of percent error to each concentration in the nutrient bud-

get was as follows: gaged inflows and outflow, ground-water outflow, and lake storage change, 15 percent; and ungaged inflow, wastewater, and precipitation, 30 percent. Total error for each nutrient budget component was computed with the following equation (Brown, 1987):

$$E = \sqrt{\left[(E_c)^2 (Q)^2\right] + \left[(E_q)^2 (C)^2\right]}, \qquad (13)$$

where

E is total standard error associated with a nutrient budget component, in kilograms;
E_c is standard error associated with a nutrient concentration, in micrograms per liter;
Q is quantity of water, in cubic hectometers;
E_q is standard error associated with quantity of water, in cubic hectometers; and
C is nutrient concentration, in micrograms per liter.

Overall error for each nutrient budget was computed with the following equation (Brown, 1987):

$$OE = \sqrt{(E_1)^2 + (E_2)^2 + \ldots + (E_n)^2}, \qquad (14)$$

where

OE is overall standard error associated with nutrient budget, in kilograms; and
E_n is total standard error associated with each budget component.

Nutrient Budgets, 1991 and 1992

Total phosphorus contributed by the St. Joe River during 1991 accounted for 54.3 percent of the total phosphorus load to Coeur d'Alene Lake (table 35). The next largest loads, 16.6 and 15.0 percent, were contributed by the Coeur d'Alene River and wastewater, respectively. Of the 19,900 kg of total phosphorus contributed by wastewater, 17,910 kg, or 90 percent, was from the municipal wastewater-treatment plants at Coeur d'Alene and Post Falls, both of which are downstream from Coeur d'Alene Lake. Total phosphorus in outflow of the Spokane River, at 88.1 percent, dominated other outflow sources. The total inflow of total phosphorus was 133,000 kg, whereas the total outflow was 54,000 kg; thus, the lake acted as a trap for total phosphorus. The residual of 79,000 kg was larger than the overall error of 13,900 kg. The overall error was 10.4 percent of the total inflow.

During 1992, total phosphorus contributed by the St. Joe River again dominated, but to a lesser degree than during 1991 (table 36). Total phosphorus contributed by wastewater was the second-largest budget component at 24.4 percent. Total phosphorus from the Coeur d'Alene and Post Falls wastewater-treatment plants accounted for about 85 percent of the 13,400 kg from wastewater. The Coeur d'Alene River was the third-largest contributor of total phosphorus at 18.1 percent. The total inflow and outflow of total phosphorus in 1992 were substantially less than in 1991, reflecting the significant reduction in 1992 hydrologic loads. The lake again acted as a trap for total phosphorus because the total outflow was less than the total inflow by 16,000 kg. The overall error of 5,660 kg was contained within the residual and was 10.3 percent of the total inflow.

During 1991, 81.2 percent of the total nitrogen load was contributed by the St. Joe and Coeur d'Alene Rivers (table 35). Ungaged surface-water inflow was the next-largest contributor at 6.7 percent. Wastewater

Table 35. Nutrient budgets and errors for total phosphorus and total nitrogen, Coeur d'Alene Lake, 1991

[Loads and errors are in kilograms]

Budget component	Total phosphorus			Total nitrogen		
	Load	Percent of total	Error	Load	Percent of total	Error
Inflow						
St. Joe River	72,100	54.3	11,000	1,040,000	45.9	155,000
Coeur d'Alene River	22,000	16.6	3,120	801,000	35.3	121,000
Plummer Creek	2,060	1.6	180	38,000	1.7	3,460
Fighting Creek	610	.5	60	12,500	.6	1,190
Carlin Creek	205	.1	20	2,820	.1	330
Wolf Lodge Creek	590	.4	40	18,600	.8	1,320
Ungaged surface-water inflow	8,750	6.6	2,040	153,000	6.7	40,100
Wastewater	19,900	15.0	6,400	127,000	5.6	42,400
Precipitation	6,460	4.9	1,000	75,000	3.3	11,500
Outflow						
Ground-water outflow to Rathdrum Prairie	5,940	11.1	1,530	122,000	5.8	30,600
Lake storage change	410	.8	30	8,140	.4	720
Spokane River	47,600	88.1	3,760	2,020,000	93.8	150,000
Summary						
Total phosphorus				**Total nitrogen**		
Total inflow = 133,000				Total inflow = 2,270,000		
Total outflow = 54,000				Total outflow = 2,150,000		
Residual (outflow-inflow) = -79,000				Residual (outflow-inflow) = -120,000		
Overall error = 13,900				Overall error = 256,000		

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Table 36. Nutrient budgets and errors for total phosphorus and total nitrogen, Coeur d'Alene Lake, 1992

[Loads and errors are in kilograms]

Budget component	Total phosphorus Load	Total phosphorus Percent of total	Total phosphorus Error	Total nitrogen Load	Total nitrogen Percent of total	Total nitrogen Error
Inflow						
St. Joe River	18,300	33.3	3,300	418,000	41.0	75,000
Coeur d'Alene River	9,980	18.1	1,600	314,000	30.8	49,000
Plummer Creek	1,130	2.1	100	21,900	2.1	1,920
Fighting Creek	410	.8	70	8,210	.8	1,490
Carlin Creek	106	.2	20	1,480	.2	330
Wolf Lodge Creek	217	.4	20	6,860	.7	620
Ungaged surface-water inflow	4,990	9.1	1,360	89,200	8.7	24,100
Wastewater	13,400	24.4	2,400	85,100	8.3	14,200
Precipitation	6,460	11.6	1,100	75,000	7.4	11,000
Outflow						
Ground-water outflow to Rathdrum Prairie	7,590	19.4	2,040	153,000	16.4	38,200
Lake storage change	200	.6	40	11,700	1.2	880
Spokane River	31,300	80.0	2,360	770,000	82.4	57,800
Summary						
Total phosphorus				**Total nitrogen**		
Total inflow = 55,000				Total inflow = 1,020,000		
Total outflow = 39,000				Total outflow = 935,000		
Residual (outflow-inflow) = -16,000				Residual (outflow-inflow) = -85,000		
Overall error = 5,660				Overall error = 117,000		

contributed 5.6 percent of the total nitrogen load; however, 117,000 kg, or 92 percent, of the total nitrogen from wastewater was input downstream from the lake. The total inflow of nitrogen in 1991 was 2,270,000 kg, whereas the total outflow was 2,150,000 kg. The residual of 120,000 kg was about 50 percent of the overall error of 256,000 kg. The overall error was 11.3 percent of the total inflow of nitrogen.

During 1992, 71.8 percent of the total nitrogen load was contributed by the St. Joe and Coeur d'Alene Rivers (table 36). Wastewater contributed 85,100 kg of the total nitrogen load; 87.8 percent was input downstream from the lake. The total inflow of nitrogen in 1992 was 1,020,000 kg; total outflow was 935,000 kg. The residual of 85,000 kg was smaller than the overall error. The overall error was 11.5 percent of the total inflow of nitrogen. On the basis of residuals and overall errors for 1991 and 1992, the total inflow and outflow of nitrogen for each year were about equal.

The nutrient budgets in tables 35 and 36 account for inflow and outflow loads of total phosphorus and total nitrogen during 1991 and 1992. Nutrient loads also were computed for total orthophosphorus and total inorganic nitrogen (sum of ammonia and nitrite plus nitrate) measured at the three major surface-water gaging stations (table 37). The percentage contributions of total inorganic nitrogen to total nitrogen were similar between 1991 and 1992 and among the three stations; on the average, total inorganic nitrogen composed about 20 percent of total nitrogen. By subtraction, about 80 percent of the total nitrogen was composed of organic nitrogen. The relation of total orthophosphorus to total phosphorus was more variable but, on the average, total orthophosphorus was about 35 percent of total phosphorus.

The nutrient budgets quantify the absolute and relative magnitudes of load sources. For 1991 and 1992, loads of total phosphorus and total nitrogen were predominantly from the St. Joe and Coeur d'Alene Rivers because they drain the largest and highest elevation areas in the study area. The combined inflows from gaged and ungaged drainage basins, other than inflows measured at the St. Joe and Coeur d'Alene gaging stations, contributed less than 13 percent of the

Table 37. Nutrient loads measured at three gaging stations near Coeur d'Alene Lake, 1991–92

[kg, kilograms; TP, total phosphorus; TOP, total orthophosphorus; TN, total nitrogen; TIN, total inorganic nitrogen]

Gaging station name and No. (fig. 4)	Year measured	Load (kg) TP	Load (kg) TOP	Percent TOP of TP	Load (kg) TN	Load (kg) TIN	Percent TIN of TN
St. Joe River at	1991	72,100	14,200	19.7	1,040,000	163,000	15.7
St. Maries (12415075)	1992	18,300	7,240	39.6	418,000	71,800	17.2
Coeur d'Alene River near	1991	22,000	10,100	45.9	801,000	170,000	21.2
Harrison (12413860)	1992	9,980	3,910	39.2	314,000	74,000	23.6
Spokane River near	1991	47,600	14,000	29.4	2,020,000	391,000	19.4
Post Falls (12419000)	1992	31,300	11,000	35.1	770,000	184,000	23.9

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total phosphorus and total nitrogen loads. However, these smaller basins may be important determinants of nearshore water quality.

The nutrient load characteristics of these small basins may be assessed with nutrient export coefficients (table 38). During 1991, nutrient export coefficients for total phosphorus ranged from 2.4 to 18 kg/km^2. During 1992, the coefficients ranged from 0.7 to 9.9 kg/km^2. The coefficient for total nitrogen ranged from 33 to 333 kg/km^2 in 1991 and from 16.3 to 197 kg/km^2 in 1992. The smaller values for 1992 reflect the substantial reduction in the 1992 hydrologic budget. The largest coefficients were for Plummer, Lake, and Fighting Creeks and the drainage area from Mica Bay to Cougar Bay. Agriculture is the major land use in about 40 percent of the area drained by these four small basins (Idaho Department of Water Resources, 1993). Plummer Creek, with the highest nutrient export coefficients, also receives point source loads from the Plummer wastewater-treatment plant and a forest-products plant in the city of Plummer.

Nutrient loads from wastewater-treatment plants were evaluated in detail to determine whether particular plants were significant contributors to the overall load from wastewater. The evaluation did not include the municipal wastewater-treatment plants at Coeur d'Alene or Post Falls because neither discharges to Coeur d'Alene Lake. The municipal wastewater-treatment plant at Page, on the South Fork Coeur d'Alene River, was the primary contributor of total phosphorus and nitrogen (table 39). During 1991, the 5,400 kg of total phosphorus discharged by the Page plant represented 25 percent of the annual load of total phosphorus for the Coeur d'Alene River at its mouth; in 1992, a

Table 38. Annual nutrient export coefficients for surface-water inflow to and outflow from Coeur d'Alene Lake, 1991–92

[kg/km^2, kilograms per square kilometer; TP, total phosphorus; TN, total nitrogen; L, lake; C, Coeur d'Alene River; S, St. Joe River; R, Spokane River; USGS, U.S. Geological Survey; SA, study area; E, estimated value; M, measured value]

Subbasin No. (fig. 3)	Subbasin name (table 4)	Status	Annual nutrient export coefficient (kg/km^2)			
			TP		TN	
			1991	1992	1991	1992
L1	City of Coeur d'Alene	E	5.7	2.1	180	65.8
L2	Fernan Creek	E	5.7	2.1	180	65.8
L3	Bennett Bay, nearshore	E	3.2	1.6	43.9	22.6
L4	Blue Creek	E	6.5	3.3	89.3	46.5
L5	Wolf Lodge Creek	M	5.7	2.1	180	65.8
L6	Wolf Lodge Bay, nearshore, northeast	E	3.1	.7	42.4	23.2
L7	Cedar Creek	E	5.7	2.1	180	65.8
L8	Wolf Lodge Bay, nearshore, southeast	E	2.9	1.2	38.8	19.4
L9	Beauty Creek	E	6.5	3.3	89.3	46.5
L10	Squaw Bay to Echo Bay, nearshore	E	6.5	3.3	89.3	46.5
L11	Turner Creek	E	6.5	3.3	89.3	46.5
L12	Carlin Bay, nearshore	E	3.2	1.6	46.1	22.6
L13	Carlin Creek	M	6.5	3.3	89.3	46.5
L14	Powderhorn Bay, nearshore	E	6.5	3.3	89.3	46.5
L15	Harrison to St. Maries, nearshore	E	9.0	5.0	164	96.5
L16	Chatcolet Lake, nearshore, south	E	2.4	1.2	33	16.3
L17	Benewah Creek	E	8.0	5.0	147	96.5
L18	Plummer Creek	M	18	9.9	333	192
L19	Windy Bay to Chatcolet Lake, nearshore	E	9.0	5.0	164	96.5
L20	Lake Creek	E	14	9.4	298	187
L21	Windy Bay, nearshore, north	E	7.4	5.0	152	96.5
L22	Fighting Creek	M	14	9.8	298	197
L23	Rockford Bay to Mica Bay, nearshore	E	3.5	2.4	71	47.6
L24	Mica Creek	E	6.0	3.0	83	41.3
L25	Mica Bay to Cougar Bay, nearshore	E	14	9.5	298	190
L26	Cougar Creek	E	7.4	4.7	152	94.3
L27	Cougar Bay, nearshore, northwest	E	4.5	2.4	89	48.5
C1–C7	Coeur d'Alene River, upstream from Harrison	M	5.8	2.6	210	82.4
S1–S5	St. Joe River, upstream from St. Maries	M	16	4.1	230	92.5
R1	Spokane River, lake outlet to USGS gaging station near State line	E	6.5	3.3	89	46.5
SA	Spokane River, upstream from USGS gaging station	M	4.6	3.0	196	74.7

Table 39. Annual loads of total phosphorus and total nitrogen to Coeur d'Alene Lake from nearshore and municipal wastewater-treatment systems, 1991–92

[kg, kilograms; TP, total phosphorus; TN, total nitrogen; WWTP, wastewater-treatment plants]

Load source (fig. 1)	Annual load for 1991 and 1992 (kg)		Percent contribution to annual load for 1991 and 1992 (kg)	
	TP	TN	TP	TN
Nearshore[1]	390	4,900	4.7	8.7
Municipal WWTP				
Clarkia	20	315	.3	.6
Santa/Fernwood	60	320	.7	.6
St. Maries	1,400	3,720	17.1	6.6
Plummer	290	1,560	3.5	2.8
Mullan	310	2,550	3.8	4.6
Smelterville	225	1,550	2.7	2.8
Page	5,400	40,500	65.7	72.5
Harrison	120	450	1.5	.8
TOTAL	8,220	55,900	100.0	100.0

[1] Sum of private, community, and commercial wastewater-treatment systems within 150 meters of lake shoreline.

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year of low streamflow, the contribution was 54 percent. The municipal wastewater-treatment plant for St. Maries, near the mouth of the St. Joe River, contributed 17.1 percent of the total phosphorus and 6.6 percent of the total nitrogen from wastewater sources. The next-largest contributor was wastewater-producing sources in the lake's nearshore area. The remaining wastewater sources each contributed less than 5 percent of the load for each nutrient.

The only other nutrient load study of Coeur d'Alene Lake was done in 1975 as part of the National Eutrophication Survey (U.S. Environmental Protection Agency, 1977). Nutrient loads for 1975 were calculated using average streamflow conditions and nutrient concentrations from periodically collected samples. For comparison, the 1991 loads were recomputed using average streamflow conditions; the results are listed in table 37. The 1975 input of total phosphorus to the lake was 180,000 kg; 98,100 kg, or 54.5 percent, was contributed by the Coeur d'Alene River, and 56,300 kg, or 31.3 percent, was contributed by the St. Joe River. For 1991, the input of total phosphorus was 90,000 kg; 11,000 kg, or 12.2 percent, was contributed by the Coeur d'Alene River, and 54,000 kg, or 60 percent, was contributed by the St. Joe River. In 1975, more than 87 percent of the 3,400,000 kg of total nitrogen input to the lake was contributed almost equally by the Coeur d'Alene and St. Joe Rivers. In 1991, 1,600,000 kg of total nitrogen was input to the lake; 572,000 kg, or 35.8 percent, was contributed by the Coeur d'Alene River, and 794,000 kg, or 49.6 percent, was contributed by the St. Joe River. The 1991 loads of total phosphorus and nitrogen to the lake were about one-half of the 1975 loads (table 40). Additionally, the Coeur d'Alene River was the predominant contributor of total phosphorus in 1975 but, in 1991, the St. Joe River was the predominant contributor. The St. Joe River was also the predominant contributor of total nitrogen in 1991, whereas the St. Joe and Coeur d'Alene Rivers contributed nearly equal amounts in 1975.

Table 40. Loads of total phosphorus and total nitrogen to Coeur d'Alene Lake, 1975 and 1991

[kg, kilograms; TP, total phosphorus; TN, total nitrogen]

Load source	1975 loads[1] (kg)		1991 loads[2] (kg)	
	TP	TN	TP	TN
Coeur d'Alene River	98,100	1,490,000	11,000	572,000
St. Joe River	56,300	1,480,000	54,000	794,000
Other[3]	25,600	430,000	25,000	234,000
TOTAL	180,000	3,400,000	90,000	1,600,000

[1] From U.S. Environmental Protection Agency (1977); loads based on long-term annual mean discharge.

[2] Measured 1991 loads reduced by 30 percent to estimate loads at long-term annual mean discharge.

[3] Includes minor tributaries, nearshore septic tanks, direct precipitation to lake surface, and wastewater-treatment plants.

Table 41. Annual nutrient export coefficients for four tributaries to Coeur d'Alene Lake, 1975 and 1991

[kg/km², kilograms per square kilometer]

Load source (fig. 4)	Annual nutrient export coefficient (kg/km²)			
	Total phosphorus		Total nitrogen	
	1975[1]	1991[2]	1975[1]	1991[2]
Coeur d'Alene River	26	4.5	389	162
St. Joe River	13	12.3	331	177
Wolf Lodge Creek	5	4.3	162	138
Plummer Creek	4	13.2	109	257

[1] From U.S. Environmental Protection Agency (1977); loads based on long-term annual mean discharge.

[2] Loads reduced by 30 percent to estimate loads at long-term annual mean discharge.

Nutrient load data for 1975 and 1991 permitted calculation of nutrient export coefficients for several tributaries sampled during both studies. Annual nutrient export coefficients for total phosphorus and nitrogen (table 41) indicate several significant changes between 1975 and 1991. Total phosphorus and nitrogen export coefficients for the Coeur d'Alene River declined substantially. The total nitrogen export coefficient for the St. Joe River also declined substantially, but the total phosphorus coefficient showed almost no change. The nutrient export coefficients for Wolf Lodge Creek were comparable for both years. The nutrient export coefficients for Plummer Creek increased substantially.

TRACE-ELEMENT BUDGETS

Data Collection and Analysis

Trace-element budgets for Coeur d'Alene Lake were determined for calendar years 1991 and 1992. The budgets accounted for the mass of selected trace elements entering the lake from the St. Joe and Coeur d'Alene Rivers and leaving the lake in the Spokane River.

Trace-element data for the two gaged inflows and the outflow were collected concurrently with nutrient data. The samples were analyzed for total arsenic and total recoverable cadmium, copper, lead, and zinc

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using methods described by Fishman and Friedman (1985). The annual loads at each station were computed with the same methods used for computation of nutrient loads.

Trace-Element Budgets, 1991 and 1992

Correspondent with annual loads of nutrients, the annual loads of trace elements were substantially larger in 1991 than in 1992 (table 42). The Coeur d'Alene River contributed larger loads of arsenic, cadmium, lead, and zinc than did the St. Joe River. Loads of copper were similar for the two rivers. The zinc loads were by far the largest; the Coeur d'Alene River contributed 847,000 kg in 1991. Lead loads were the next largest; the Coeur d'Alene River contributed 273,000 kg in 1991. The sum of loads for the St. Joe and Coeur d'Alene Rivers was compared to the outflow load from the Spokane River. Except for copper, the outflow loads were substantially less than the sum of inflow loads. The lake, therefore, acted as a trap for arsenic, cadmium, lead, and zinc during 1991 and 1992.

On the basis of annual loads, the Coeur d'Alene River was the major contributor of arsenic, cadmium, lead, and zinc to Coeur d'Alene Lake. The loads were normalized by dividing the load, in kilograms, by the drainage area, in square kilometers, to derive a trace-element export coefficient. The trace-element export coefficients for the St. Joe and Coeur d'Alene Rivers reveal large differences (table 43), especially for lead and zinc export. The export of arsenic and cadmium for the Coeur d'Alene River was about twice as large as that for the St. Joe River; copper export was about equal for the two rivers.

Table 42. Trace-element loads measured at three gaging stations near Coeur d'Alene Lake, 1991–92

[kg, kilograms; locations shown in fig. 4]

Trace element	Loads (kg)							
	St. Joe River at St. Maries		Coeur d'Alene River near Harrison		Sum of St. Joe and Coeur d'Alene Rivers		Spokane River near Post Falls	
	1991	1992	1991	1992	1991	1992	1991	1992
Arsenic	3,370	1,670	6,400	2,990	9,770	4,660	6,280	3,140
Cadmium	4,850	1,870	8,100	3,900	12,950	5,770	6,280	3,140
Copper	19,900	9,780	20,400	9,480	40,300	19,300	40,400	17,800
Lead	26,600	10,000	273,000	57,700	300,000	67,700	45,300	20,200
Zinc	82,400	43,500	847,000	409,000	929,000	452,000	639,000	305,000

Table 43. Annual trace-element export coefficients for two gaging stations near Coeur d'Alene Lake, 1991–92

[All values in kilograms per square kilometer; locations shown in fig. 4]

Trace element	St. Joe River at St. Maries		Coeur d'Alene River near Harrison	
	1991	1992	1991	1992
Arsenic	0.75	0.37	1.7	0.78
Cadmium	1.1	.41	2.1	1.0
Copper	4.4	2.2	5.4	2.5
Lead	5.9	2.2	72	15
Zinc	18	9.6	222	107

NUTRIENT LOAD/LAKE RESPONSE MODEL

Model Description

A nutrient load/lake response model was used to provide a mathematical method for simulating Coeur d'Alene Lake's limnological responses to alterations in water and nutrient loads delivered to the lake from numerous sources. The empirical mathematical model simulated the following eutrophication-related variables: concentrations of total phosphorus, total nitrogen, and chlorophyll-*a*; secchi-disc transparency; and hypolimnetic dissolved-oxygen deficit.

The model was developed for the U.S. Army Corps of Engineers Waterways Experiment Station as part of its Environmental and Water Quality Operational Studies Program. The model was developed because most empirical lake-eutrophication models are inadequate to simulate eutrophication in reservoirs. Walker (1981, 1982, 1985, 1987) thoroughly described the model's conceptual basis, development history, and application procedures.

The model empirically relates eutrophication characteristics to tributary nutrient loads, tributary and lake hydrology, and lake morphometry. Three programs, FLUX, PROFILE, and BATHTUB, compose the model. The FLUX program quantifies tributary loads of water and nutrients using a variety of calculation methods. The PROFILE program generates statistical summaries of water-quality conditions in the water body within a temporal and spatial context. The BATHTUB program applies nutrient-balance models and eutrophication-response models within a spatially segmented hydraulic framework that accounts for advection, diffusion, and sedimentation.

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The BATHTUB program is a highly evolved version of empirical lake-eutrophication models, and incorporates additional variables to account for the important differences between lakes and reservoirs. Some of BATHTUB's enhancements include nonlinear nutrient-sedimentation kinetics, inflow nutrient partitioning, seasonal and spatial variations, and algal growth limitation by factors such as phosphorus, nitrogen, light, and flushing rate. If error estimates are provided for input variables, BATHTUB can express output variables in probabilistic terms.

An important feature of the BATHTUB program is the provision for modeling linked segments of the lake to account for important spatial variations in water quality. Segment boundaries can be selected on the basis of factors such as lake morphometry, important sources of water and nutrients, observed spatial variations in water quality, and lake hydrodynamics.

Model Application

Coeur d'Alene Lake and the Spokane River outlet arm were divided into seven segments (fig. 22). Segment 1 includes the shallow, southern end of the lake south of Conkling Point. The four shallow lakes, Benewah, Chatcolet, Hidden, and Round, are within this segment. The St. Joe River is routed via levees through most of this segment. Breithaupt (1990) reported the St. Joe River had little influence on water quality in Chatcolet Lake. Therefore, the St. Joe River was routed into segment 2, which begins north of Conkling Point and extends to just south of the mouth of the Coeur d'Alene River. This segment is also relatively shallow. Segment 3 extends from the mouth of the Coeur d'Alene River to just south of Carlin Bay. This segment represents the mixing zone for the St. Joe and Coeur d'Alene Rivers because it contains a large volume and includes a turbulence-inducing right-angle turn to the north. Segment 4 contains the deepest area of the lake and extends from Carlin Bay to just south of the lake's large northern basin. Segment 5 includes the eastern end of Wolf Lodge Bay. This segment is somewhat isolated hydrologically from the main flow pattern in the lake. Segment 6 includes the remainder of the lake's deep, northern basin and also the outlet to the Spokane River. Segment 7 is the Spokane River arm from the lake outlet to Post Falls Dam. This last segment was included to quantify loads of water and nutrients so that the hydrologic and nutrient budgets could account for the influence of this segment. Characteristics such as surface area, volume, mean depth, and maximum depth for each segment are listed in table 44.

Water-quality characteristics for each segment were computed with PROFILE using data from limnetic stations 1 through 6 and the outlet station on the Spokane River. The water-quality characteristics input to BATHTUB represented mean annual values for the euphotic zone for calendar year 1991 or 1992. The euphotic zone was modeled because the empirical relations used by BATHTUB were derived largely from studies of euphotic zones.

The water and nutrient loads input to BATHTUB were derived from the previously discussed hydrologic and nutrient budgets for 1991 and 1992. Each model segment received inflows from the subbasins that delivered water and nutrients to that segment. The contributing subbasins are illustrated in figure 3; their contribution to each segment was apportioned if the subbasin affected more than one segment. Contributions of the wastewater-treatment plants at Plummer, St. Maries, Harrison, Coeur d'Alene, and Post Falls were input to segments 1, 1, 3, 7, and 7, respectively. Inputs from nearshore septic-tank systems were allocated to each segment, as were gains and losses from precipitation and evaporation.

The model was calibrated using 1991 data. After calibration, the model's applicability to Coeur d'Alene Lake was verified using 1992 data. After calibration and verification, the model was used to simulate the lake's responses to various nutrient-management scenarios.

Simulations of nutrient-management scenarios were based on decreases or increases in nutrient loads delivered to the lake by specific input sources. Nutrient loads were altered by decreasing or increasing nutrient concentrations of the input sources. The volume of water delivered by the input source was not altered because nutrient-management scenarios were assumed to affect concentrations, not flows. Limnological responses to alterations in nutrient loads were simulated with 1991 data. The magnitudes of the responses were assessed by comparing them with 1991 conditions estimated by the model. The output format of the simulations allowed assessment of changes in the mean value for each response variable, either within a segment or on an area-weighted, lakewide basis. The weighting factor for each segment is listed in table 44 and is based on a segment's surface area in relation to the combined

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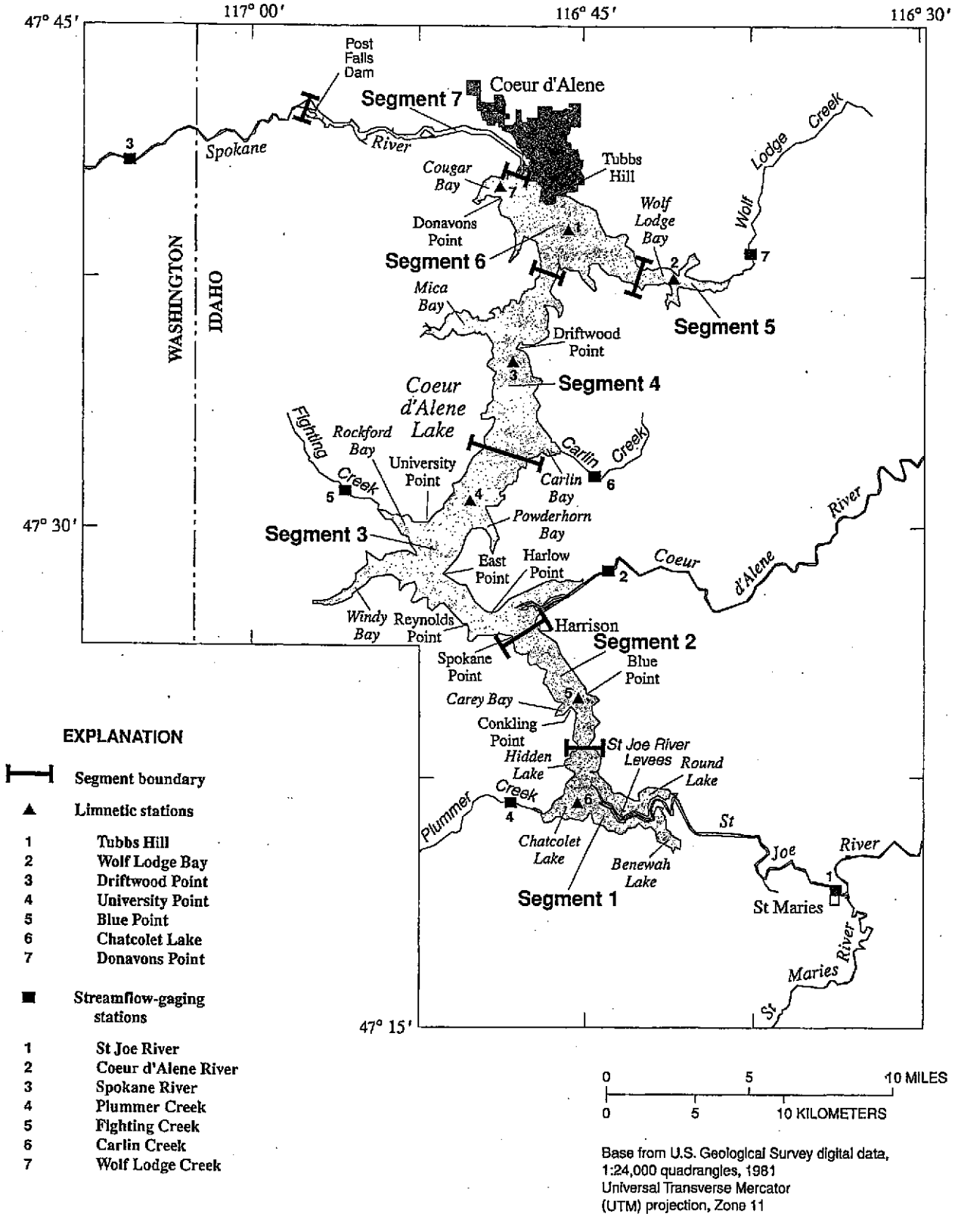


Figure 22. Segmentation of Coeur d'Alene Lake for nutrient load/lake response model.

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Table 44. Characteristics of the seven segments of Coeur d'Alene Lake modeled by BATHTUB

[km^2, square kilometers; km^3, cubic kilometers; m, meters; L, limnetic; T, tributary]

Characteristics and units	Segment (fig. 22)						
	1	2	3	4	5	6	7
Surface area, km^2	15.6	11.7	41.5	29.5	4.45	26.2	3.0
Volume, km^3	.03	.12	.95	.97	.06	.71	.01
Mean depth, m	1.9	11.3	23.2	33.4	15.8	27.5	3.2
Maximum depth, m	12	23	45	63.7	30	55	8
Segment weight[1]	.12	.10	.31	.22	.03	.20	.02
Important tributary inflow source	Plummer Creek	St. Joe River	Coeur d'Alene River	None	Wolf Lodge Creek	None	None
Outflow routed to segment number	2	3	4	6	6	7	Outlet
Water-quality sampling station for segment	L 6	L 5	L 4	L 3	L 2	L 1	T 7

[1]Based on surface area of segment divided by surface area of lake and outlet arm.

surface area of the lake and the Spokane River outlet arm.

Model Calibration and Verification

The model was calibrated with 1991 data and by selecting submodels for the nine model options (table 45) discussed in the applications manual (Walker, 1987). The results of model calibration for each segment and for the area-weighted, lakewide mean values are summarized in table 46. The variables total phosphorus, total nitrogen, and hypolimnetic dissolved-oxygen deficit required calibration; the other variables did not. The ratios between observed and estimated mean values for the seven segments ranged from 0.9 to 1.5; on a lakewide basis, the ratios ranged from 1.0 to 1.2.

The model was verified with 1992 data and the submodels listed in table 42; the results are summarized in table 47. The ratios between observed and estimated mean values for the seven segments ranged from 0.5 to 2.4 and, for the lakewide comparison, from 0.7 to 1.5.

The comparison of observed and estimated mean values is not the only criterion on which to judge the model's performance. The model output displays the mean value, plus or minus one standard error, for each observed and estimated value. These statistical estimates are computed on the basis of errors associated with the model, as well as errors associated with each input variable. The presence or absence of overlap in the standard errors for each variable and segment is listed in table 48. For the calibration, the standard errors for all variables overlap in each segment and lakewide. For the verification, the standard error for total phosphorus does not overlap in segments 1, 6, and 7. The standard error for nitrogen does not overlap in segment 1 and, for chlorophyll-*a*, does not overlap in segment 5. The standard errors for all variables overlap lakewide.

Table 45. Submodel selection for calibration and verification of nutrient load/lake response model, Coeur d'Alene Lake

Model option	Submodel selected	Submodel description
Conservative substance	0	Do not compute.
Phosphorus sedimentation	1	Second order, available phosphorus.
Nitrogen sedimentation	1	Second order, available nitrogen.
Mean chlorophyll-*a*	4	Phosphorus, linear.
Secchi-disc transparency	1	Secchi-disc transparency versus chlorophyll-*a* and turbidity.
Dispersion	1	Fischer and others (1979); Walker (1985).
Phosphorus calibration	2	Multiply estimated concentrations by calibration factors.
Nitrogen calibration	1	Multiply estimated decay rates by calibration factors.
Error analysis	1	Compute using input data error and model error terms.

Simulation Results

A wide variety of simulations was possible owing to the complexity of Coeur d'Alene Lake and its drainage basin, as well as to a diverse assortment

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of nutrient-reduction responses that could be tested and evaluated. The five simulations reported herein were designed to address two principal questions: (1) Would large increases in nutrient loads cause the lake's hypolimnion to become anoxic, and (2) would the lake's water quality be substantially improved by large reductions in nutrient loads.

The first question required an estimate of the hypolimnetic dissolved-oxygen deficit needed to produce an anoxic hypolimnion. A dissolved-oxygen data set was devised that represented a steady loss of hypolimnetic dissolved oxygen over the duration of summer thermal stratification. The data set was processed by the PROFILE program to yield the hypolim-

Table 46. Results of model calibration with 1991 data, Coeur d'Alene Lake

[TP, total phosphorus, in micrograms per liter; TN, total nitrogen, in micrograms per liter; CHL, chlorophyll-*a*, in micrograms per liter; SD, secchi-disc transparency, in meters; HOD, hypolimnetic dissolved-oxygen deficit, in milligrams per cubic meters per day]

Segment (fig. 22)	Variable	Mean value		Ratio of observed to estimated value
		Observed	Estimated	
1	TP	14.2	9.4	1.5
	TN	365	301	1.2
	CHL	2.4	2.6	.9
	SD	2.7	2.4	1.1
2	TP	8.8	6.4	1.4
	TN	329	247	1.3
	CHL	1.8	1.8	1.0
	SD	3.6	3.3	1.1
3	TP	5.6	5.9	.9
	TN	309	242	1.3
	CHL	1.5	1.7	.9
	SD	4.9	4.3	1.1
4	TP	4.6	4.7	1.0
	TN	292	243	1.2
	CHL	1.2	1.3	.9
	SD	5.4	4.7	1.1
5	TP	4.4	4.3	1.0
	TN	267	240	1.1
	CHL	1.5	1.2	1.2
	SD	5.4	5.0	1.1
6	TP	5.2	5.0	1.0
	TN	289	248	1.2
	CHL	1.5	1.4	1.1
	SD	5.8	5.1	1.1
	HOD	17.7	17.6	1.0
7	TP	5.2	5.5	.9
	TN	289	253	1.1
	CHL	1.5	1.5	1.0
	SD	3.2	3.0	1.1
Lakewide	TP	6.5	5.9	1.1
	TN	308	251	1.2
	CHL	1.6	1.6	1.0
	SD	4.8	4.2	1.1

Table 47. Results of model verification with 1992 data, Coeur d'Alene Lake

[TP, total phosphorus, in micrograms per liter; TN, total nitrogen, in micrograms per liter; CHL, chlorophyll-*a*, in micrograms per liter; SD, secchi-disc transparency, in meters; HOD, hypolimnetic dissolved-oxygen deficit, in milligrams per cubic meters per day]

Segment (fig. 22)	Variable	Mean value		Ratio of observed to estimated value
		Observed	Estimated	
1	TP	5.2	9.6	0.5
	TN	206	290	.7
	CHL	3.3	2.7	1.2
	SD	3.0	2.7	1.1
2	TP	5.0	5.5	.9
	TN	219	214	1.0
	CHL	2.7	1.5	1.8
	SD	4.9	4.6	1.1
3	TP	4.2	5.0	.8
	TN	220	213	1.0
	CHL	2.1	1.4	1.5
	SD	5.6	5.1	1.1
4	TP	2.9	4.0	.7
	TN	216	215	1.0
	CHL	2.1	1.1	1.9
	SD	6.5	6.0	1.1
5	TP	3.8	3.7	1.0
	TN	212	220	1.0
	CHL	2.4	1.0	2.4
	SD	5.8	5.7	1.0
6	TP	2.4	4.5	.5
	TN	211	222	1.0
	CHL	1.8	1.2	1.5
	SD	6.9	6.2	1.1
	HOD	18.7	16.6	1.1
7	TP	2.4	5.0	.5
	TN	211	228	.9
	CHL	1.8	1.4	1.3
	SD	3.2	3.0	1.1
Lakewide	TP	3.7	5.2	.7
	TN	215	225	1.0
	CHL	2.2	1.5	1.5
	SD	5.6	5.2	1.1

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Table 48. Presence or absence of overlap in standard errors for observed and estimated values of five variables for calibration and verification model runs, Coeur d'Alene Lake

[LW, lakewide; Y, overlap present; N, overlap not present; —, not measured]

Variable	Calibration								Verification							
	Segment No. (fig. 22)								Segment No. (fig. 22)							
	1	2	3	4	5	6	7	LW	1	2	3	4	5	6	7	LW
Total phosphorus	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	Y
Total nitrogen	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Chlorophyll-*a*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Secchi-disc transparency	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hypolimnetic dissolved-oxygen deficit	—	—	—	—	—	Y	—	—	—	—	—	—	—	Y	—	—

netic dissolved-oxygen deficit necessary to produce an anoxic hypolimnion. This value, 73 $(mg/m^3)/d$, applies to the hypolimnion of segment 6 because the BATHTUB program specifies that the hypolimnetic dissolved-oxygen deficit be computed for the water body's deepest part that is nearest the outlet.

Simulations 1 (table 49) and 2 (table 50) assessed the effects of doubling and quadrupling nutrient loads to the lake. The doubled nutrient loads in simulation 1 increased lakewide concentrations of total phosphorus, total nitrogen, and chlorophyll-*a* by 2.3, 161, and 0.7 µg/L, respectively; secchi-disc transparency decreased by 0.2 m. The quadrupled nutrient loads in simulation 2 increased lakewide concentrations of total phosphorus, total nitrogen, and chlorophyll-*a* by 6, 437, and 1.7 µg/L, respectively; secchi-disc transparency decreased by 0.6 m. In simulation 1, the hypolimnetic dissolved-oxygen deficit increased from its simulated 1991 base value of 17.6 to 20.8 $(mg/m^3)/d$, whereas in simulation 2, the deficit increased to 25.1 $(mg/m^3)/d$. Both increases in the hypolimnetic dissolved-oxygen deficit produced values well below the 73 $(mg/m^3)/d$ simulated with an anoxic hypolimnion in Coeur d'Alene Lake. On the basis of the results of these two simulations, Coeur d'Alene Lake has a large assimilative capacity for nutrients with respect to development of an anoxic hypolimnion.

Three nutrient-reduction simulations were selected by study cooperators. Simulation 3 assessed nutrient reductions from wastewater-treatment systems. Simulation 4 assessed nutrient reductions in the Coeur d'Alene and St. Joe River Basins because they

Table 49. Simulation 1: Limnological response to doubling phosphorus and nitrogen loads contributed to Coeur d'Alene Lake by the Coeur d'Alene and St. Joe Rivers

[µg/L, micrograms per liter; m, meters; $(mg/m^3)/d$, milligrams per cubic meters per day; —, not measured; LW, area-weighted lakewide value]

Segment (fig. 22)	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-*a* (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [$(mg/m^3)/d$]	
	1991	Response	1991	Response	1991	Response	1991	Response	1991	Response
1	9.4	12.5	301	467	2.6	3.5	2.4	2.3	—	—
2	6.4	10.1	247	420	1.8	2.8	3.3	3.0	—	—
3	5.9	8.7	242	411	1.7	2.4	4.3	4.0	—	—
4	4.7	6.5	243	403	1.3	1.8	4.7	4.4	—	—
5	4.3	4.9	240	320	1.2	1.4	5.0	4.9	—	—
6	5.0	6.6	248	402	1.4	1.9	5.1	4.8	17.6	20.8
7	5.5	7.0	253	406	1.5	2.0	3.0	2.9	—	—
LW	5.9	8.2	251	412	1.6	2.3	4.2	4.0	—	—

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Table 50. Simulation 2: Limnological response to quadrupling phosphorus and nitrogen loads contributed to Coeur d'Alene Lake by the Coeur d'Alene and St. Joe Rivers

[µg/L, micrograms per liter; m, meters; (mg/m^3)/d, milligrams per cubic meters per day; —, not measured; LW, area-weighted lakewide value]

Segment (fig. 22)	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-*a* (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
	1991	Response	1991	Response	1991	Response	1991	Response	1991	Response
1	9.4	17.5	301	760	2.6	4.9	2.4	2.1	—	—
2	6.4	16.4	247	740	1.8	4.6	3.3	2.7	—	—
3	5.9	13.2	242	706	1.7	3.7	4.3	3.5	—	—
4	4.7	9.3	243	673	1.3	2.6	4.7	4.1	—	—
5	4.3	5.7	240	446	1.2	1.6	5.0	4.8	—	—
6	5.0	8.9	248	657	1.4	2.5	5.1	4.5	17.6	25.1
7	5.5	9.3	253	661	1.5	2.6	3.0	2.7	—	—
LW	5.9	11.9	251	688	1.6	3.3	4.2	3.6	—	—

contributed most of the nutrients to the lake. Simulation 5 assessed nutrient reductions contributed by nearshore subbasins where agricultural land use adjacent to the southern and western margins of the lake is significant.

Simulation 3 (table 51) assessed the complete removal of nutrient loads from nearshore, domestic, and commercial septic-tank systems and the municipal wastewater-treatment plants listed in table 39. A total of 8,220 kg of phosphorus and 55,900 kg of nitrogen was removed from the lake's 1991 nutrient load by this simulation. Nutrient inputs from the municipal wastewater-treatment plants at Coeur d'Alene and Post Falls also were removed but did not affect the lake, only its outlet arm (segment 7). Relative to simulated 1991 base values, simulated phosphorus, nitrogen, and chlorophyll-*a* concentrations in all seven segments declined between 0.5 and 1.9, 13 and 28, and 0.1 and 0.5 µg/L, respectively. Secchi-disc transparency in all segments increased between 0 and 0.3 m. The hypolimnetic dissolved-oxygen deficit in segment 6 declined from 17.6 to 15.8 (mg/m^3)/d. On a lakewide basis, phosphorus, nitrogen, and chlorophyll-*a* concentrations declined 1.2, 18, and 0.3 µg/L, respectively, whereas secchi-disc transparency increased 0.2 m.

Simulation 4 (table 52) assessed a 20-percent reduction in nutrient loads contributed to the lake by the Coeur d'Alene and St. Joe Rivers. The reductions were attributable to large-scale implementation of best-management practices (BMP's) for forestry and agricultural industries in subbasins C1 to C7 and S1 to S5 (fig. 3 and table 4). Relative to simulated 1991 base

Table 51. Simulation 3: Limnological response to 100-percent removal of phosphorus and nitrogen loads contributed to Coeur d'Alene Lake by nearshore septic-tank systems and wastewater-treatment plants

[µg/L, micrograms per liter; m, meters; (mg/m^3)/d, milligrams per cubic meters per day; —, not measured; LW, area-weighted lakewide value]

Segment (fig. 22)	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-*a* (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
	1991	Response	1991	Response	1991	Response	1991	Response	1991	Response
1	9.4	7.5	301	283	2.6	2.1	2.4	2.5	—	—
2	6.4	5.6	247	230	1.8	1.6	3.3	3.3	—	—
3	5.9	5.0	242	227	1.7	1.4	4.3	4.4	—	—
4	4.7	3.8	243	225	1.3	1.1	4.7	4.8	—	—
5	4.3	3.8	240	227	1.2	1.1	5.0	5.1	—	—
6	5.0	3.7	248	225	1.4	1.0	5.1	5.4	17.6	15.8
7	5.5	3.7	253	225	1.5	1.0	3.0	3.1	—	—
LW	5.9	4.7	251	233	1.6	1.3	4.2	4.4	—	—

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Table 52. Simulation 4: Limnological response to 20-percent reduction in phosphorus and nitrogen loads contributed to Coeur d'Alene Lake by the Coeur d'Alene and St. Joe Rivers

[µg/L, micrograms per liter; m, meters; (mg/m^3)/d, milligrams per cubic meters per day; —, not measured; LW, area-weighted lakewide value]

Segment (fig. 22)	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-*a* (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
	1991	Response	1991	Response	1991	Response	1991	Response	1991	Response
1	9.4	8.7	301	266	2.6	2.4	2.4	2.4	—	—
2	6.4	5.6	247	205	1.8	1.6	3.3	3.3	—	—
3	5.9	5.2	242	206	1.7	1.5	4.3	4.4	—	—
4	4.7	4.2	243	209	1.3	1.2	4.7	4.8	—	—
5	4.3	4.2	240	222	1.2	1.2	5.0	5.0	—	—
6	5.0	4.6	248	215	1.4	1.3	5.1	5.2	17.6	16.7
7	5.5	5.1	253	220	1.5	1.4	3.0	3.0	—	—
LW	5.9	5.3	251	216	1.6	1.5	4.2	4.3	—	—

values, phosphorus, nitrogen, and chlorophyll-*a* concentrations in all segments declined between 0.1 and 0.8, 18 and 38, and 0 and 0.2 µg/L, respectively. Secchi-disc transparency in all segments increased between 0 and 0.1 m. The hypolimnetic dissolved-oxygen deficit in segment 6 declined 0.9 (mg/m^3)/d. On a lakewide basis, concentrations of phosphorus, nitrogen, and chlorophyll-*a* declined 0.6, 35, and 0.1 µg/L, respectively; secchi-disc transparency increased 0.1 m.

Simulation 5 (table 53) assessed a 25-percent reduction in nutrient loads contributed to the lake from nearshore subbasins where agriculture constitutes more than 20 percent of land use. Those subbasins included L14, L15, L18–L23, L25, and R1 (fig. 3 and table 4). The reductions in nutrient loads were to be achieved through implementation of BMP's on agricultural lands. Relative to simulated 1991 base values, phosphorus, nitrogen, and chlorophyll-*a* concentrations in all segments declined between 0 and 0.4, 2 and 14, and 0 and 0.1 µg/L, respectively; secchi-disc transparency did not change. The hypolimnetic dissolved-oxygen deficit in segment 6 decreased 0.2 (mg/m^3)/d. On a lakewide basis, concentrations of phosphorus and nitrogen declined 0.2 and 5 µg/L, respectively; chlorophyll-*a* and secchi-disc transparency were unchanged.

Of the three nutrient-reduction simulations, nutrient reduction from wastewater-treatment systems (simulation 3) produced the largest changes in phosphorus, chlorophyll-*a*, and secchi-disc transparency. The

Table 53. Simulation 5: Limnological response to 25-percent reduction in phosphorus and nitrogen loads contributed to Coeur d'Alene Lake by selected nearshore subbasins where agriculture constitutes more than 20 percent of land use

[µg/L, micrograms per liter; m, meters; (mg/m^3)/d, milligrams per cubic meters per day; —, not measured; LW, area-weighted— lakewide value]

Segment (fig. 22)	Total phosphorus (µg/L)		Total nitrogen (µg/L)		Chlorophyll-*a* (µg/L)		Secchi-disc transparency (m)		Hypolimnetic dissolved-oxygen deficit [(mg/m^3)/d]	
	1991	Response	1991	Response	1991	Response	1991	Response	1991	Response
1	9.4	9.0	301	287	2.6	2.5	2.4	2.4	—	—
2	6.4	6.3	247	238	1.8	1.8	3.3	3.3	—	—
3	5.9	5.8	242	238	1.7	1.6	4.3	4.3	—	—
4	4.7	4.6	243	239	1.3	1.3	4.7	4.7	—	—
5	4.3	4.3	240	238	1.2	1.2	5.0	5.0	—	—
6	5.0	5.0	248	244	1.4	1.4	5.1	5.1	17.6	17.4
7	5.5	5.4	253	249	1.5	1.5	3.0	3.0	—	—
LW	5.9	5.7	251	246	1.6	1.6	4.2	4.2	—	—

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reduction of nutrients gained by application of BMP's in the Coeur d'Alene and St. Joe River Basins (simulation 4) produced the largest decline in nitrogen. The implementation of BMP's in the nearshore subbasins (simulation 5) produced negligible changes in lake water quality.

HISTORICAL TRENDS IN WATER QUALITY

This study of Coeur d'Alene Lake was initiated largely in response to concerns over eutrophication and its potential to mobilize trace elements stored in the lakebed sediments. Eutrophication is a natural process but can be accelerated by increased nutrient inputs caused by human activities, a process commonly termed cultural eutrophication. The commonly held view is that a lake begins the cultural eutrophication process as human activity increases in its drainage basin. Cultural eutrophication may not be readily perceived by the public because nutrient loads may increase for years before a distinct increase in lake productivity is noticeable. However, the results of this lake study and a review of historical data raised doubts as to the applicability of this commonly held view to Coeur d'Alene Lake.

The review of historical data raised a perplexing issue: dissolved-oxygen deficits during 1911–12 were substantial (Kemmerer and others, 1923). On the basis of the common perception of cultural eutrophication, the dissolved-oxygen deficit would be expected to be of relatively recent origin. Instead, the deficits during 1911–12 were as pronounced as those measured during 1991–92. By 1991–92, more than 80 percent of the lakeshore had been developed (Milligan and others, 1983); the population in the contributing drainage basin was about 92,000; and land disturbances from agriculture, timber harvest, and mining had been taking place for a century. In contrast, during 1911–12, the lakeshore was sparsely developed, the population was about 36,000, and land disturbances had begun less than 25 years previously. An important question was whether the pre-1911 level of land disturbance could generate enough nutrients and oxygen-demanding substances to deplete dissolved oxygen in the lake during 1911–12. An early section of this report, "Human Effects on Water Quality," described how the population in the mid-1880's increased abruptly in response to the discovery of precious metals in the Coeur d'Alene River drainage. Timber harvest increased rapidly to supply material for mining and ore-processing activities, railroad construction, and construction of communities. These communities had no sewage treatment other than collection and disposal, often directly to the nearest waterway. A substantial dissolved-oxygen deficit again was measured in 1932 (Ellis, 1940) and, as late as 1975, the National Eutrophication Survey (U.S. Environmental Protection Agency, 1977) reported the same. These historical observations led to the hypothesis that nutrient and oxygen-demanding substances have been delivered to the lake over most of this century in amounts large enough to cause substantial declines in dissolved oxygen.

To test this hypothesis, estimates were made of the magnitude of nutrient loads delivered to Coeur d'Alene Lake in 1880, 1910, 1940, and 1970. Load estimates focused on phosphorus because it is the nutrient most likely to limit phytoplankton growth in Coeur d'Alene Lake. Estimates were made for two categories: natural background loads and incremental additions attributable to human activities. Data for four load sources—timber harvest, sewage, mining and ore processing, and phosphate fertilizer production—were sufficient to estimate phosphorus loads from human activities.

The initial task was to estimate natural background loads of phosphorus prior to the discovery of precious metals in the study area. Before the 1880's, most of the study area was forested. The forested area was estimated by subtracting the combined areas for water, wetlands, barren land, mined land, rangeland, Spokane River outlet area, and agricultural land from the total land area (table 5). This procedure yielded a forested area of 880,000 ha. Soil erosion from forested land in north Idaho averages 1,120 kg/ha (U.S. Department of Agriculture, 1994a, 1994b). The phosphorus content of soil and rock in the study area is about 500 mg/kg, on the basis of sample results from the National Uranium Resource Evaluation Program (Cole Smith, U.S. Geological Survey, written commun., 1994). Multiplication of the average soil erosion rate by the average phosphorus content yields a value of 0.56 kg/ha of phosphorus eroded per year. Only part of the eroded soil and associated phosphorus is delivered to major streams and rivers. The U.S. Department of Agriculture (1994a, 1994b) estimated a delivery rate of 5 percent for forest lands in the Coeur d'Alene Basin. Therefore, the 880,000 ha annually yielded about 24,600 kg of phosphorus to Coeur d'Alene Lake prior to 1880.

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Phosphorus loads from forested lands where timber was harvested were estimated for two periods that represented different harvest methods and intensities. The two periods, 1890 to 1930 and 1930 to 1975, were chosen on the basis of historical information (Hult, 1968; Rabe and Flaherty, 1974; Fahey, 1978; Wood, 1984; and U.S. Department of Agriculture, 1994a).

The 1890 to 1930 period included the beginning of large-scale timber harvest in support of the new and rapidly expanding mining industry in the Coeur d'Alene River Basin. Harvesting of the extensive white pine forests of the St. Joe River Basin began around 1900. Railroad construction was extensive during this time, largely in support of the mining and timber harvest industries. Large amounts of timber were harvested for railroad rights-of-way. Railroad construction involved large amounts of slash burning, which contributed ash and associated nutrients to nearby watercourses. The timber harvest methods were highly disruptive to the soil and often were conducted close to watercourses to facilitate waterborne delivery of logs to downstream loading facilities. Several large-scale forest fires and floods during this period compounded the erosion problems created by the mining and timber harvest industries.

Timber harvest during the following period, 1930 to 1975, increased greatly as extensive networks of logging roads were built to accommodate more mechanized methods of timber harvest. These new methods increased erosion and sediment delivery rates because the roads disrupted natural drainage patterns and compacted soils. The use of clearcuts, many spanning headwater streams, increased peak runoff and erosion rates. The type and intensity of harvest practices during this period likely resulted in the largest inputs of phosphorus to Coeur d'Alene Lake.

Phosphorus loads from forested lands were estimated to be the product of area harvested, soil erosion rate, sediment delivery rate, and a soil phosphorus content of 500 mg/kg. The phosphorus contribution from unharvested or regenerated areas was computed similarly and added to phosphorus contributed from harvested areas. The contributing harvested or unharvested/regenerated areas for 1890 to 1930 were 100,000 ha and 780,000 ha, respectively, and, for 1930 to 1975, were 200,000 ha and 680,000 ha, respectively. Soil erosion and sediment delivery rates for harvested areas during 1890 to 1930 were 3,360 kg/ha and 20 percent, respectively, and, during 1930 to 1975, were 3,360 kg/ha and 25 percent, respectively. For unharvested/regenerated areas, soil erosion and sediment delivery rates were 1,120 kg/ha and 5 percent, respectively.

The estimated annual load of phosphorus to Coeur d'Alene Lake from forested land during 1890 to 1930 was 55,400 kg—33,600 kg from harvested areas and 21,800 kg from unharvested/regenerated areas. The estimated annual load of phosphorus during 1930 to 1975 was 103,000 kg—84,000 kg from harvested areas and 19,000 kg from unharvested/regenerated areas.

Phosphorus loads attributable to sewage were estimated using population data and the annual per capita contribution of phosphorus in raw sewage, given as a median of 1.28 kg by Falter and Good (1987). Until the mid-1970's, sewage treatment in the study area was primarily collection and disposal of untreated sewage to the nearest water body. In 1910, the combined population of Kootenai and Shoshone Counties (Benewah County was established in 1915) was about 36,000; the population contributing sewage directly or indirectly to tributaries to Coeur d'Alene Lake was about 24,000. Thus, in 1910, about 30,700 kg of phosphorus was available for transport to the lake. In 1940, the combined population of the three counties was about 51,000 and the contributing population was about 34,000. The estimated phosphorus load in 1940 was about 43,500 kg. In 1970, the contributing population was about 45,000 and the estimated phosphorus load was about 57,600 kg. Not all of this phosphorus reached Coeur d'Alene Lake; a small amount was not discharged to water bodies, according to a study by Cornell, Howland, Hayes, and Merryfield, Engineers and Planners (1964). They noted that domestic sewage from all areas of the South Fork Coeur d'Alene River was discharged to the river without treatment. Some of the phosphorus load discharged to water bodies in a specific year was incorporated into riverbed sediments and biota. Most of this phosphorus eventually would make its way to the lake in later years by way of erosion and transport processes. Estimates of phosphorus load from sewage discharged to Coeur d'Alene Lake were reduced by 25 percent to be conservative. Thus, the estimates for 1910, 1940, and 1970 are 23,000, 33,000, and 43,000 kg, respectively.

Mining and ore-processing activities were additional sources of phosphorus to Coeur d'Alene Lake. As stated earlier, the average phosphorus content of soil and rock in the study area is about 500 mg/kg. Prior to about 1912, most ore processing was done

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by jigging, which was inefficient for removing zinc and left relatively coarse-grained waste for disposal to the river. Beginning about 1912, a more efficient flotation method was introduced for ore processing (Casner, 1989). As this new process became dominant, water pollution problems for the Coeur d'Alene River increased substantially because much larger quantities of low-grade ore were processed; wastes were much finer grained and, thus, traveled farther downstream; and additives increased the toxicity of the waste discharge (Woodward-Clyde Consultants and Terragraphics, 1986). An average of 454 million kg of tailings was directly or indirectly discharged annually to the South Fork Coeur d'Alene River from about 1920 to the late 1960's when large-scale settling ponds began to receive the tailings (Woodward-Clyde Consultants and Terragraphics, 1986). If all the tailings were transported to the lake, then about 227,000 kg of phosphorus would annually enter the lake. Much of this phosphorus would be associated with sediment particles and would be subject to alternating episodes of erosion and deposition in the Coeur d'Alene River. From 1920 to 1970, one-fourth of the annual load of phosphorus, or 57,000 kg, was estimated to reach Coeur d'Alene Lake. Prior to 1910, the annual phosphorus input to the lake was only about 10,000 kg because the less-efficient jigging process input larger sized particles and smaller amounts of tailings to the South Fork Coeur d'Alene River. After 1970, the annual phosphorus load declined to about 10,000 kg and was partly supplied by erosion of previously deposited tailings.

The fourth quantifiable source of phosphorus to the lake was from the phosphate fertilizer plant at Kellogg, which began operation in 1960. The plant annually discharged about 1.8 hm^3 of waste with a phosphorus concentration of 6,200 µg/L to Silver King Creek, a tributary to the South Fork Coeur d'Alene River (Cornell, Howland, Hayes, and Merryfield, Engineers and Planners, 1964). In 1970, the effluent was removed from the river and routed to a central impoundment area. The annual phosphorus load from 1960 to 1970 was 11,200 kg, all of which eventually reached the lake because phosphorus was released in the dissolved state.

The foregoing estimates of historical loads of phosphorus to Coeur d'Alene Lake did not include several potentially large, but unquantifiable, sources such as soil erosion from extensive wildfires, severe floods, and agricultural development in the lake's southern drainages. The overall estimates were made on the conservative side in recognition of the uncertainties inherent in such estimations. On the basis of these estimates, annual loads of phosphorus were developed for 1880, 1910, 1940, and 1970 (table 54). The post-1880 phosphorus loads were about three to eight times larger than the 1880 natural background load of 24,600 kg. The load for 1970 was comparable to the 180,000 kg of phosphorus measured during the 1975 National Eutrophication Survey of the lake (U.S. Environmental Protection Agency, 1977).

On the basis of the magnitude of these historical phosphorus loads, the substantial dissolved-oxygen deficits measured during 1911–12 and 1932 might be assumed to be entirely a result of Coeur d'Alene Lake being mesotrophic or eutrophic as early as 1910. However, this is only part of the explanation because two other important processes also could have affected the dissolved-oxygen deficit. Post Falls Dam raised the level of Coeur d'Alene Lake in 1906 and inundated the shallow lakes and wetlands at the lake's southern end, the former lakeshore, and the lower reaches of the Coeur d'Alene and St. Joe Rivers. When these fertile wetland and terrestrial soils were inundated, they leached nutrients and oxygen-demanding substances into the lake. The timing of leaching coincided with the dissolved-oxygen deficit measured during 1911–12. The second, and more important, process was the addition of oxygen-demanding substances from sewage inflows. The biochemical oxygen demand (BOD) for raw sewage is about 77,000 mg of oxygen per day per capita, or 28 million mg per year per capita (Cornell, Howland, Hayes, and Merryfield, Engineers and Planners, 1964). BOD is satisfied by the addition of oxygen, which facilitates the aerobic decomposition process. The reaeration of water is highly dependent on water depth and velocity to produce turbulence for entrainment and distribution of oxygen throughout the water column (Velz, 1970). Following the 1906 impoundment of Coeur d'Alene Lake, the lower reaches of the Coeur d'Alene and St. Joe Rivers became deeper and slower because their streamflow was impeded by the lake. Reaeration was lessened and, as a consequence, BOD was satisfied more slowly. The lake's increased phosphorus loads also played a role in the depletion of dissolved oxygen because increased production of organic matter exerted oxygen demands by respiration and decomposition. The proportional effects of these three oxygen-demanding processes (nutrient and BOD leaching from inundation, sewage inputs, and increased phosphorus loads) were not

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Table 54. Estimated annual loads of phosphorus from five sources to Coeur d'Alene Lake in 1880, 1910, 1940, and 1970

[kg, kilograms]

Load source	Annual load (kg)			
	1880	1910	1940	1970
Background	24,600	21,800	19,000	19,000
Sewage	0	23,000	33,000	43,000
Timber harvest	0	33,600	84,000	84,000
Mining and ore processing	0	10,000	57,000	10,000
Phosphate fertilizer production	0	0	0	11,000
TOTAL	24,600	88,400	193,000	167,000

readily quantifiable but were significant enough to produce mesotrophic conditions in the lake.

Prior to the late 1960's, the dissolved-oxygen demands attributable to biological production stimulated by phosphorus loads probably were muted by the extremely turbid conditions created in Coeur d'Alene Lake by the inflow of fine-grained sediments from mining, ore-processing, and timber harvest activities. In 1911, Kemmerer and others (1923) reported that the sediment plume from the Coeur d'Alene River extended far into Coeur d'Alene Lake and that railroad construction along the St. Joe River had muddied the southern end of the lake. In his 1932 study, Ellis (1940) reported that local residents and steamboat captains described the entire surface of Coeur d'Alene Lake as being discolored by mining sediments. Such turbid conditions would have severely reduced the depth of the euphotic zone and thereby reduced the lake's capacity to produce organic matter by photosynthesis. The mine wastes also contained high concentrations of trace elements potentially toxic to phytoplankton. Bioassays conducted by Bartlett and others (1974) and Wissmar (1972) at Coeur d'Alene Lake indicated that concentrations of cadmium, copper, and zinc were high enough to inhibit phytoplankton growth.

Coeur d'Alene Lake may not have responded fully to its phosphorus loads until after the late 1960's, when settling basins built by the mining companies began to reduce the influx of sediment and sediment-associated trace elements delivered by the Coeur d'Alene River. Following that, the inhibitory effects of trace elements were reduced and photosynthetic production of organic matter increased as the euphotic zone deepened. By the time of the 1975 National Eutrophication Survey, Coeur d'Alene Lake contained concentrations of phosphorus and chlorophyll-*a* in the mesotrophic range, blue-green algae were common, and the summer hypolimnion was severely depleted of dissolved oxygen (U.S. Environmental Protection Agency, 1977). The lake has responded favorably to nutrient reductions implemented in the 1970's by moving from mesotrophic to oligotrophic over the past two decades. The substantial dissolved-oxygen deficits measured during 1991 and 1992 indicated that the lake still had an excessive oxygen demand in the hypolimnion during summer stratification. However, two dissolved-oxygen profiles collected by the USGS during 1993 and 1994 near limnetic station 3 showed slightly reduced depletion of dissolved oxygen in the hypolimnion. In late September 1993, the minimum saturation in the hypolimnion was 74 percent. Similarly, the minimum saturation was 70 percent in mid-October 1994. Whether this is part of an improving trend or just an anomaly cannot be judged at this point, but future monitoring of dissolved oxygen in the late summer months could answer this important question.

The shift in trophic state from mesotrophic to oligotrophic from 1975 to 1992 was unexpected. In 1975, the National Eutrophication Survey (U.S. Environmental Protection Agency, 1977) reported concentrations of phosphorus and chlorophyll-*a* in the range of mesotrophic conditions. However, concentrations of phosphorus and chlorophyll-*a* measured during the present study were in the range of oligotrophic conditions. Phosphorus loads in 1991 were about half those measured in 1975. Therefore, Coeur d'Alene Lake's shift from mesotrophic to oligotrophic conditions can be attributed to reductions in nutrient loads between 1975 and 1992.

Reductions in nutrient loads resulted from the cumulative effects of numerous actions. Two of the more visible reductions resulted from decreases in direct discharge of mining and smelting wastes to the South Fork Coeur d'Alene River and diversion of untreated sewage to municipal wastewater-treatment plants. In 1968, most of the mining and smelting waste discharges to the South Fork Coeur d'Alene River were diverted to settling ponds. Beginning in 1974, effluents from the largest settling pond, the central impoundment area, were treated prior to discharge. Termination of smelting operations at the Bunker Hill complex in 1981 further reduced loads to the river. In the mid-1970's, many of the communities along the Coeur d'Alene and

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St. Joe Rivers began to divert their untreated sewage to municipal wastewater-treatment plants. The largest facility at Page began operation in late 1975. By the early 1980's, most communities along the Coeur d'Alene River had some form of municipal wastewater treatment. In the St. Joe River drainage, St. Maries began sewage treatment in the mid-1960's and upgraded the treatment process in 1978. The smaller communities of Avery, Calder, and Clarkia installed sewage-treatment plants between 1980 and 1985.

Although not as visible, additional reductions in nutrient loads were gained by implementation of BMP's for timber harvest and agricultural activities. Specific BMP's for timber harvest activities became mandatory in Idaho in 1974. Application of BMP's for agricultural activities is voluntary and is guided by Idaho's State Agricultural Water Quality Program and Federal agricultural policies and programs. These programs have been important factors in reducing water-quality degradation caused by agricultural practices.

SUMMARY

This study of Coeur d'Alene Lake was undertaken because of concerns over the potential for release of previously deposited nutrients and trace elements from the lakebed if an anoxic hypolimnion were to develop as a consequence of eutrophication. The primary purpose of the study was to determine the lake's assimilative capacity for nutrients. The scope included characterization of water quality in the limnetic and littoral zones of the lake, quantification of hydrologic and nutrient budgets, development of a nutrient load/lake response model, and characterization of trace-element enrichment in surficial and subsurface lakebed sediments. Additionally, previous studies of the lake were reviewed to assess historical trends in water quality.

The trophic state of the lake's limnetic zone was determined to be oligotrophic on the basis of concentrations of total phosphorus, total nitrogen, and chlorophyll-*a*. The phytoplankton community was highly diverse, dominated by diatoms, and contained a low percentage of blue-green algae. Nitrogen-to-phosphorus ratios showed phosphorus as the nutrient most likely to limit phytoplankton growth. Despite its oligotrophy, the deeper areas of the lake had a substantial hypolimnetic dissolved-oxygen deficit during the late summer. The shallow, southern end of the lake contained anoxic near-bottom water in the late summer. Median concentrations of copper, lead, and zinc in the water column exceeded water-quality criteria for the protection of freshwater biota. Phytoplankton bioassays demonstrated that the dissolved, uncomplexed zinc concentrations typical for the lake were highly inhibitive of phytoplankton growth.

Water quality in the littoral zone was similar to that in the limnetic zone. Aquatic macrophytes were abundant in the shallow, southern lake area and in the heads of many of the bays with sedimentary deltas. The growth rate of periphyton at selected nearshore sites was positively correlated with littoral-zone concentrations of total phosphorus and the percentage of agricultural land in the nearshore subbasins.

Surficial and subsurface samples of the lakebed sediments contained highly enriched concentrations of antimony, arsenic, cadmium, copper, lead, mercury, silver, and zinc. Approximately 85 percent of the lakebed surface area was highly enriched; only the southern lake area south of Conkling Point contained background concentrations. Most of the enriched trace elements were associated with ferric oxides and thus were subject to redissolution under the reducing conditions that can occur in an anoxic hypolimnion. Previously, the trace elements in the lakebed sediments were thought to be associated with sulfides and, under reducing conditions, would remain immobile and thus unlikely to migrate back into the water column. On the basis of sediment-quality guidelines, concentrations of arsenic, cadmium, lead, and zinc in the lakebed sediments of Coeur d'Alene Lake were indicative of severe pollution that can significantly affect benthic organisms.

The hydrologic and nutrient budgets for the lake were dominated by the St. Joe and Coeur d'Alene Rivers. The lake retained a large percentage of its influent load of phosphorus but only a small percentage of its nitrogen load. The Coeur d'Alene River contributed the largest loads of arsenic, cadmium, lead, and zinc to Coeur d'Alene Lake. The lake retained most of its lead load and smaller percentages of its arsenic, cadmium, and zinc loads.

A nutrient load/lake response model was used to determine the response of the hypolimnetic dissolved-oxygen deficit to increased and decreased nutrient loads. The results indicated the lake has a large assimilative capacity for nutrients before anoxic conditions develop in the hypolimnion. Several nutrient-reduction scenarios were modeled to assess their potential improvements in water quality. If nutrient loads from

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wastewater-treatment systems were eliminated, then the lakewide concentrations of total phosphorus and chlorophyll-*a* would decrease 1.2 and 0.3 µg/L, respectively. If BMP's for forestry and agricultural activities achieved a 20-percent nutrient-load reduction for the Coeur d'Alene and St. Joe River drainages, then lakewide concentrations of total phosphorus and chlorophyll-*a* would decrease 0.6 and 0.1 µg/L, respectively.

The review of historical studies of Coeur d'Alene Lake and its drainage basin yielded important insights into the lake's response to human development. The lake has received substantial loads of nutrients and oxygen-demanding substances since the late 1800's, as evidenced by the severe hypolimnetic dissolved-oxygen deficits recorded during 1911–12. In 1975, the lake was considered mesotrophic and received total phosphorus loads twice as large as those recorded in 1991. Construction of municipal wastewater-treatment plants began in the mid-1970's, concurrent with implementation of BMP's for forestry and agricultural industries. The net effect of reduced nutrient loads allowed the lake to shift from mesotrophy to oligotrophy between the mid-1970's and the time of this study.

CONCLUSIONS

The primary research question addressed by this study of Coeur d'Alene Lake was, "Has Coeur d'Alene Lake advanced far enough in the eutrophication process to have a substantial risk to develop an anoxic hypolimnion, which would increase the potential for release of nutrients and trace elements from the lakebed sediments into the overlying water column?" The justification for originally posing the question was based on two key issues gleaned from previous studies of the lake. First, Coeur d'Alene Lake exhibited classic symptoms of eutrophication: elevated concentrations of nitrogen, phosphorus, and chlorophyll-*a*; extensive growths of blue-green algae; and a substantial hypolimnetic dissolved-oxygen deficit. Second, the lakebed sediments contained highly enriched concentrations of trace elements such as arsenic, cadmium, lead, and zinc.

With completion of this study, the research question can be answered. On the basis of results from the nutrient load/lake response model, Coeur d'Alene Lake has a large assimilative capacity for nutrients and, thus, is unlikely to develop an anoxic hypolimnion unless nutrient loads to the lake increase substantially. Lakebed geochemistry analyses revealed that most of the trace elements in surficial and subsurface sediments are associated with a ferric oxide phase and, thus, under reducing (anoxic) conditions, the trace elements would be readily solubilized and available for release to the overlying water column. Prior to this study, the trace elements were thought to be associated with sulfides and, thus, would not be solubilized under reducing conditions. The greater potential for release of trace elements from the lakebed sediments is mitigated by the lake's resistance to developing an anoxic hypolimnion.

The two cooperators intend to use the study results to develop a lake management plan for Coeur d'Alene Lake. Study results indicate distinct spatial differences in water quality that merit consideration in the lake management plan. Biological productivity of the lake's southern end, represented by limnetic station 6 and model segment 1, is greater than biological productivity in the rest of the lake, as demonstrated by several features: highest concentrations of total phosphorus, dissolved orthophosphorus, dissolved inorganic nitrogen, and chlorophyll-*a*; smallest secchi-disc transparencies; a range of dissolved-oxygen saturation from 0 to 133 percent; extensive growths of aquatic macrophytes; and the only limnetic station with blue-green algae. Although the southern end of the lake is the most biologically productive, it is relatively free of the trace-element enrichment observed in the lakebed sediments throughout the rest of the lake.

One area where water quality is affected by high biological productivity and trace-element enrichment of the lakebed sediments is the area south of the mouth of the Coeur d'Alene River and north of Conkling Point, represented by limnetic station 5 and model segment 2. Dissolved-oxygen concentrations at limnetic station 5 were as low as 2.8 mg/L during October 1991 and might eventually reach anoxia if biological productivity in the adjacent southern end of the lake were to increase substantially. The area of the lake represented by model segment 2 may be the most likely to release trace elements from the lakebed sediments after an anoxic hypolimnion developed.

Much of this study focused on defining the lake's response to nutrient loads. The two cooperators then could design a lake management plan to control biological production by controlling nutrient loads delivered to the lake from its drainage basin. The focus on nutrient management may need some modification because the phytoplankton bioassays demonstrated that phytoplankton growth is strongly inhibited by concentra-

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tions of dissolved, uncomplexed zinc typical in much of the lake. Total recoverable and dissolved zinc concentrations were well in excess of Federal water-quality criteria for protection of freshwater biota. If zinc concentrations were reduced, the inhibitory effects of zinc would be lessened and phytoplankton growth would increase unless nutrient load reductions were implemented to counteract the lessened inhibition.

A lingering question concerns the continued existence of the hypolimnetic dissolved-oxygen deficit in the lake's northern basin, even though the trophic state variables for limnetic stations 1 and 3 indicate oligotrophy. Results from the phytoplankton bioassays offer some insight into the question and have been used to develop the following research question (J.S. Kuwabara, U.S. Geological Survey, written commun., 1994): "Is the hypolimnetic dissolved-oxygen deficit a result of oxygen demands exerted by the advective transport of zinc-inhibited phytoplankton that settle through the water column into the lake's northern basin?" This study has shown that the distribution of dissolved, uncomplexed zinc has a strong longitudinal gradient in the lake; concentrations are noninhibitory only in the lake's southern end, the lake's most biologically productive area. As phytoplankton are defectively transported northward, they encounter the plume of the Coeur d'Alene River where concentrations of dissolved, uncomplexed zinc are highly inhibitory. The resultant inhibition of phytoplankton growth is hypothesized to produce a sestonic "rain" of dead and dying phytoplankton that settles into the hypolimnion of the lake's northern basin and produces the hypolimnetic dissolved-oxygen deficit when the lake is thermally stratified. Unfortunately, this research question cannot be adequately evaluated with the data base assembled by this study.

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COEUR D'ALENE LAKE MANAGEMENT PLAN

EXECUTIVE SUMMARY

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Coeur d'Alene Tribe

Clean Lakes Coordinating Council

Idaho Division of Environmental Quality

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COEUR D'ALENE LAKE

MANAGEMENT PLAN

Kootenai, Benewah and Shoshone Counties, Idaho

Approval, Recommendation, Policy Statements and Comments

The Clean Lakes Coordinating Council approves and recommends the Coeur d'Alene Lake Management Plan to the county commissions and the Coeur d'Alene Tribal Council. The council provides these additional policy statements and comments:

- That the Clean Lakes Coordinating Council is empowered to coordinate the implementation of the plan;
- That the council does not promote or support land use that degrades water quality, but encourages those land uses that protect this valuable resource;
- That recognizing that the timber and surface mining industries are the only land users which have mandatory best management practices (BMPs), we recommend that reasonable and mandatory BMPs be developed for other land users;
- That recognizing that each waterbody has somewhat different chemical characteristics, the council recommends that site specific water quality criteria be developed for the lake as funding permits.

Susan MacLeod, Chairperson Date 3-19-96

Robert ~~Bob~~ Hammes Date 3-19-96

Dr. Orland P. Scott Date 3/19/96

Robert Hall Date 3/19/96

Bill Seaton Date 3/19/96

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COUNTY COMMISSIONS APPROVAL

ACCEPTED BY THE BENEWAH COUNTY BOARD OF COMMISSIONERS:

Jack Buell Date

George Mills Jr. Date

N.L. (Bud) McCall Date

ACCEPTED BY THE KOOTENAI COUNTY BOARD OF COMMISSIONERS:

Dick Compton Date 9/19/96

Dick Panabaker Date 9/19/96

Bob Macdonald Date 9/19/96

ATTEST
DANIEL J. ENGLISH, CLERK
BY: Deputy Clerk

ACCEPTED BY THE SHOSHONE COUNTY BOARD OF COMMISSIONERS:

Sherry Krulitz 4/22/96
Sherry Krulitz Date

Jack King 4-22-96
Jack King Date

R. Gary Waters 4/22/96
R. Gary Waters Date

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COEUR D'ALENE TRIBE APPROVAL
of the
COEUR D'ALENE LAKE MANAGEMENT PLAN

ACCEPTED BY THE COEUR D'ALENE TRIBE:

Ernest L. Stensgar 7/8/96
Ernest L. Stensgar, Chairman Date

Resolution Number CDA 215-A (96)

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APPROVAL OF LAKE MANAGEMENT PLAN CDA Resolution 215(96)-A

WHEREAS, the Coeur d'Alene Tribal Council has been empowered to act for and on behalf of the Coeur d'Alene Tribe, pursuant to the Revised Constitution and By-Laws, adopted by the Coeur d'Alene Tribe by referendum, November 10, 1984, and approved by the Secretary of the Interior, Bureau of Indian Affairs, December 21, 1984; and

WHEREAS, the Coeur d'Alene Tribe assisted in the development of the Coeur d'Alene Lake Management Plan; and

WHEREAS, the management plan for Lake Coeur d'Alene is in its final format and has been reviewed by the Tribal staff and now requires acceptance by the Coeur d'Alene Tribal Council; and

WHEREAS, the Coeur d'Alene Tribal Natural Resource Department recommends approval by the Trial Council.

NOW THEREFORE BE IT RESOLVED, the Coeur d'Alene Tribal Council accepts the recommendation of the Natural Resource Department and approves the management plan prepared for Lake Coeur d'Alene; and,

FURTHER BE IT RESOLVED, that the Coeur d'Alene Tribal Council authorizes the Chairman to sign the Lake Management Plan for Coeur d'Alene Lake.

CERTIFICATION

The foregoing resolution was adopted at a meeting of the Coeur d'Alene Tribal Council held at the Tribal Headquarters, near Plummer, Idaho on June 17, 1996, with the required quorum present, by a vote of 6 FOR and 0 AGAINST.

Ernest L. Stensgar, Chairman
Coeur d'Alene Tribal Council

Norma Peone, Secretary
Coeur d'Alene Tribal Council

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COEUR D'ALENE LAKE MANAGEMENT PLAN

EXECUTIVE SUMMARY

INTRODUCTION

The lake management study was initiated in 1991 in response to long-term concerns over water quality degradation. These concerns centered around increases in nutrients, which resulted in increased plant growth, decreased water clarity and heavy-metal contamination of lakebed sediments. The study was funded and conducted cooperatively by the U.S. Geological Survey, Idaho Division of Environmental Quality, and Coeur d'Alene Tribe. It had three objectives:

1) Determine the lake's ability to receive and process nutrients (phosphorus and nitrogen) in order to devise means to prevent declines in water quality;

2) Determine the potential for the release of heavy metals from lakebed sediments into the overlying lake water; and

3) Develop a lake management plan that will identify actions needed to meet water quality goals.

The agencies cooperating to develop the Lake Coeur d'Alene Management Plan sought to develop a comprehensive plan addressing water quality and non-water quality issues. A comprehensive treatment of water quality issues was developed, but recreational, access, aesthetic and use issues were not fully addressed. The body of this document is Part 1 of the plan addressing water quality. Part 2 of the plan requires further development although some action items addressing non-water quality problems were developed by the technical advisory groups who developed part 1 of the plan.

WATER QUALITY MANAGEMENT ZONES AND GOALS

Viewed as a whole, Coeur d'Alene Lake exhibits relatively high water quality. Yet both the study data and public and agency perceptions reveal specific geographical areas of concern and specific water quality problems. It is not appropriate to apply a single management strategy to the entire lake and watershed. Therefore, the lake has been divided into four water quality management zones. Each zone focuses on specific issues, goals, and management approaches pertinent to that zone. The four zones are:

1) **Nearshore** (water depths less than 20 feet)

2) **Shallow, southern lake** (south of the mouth of the Coeur d'Alene River and including the shallow lakes such as Benewah, Chatcolet, Hidden, and Round)

3) **Lower rivers** (lower reaches of the St. Joe and Coeur d'Alene Rivers that are affected by backwater from the lake)

4) **Deep, open water** (north of the mouth of the Coeur d'Alene River)

Water quality issues within the **nearshore management zone** include, but are not limited to: excessive growth of microscopic

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aquatic plants attached to underwater materials (periphyton), excessive growth of large aquatic plants (macrophytes), bacterial contamination, protection of drinking water drawn from the lake, toxicity of heavy metals, and lake level fluctuations. Zinc levels in the water currently exceed levels identified by federal criteria as harmful to freshwater aquatic life.

Water quality issues within the shallow, **southern lake management zones** include, but are not limited to: depletion of dissolved oxygen, presence of high concentrations of heavy metals in the lakebed sediments, toxicity of heavy metals to aquatic life in the lakebed and lake water, sedimentation, reduced water clarity, and excessive growth of aquatic plants. The heavy metal concerns are restricted to the area north of Conkling Point. Zinc concentration exceeds criteria protective of aquatic life. Freshwater insects, fish, and animals that live in other areas of the lake are curtailed in much of the southern lake during the summer because of dissolved oxygen depletion.

Water quality issues within the **lower rivers management zone** include, but are not limited to: bank erosion, nutrient loading from nonpoint pollution sources, excessive growth of aquatic plants, and bacterial contamination. In the Coeur d'Alene River, heavy metal contamination of the riverbank sediments and water is very high; levels of zinc, cadmium, copper, and lead exceed levels identified as harmful for aquatic life by federal criteria. In addition, lead levels in the Coeur d'Alene River water exceed federal drinking water standards for humans; however, these criteria are applicable at the tap, not in the water body.

Water quality issues within the **deep, open water management zone** include, but are not limited to: depletion of dissolved oxygen in the summer, presence of high concentrations of heavy metals in the lakebed, and toxicity of heavy metals to aquatic life in the lakebed and lake water. Levels of zinc in the lake water exceed freshwater life criteria. Concentrations of cadmium, lead, and zinc in hypolimnetic water, exceed federal acute and/or chronic criteria for aquatic life.

In each of the four management zones, the public has chosen **the goal of "slow improvement in water quality."** Goals of "no action" or "maintain current water quality" were not legally acceptable because of state and federal water quality criteria and standards have been exceeded. The goal of "rapid improvement in water quality" was rejected because of implementation costs.

The environmental factors controlling phytoplankton algae production in lakes are numerous; nutrients, particularly phosphorus, have repeatedly been found to be major factors. Trace elements have infrequently been reported as significantly affecting phytoplankton production, either as a nutritional deficiency or as a toxicant. In the case of Coeur d'Alene Lake, the phytoplankton bioassays indicated that the biologically available, dissolved concentrations of zinc in the northern two-thirds of the lake exert a strong suppression on phytoplankton growth. Similar results were reported by two studies conducted on the lake in the early 1970's. These results raise an important issue for water quality management in Coeur d'Alene Lake: If zinc concentrations were reduced to comply with federal water quality criteria, would the

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lake's phytoplankton production markedly increase? If the answer to the question is affirmative, then nutrient loadings would need to be reduced, perhaps significantly, in order to counteract the lifting of zinc's suppressive effect on phytoplankton production.

TRENDS IN LAKE WATER QUALITY

Despite the issues and concerns listed, Coeur d'Alene Lake's water quality has improved during the last 15-20 years. This positive trend is attributable to the enactment of environmental laws by federal, state, and local governments, and a growing societal awareness of environmental issues. Settling ponds for mining and smelting wastes were installed in the late 1960's and effective sewage treatment began in the Silver Valley in the mid-1970's and into the 1980's. State and local standards for subsurface sewage disposal were also made more stringent. State laws now require the use of best management practices (BMPs) for reducing water quality effects of timber harvest activities. Encouraged by economics, as well as by state and federal programs, agricultural practices that reduce erosion and sedimentation have also come into more widespread use. All of these factors, along with a growing environmental awareness and the transition to an economy less dependent on natural resources extraction, have contributed to the recent improving trend in water quality in Coeur d'Alene Lake.

Coeur d'Alene Lake has become visibly "cleaner" in recent years, but the potential exists for serious and widespread water quality degradation given present trends in population growth and lake use, coupled with the extent of past pollution. Significant depletion of dissolved oxygen still occurs in deep, bottom waters during the late summer. The shallow, southern lake area and several bays are becoming shallower because of sediment eroded from agricultural and timber lands as well as from nearshore areas being developed for residential and recreational uses. Southern lake waters are becoming infested with aquatic plants. Excessive growth of attached algae can be seen on shoreline rocks, docks, and boats in some nearshore areas. Sewage treatment facilities in the basin still contribute a significant portion of the lake's potentially controllable nutrient load. The bed and banks of the lower reaches of the Coeur d'Alene and St. Joe Rivers continue to be eroded and transport heavy loads of sediment and nutrients into the lake. Much of the bottom of the lake is blanketed with sediment containing high levels of heavy metals as well as substantial amounts of nutrients. Contaminated wastes from past mining in the Coeur d'Alene River drainage continue to flow into the lake in sizeable amounts. Perhaps the greatest threat to Coeur d'Alene Lake is the potential for reversal of the recent improvements in water quality. Such a reversal could be brought on by the rapid increases in lake use, population growth, and land development now occurring throughout the basin. Unless preventative measures are initiated soon, the recent improvements in lake water quality could be eroded or lost.

RECOMMENDED MANAGEMENT ACTIONS

The public was involved in the lake management planning process via its participation on the following five technical advisory groups (TAGs): forest practices, agriculture, development (with a recreation

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subgroup), southern lake, and rivers. Each TAG considered water quality issues and management goals and then developed management actions to achieve those goals. About 80 people participated. They represented local, state and federal agencies, industry, environmental organizations, and community and business associations. The management actions developed by the TAGs were then applied to the appropriate water quality management zones.

Management goals for the **nearshore zone** is to be achieved with management actions developed by the TAGs for forest practices, agriculture, and development. The majority of these management actions involve application of BMPs to control erosion from small watersheds that feed the lake. Reductions will also be sought for nutrient inputs from nearshore domestic septic systems and municipal wastewater treatment plants.

Within the shallow, **southern lake zone,** management goals can be achieved by reducing the nutrient loads within the lakebed sediments, contributed by watersheds plus erosion of riverbanks and lakeshores. Mechanical harvesting can be employed to periodically remove nutrients contained in the abundant aquatic macrophytes which grow in this zone. Nutrient loads from contributing watersheds can be reduced by application of BMPs on agricultural and forested lands. Additional reductions can be gained by upgrading several municipal wastewater treatment plants that contribute nutrient loads to this zone. To reduce erosion of riverbanks and the lakeshores, the southern lake TAG suggests establishment of "no wake" zones and management of boat traffic within this zone.

The management goals for **the lower rivers zone** will be achieved by reducing accelerated riverbank erosion by **25 percent** in the St. Joe River and by **50 percent** in the Coeur d'Alene River over the next decade. After acquiring better knowledge on the location and severity of erosion, bank stabilization projects can be undertaken, probably with assistance from the Army Corps of Engineers. Educational materials will be developed to inform boat operators of ways they can reduce their negative impacts on riverbanks. Landowners will be informed of riverbank stabilization methods they can employ which have been approved by the Corps of Engineers.

The deep, **open water zone** integrates the water quality effects of natural and human influences throughout the basin. Management goals for this zone will be achieved partially by management actions undertaken within the other three zones; however, the majority of the lake's nutrient loading comes from the Coeur d'Alene and St. Joe River basins. Within these two basins, important management actions to be implemented include erosion control from forested lands and reductions in nutrient loadings from municipal wastewater treatment plants. Formation of a lake basin commission is suggested as a means to coordinate the diverse, incremental efforts that will be required to achieve the long-term goals of the lake management plan.

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Numeric Values for current, desired, and criteria/standards-based water quality conditions in the deep, **nearshore management zone.**

	Desired Condition[11]	Current Condition[1]	Standard or Recommended Level[10]
Dissolved Oxygen (mg/L)[2]	8.6	8.6	6.0[3]
Total P (μg/L)(ppb)[2]	5-10	5.0[8]	25.0
Zinc (μg/L)(ppb)[2]	32.7	56	32.7
Clarity (Secchi depth meters)	7.6	7.6[4]	none
Coliform bacteria	500/100 ml 200/100 ml 50/100 ml	- - -	500/100 ml[5] 200/100 ml[6] 50/100 ml[7]

1. Average condition of 19 bays unless otherwise noted.
2. Seven-day average.
3. Standard applies to all waters except the lowest 7 meters of the water column at depths greater than 35 meters.
4. Average of 19 bays 7.6 meters; worst case Fuller's 5.2 meters.
5. At any time.
6. In no more than 10% of the samples taken over a 30 day period.
7. Geometric mean of samples taken over a 30 day period.
8. Average total phosphorus for 19 bays over two years; worst case, Kidd Island Bay, 16 μg/L.
9. Average of 19 bays; worst case Kidd Island Bay, 150/100ml.
10. Standard based Idaho Water Quality Standards and wastewater treatment requirements, EPA "Gold Book" criteria (as interpreted by National Toxic Rule) or phosphorus levels recommended to prohibit nucience aquatic weed growth.
11. Based on interpretation of Idaho Antidegradation policy and special resource waters designation of Lake Coeur d'Alene.
12. Trace (heavy) metals criteria are based on the hardness (mg/L $CaCO_3$) of the waterbody for which it is applied. The criteria is calculated as a function of the exponential of the logarithm of the hardness value. The National Toxic Rule and proposed Idaho water quality standards for metals operate in a hardness range of 25 to 400 mg/L $CaCO_3$ (Federal Register 57: 246, 1/22/92, 60917). The zinc goal developed for drafts of the Coeur d'Alene Lake Management Plan was calculated to be 18.4 μg/L based on the incorrect use of the lake hardness which averages 19 mg/L. Based on the National Toxics Rule, under which Idaho is currently listed, and proposed Idaho water quality standards, the criteria should be calculated at a hardness of 25 mg/L $CaCO_3$. The correct zinc criteria is 32.7 μg/L.

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Numeric Values for current, desired, and criteria/standards-based water quality conditions in the shallow, **southern-lake management zone.**

	Desired Condition[6]	Current Condition[1]	Standard or Recommended Levels
Dissolved Oxygen (mg/L)[2]	8.4	8.4	6.0
Total P (μg/L)[2]	12.0	18.3[4]	25.0[5]
Zinc (μg/L)(ppb)[2,3]	32.7	39.0	32.7
Clarity (Secchi depth meters)	4.0	3.0	none

1. Average of Chatcolet and Blue Point Stations unless otherwise noted.
2. Seven-day average.
3. Applies to area of southern lake north of Conkling Point.
4. Average total phosphorous = 18.3 μg/L; worst case Chatcolet Lake 26.9 μg/L.
5. Standard based on Idaho water quality standards and wastewater treatment requirements, EPA "Gold Book" criteria (as interpreted by National Toxic Rule) or phosphorus levels recommended to prohibit nucience aquatic weed growth.
6. Based on interpretation of Idaho Antidegradation policy and special resource water designations of Lake Coeur d'Alene.

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Numeric Values for current, desired, and criteria/standards-based water quality conditions in the deep, **open-water management zone.**

	Desired Condition[9]	Current Condition[1]	Standard or Recommended Level[8]
Dissolved Oxygen (mg/L)[2]	7.0	7.0	6.0[3]
Total P (μg/L)(ppb)[2]	9.0	9.0	25.0
Zinc (μg/L)(ppb)[2]	32.7	143	32.7
Clarity (Secchi[2] depth meters)	6.0	6.0[4]	none
Coliform bacteria	500/100 ml	-	500/100 ml[5]
	200/100 ml	-	200/100 ml[6]
	50/100 ml	-	50/100 ml[7]

1. Average of values of Tubbs Hill, Wolf Lodge, Driftwood and University Point Stations.
2. Seven-day average.
3. Standard applies to all waters except the lowest 7 meters of the water column at depths greater than 35 meters.
4. Worst case during winter runoff at University Point, Station 1.0 meters.
5. At any time.
6. In no more than 10% of the samples taken over a 30 day period.
7. Geometric mean of samples taken over a 30 day period.
8. Standard based on Idaho water quality standards and wastewater treatment requirements EPA "Gold Book" criteria (as interpreted by National Toxic Rule) or phosphorus levels recommended to prohibit nucience aquatic weed growth.
9. Based on interpretation of Idaho Antidegradation policy and special resource water designation of Lake Coeur d'Alene.

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COEUR D'ALENE LAKE MANAGEMENT PLAN

ACTION ITEMS

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Table 22. Management actions recommended by forest practices technical advisory group.

Management Actions	Priority	Lead	Estimated Cost	Funding Sources
Action 1: Adopt minimum 30' Stream Protection Zone (SPZ) for all CDA basin streams not capable of supporting significant fisheries (Class II).	2	IDL	Minimal	IDL
Action 2: Implement pre-operation inspection for all proposed timber harvest and related road construction.	1	IDL	$75,000/yr	IDL
Action 3: Streamline stream alteration permit process; make application procedure less time-consuming and more user-friendly to foster compliance.	2	IWR	Minimal	IWR
Action 4: Develop more prescriptive stream-crossing and stream alteration BMPs that provide a high level of water quality protection from road sediments. Promote more administration and/or enforcement of the Stream Alteration Act within the basin for crossing, alteration proposals.	2	IWR IDL	Minimal	IWR,IDL
Action 5: Add one additional full time FPA administrator in the basin to IDL staff, to inspect forest practices and enforce the FPA rules and regulations.	1	IDL	60,000/yr	Legislature
Action 6: Include intensive, continuous Information and Education program in lake plan that is aimed at forestland owners, loggers, road contractors, having demonstration sites for state-of-the-art forest management.	3	IDL, U of I C.E.S	20,000	IDL, Forest Industry
Action 7: Adopt Idaho FPA proposed "Cumulative Watershed Effects" process and implement it. Train public and operators in its use.	1	IDL, legislature	$8,000-$15,000 Watershed	
Action 8: Minimize road construction impacts in basin by cooperating on joint access development to forest stands.	3	All landowners	Minimal	
Action 9: Secure necessary funding to meet present and future maintenance needs on forest roads.	1	IDL Counties, USFS, BLM Industrial Forestland Owners		USFS,BLM, IDL, Legislature, Forest Industry
Action 10: Encourage landowners to manage forestlands to minimize potential water quality impacts of high-intensity wildfire while maintaining other resources.	3	All landowners		

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Action 11: Idaho FPA Advisory Committee should review current state of FPA compliance and enforcement; develop recommendations for additional compliance incentives.	2	IDL, FPAAC,Id Land Board	Minimal	

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Table 23. Management actions recommended by agriculture technical advisory group.

Pollution Management Actions **Goal: Reduce non point source pollution from agriculture lands by increasing the voluntary implementation of BMPs* on cropland, hayland, pasture and confined animal feeding areas in order to reduce the amount of sediment, nutrients, pesticides and bacteria reaching Coeur d'Alene Lake and its tributaries.**	Priority	Lead	Estimated Cost	Funding Sources
Action 1: Continue to aggressively encourage voluntary implementation of BMPs through existing SCD, SCS and ASCS programs.	1	SCD	$20K	County State
Action 2: Focus attention on those tributaries which produce high levels of nutrients, sediment, pesticides and bacteria from agricultural sources.	1	SCD	N.A.	N.A.
Action 3: Encourage Soil Conservation Districts to apply for state Agricultural Water Quality Program planning and implementation grants on priority Stream Segments within the Coeur d'Alene Lake Basin. Coordinate with CdA Tribe on reservation lands.	1	SCD	$100k/Plan $1M/imp	WPCA; Farmer match
Action 4: Conduct a River Basin Study of the St. Joe River sponsored by the Benewah Soil Conservation District and carried out by the USDA agencies.	1	SCD	$225K	USDA
Action 5: Make structural sediment and erosion control practices high priority for all current and future agriculture programs and projects which supply financial and/or technical assistance to agricultural producers. These practices should be tied to vegetation improvements, i.e., grassed waterways and riparian planting.	1	SCD	N.A.	N.A.
Action 6: Continue existing cropland management practices through aggressive implementation of federal Farm Bill requirements and other programs.	1	SCD	N.A.	N.A.
Action 7: Implement an aggressive information and education program within the basin to increase agricultural producer's and the general public's knowledge of the technical and financial assistance available for BMP installation and the benefits to the lake, the land and the producer when BMPs are installed and maintained. Included in the Information and Education program should be the demonstration of new technology and management practices. Encourage On Farm Testing.	1	CES SCD CBRP	$35K	CES SAWQP CBRP
Action 8: Provide assistance to hobby farms which are impacting water quality; provide them with livestock management BMPs.	1	CES CBRP		SCD
Action 9: Provide technical and financial assistance to confined animal feeding operations to implement livestock BMPs.	2	SCD		SCD

Action 10: Restore natural vegetation buffers along creeks and drainageways to minimize runoff from adjacent lands through education and/or seek tax incentives for placing in reserve.	1	SCD SCS County		County
Action 11: Implement water quality monitoring to determine effectiveness of agricultural BMP installation and maintenance on SAWQP streams.	1	DEQ	$30K	WPCA
Action 12: Request that ASCS approve Benewah County for participation in Integrated Crop Management program.	1	ASCS		ASCS ACP
Action 13: Encourage zoning ordinances that preserve land for agricultural use.	2	County		County
Action 14: Identify and provide technical assistance for streambank stabilization for streams in agricultural areas.	2	Private SCD Tribe		ACP

Notes:

Action 4. River Basin Studies quantify the production of sediment and nutrients from land uses within the study area in order to identify potential remediation actions to reduce production of sediment and nutrients from erosional processes.

* As defined by the SCS Field Office Technical Guide and the Idaho Agricultural Pollution Abatement Plan.

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Table 24. Management actions recommended by development technical advisory group for stormwater.

Stormwater Management Actions **Goal: Maintain current phosphorus export in most cost effective manner.**	Priority	Lead	Estimated Cost	Funding Sources
<u>Existing Stormwater Runoff</u> Action 1: Provide information and technical assistance to businesses, recreationists, cities, agencies, property owners and the general public. a) Develop "Master Gardener's" type program . b) Develop a homeowners kit with info about landscaping and other methods of reducing and treating stormwater. c) Provide staff to conduct stormwater audits for businesses and property owners. d) Promote, in conjunction with the University of Idaho Cooperative Extension, the use of "lake friendly" products such as lawn fertilizer which does not contain phosphorus, and grass species which require less fertilizer. e) Inform the public on the effects of their actions, such as burning on the lakeshore and in road side ditches, boat washing, etc.	1	KC, SC, BC, DEQ	variable	fees, EPA §319, storm water utility, State of Idaho, Counties
<u>Stormwater Runoff From New Development</u> Action 2: Provide contractors, utility companies and the public with information on stormwater management. a) Encourage companies such as Washington Water Power to incorporate erosion control into the siting, installation, and maintenance of utilities. b) Provide information on the effects of burning construction debris on the lake shore and weeds in ditches along the road side. c) Require permit applicants to pass a test on stormwater management concepts.	1	KC, SC, BC, DEQ	variable	EPA §319 program, storm water utility, State of Idaho, Counties

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Action 3: Expand existing stormwater treatment and erosion control requirements in the portions of Kootenai County which are in the Cd'A Lake Basin, to better prevent phosphorus and sediment loading from grading and development activities.			See notes	EPA §319 and §104.B3, storm water utility, fees, State of Idaho, Counties
a) Establish a stormwater ordinance requiring that development projects include a combination of stormwater treatment and pollution trading which will result in no net increase in phosphorus loading to Lake Coeur d'Alene. Expand Kootenai Counties BMP handbook to include other treatment options, in addition to swales.	1-2	KC, Cities in KC, DEQ,CT		
b) Identify phosphorus sources which might be reduced to offset increased phosphorus export from new development.	1	DEQ,PHD, USFS,KC,high-way districts		
c) Establish an ordinance requiring that erosion from development related grading projects be controlled.	1	KC,Cities in KC,CT		
d) Improve enforcement of existing erosion control requirements, including maintenance requirements. Hire staff to enforce stormwater/erosion/grading ordinances.	1	KC		
e) Establish performance standards which will minimize the quantity of sediment leaving property boundaries. (For example, prohibit increases in sediment export, or if sediment export is allowed, limit it to identified numeric standards; require stabilization within 7-14 days of soil disturbance).	2	KC,Cities in KC,DEQ, PHD,CT		
f) Adopt a Health District regulation requiring erosion control during the installation of subsurface sewage disposal systems.	3	PHD		
g) Explore funding options for stormwater and erosion control programs, including a stormwater utility.	1	KC,DEQ, PHD		
Action 4: Implement stormwater and erosion control programs throughout the remainder of the Cd'A Basin which are at least as stringent as that in place in Kootenai County in 1994.	1	SC,BC,CT, Cities in 3 Counties	variable	EPA§319,fees, utility, State of Idaho, counties
Action 5: Identify areas with a high erosion risk on plat maps of new subdivisions to inform prospective buyers/builders of the true cost involved in site development.	1-2	KC,SC,BC		developers

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Action 6: Review the need to increase minimum lot sizes, increase surface water setbacks, and preserve native vegetation buffers. If necessary, develop ordinances designed to minimize sediment and phosphorous export, maintain stable lakeshores and streambanks, and ensure there will be no net increase in phosphorous exported from new development. Any new ordinances should be based on the performance standard of "no net increase" in phosphorous. New standards should apply to new, existing and platted lots along the lakeshore and its tributaries. Any variances granted should be contingent upon the project achieving no net increase in sediment and phosphorous export from development sites.	2-3	KC,BC,SC, CT, Cities in CdA Basin, DEQ		
Action 7: Prohibit burning of construction debris on lakeshores and adjacent to streams and drainageways.		KC, SC, BC, local Fire Districts		

Notes:

Action 1a. - The University of Idaho Cooperative Extension System has a Water Watch manual which may be adapted for this purpose. The UI has conducted Master Water Watch programs in the past and is willing to do so again if funding is available and other agencies participate in planning and recruiting participants.

Action 2a. - Erosion control techniques for installation of utilities might include reseeding of disturbed areas, locating utilities away from streams and drainages, and timing projects to avoid rainy seasons.

Action 3a. - This would essentially be a pollution trading system, designed to offset new phosphorus loads by reducing existing loads. Mitigation actions might include: providing funds for upgrading the Page sewage treatment plant (to increase its phosphorus removal capabilities); replacing substandard septic systems; removing unneeded dirt roads; or surfacing poorly constructed dirt roads which are eroding into Lake Cd'A or its tributaries.

Existing BMP handbooks emphasize the use of grassed infiltration areas or "swales" for treating stormwater. While swales are an excellent stormwater treatment method on the Rathdrum Aquifer, they are often unsuitable in lake watersheds with steeper slopes, less permeable soils, and high water tables. Other stormwater treatment methods should be emphasized in these areas.

The cost of implementing these actions will vary depending on the number and site characteristics of new developments, and on the desired effectiveness of the program; costs probably range from $50,000 - $120,000 per year.

Action 3g. - If a stormwater utility were formed it would be important to clearly define how the monies would be used (e.g. inspection and maintenance of stormwater systems).

Action 5 - The purpose of this action would be to ensure that prospective buyers are aware that building on erosion prone sites may be difficult or impossible, and very costly.

Action 6 - The Basin Development TAG agreed that the need for increased setbacks and native vegetation buffers should be examined. They agreed that setbacks and buffers should be adequate to minimize sediment and phosphorus entering the lake, and to maintain a stable lakeshore and streambanks. Any new requirements should be based on water quality performance standards (such as a certain level of treatment, or a certain allowable quantity of phosphorus discharge), allowing setbacks to vary based on slope, soil type, vegetative cover etc. Also it was suggested that any buffer requirements be

waived in cases where there is no vegetation (e.g. a rock slope or bluff). Any variances granted should be contingent upon the project achieving no net increase in phosphorous and sediment export from development sites. The TAG could not agree on a width to recommend for buffer strips, if they are needed; suggested minimums ranged from 25 feet to 75 feet plus 4 feet for each % of slope.

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Table 25. Management actions recommended by development technical advisory group for roads.

Road Management Actions **Goal: Substantially reduce sediment and phosphorus export from use and maintenance of existing roads; manage new roads so there is no net increase in phosphorus export.**	Priority	Lead	Estimated Cost	Funding Sources
Action 1: Identify owners of problem roads and driveways (USFS, state, County, Highway District, City and private) and encourage them to either obliterate or upgrade the roads in affordable increments. Use road improvements in pollution trading to offset increased phosphorus loads from new development. Encourage the use of the most cost effective, simple, expedient alternatives.	2	KC, USFS, IDL,BC,SC, highway dists., DEQ	Obliteration: ≈$105-$635/lb. P Reconstruction: ≈$2,800-$4,900/lb. P plus periodic maintenance and oversight of maintenance	EPA §319, fees, SW utility, developers, State, counties
Action 2: Develop regulations establishing minimum construction standards for private, residential roads and driveways, and require that existing roads being converted to residential use be upgraded to meet these standards, recognizing practical site limitations (e.g. permit variances for existing roads if it will decrease or not significantly increase sediment export to the lake or its tributaries). Provide land owners who are harvesting timber, with information on residential road construction standards through the Idaho Dept. of Lands.	1	KC,BC,SC, CT,IDL,ITD, DEQ, highway dists.		fees, developers, counties
Action 3: Incorporate water quality protection strategies into existing road standards, policies, procedures and decisions. Evaluate and, if necessary, revise or eliminate excessive requirements which impair water quality (e.g. wide roads and right of ways, maximum 6% grade requiring longer roads with more cuts and fills).	1	ITD,KC, BC,SC, Cities in Basin, CT, highway dists, DEQ		May be possible with existing staff
Action 4: Prevent sediment from entering road ditches from adjacent properties by adopting and enforcing erosion control and grading ordinances for development activities.	2	KC,BC,SC, Cities in Basin,CT,ITD highway dists.		See storm-water section
Action 5: Support adoption of ordinances, funding mechanisms, and programs which reduce road impacts to water quality.	2	General Public	N/A	N/A
Action 6: Request that the state, cities, counties and highway districts identify and prioritize road related water quality improvement needs, that they develop long range plans for correcting existing problems, and that they complete at least one high priority project each year.	1	highway dists, SC,BC,ITD, Cities in Basin		EPA §319, State of Idaho, counties

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Action 7: Provide state, county, city and highway district personnel, businesses, and the public with technical assistance, including a) assistance in identifying situations and site specific problems affecting water quality, and b)information on maintenance and construction BMPs which can be used to reduce road impacts to water quality. Request that ITD personnel act as mentors to county and highway district staff, and that they assist with training of county road crews by inviting them to training seminars, and by providing them with printed material and video tapes of ITD seminars.	1	ITD,DEQ,KC, highway dists.		EPA §319, State of Idaho, counties
Action 8: Use LIDs (local improvement districts) to fund road improvements in populated areas.	2	KC,SC,BC, cities in Basin		private
Action 9: Encourage road jurisdictions to conserve financial resources by consolidating and/or sharing equipment, staff and functions (e.g. share wash pads, hire a grant writer for road improvement grants, consider having highway districts take over some functions of city road departments, if mutually agreed upon).	3	USFS,ITD, highway dists. BC,SC, Cities in Basin,PAC, IDL		May be possible with existing staff
Action 10: Secure grants and other funding sources for road related water quality improvement projects. Develop local, innovative funding of road programs which improve water quality, and which do not rely on property taxes.	1	PAC, highway dists., SC,KC, BC,ITD,CT, Cities in Basin		EPA §319, vehicle license fees
Action 11: Increase the general public's awareness of BMPs which should be used to control erosion and manage stormwater runoff, so they will recognize problems when they see them. Emphasize maintenance of private roads and driveways.	1	CLCC, ITD, KC,SC,BC, DEQ	variable	EPA §319, State of Idaho, counties
Action 12: Provide ITD and other road jurisdictions with vigorous, direct, constructive input about problem sites (e.g. bare slopes, erosion problems). Request that road jurisdictions use vegetative buffers between disturbed areas and streams/ drainages leading to streams.	1	General Public	N/A	N/A
Action 13: Strongly encourage ITD to complete the revegetation of the Mica grade and I-90 east of Cd'A (above Wolf Lodge Bay).	1	ITD		State of Idaho
Action 14: Request that volunteers responsible for litter collection on state highways also identify problem areas for ITD. Encourage, train and assist these groups to plant trees and other vegetation on cuts and fills.	3	ITD		State of Idaho
Action 15: Encourage the public to review proposed construction projects.	2	ITD,General Public	N/A	N/A

Action 16: Evaluate the level of treatment and stormwater retention needed for roads and highways in the Basin; expand regulations and policies as needed to prevent contaminants from reaching the water.	1	DEQ,CT and all road jurisdictions in the Basin		EPA §319, State of Idaho
Action 17: Request that road jurisdictions (ITD, highway districts, counties) control erosion during maintenance activities.	1	all road jurisdictions in the Basin		State of Idaho, counties

Notes:

Action 3 - The new Kootenai County road standards are in conflict with the stormwater ordinance and the related provision in the subdivision ordinance. It may be beneficial to water quality to permit private and small subdivision roads to serve the residential needs of a rural neighborhood without requiring large cutbacks and switchbacks which remove an excessive amount of vegetation. Variances should allow narrower roads with greater slope and more vegetative cover if it will reduce the quantity of contaminants flowing into the water, without compromising safety.

Action 6 - Road jurisdictions will need technical assistance to identify erosion and stormwater problems, and to develop mitigation plans.

Action 9 - The highway districts in Kootenai County already share some equipment and assist the cities on a case by case basis. Any consolidation of district services would have to be mutually acceptable to all involved agencies.

Action 10 - The Lake Cd'A Property Owners Association may wish to participate in raising grant match monies for specific projects which will enhance lake water quality.

Action 12 - These buffers could be temporary, used only during construction, which might eliminate the need to purchase easements.

Action 17 - Erosion control actions which might be appropriate during maintenance activities include seeding ditches following cleaning and using loose straw and silt fence on soils disturbed during replacement of culverts.

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Table 26. Management actions recommended by development technical advisory group for wastewater.

Wastewater Management Actions Goal: Eliminate and/or reduce discharge of nutrients in wastewater. Prevent impacts to beneficial uses as defined in the Idaho Water Quality Standards (beneficial uses include swimming, domestic drinking water etc.).	Priority	Lead	Estimated Cost	Funding Sources
Action 1: Request that DEQ, EPA, and a citizen committee use the Total Maximum Daily Load process to evaluate impacts, conduct a financial evaluation of alternatives, and if needed, select methods of reducing phosphorous loads from wastewater treatment plants, beginning with the South Fork Sewer District's Page facility. Consider Basin wide funding alternatives.	1	DEQ,EPA CT	See Notes	Federal grants, State of Idaho, fees
Action 2: a) Identify old, substandard sewage disposal systems located along the tributaries and lakeshore in the Cd'A Basin. Develop a data base which can be used to locate and prioritize systems needing attention; b) Prioritize systems for upgrade and/or replacement based on their probable nutrient contribution to the lake.	(a) 1 (b) 2	PHD, DEQ, CT		EPA§ 319, State of Idaho, counties
Action 3: Encourage replacement of substandard sewage disposal systems by: a) Allowing nutrient loads for new development to be offset with upgrades of off site systems through a pollution trading system. b) Developing cost share and other incentives.	2	KC, DEQ	≈$4,400-$6,100 per pound P removed	private, developers, State of Idaho, EPA §319
Action 4: Improve maintenance of private sewage systems throughout the Cd'A Basin. Develop an operation, permitting or monitoring system and periodically inspect systems to ensure they are being maintained and are functioning properly. Vary inspection frequency according to need or use. Periodically mail maintenance reminders to homeowners with private systems.	1	PHD		fees, private, counties
Action 5: Use septic maintenance companies to help educate and communicate with homeowners about substandard sewage systems.	3	PHD		may be possible with existing staff
Action 6: Evaluate and if appropriate, modify private, Health District and state inspections of new sewage systems to ensure that systems are properly installed, and that inspection programs are as efficient as possible.	2	PHD, DEQ		may be possible with existing staff
Action 7: During plan reviews of both new and replacement sewage systems, consider clustering of the systems if it will have less impact on water quality than small, individual systems.	1 ongoing	DEQ, KC		may be possible with existing staff

Action 8: Study the effect of nitrogen on water quality, particularly in near shore areas. Where nitrogen is effecting water quality, identify and/or develop and install sewage systems which are more effective at removing nitrogen from effluent.	2	USGS, DEQ		EPA grants, State of Idaho
Action 9: Develop a method of pollution trading and/or credits so that increased phosphorus loads from new development can be offset by upgrading sewage treatment plants (i.e. new developments could have the option of mitigating their impact by contributing to a fund for needed upgrades).	2	DEQ,EPA		EPA grants, State of Idaho
Action 10: Ban phosphorus from commercial and residential laundry detergent and other cleaning products (e.g. dish washing detergent) throughout the Cd'A Basin.	1	KC,BC, SC, All Cities	minimal	existing staff

Notes:

Action 1 - It was determined that evaluation and selection of specific phosphorus reducing actions for the South Fork Sewer District's Page facility and other Waste Water Treatment Plants were beyond the scope of the planning committee. They recommend that a special committee be developed with representatives of DEQ, the sewer districts and interested citizens. It was also recommended that an economist be consulted during the evaluation process.

As part of this wastewater review process, the effect of groundwater and stormwater infiltration on sewage lines should be explored. It appears that flows to both the Page and Plummer sewage treatment plants are higher then they need to be due to infiltration.

Providing alum treatment at the Page Plant will cost approximately $17-$34 per pound phosphorus removed to construct treatment facilities, plus approximately $17 per year per pound phosphorus to purchase alum. The cost of personnel, a billing system (if an additional one is needed), and periodic maintenance costs are not known.

Action 2 - The tax assessors may be able to help locate new systems, as this is something they look for when establishing property values.

Action 4 - This might be accomplished by contracting with septic system pumpers for operational inspections. The pumpers could be trained and certified by the Health District, and could provide the Health District with an evaluation report on each system they inspect.

Action 6 - As part of this evaluation consider transferring review and inspection authority for all engineered systems to DEQ.

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Table 27. Management actions recommended by development technical advisory group for miscellaneous topics.

Implementation/ Funding/ Water Quality Stds./ Miscellaneous Management Actions	Priority	Lead	Estimated Cost	Funding Sources
Action 1: Require local, state and federal agencies to coordinate data gathering efforts.	1	DEQ		existing staff
Action 2: Establish a citizens committee to assist in developing and implementing a public information and education program for the Cd'A Basin, and in lobbying for plan implementation.	1	CBRP,CAC		State of Idaho
Action 3: Encourage the development of and promote "lake friendly" products (e.g. boat cleaner, pesticides/ herbicides, phosphorus free lawn fertilizer).	1	CLCC		State of Idaho
Action 4: Incorporate water quality protection strategies into county Comp Plans, and Zoning, Grading and Subdivision Ordinances.				
Action 5: Consider expanding the Cumulative Effects program to address all watershed activities; manage cumulative effects Basin wide.	2	IDL, CBRP		
Action 6: Establish funding for plan implementation, with an emphasis on fees for service, user fees, and Federal funding. Avoid the use of state and County monies (which are based on property and income taxes). Implement this plan in the most cost effective manner, using alternatives which remove the most phosphorus per dollar expended.				
Action 7: Fund a coordinator(s) to oversee implementation of this plan.		DEQ,EPA, CDA Tribe, CLCC,KC, BC,SC		
Action 8: Form a private foundation to seek implementation funding.				
Action 9: Contract with a stormwater hydrologist for technical support for jurisdictions developing and enforcing stormwater management ordinances for the Basin.		KC, BC, DEQ		

Action 10: Revise state Water Quality Standards for the Cd'A Basin to make them less ambiguous, more enforceable, and more effective at preventing sediment, phosphorus and other contaminants from entering Lake Cd'A and its tributaries. a) Develop erosion control, stormwater management, road maintenance and vegetative buffer (if needed) requirements and BMP's for the Cd'A Basin and reference them in the Water Quality Standards. b) Develop broader, more proactive standards which will prevent the loss of beneficial uses and ensure that those uses are maintained for future generations. Use common terms and explanations to clarify the intent of ambiguous or technical sections of the Standards. c) Expand sediment criteria for domestic water supplies, to include Lake Cd'A and any tributaries with 15 or more homes using the water for domestic purposes (i.e. drinking water). d) Evaluate and if necessary make improvements to the enforcement provisions of the Standards.	1	DEQ,CT		State of Idaho

Notes:

Action 1 - The purpose of this action is to minimize duplication and assure that publicly funded monitoring projects produce compatible data which can be used by all agencies, for different projects. For example, if two agencies are conducting monitoring in the same location, they may be able reduce transportation and salary expenses by having one individual collect samples for both agencies.

Action 4 - Present Kootenai County with a copy of this plan as soon as possible so that they may incorporate it into their new zoning ordinance. Also present Shoshone County, Benewah County, the CDA Tribe and others with a copy so they may start incorporating this plan into their regulations and ordinances.

Action 6 and 7 - Implementation oversight should be provided by a Board consisting, at a minimum, of representatives of DEQ, EPA, the Coeur d'Alene Tribe, and Kootenai, Benewah and Shoshone Counties. A mechanism should also be developed to keep citizens involved in plan implementation.

Action 10 -

a. Include all stakeholders in the development of these requirements and BMP's.

b. For example, develop sediment standards which apply to all tributaries, and which are designed to minimize the quantity of sediment reaching the lake (and thus prevent unacceptable changes to lake water quality and beneficial uses). Sediment criteria for fish and drinking water systems should be retained, but should be supplemented by a broader, basin wide standard.

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Table 28a. Management actions recommended by recreation subgroup of the development technical advisory group.

Public Education Goal: Provide for enjoyable, recreational experiences on the lake while promoting water quality protection and safety.	Priority	Lead	Estimated Cost	Funding Sources
Action 1: Promote and support implementation of Ordinance No. 140-A, which regulates boat wakes.	1	KC		
Action 2: Develop education materials regarding setback and containment of campfires on beaches, etc.	1	CLCC		

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Table 28b. Gray and Black Water Disposal Options	Priority	Lead	Estimated Cost	Funding Sources
Action 1: Develop pamphlet describing proper disposal at pump-out stations. Encourage operator instruction.	1	CLCC		
Action 2: Develop a current comprehensive map of all the pump-out station locations.	1	CLCC, PHD		
Action 3: Encourage increased number of pump-out stations at marina locations. (It was suggested that marinas may wish to charge a pump-out fee or a discount with gasoline purchase, for example.)	1	BC,KC, PHD		
Action 4: Promote installation of sealed disposal systems for grey water.	1	PHD		
Action 5: Promote the use and funding for waterborne outhouses on the lake.	2	IDPR		
Action 6: Require holding tanks for gray water disposal for new manufactured boats.		KC, BC, USCG		

Table 28c. Industrial Uses on the Lake	Priority	Lead	Estimated Cost	Funding Sources
Action 1: Examine impact of industrial uses on the lake. Such as log transport, evaluate impacts of log transport and storage. Examine the logging operations (storage on the lake), as these effect nutrient levels.	2	IDL,DEQ		
Action 2: Develop support for public land managers of recreation sites contaminated with metals (IDFG, IDPR, USFS, BLM) to develop barriers between the public and metals and to provide sources of potable water.	1	IDFG,BLM USFS, IDPR		

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Table 29. Management actions recommended by southern lake technical advisory group.

Southern Lake Management Actions **Goal: Reduce nutrient loading to the Southern Lake in the Most effective and cost efficient manner.**	Priority	Lead	Estimated Cost	Funding Sources
<u>Reduction of Nutrient Load in Lake Bed Sediments</u> Action 1: Slowly reduce nutrient load by systematically harvesting macrophytes. Investigate and implement mechanical harvest for co-generation, fertilization, compost or methanol production.	1	Tribe, DEQ, I&FG, IP&R, I.D.L., CLCC		Tribe, Federal Program, Develop Corp, Panhandle area Council Dept. of Commerce, Parks & Rec. User fee of $3/boat
<u>Reduce sediment/nutrients loading from river/lake bank erosion.</u> Action 2: Control bank & bottoms sedimentation by expanding and enforcing no-wake zones, controlling log boom scower and managing the size and speed of boats.		Counties IP.&R., Corp. of Eng., I.D.L.		Coast Guard Grant, County Fees

The Southern Lake Technical Advisory Group recommends to the Lake Planning Workgroup that the only action item that should be considered is the development of an "Integrated Aquatic Plant Management Plan". The emphasis of the "Plan" should focus on removal of aquatic plants from the Southern Lake by means of Mechanical Harvesting. During the sco[illegible]g process many alternatives were considered and dismissed for various reasons but primarily because of environmental impacts. Methods of aquatic plant management that were considered including moving, biological control, bottom barriers, rotovating, dredging, herbicides, and mechanical harvesting. Because of the size and complexity of the Southern Lake, a combination of some of the above mentioned methods most likely will need to be addressed in the "Plan".

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Table 30. Management actions recommended by rivers technical advisory group.

Bank Erosion/Stabilization Actions Goal: Reduce accelerated stream bank erosion on the lower St. Joe by 25% and Coeur d'Alene River by 50% over the next decade.	Priority	Lead Agency(s)	Estimated Cost	Funding Source
Action 1: Inventory rapidly and moderately eroding banks in the slackwater reaches of the Coeur d'Alene (CdA) and St. Joe banks.	1	DEQ USGS	minimal	Current monitoring resources
Action 2: Develop an informational pamphlet for distribution to boat registrants education them on the damage caused by boat wakes to river banks.	1	CBRP	$2,500	CBRP Public Education Budget
Action 3: Develop and support legislation enabling counties to assess user fees dedicated to lake protection activities including bank stabilization.	1	CBRP, CAC,local legislators	minimal	CBRP mechanism counties
Action 4: Develop a standardized and cost efficient bank stabilization method for eroding Coeur d'Alene River banks.	1	ACOE,IDWR,IDL,DEQ, IDFG, USF&WS	minimal	Agency budgets
Action 5: Develop a log or tree revetment demonstration project for undeveloped banks of the St. Joe River. Log or tree revetments are logs or trees placed and anchored under an undercut bank to absorb the wave energy and resist further bank undercutting.	1	CBRP Cooperating agencies	$8,000	CBRP, DEQ, EPA
Action 6: Armor and vegetate rapidly eroding banks as budget allows according to priorities of Rivers TAG (list). Priorities will be established after the bank erosion inventory is completed.	1	ACOE, IDL, IDWR, IDFG, & DEQ	$1,000,000±	Federal Grants State WPCA Users Fees counties
Action 7: Develop support for public land managers (IDFG, IDL, USFS, BLM) to implement bank stabilization on the public lands. Armor banks at all existing recreation sites and any new sites developed.	1	CBRP, CAC	minimal	CBRP mechanism

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Action 8: Identify sources of trace (heavy) metal loads in the CdA River between Cataldo and Harrison with special attention to: a) Need for tailings removal from banks or channel b) Advantage of stabilizing water levels in the river or its wetlands. c) Assess if bank stabilization will be effective in curtailing metals loading. d) Monitoring of the bank erosion rate.	2	USGS, NRDA, Trustees, DEQ, CBRP, WWP	$75,000	Federal grants State WPCA

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Bank Stabilization Permit Actions	Priority	Lead Agency(s)	Estimated Cost	Funding Source
Goal: Educate private landowners and governmental managers engaged in bank stabilization on the St. Joe and Coeur d'Alene Rivers on the nationwide permit available, stabilization guidelines and suggested approaches.				
Action 1: Develop a pamphlet explaining the Army Corp of Engineers bank stabilization permit, stabilization design features and recommendations on methods to develop beach and wildlife areas.	1	ACOE, IDWR, IDL, DEQ, IDFG, USF & WS	$2,500	CBRP mechanism

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WATER QUALITY STUDIES
OF THE
SPOKANE RIVER
~~BETWEEN~~
COEUR D'ALENE, IDAHO
AND
POST FALLS, IDAHO
1988

Prepared by
John Yearsley
Bruce Duncan

pg 35

EPA--Region 10
1200 Sixth Avenue
Seattle, Washington 98101
August 1989

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INTRODUCTION

During the period August 15-18, 1988 EPA Region 10 conducted a field study of water quality survey in the Spokane River between the outlet of Lake Coeur d'Alene and Post Falls Dam (Figure 1). The primary purpose of this field study was to assess water quality in the Spokane River during a period of low river flow and elevated water temperature. In addition, there is a need for data to support the mathematical model of dissolved oxygen (DO) in the reach of the Spokane River between its outlet from Lake Coeur d'Alene and the Post Falls Dam. A model of the dissolved oxygen budget of this reach of the river has been used to develop permit limitations for the City of Coeur d'Alene under EPA's National Pollution Discharge Elimination System Permit (NPDES) program. It will also be used to evaluate the impact of additional discharges to this segment, including the proposed discharge by the City of Hayden Lake.

The reach of the river between the outlet of Lake Coeur d'Alene and Post Falls Dam presently receives the discharge from the waste treatment plant of the City of Coeur d'Alene. Coeur d'Alene has submitted plans to increase the discharge from this treatment plant. The City of Hayden Lake is also considering locating the outfall from their treatment plant in this reach of the river. Results from previous studies of water quality by the EPA (Yearsley, 1980) and the USGS (Seitz and Jones, 1982) have shown that under certain hydrologic conditions dissolved oxygen in the river decreases downstream from the treatment plant discharge. Furthermore, the results of mathematical modelling (Yearsley, 1987) indicate that the proposed increases in discharge of oxygen demanding material could lead to conditions for which the water quality standards of the State of Idaho would be exceeded. Other water quality issues which have been identified in the Spokane River basin are heavy metals toxicity and excess nutrient loadings. The heavy metals toxicity is associated with mining activities on the Coeur d'Alene River, which discharges into Lake Coeur d'Alene. Excess nutrients in the Spokane River have been identified as the cause of accelerated rates of eutrophication in Long Lake, in

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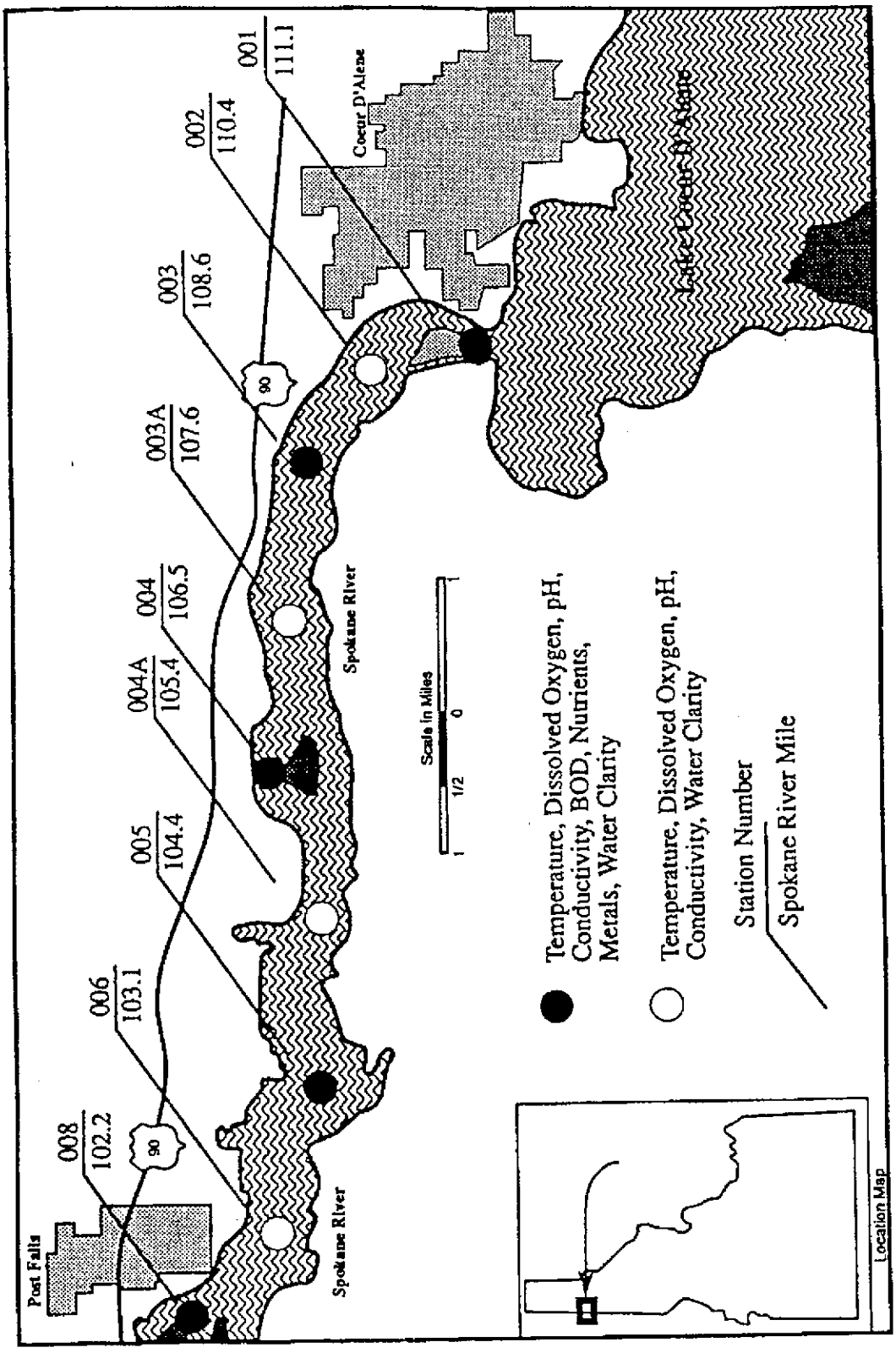


Figure 1. Location map for the field study of the Spokane River, August 16-18, 1988 showing water quality sampling stations

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the State of Washington. The Spokane River, which receives effluent from a number of municipal and industrial sources, discharges to Long Lake several miles downstream from Post Falls.

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FIELD STUDIES

In support of the objectives of assessing water quality , the field study program included measurements of water quality constituents and parameters in both the receiving waters and in effluent of municipalities presently discharging or considering discharge to the segment of the Spokane River between Lake Coeur d'Alene and Post Falls Dam. Table 1 shows the survey dates and the type of information collected. Data collected during the survey, including in situ and laboratory measurements, are given in Appendix A.

Receiving Waters

Data collected in the receiving waters included both observations made in the field and measurements from samples shipped to the EPA Regional Laboratory at Manchester, Washington. Temperature, DO, conductivity and pH measurements made in the field with a Hydrolab Model 4000 Calibration procedures for the Hydrolab Model 4000 were done in conformance with the manufacturers recommendations. The receiving water monitoring program was designed so that data could be used to characterize the distribution of water quality in both space and time. *In situ* measurements of temperature, DO, conductivity and pH were made at several depths; in the right, middle and left one-thirds of the river at each of the locations shown in Figure 1. This spatial sampling schedule was followed once in the morning and once in the afternoon each day during the period of August 16-18, 1988.

Samples for the laboratory analysis of biological oxygen demand (BOD), nutrients, and heavy metals were obtained at each of the locations shown Figure 1 by make a composite from samples taken at several depths and at the right, middle and left sections of the station. The samples of this type were collected during the morning only. The samples were stored in polyethylene containers, packed in ice and shipped daily, via air freight, to the Regional Laboratory at Manchester, Washington. Methods used for measurements made in the laboratory follow procedures described in EPA (1983).

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Table 1. Sampling activities for Spokane River field study, August 16-18, 1989

Medium	Parameters	Spatial Distribution	Sampling Frequency
Receiving water	Temperature, DO, pH, conductivity, Secchi disk	Vertical profiles at 1/4, 1/2 and 3/4 of the river width	Twice daily August 16-18, 1989
	BOD (5-, 10, 15- and 20-day)	Composite from surface, mid-depth and bottom at 1/4, 1/2 and 3/4 of river width	Once daily August 16-18, 1989
	Total Metals As		
	Total Recoverable Metals Cd,Cr,Cu,Fe,Pb, Hg,Zn		
	Nutrients Total P Ammonia N NO_2+NO_3-N Kjeldahl N		
Point source	Temperature, DO, pH, conductivity	Twenty-four hour composite	Once daily August 15-18, 1989
	BOD (5-, 10, 15- and 20-day)	Twenty-four hour composite	Once daily August 16-18, 1989
	Total Metals As		
	Total Recoverable Metals Cd,Cr,Cu,Fe,Pb, Hg,Zn		
	Nutrients Total P Ammonia N NO_2+NO_3-N Kjeldahl N		
	Suspended Solids		

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Locations of receiving water sampling stations for which laboratory analyses were performed are shown in Figure 1.

Point Sources

Samples from the municipal treatment facilities in Hayden Lake and Coeur d'Alene were obtained from 24-hour composites of the each treatment plants effluent . For those samples analyzed at the Regional Laboratory, handling and measurement procedures were the same as for the receiving water samples as described above. Flow measurements were obtained from measurement devices maintained at each facility.

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RESULTS

Receiving Waters

For purposes of analyzing the results, the receiving water data (Appendix A) were aggregated in terms of time and depth-averages. The averaging method used to aggregate the data is described in Appendix B.

River Flow and River Surface Elevation

River flow was not measured as part of the EPA Region 10 study. However, the U.S. Geological Survey maintains a stream gage just below Post Falls Dam. Provisional records from this station and observations of river surface elevation were made available by Mr. Stuart Gutenberg of the USGS in Sand Point , Idaho. Data for the month of August are presented in Table 2.

Water Temperature

Average, maximum and minimum water temperatures measured during the field studies are shown in Figure 2. Averages are by station, across days. Maxima and minima are the highest and lowest temperature, respectively, measured at each station during three-day study. The distribution of water temperature during this field study was similar to that found during the field study of August 16-17, 1979 (Yearsley, 1980). Average temperatures ranged from 21.4 °C to 22.9 °C. For those segments of the river with water depths less than approximately seven meters, temperatures were nearly uniform from top to bottom and from left bank to right bank. In those segments for which water depth was greater than seven meters (Station 6 , 8 and Post Falls Dam), there was a thermocline from a depth of seven meters to the bottom. Vertical profiles of temperatures at a station with depth less than seven meters (Station 5) and greater than seven meters (Station 6) are shown in Figure 3.

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Table 2. Daily discharge in the Spokane River near Post Falls and gage height in Lake Coeur d'Alene during August 1989 (preliminary information from the USGS).

Day	Discharge (cfs)	Gage Height (feet)
1	684	2127.82
2	729	2127.80
3	545	2127.82
4	431	2127.83
5	463	2127.82
6	494	2127.83
7	476	2127.80
8	470	2127.81
9	393	2127.81
10	344	2127.81
11	338	2127.80
12	334	2127.81
13	348	2127.82
14	346	2127.82
15	337	2127.82
16	338	2127.79
17	357	2127.80
18	350	2127.81
19	346	2127.79
20	344	2127.79
21	346	2127.78
22	344	2127.78
23	340	2127.78
24	338	2127.79
25	340	2127.78
26	336	2127.75
27	327	2127.75
28	318	2127.76
29	319	2127.77
30	329	2127.75
31	359	2127.72

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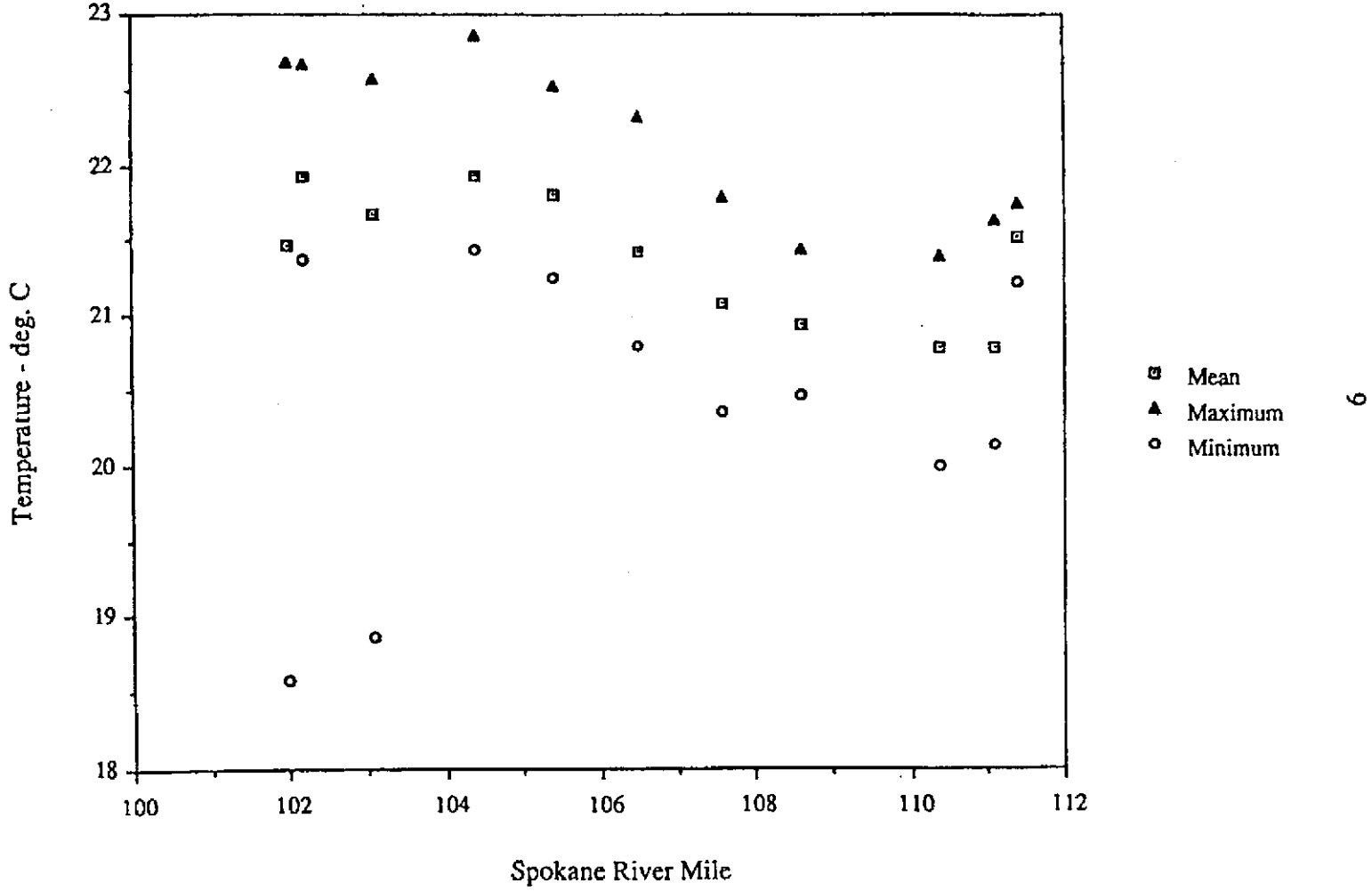


Figure 2. Mean, maximum and minimum temperature in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

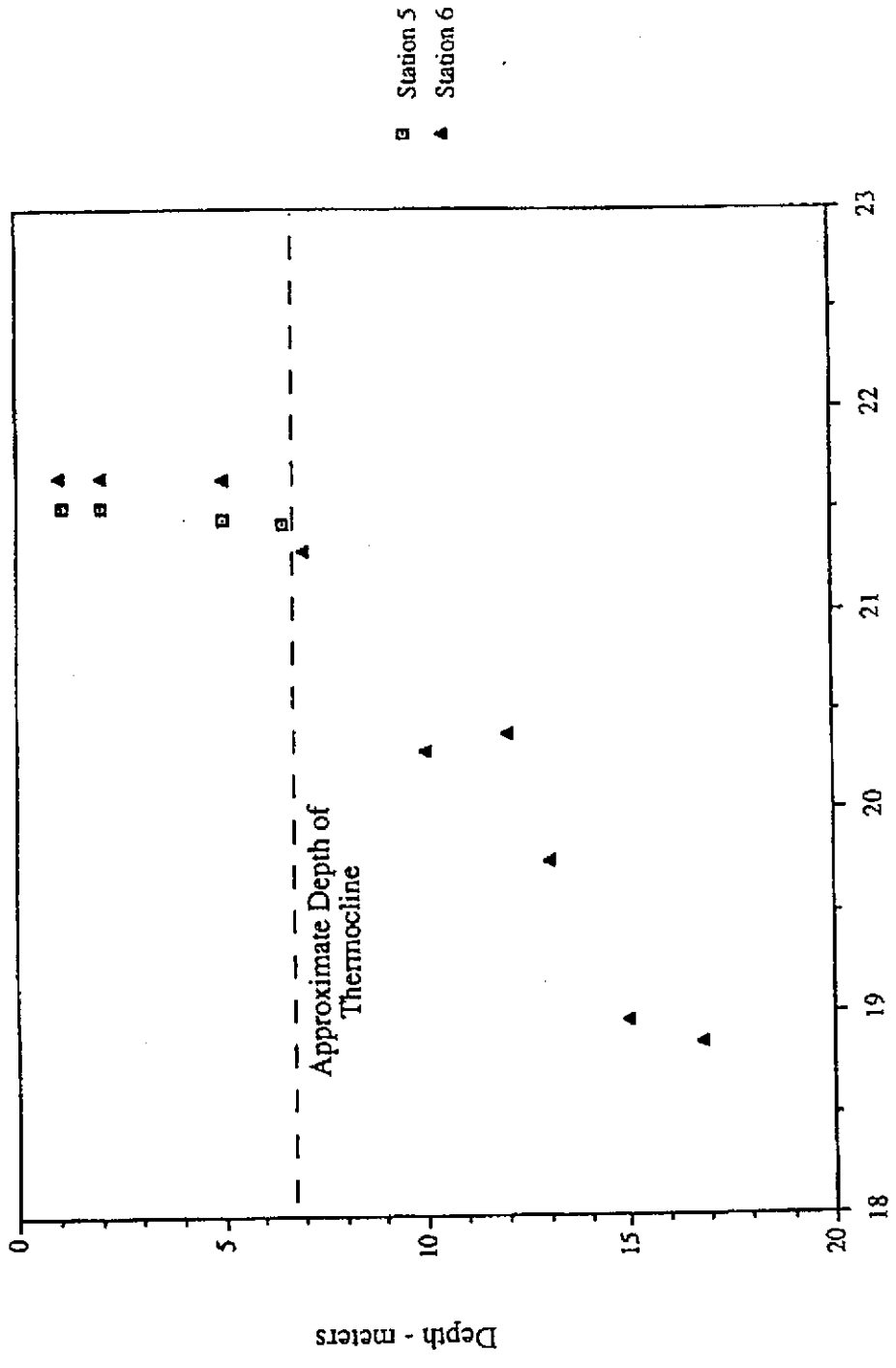


Figure 3. Vertical profiles of temperature at Stations 5 and 6 on August 18, 1988.

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The lowest temperature observed at depth during the study was 18.6 °C at Post Falls Dam Data collected in the State of Idaho's Volunteer Monitoring Program (Appendix C) show that temperature of the water surface was 19 °C between May 25, 1988 and June 25, 1988. This implies that the water at depth with temperatures of less than 19 °C had been there for at least five to six weeks.

Dissolved Oxygen

Daily cross-sectional averages of concentrations and saturation levels for dissolved oxygen, measured at each station during the field study, are shown Figure 4. Stations 1-5 show a consistent increase in the average concentration from morning to afternoon. These stations are all fairly shallow and well-mixed from top to bottom. Water transparency, as measured by Secchi disk, were generally in the range of 3.0 to 4.0 meters at these stations. . Assuming that the depth of active photosynthesis is given by 1.7*Secchi depth, Stations 1-5 are shallow enough that the cross-sectional average is affected by photosynthetic activity. Stations 6, 8 and Post Falls Dam show a consistent increase from morning to afternoon for cross-sectional averages only for the top five meters. The total cross-sectional average at these three stations is controlled by the extremely low values of DO occurring at depth. Photosynthesis has a much smaller role in the DO at depth. As a result, the deeper stations have less diurnal variability in depth-averaged value of DO than do the shallow stations.

When the flow in the Spokane River is low, vertical mixing is reduced and, as described above, a thermocline develops at those locations for which water depth is greater than approximately seven meters. The vertical distribution of DO is also affected by the reduced mixing and at DO also decreases rapidly at depths greater than approximately seven meters. Vertical profiles of DO at a shallow station (Station 5) and a deep station (Station 6) are compared in Figure 5.

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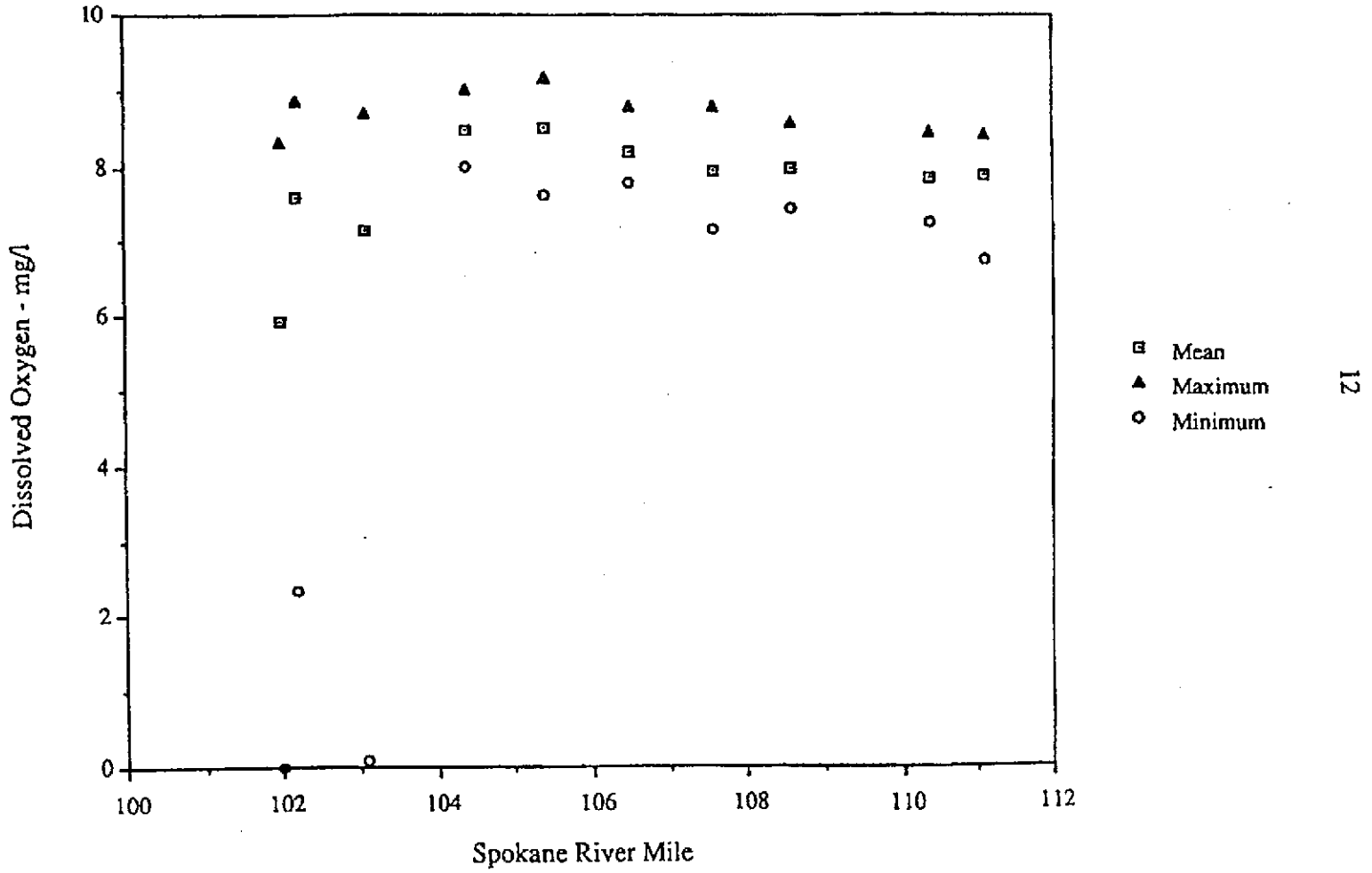


Figure 4. Mean, maximum and minimum dissolved oxygen in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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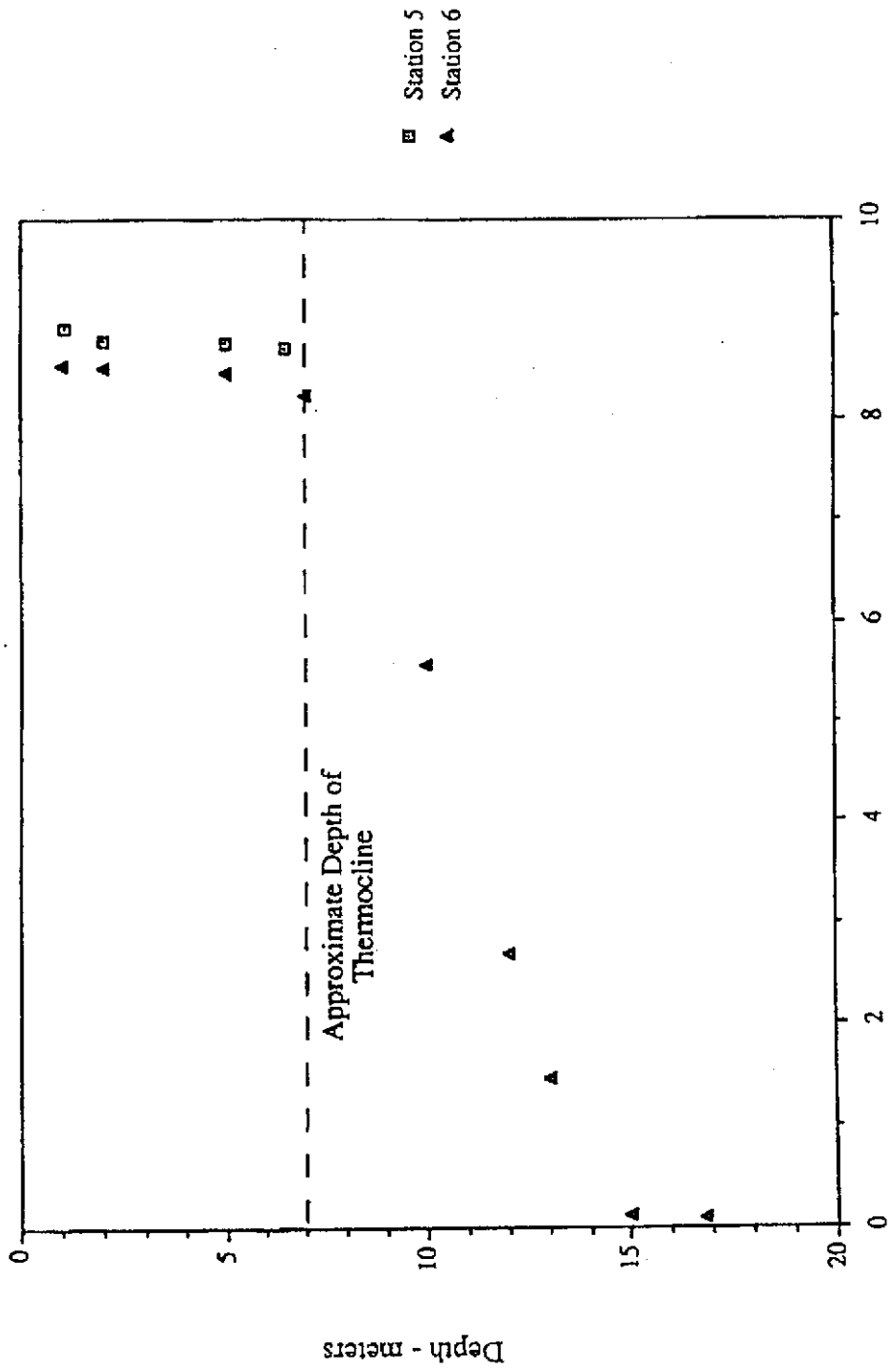


Figure 5. Vertical profiles of dissolved oxygen (DO) at Stations 5 and 6 on August 18, 1988.

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Conductivity and pH

Conductivity and pH were measured both in the field with the Hydrolab Survey Model 4000 and in the laboratory. Cross-sectional averages of the conductivity measured in the field for the three-day sampling period are given in Figure 6.

Average pH increases monotonically downstream from the outlet of Lake Coeur d'Alene, as shown in Figure 7.

Nutrients

Concentrations of total phosphorus, nitrate+nitrite-nitrogen, Kjeldahl nitrogen and total ammonia-nitrogen, averaged over the three-day period of the field study, are shown in Figures 8 through 11. Average total phosphorus were below the detection level (0.01 mg/l) at the outlet of Lake Coeur d'Alene. Average total phosphorus increased to 0.055 mg/l at the first river sampling station downstream from the STP. As shown in Figure 8, the average concentration of total phosphorus decreased in a downstream direction after the initial pulse was introduced by the STP. Possible sinks for total phosphorus include uptake by attached algae and macrophytes and uptake by planktonic algae which eventually settle to the bottom of the river. No data were collected during this survey for testing either of these hypotheses.

Nitrate+nitrite-nitrogen in the Spokane River was below the level of detection (0.01 mg/l) throughout the field study (Fig. 9). Both Kjeldahl nitrogen and total ammonia-nitrogen were greater at the station just downstream from the discharge of the STP, as shown in Figures 10 and 11. However, Kjeldahl nitrogen and ammonia-nitrogen decreased downstream after the initial increase. Volatilization, nitrification, and algal uptake are potential sinks for ammonia. When nitrification occurs, the loss in ammonia-nitrogen should be accompanied by an increase in nitrate-nitrogen. The measurements of nitrate+nitrite-nitrogen made in this study do not show an increase in nitrate+nitrite-nitrogen corresponding to the decrease in ammonia-nitrogen. Insufficient information was available to determine the importance of volatilization or algal uptake to the nitrogen budget.

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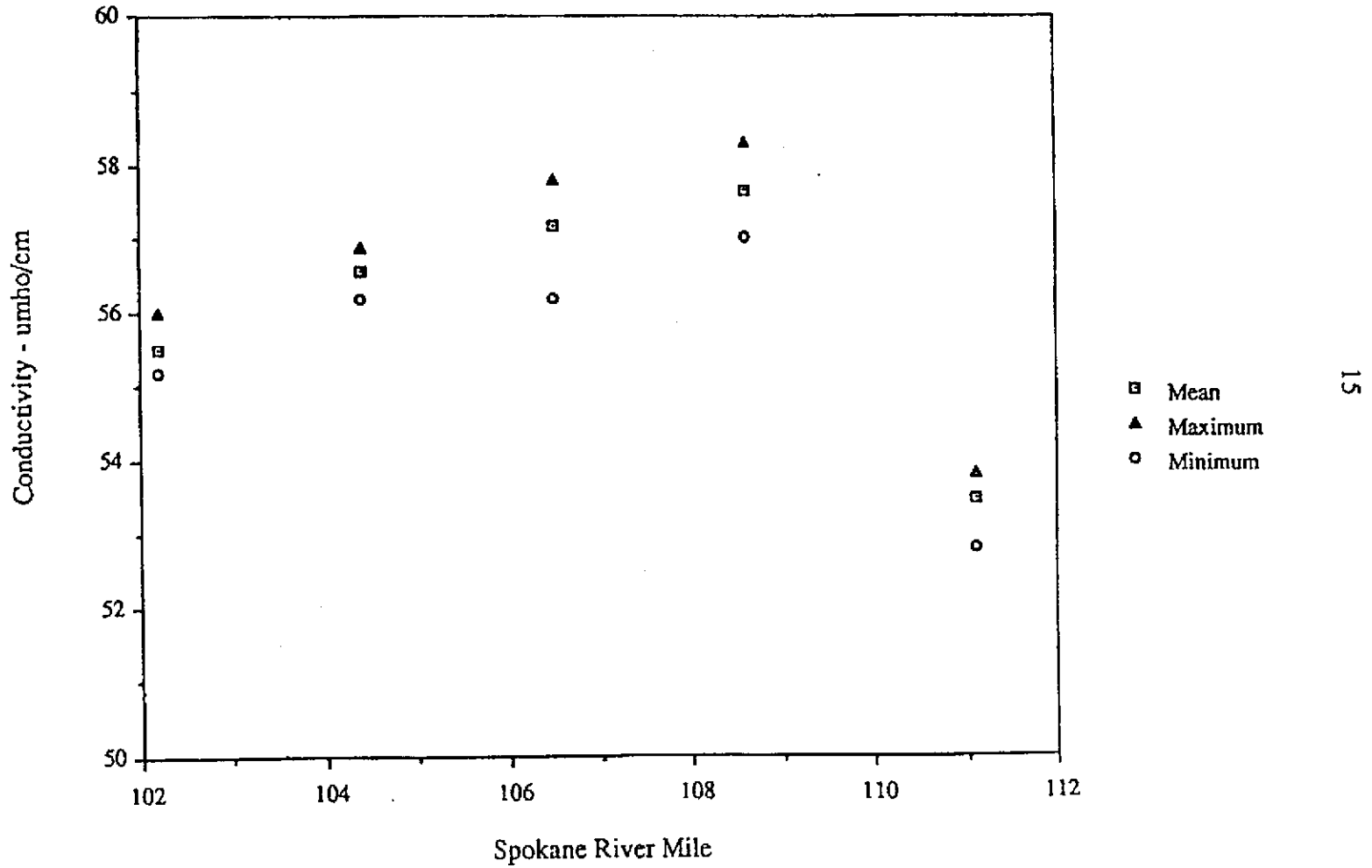


Figure 6. Mean, maximum and minimum conductivity in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field of study of August 16-18, 1988.

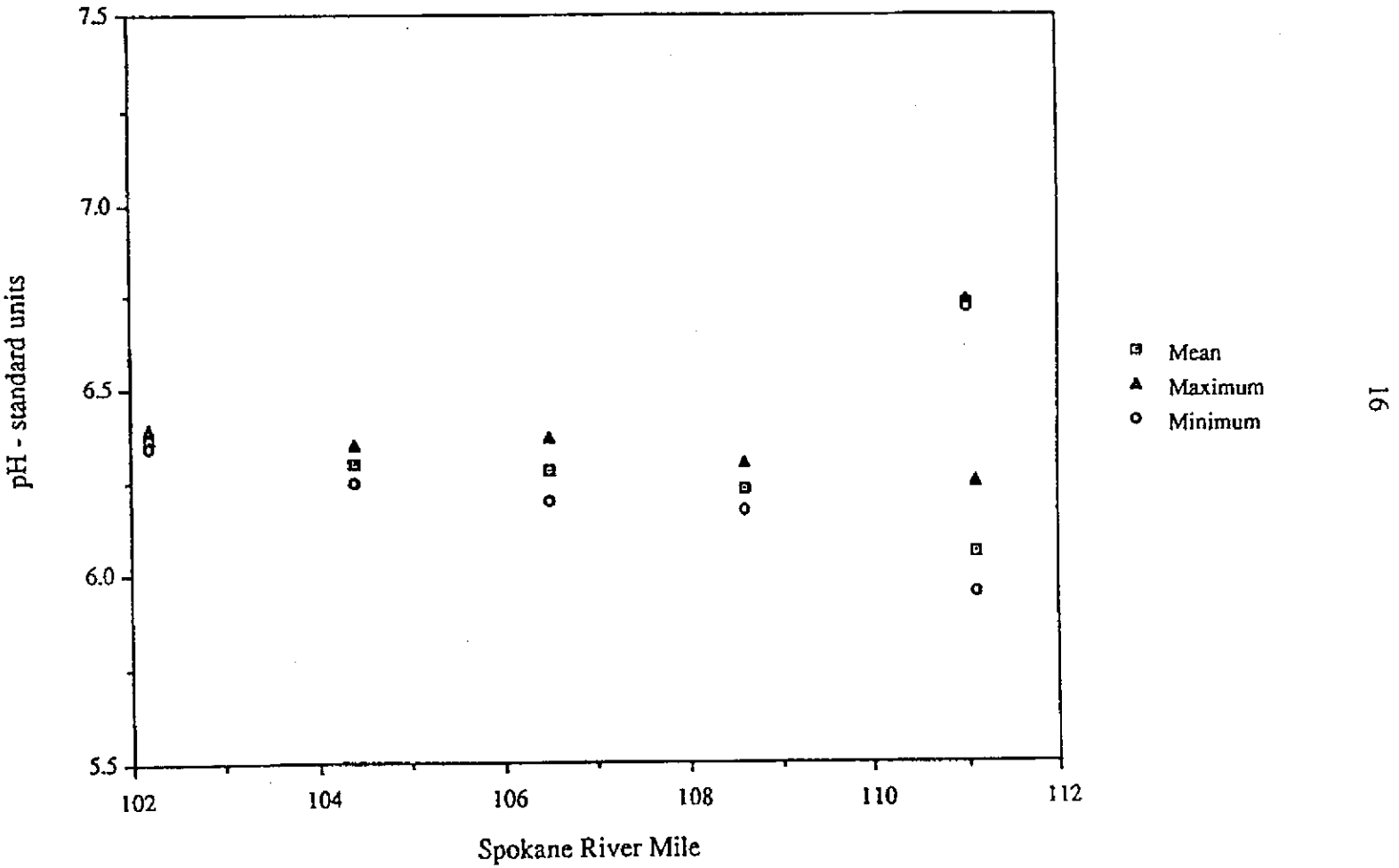


Figure 7. Mean, maximum and minimum pH in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

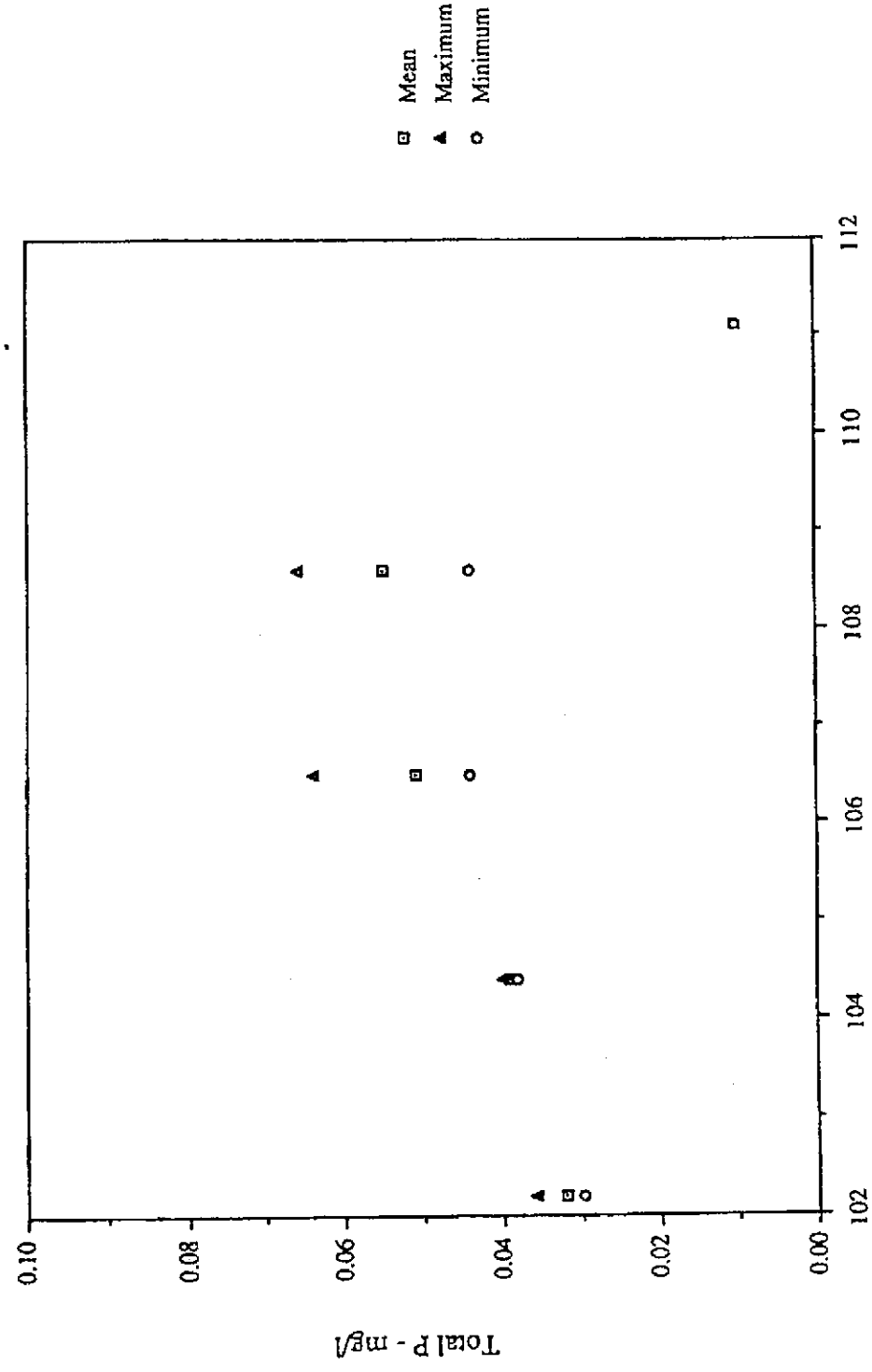


Figure 8. Mean, maximum and minimum total phosphorus in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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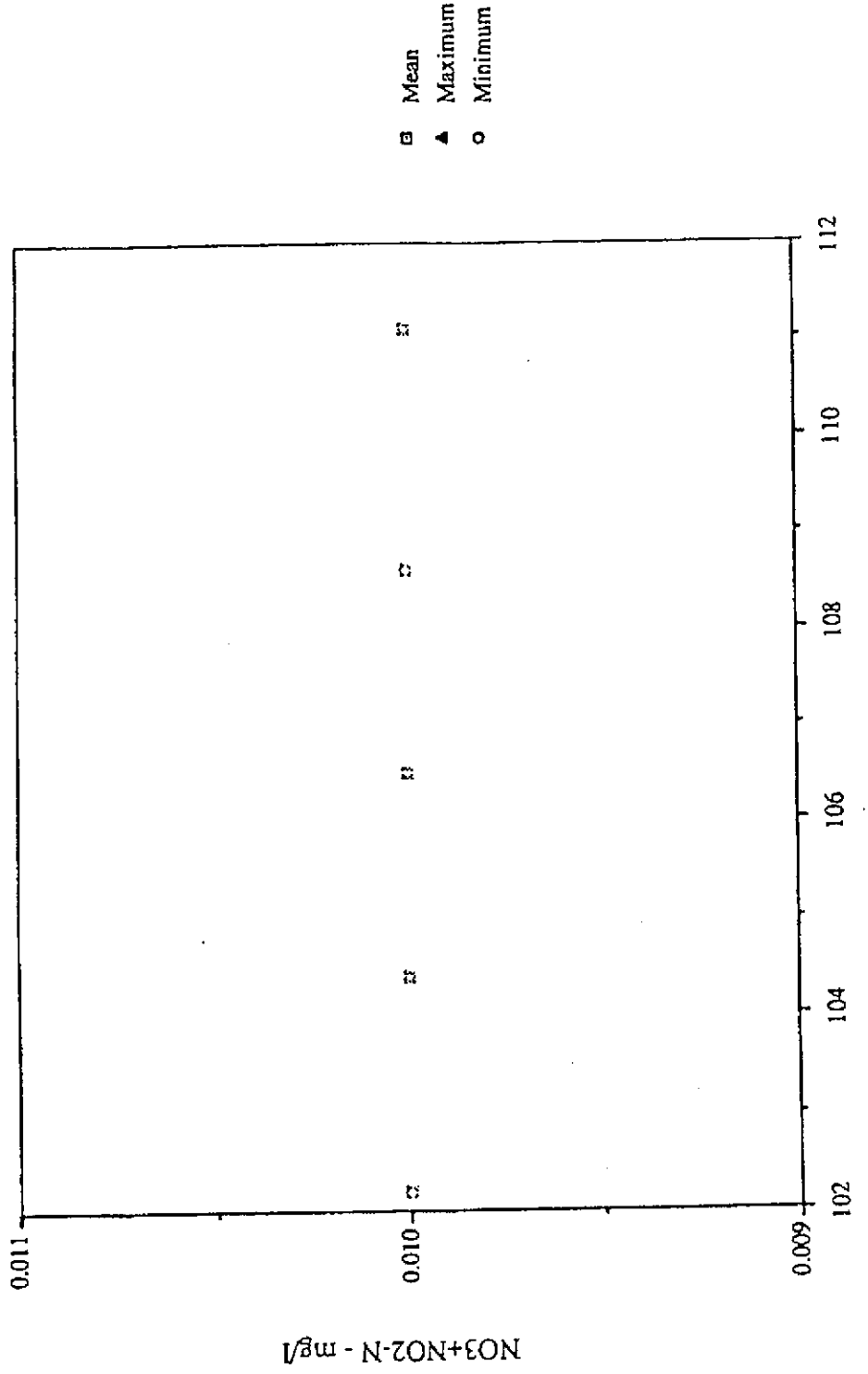


Figure 9. Mean, maximum and minimum NO2+NO3-Nitrogen in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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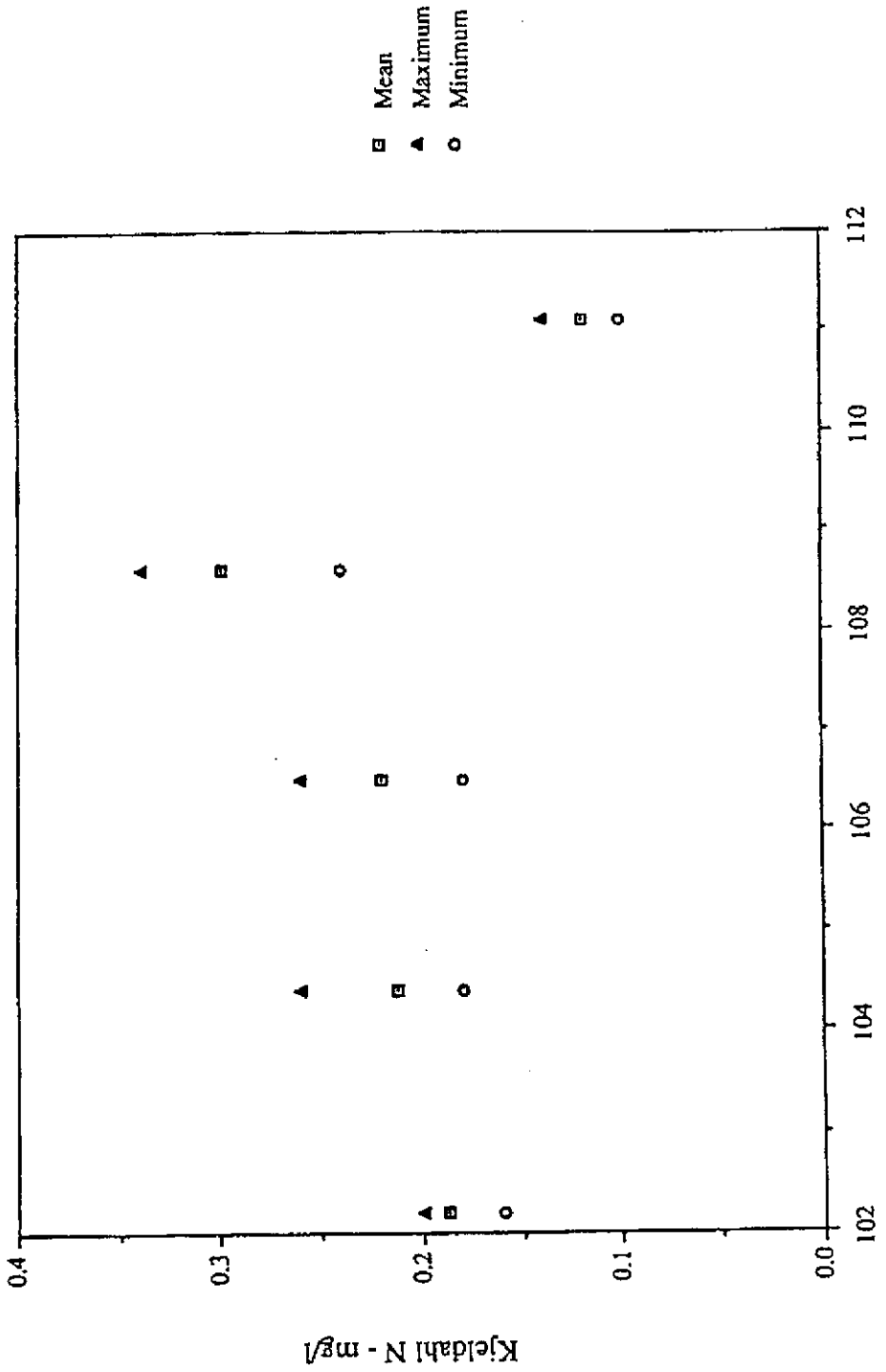


Figure 10. Mean, maximum and minimum Kjeldahl Nitrogen in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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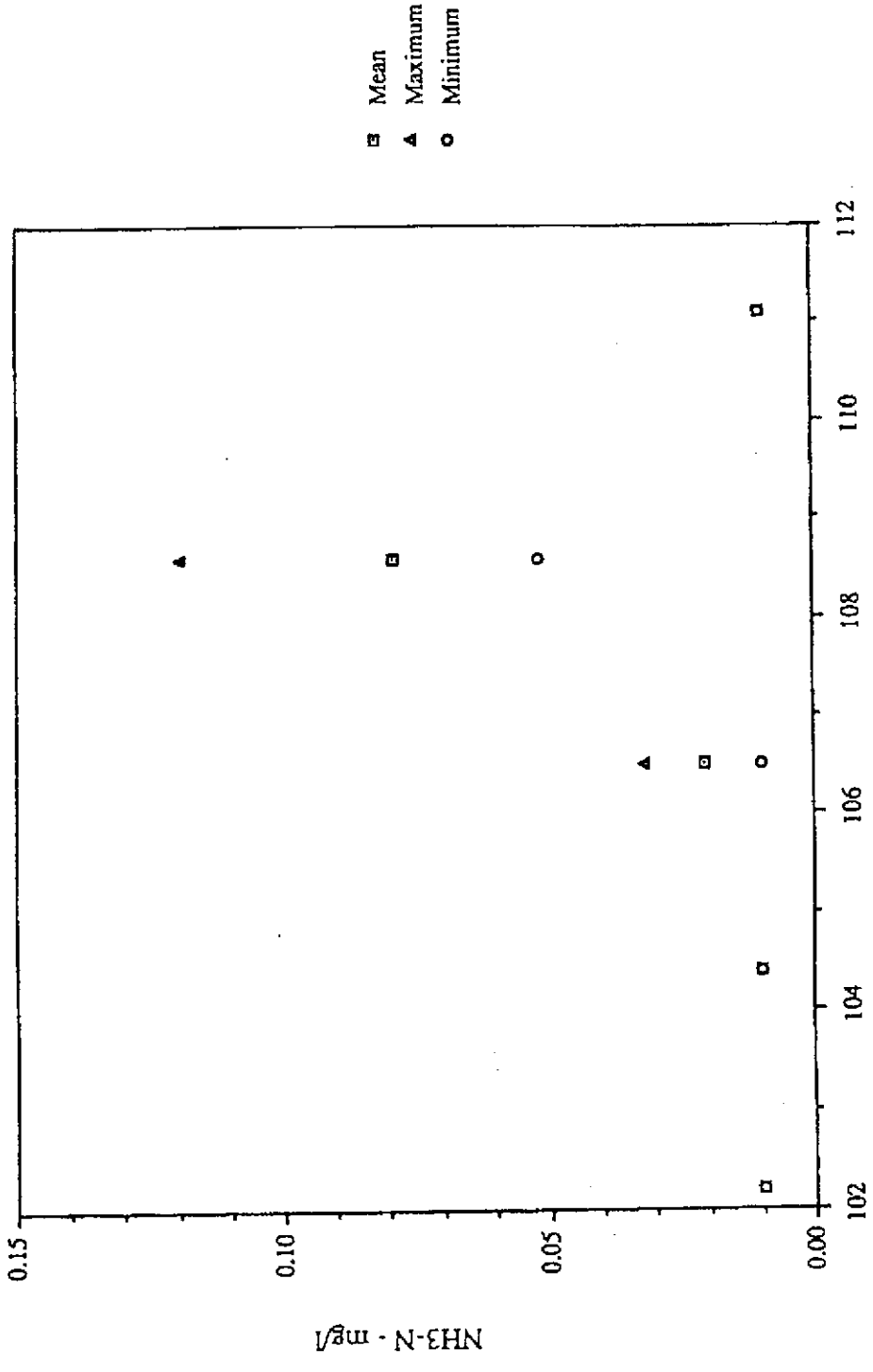


Figure 11. Mean, maximum and minimum NH3 Nitrogen in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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Biological Oxygen Demand (BOD)

Ultimate BOD, L_{ult}, and rates of deoxygenation, K_1, were determined from standard, uninhibited 5-, 10-,15-,20- and 60-day BOD measurements from samples obtained on each of the three days during the field study. The parameters L_{ult} and K1 were estimated by minimizing the squared difference between the observations and the equation for BOD:

$$L = L_{ult} e^{-K_1 t} \qquad (1)$$

where,

L = the BOD at any time, t, mg/l

L_{ult} = the ultimate BOD, mg/l

t = time, days

K_1 = the deoxygenation rate constant, $days^{-1}$.

The simplex method for minimizing a nonlinear function (Nelder and Mead, 1964) was used to find the minimum. The mean, maximum and minimum ultimate BOD for the receiving water stations are shown in Figure 12, the estimated values of the deoxygenation rates, K_1, are shown in Table 3.

Table 3. Mean, maximum and minimum of the estimated deoxygenation rate, K_1, in the Spokane River during the field study of August 16-18, 1988.

Spokane River Mile	Deoxygenation Rate, K_1, $days^{-1}$		
	Mean	Maximum	Minimum
111.1	0.05	0.06	0.04
108.6	0.05	0.05	0.05
106.5	0.08	0.13	0.06
104.4	0.09	0.14	0.06
102.2	0.08	0.10	0.06

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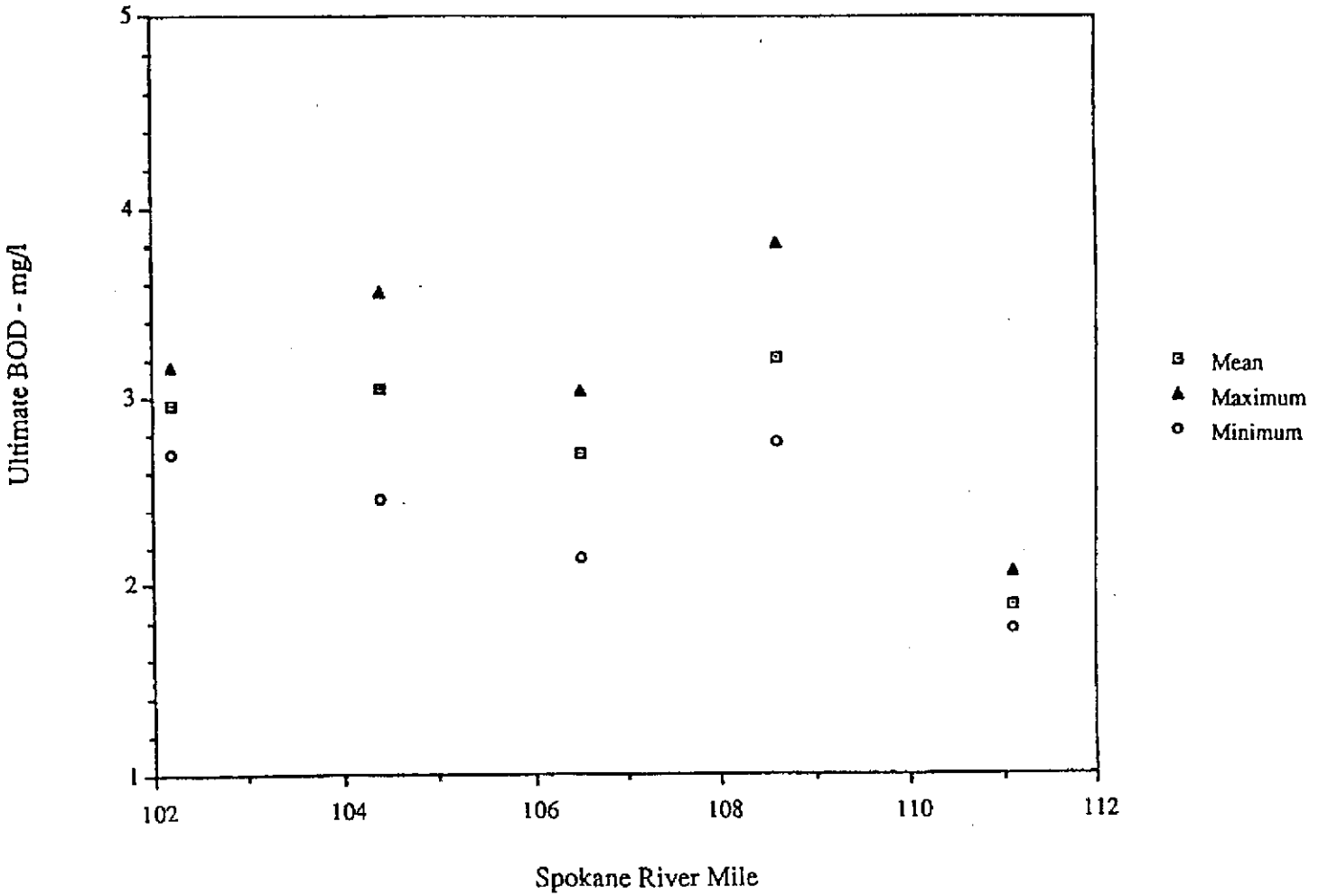


Figure 12. Mean, maximum and minimum ultimate BOD in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

Alkalinity and Hardness

Mean, maximum and minimum of observed alkalinity and hardness in the Spokane River during the field study are shown in Figures 13 and 14, respectively. Both hardness and alkalinity increase downstream implying a continuous inflow along the entire reach. Groundwater inflow (Drost and Seitz, 1978) represents a potential source.

Metals

Average concentrations of total arsenic, total recoverable cadmium, total recoverable copper, total recoverable chromium,total recoverable iron, total recoverable lead, total mercury, and total recoverable zinc are shown in Figures 15 through 22.

Point Sources

Water samples from the Coeur d'Alene STP, composited over a 24-hour period, were collected on August 16, 17, 18, and 19, 1989. The average, maximum and minimum for measurements of flow rates, nutrients, metals, BOD and conductivity are given in Table 4. Average flow of the STP on each of these days was obtained from the flow-measuring device operated by the STP. Loadings were estimated as the product of the average flow times the measured concentration of the composited sample. The loadings estimated in this way are also given in Table 4.

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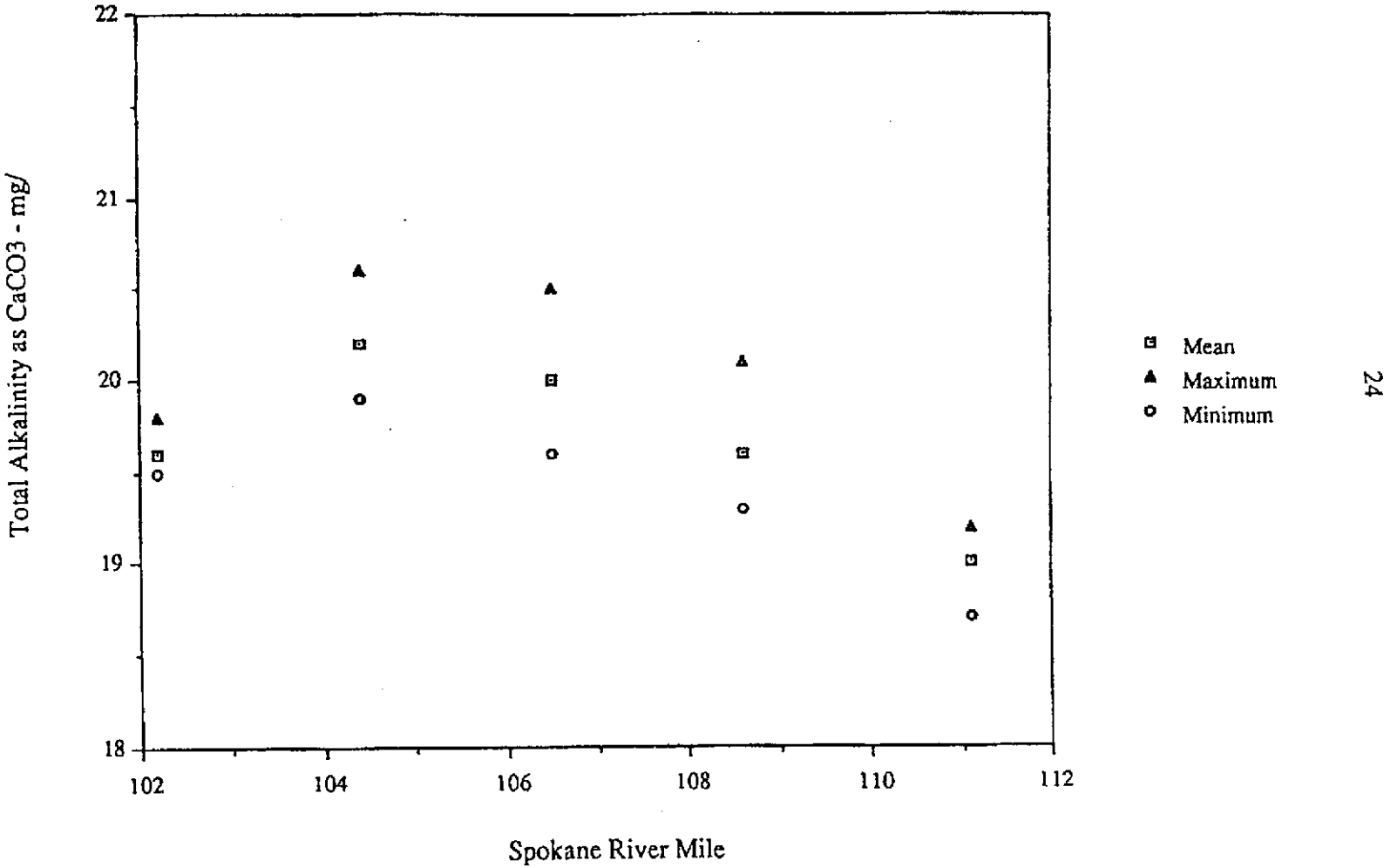


Figure 13. Mean, maximum and minimum alkalinity in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

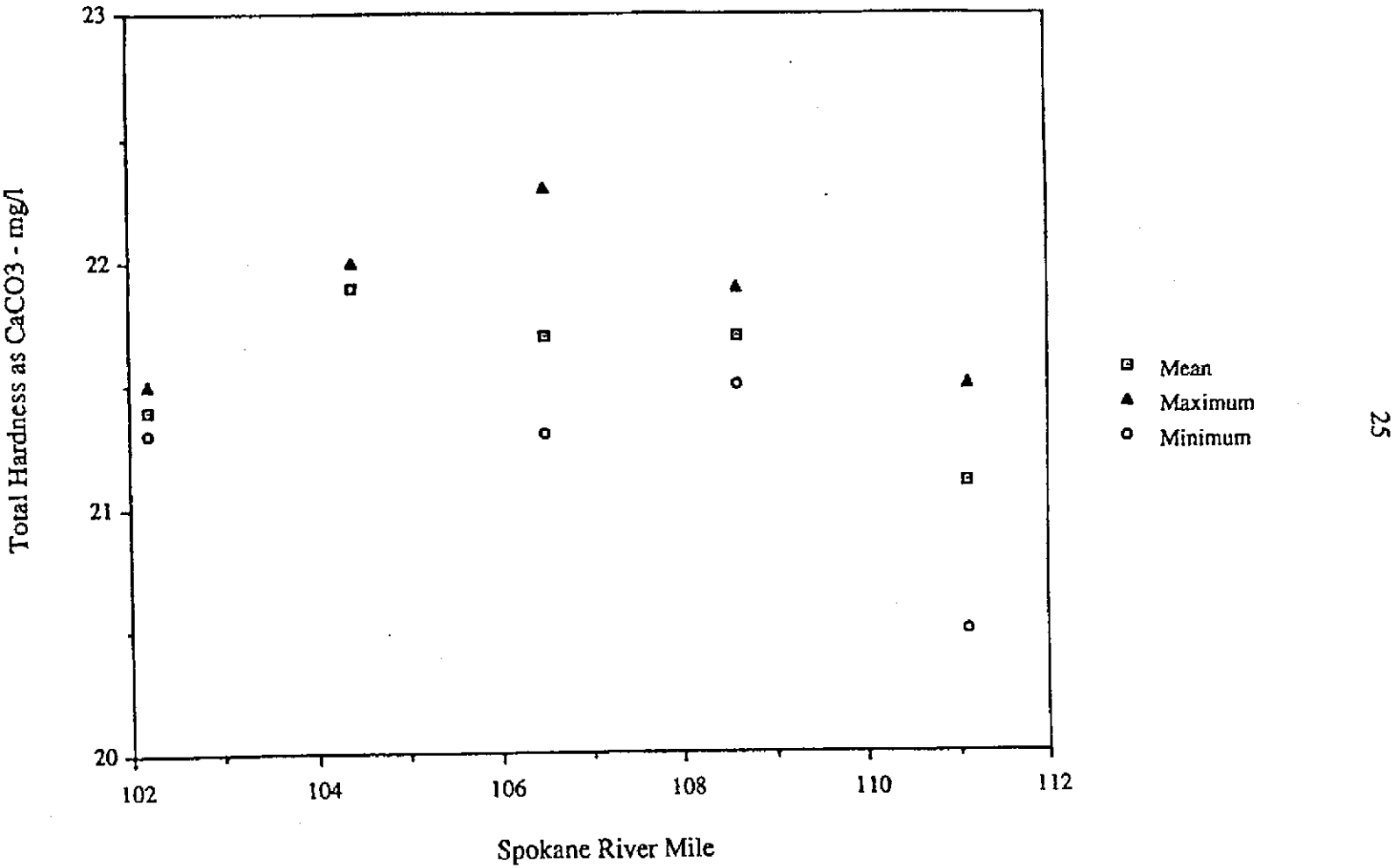


Figure 14. Mean, maximum and minimum hardness in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

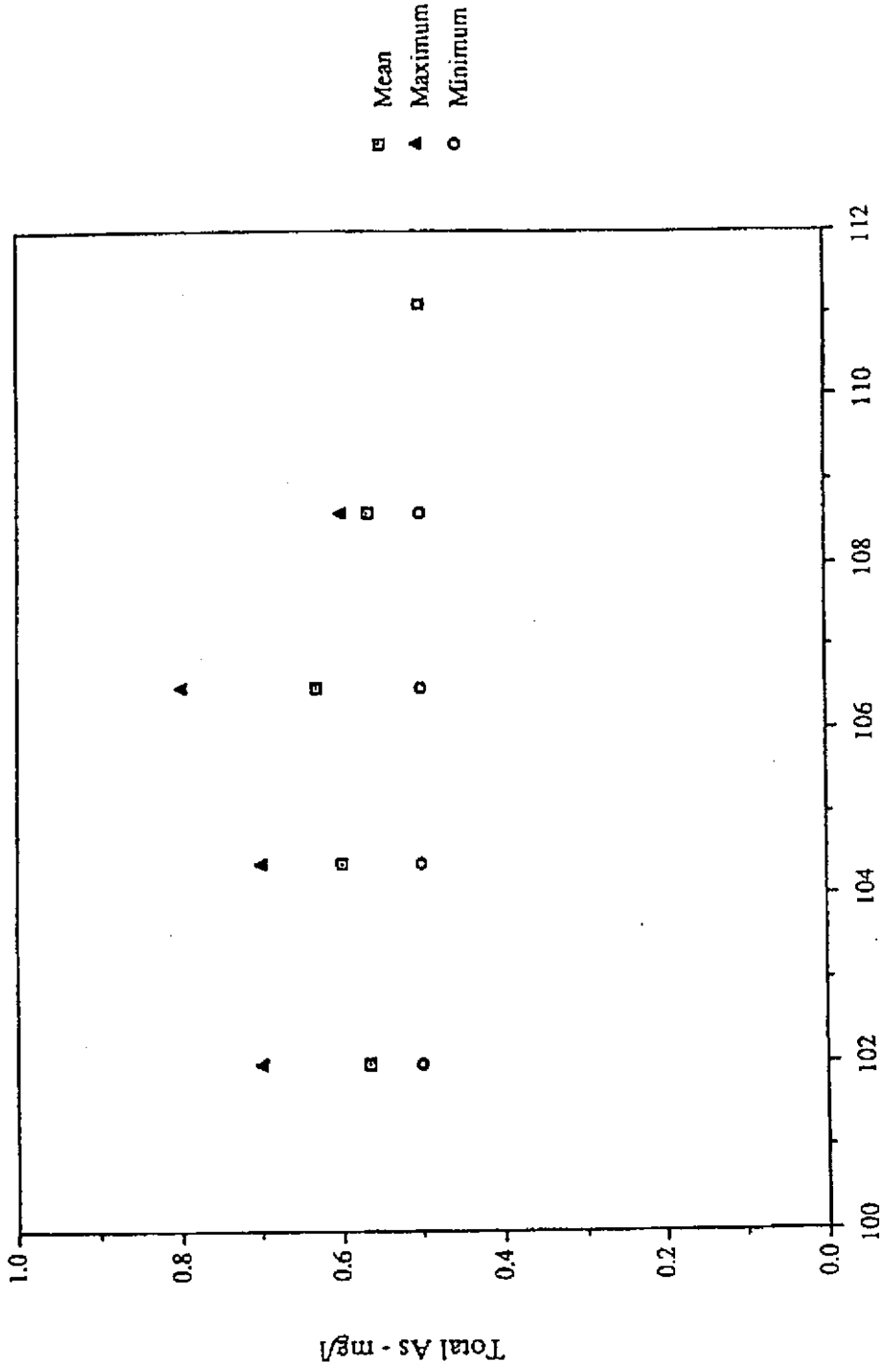


Figure 15. Mean, maximum and minimum total arsenic in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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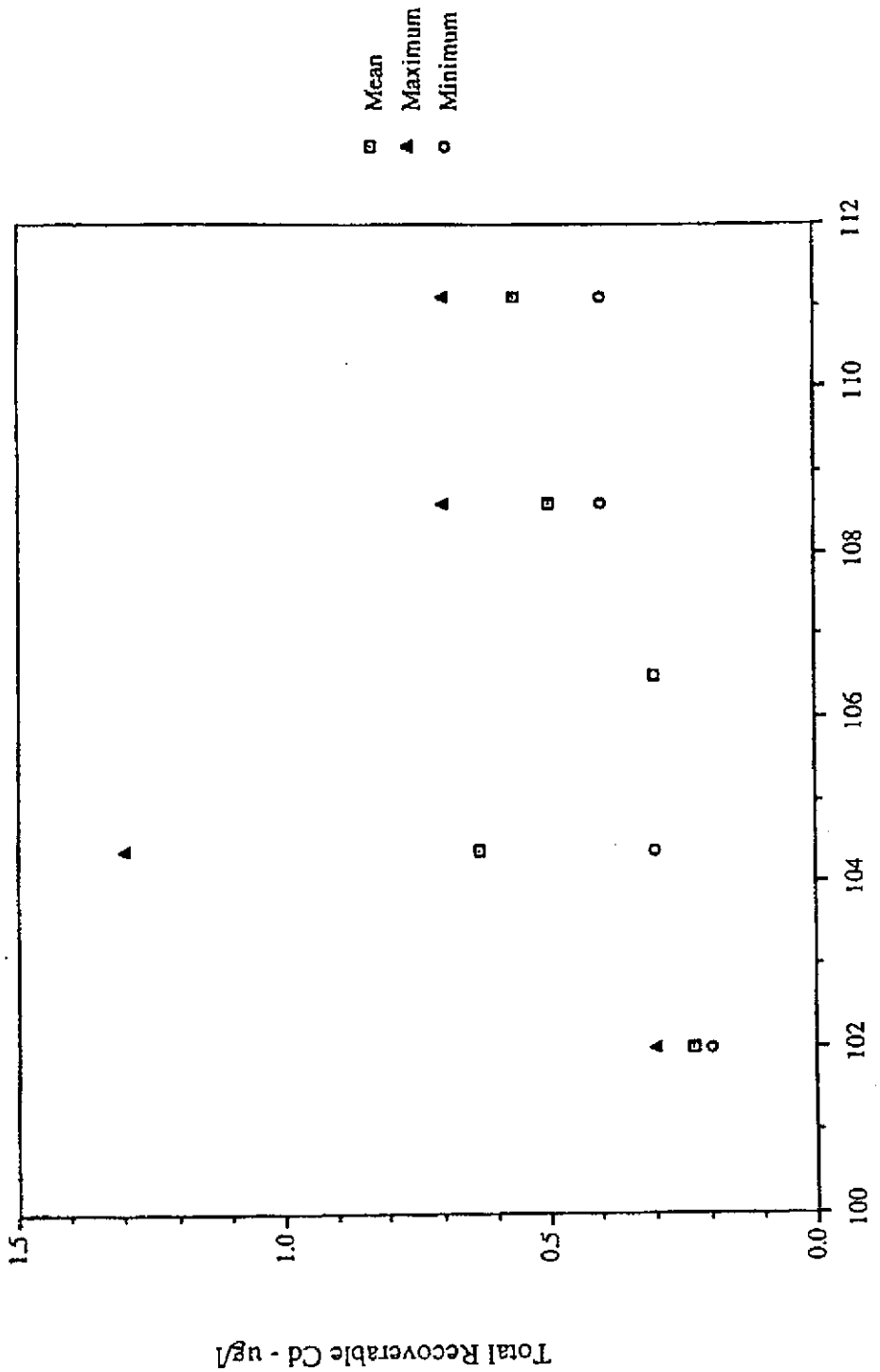


Figure 16. Mean, maximum and minimum total recoverable cadmium in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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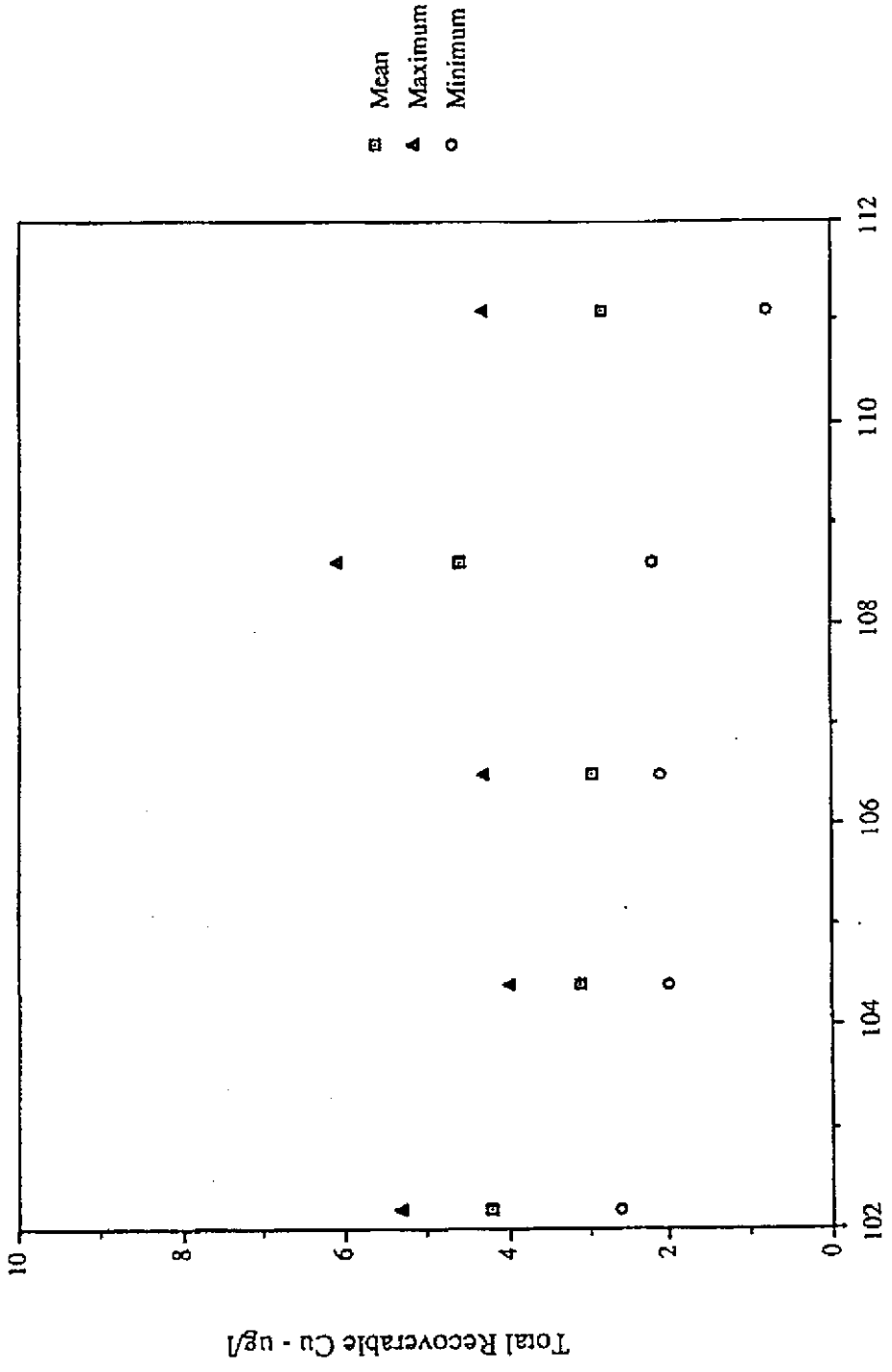


Figure 17. Mean, maximum and minimum total recoverable copper in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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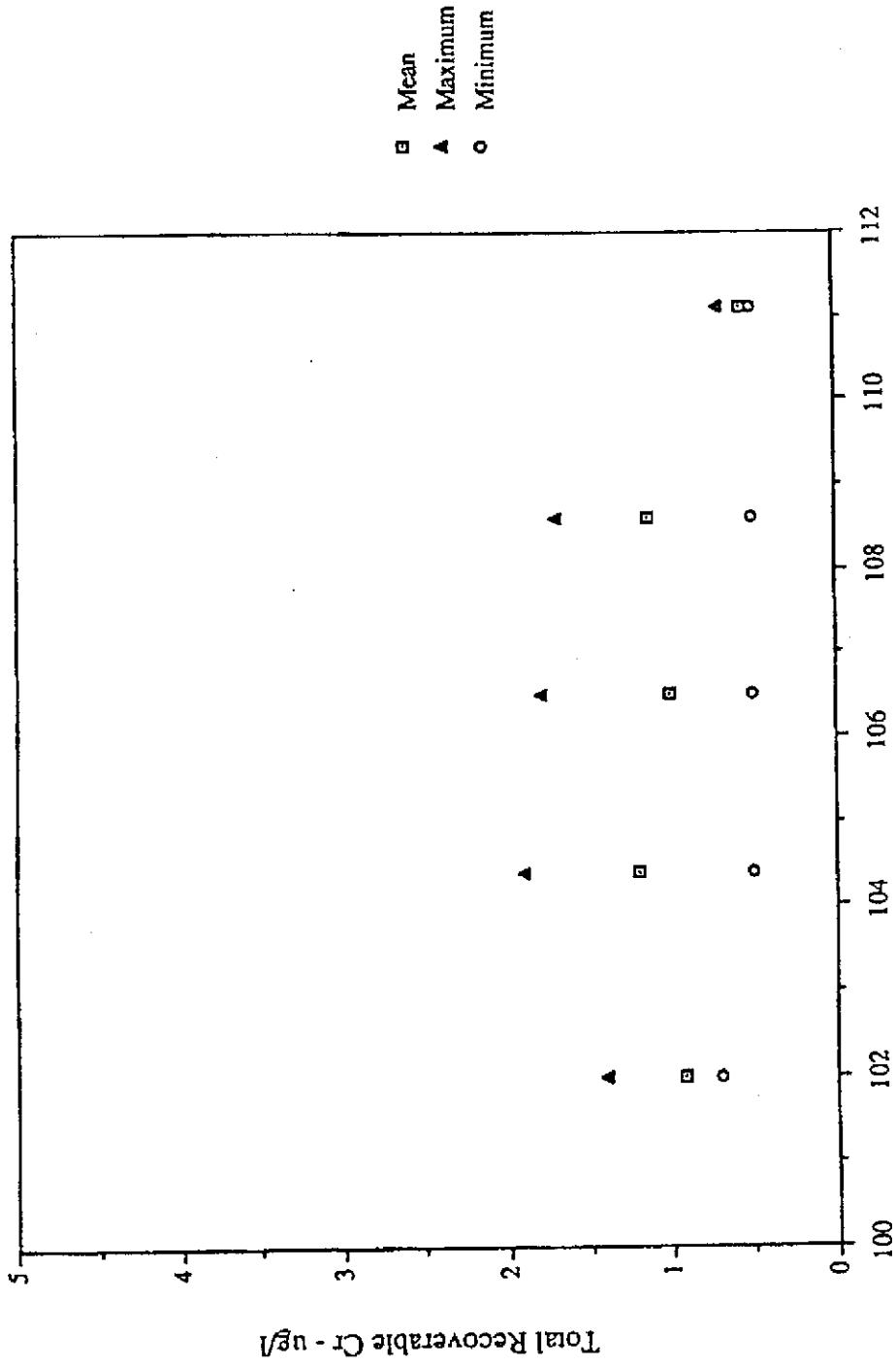


Figure 18. Mean, maximum and minimum total recoverable chromium in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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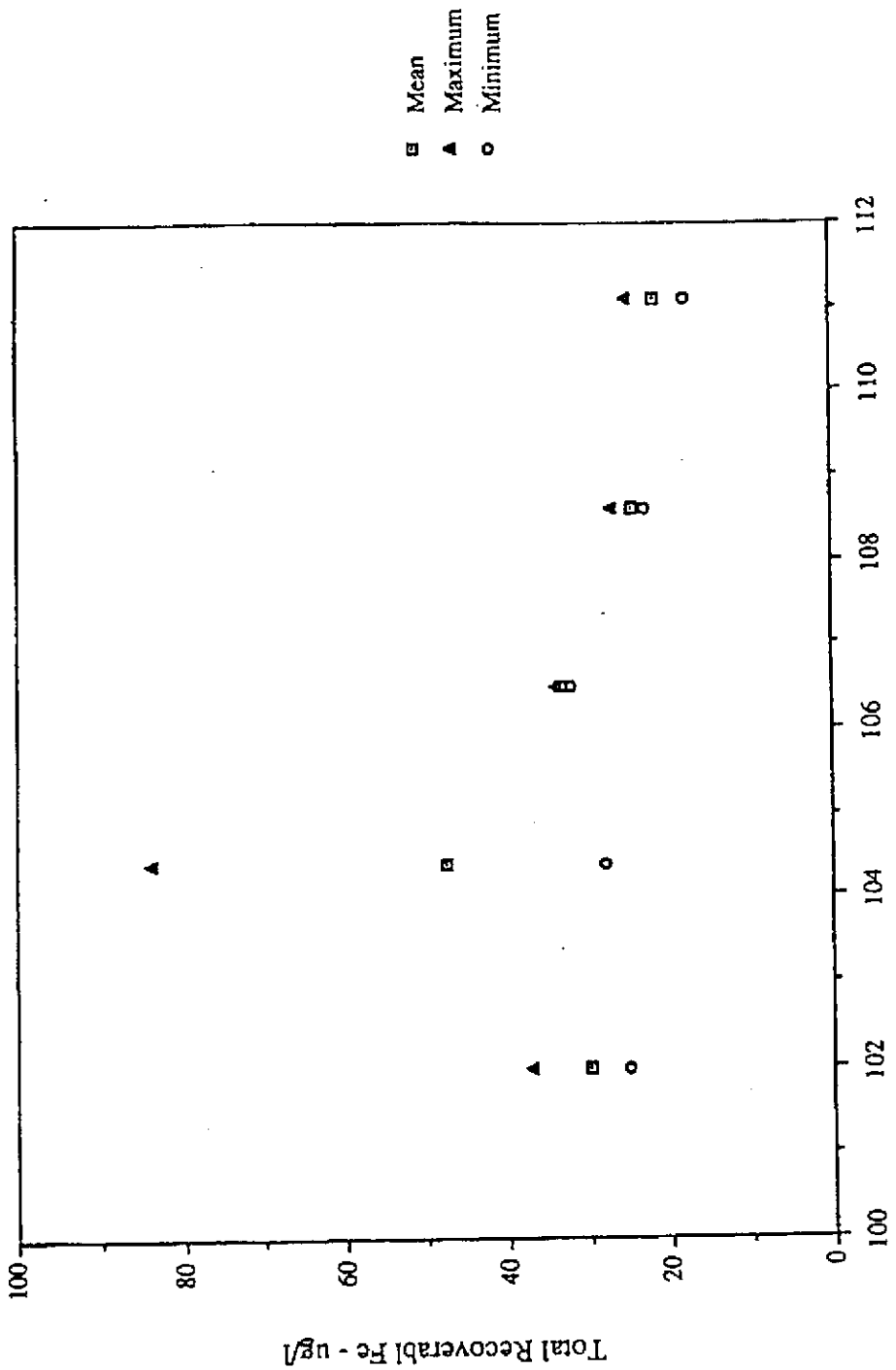


Figure 19. Mean, maximum and minimum total recoverable iron in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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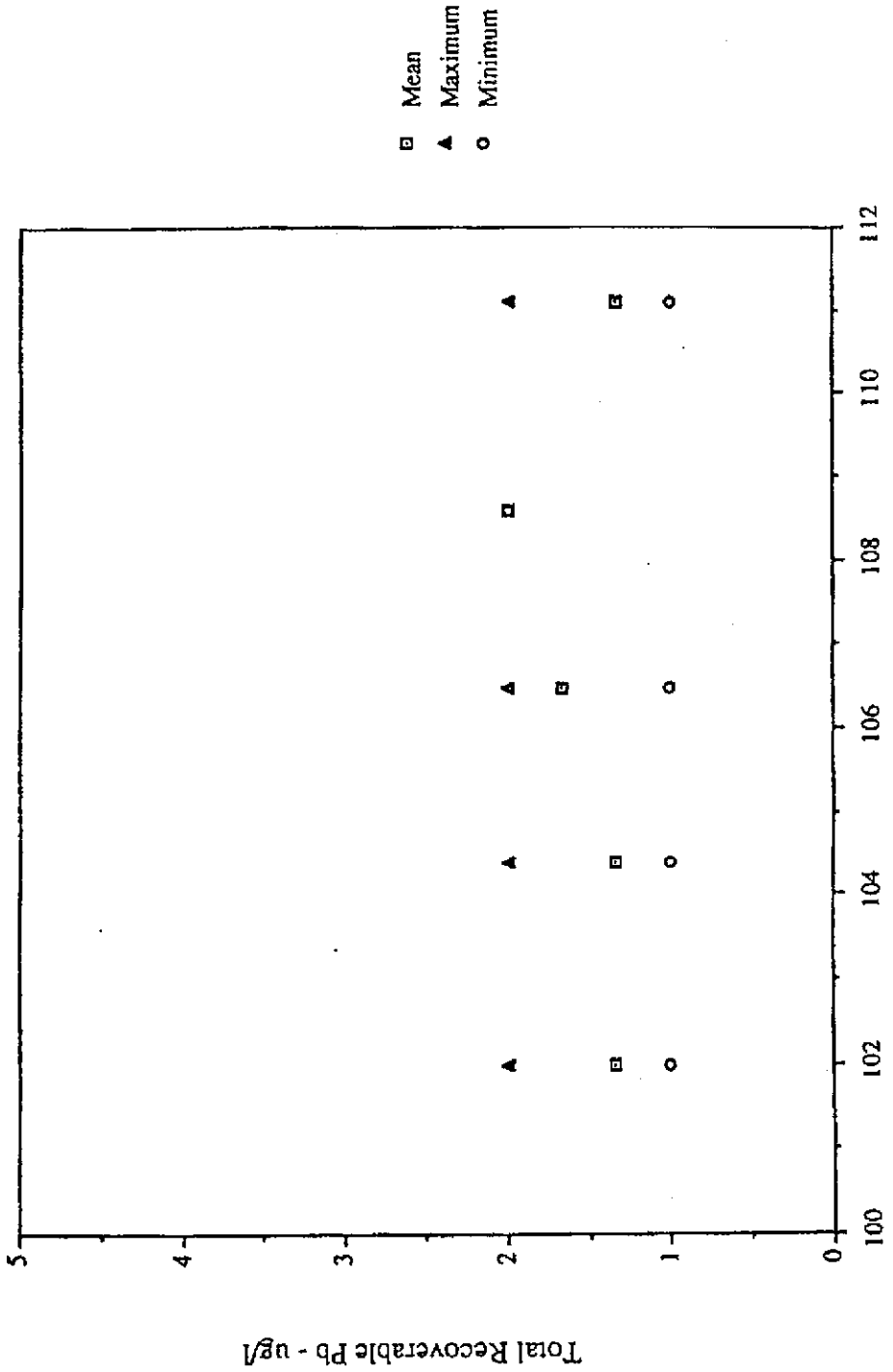


Figure 20. Mean, maximum and minimum total recoverable lead in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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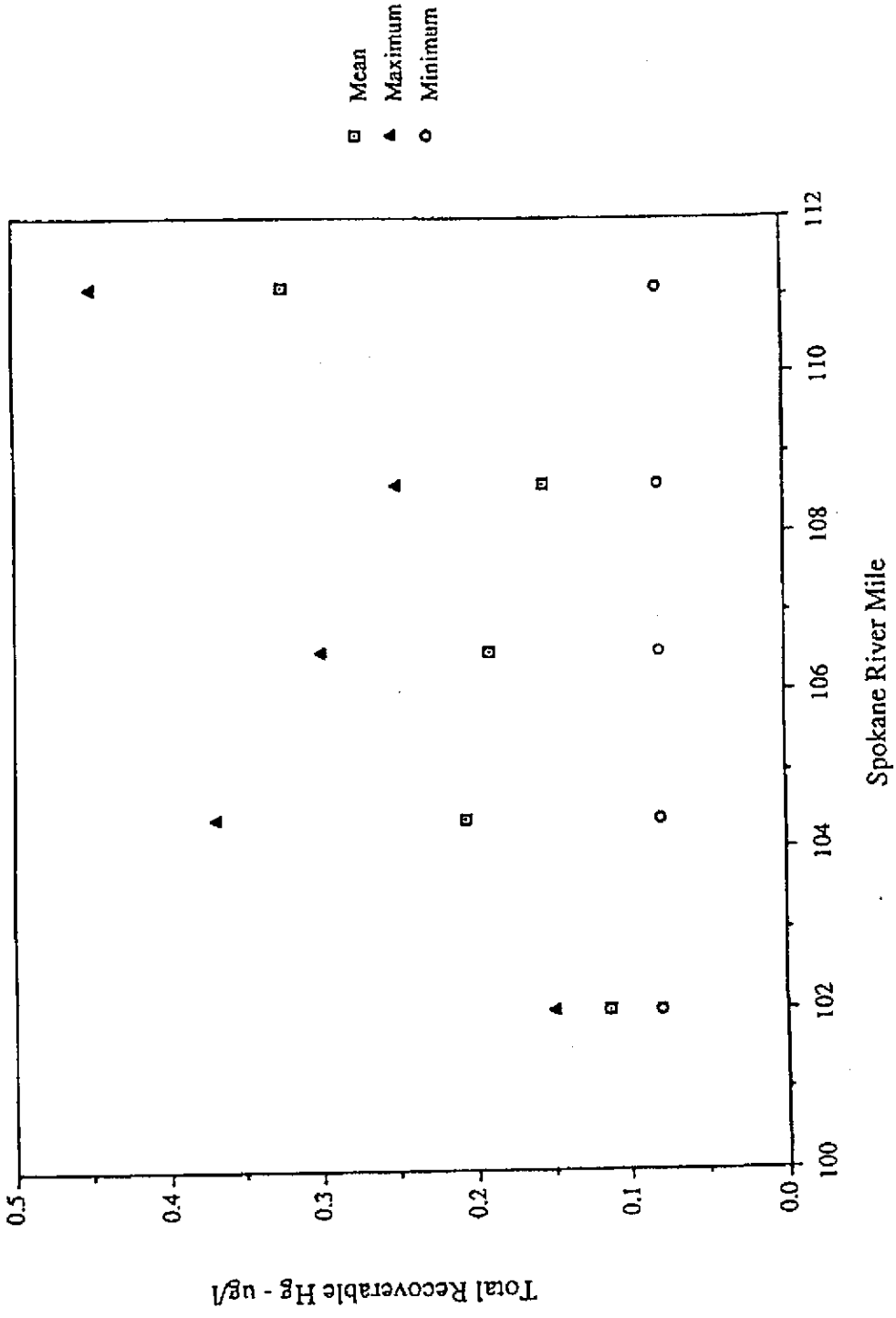


Figure 21. Mean, maximum and minimum total recoverable mercury in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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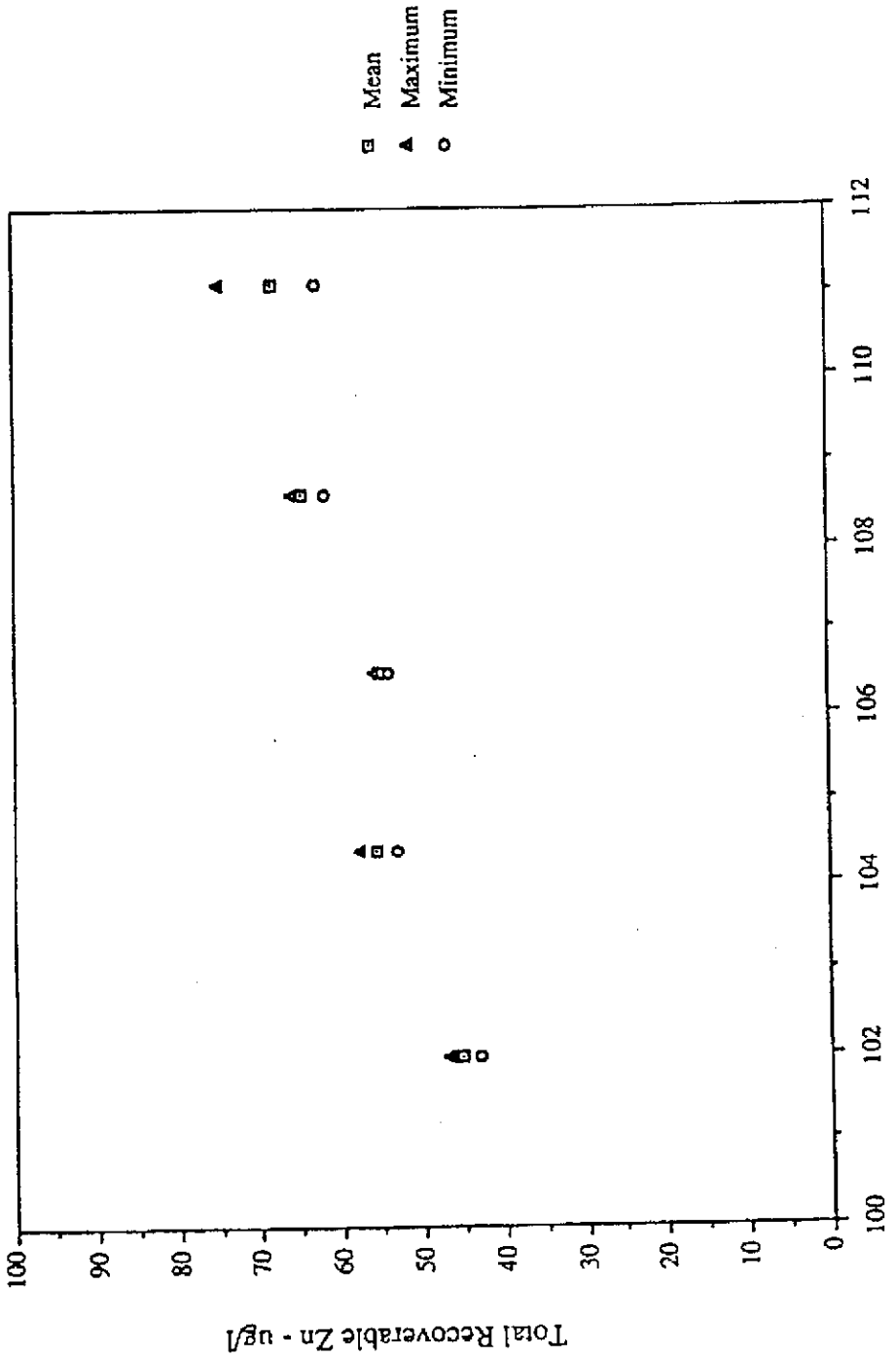


Figure 22. Mean, maximum and minimum total recoverable zinc in the Spokane River between Lake Coeur d'Alene and Post Falls Dam during the field study of August 16-18, 1988.

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Table 4. Mean, maximum and minimum values of water quality characteristics of the effluent of City of Coeur d'Alene's STP during the field study of August 16-18, 1988. Loadings for BOD, nutrients and metals are also shown.

Parameter	Parameter Value			Loading
	Mean	Maximum	Minimum	Pounds/Day
Flow - cfs	4.24	4.45	4.09	---
Deoxygenation Rate, K_1 - days^{-1}	0.07	0.08	0.06	---
pH - standard units	6.7	6.7	6.7	---
Conductivity - µmho/cm	674	677	672	---
Alkalinity as $CaCO_3$ - mg/l	197	202	193	---
Hardness as $CaCO_3$ - mg/l	71	110	32	---
NH_3-Nitrogen - mg/l	15.8	16.6	14.7	360
NO_2+NO_3-Nitrogen - mg/l	1.2	1.6	0.8	28.1
Kjeldahl Nitrogen - mg/l	22.3	23.0	21.5	510
Total Phosphorus - mg/l	7.0	7.2	6.8	160
Total As - µg/l	1.5	1.8	1.4	0.04
Total Recoverable Cd - µg/l	0.70	1.0	0.5	0.02
Total Recoverable Cu - µg/l	5.9	14.4	1.6	0.10
Total Recoverable Cr - µg/l	3.5	4.0	3.1	0.08
Total Recoverable Pb - µg/l	5.3	7.0	4.0	0.10
Total Recoverable Hg - µg/l	0.11	0.17	0.08	0.003
Total Recoverable Zn - µg/l	31	51	0	0.71

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CONCLUSIONS

The results of the field study conducted during the period August 16-18, 1988 were were similar to those of earlier studies (Yearsley, 1980) in a number of ways. Major conclusions derived from the results include:

- Dissolved oxygen was low at those locations in the river where a thermocline had formed. The depth of the thermocline was generally at a depth of approximately seven meters and was observed in two segments of the river. One of these segments was near Ford Rock (Spokane River Mile 104.4) and the other was in the forebay of Post Falls Dam (Spokane River Mile 102.2).
- The City of Coeur d'Alene's STP contributes a significant load of phosphorus to the Spokane River. Upstream from the STP discharge the observed concentration of total phosphorus was below the detection limit of 0.01 mg/l. The mean value of observed total phosphorus downstream from the STP was 0.055 mg/l. The estimated average loading of total phosphorus from the STP was 160 pounds/day during this period.
- In addition, the results of the August 16-18, 1988 field study showed that the City of Coeur d'Alene' STP contributed significantly to the BOD loading and to the loading of nitrogen, primarily in the form or organic nitrogen and ammonia.

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Yearsley, J.R. 1980. Water quality studies of the Spokane River between Coeur d'Alene, Idaho and Post Falls, Idaho, 1978-1979. EPA Region 10, Seattle, WA. 53 pp.

Yearsley, J.R. 1987. An estimate of NPDES permit limits for the Cities of Post Falls and Coeur d'Alene, Idaho. ESD, EPA Region 10, Seattle, WA.

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APPENDIX A

Measurements of Water Quality in the Receiving Waters and from Point Sources in the Spokane River between Coeur d'Alene and Post Falls, Idaho

In situ measurements of water quality in the Spokane River between Coeur d'Alene and Post Falls, Idaho during the period August 16-18, 1988 are given in Table A-1. Station locations can be obtained from Figure 1. Laboratory measurements of various water quality characteristics from both receiving waters and point sources are given in Table A-2. The key relating laboratory sample numbers and station location is given in Table A-3.

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/16/88	630	#1 Right	0.9	20.34	7.45	88.3	48	7.54	
08/16/88			2.8	20.37	8.07	95.7	48	7.79	
08/16/88	650	#1 Mid	0.3	20.14	8.16	96.3	48	7.45	3.0
08/16/88			2.0	20.17	8.09	95.6	48	7.66	
08/16/88	700	#1 Left	0.8	20.20	8.08	95.5	49	7.37	
08/16/88			2.4	20.22	7.93	93.8	49	7.59	
08/16/88	713	#2 Right	0.7	20.31	7.95	94.2	53	7.45	
08/16/88			3.2	20.35	7.88	93.4	52	7.53	
08/16/88	718	#2 Mid	0.7	20.39	7.92	94.0	51	7.55	4.0
08/16/88			2.8	20.31	7.91	93.7	49	7.41	
08/16/88	723	#2 Left	0.7	20.24	7.97	94.3	49	7.52	
08/16/88			2.1	19.99	7.88	92.8	50	7.29	
08/16/88	734	#3 Right	0.3	20.80	7.78	93.0	52	7.51	
08/16/88			2.6	20.86	7.60	91.0	53	7.20	
08/16/88	746	#3 Mid	0.9	20.94	7.84	94.0	53	7.21	3.8
08/16/88			3.3	20.97	7.77	93.2	53	7.24	
08/16/88	754	#3 Left	0.8	20.91	8.06	96.6	53	7.32	
08/16/88			2.4	20.90	7.96	95.4	53	7.04	
08/16/88	805	#3A Right	0.8	21.26	7.23	87.2	53	6.75	
08/16/88			2.8	21.30	7.18	86.7	53	7.11	
08/16/88	813	#3A Mid	0.9	21.27	7.68	92.7	54	7.29	3.5
08/16/88			3.1	21.24	7.87	94.9	53	7.28	
08/16/88	820	#3A Left	0.9	21.31	7.86	94.9	52	7.16	
08/16/88			3.1	21.16	7.87	94.7	53	7.25	
08/16/88	833	#4 Right	0.6	21.42	8.10	98.0	53	7.18	4.0
08/16/88			5.5	21.45	8.05	97.5	53	7.38	
08/16/88	842	#4 Mid	0.5	21.48	8.08	97.9	52	7.04	3.8
08/16/88			5.1	21.33	7.79	94.0	52	7.40	
08/16/88	851	#4 Left	0.8	21.50	7.97	96.6	53	7.01	
08/16/88			3.5	21.52	7.97	96.6	53	7.36	
08/16/88	905	#4A Right	0.7	21.72	8.61	104.8	53	7.07	
08/16/88			2.6	21.75	8.57	104.4	52	7.50	
08/16/88	906	#4A Mid	0.7	21.82	8.52	103.8	54	7.48	3.5
08/16/88			5.6	21.81	8.46	103.1	52	7.52	
08/16/88	910	#4A Left	0.9	21.82	8.51	103.7	52	7.38	3.3
08/16/88			6.5	21.78	8.32	101.4	52	7.47	
08/16/88	918	#5 Right	0.7	21.93	8.71	106.4	52	7.32	
08/16/88			5.9	21.88	8.40	102.5	52	7.57	
08/16/88	929	#5 Mid	0.8	21.92	8.72	106.5	52	7.52	
08/16/88			5.9	21.82	8.65	105.4	52	7.77	
08/16/88	935	#5 Left	0.9	21.95	8.73	106.7	52	7.46	3.6
08/16/88			5.0	21.90	8.73	106.6	52	7.84	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Sta loc	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/16/88	954	#6 Right	0.8	22.04	8.26	101.1	52	7.43	4.5
08/16/88			2.0	22.03	8.29	101.4	51	7.53	
08/16/88			5.0	21.91	8.15	99.5	52	7.50	
08/16/88			7.0	21.91	7.64	93.3	52	7.34	
08/16/88			7.7	21.81	7.09	86.4	51	7.13	
08/16/88	1001	#6 Mid	0.8	22.05	8.41	102.9	52	7.48	4.2
08/16/88			2.0	22.03	8.39	102.6	52	7.33	
08/16/88			5.0	21.98	8.33	101.9	52	7.64	
08/16/88			7.0	21.83	7.53	91.8	52	7.26	
08/16/88	1008	#6 Left	0.2	22.05	8.46	103.6	52	7.37	
08/16/88			2.0	22.04	8.39	102.7	52	7.52	
08/16/88			3.0	21.99	8.42	102.9	52	7.58	
08/16/88	1020	#8 Right	0.9	22.05	8.31	101.8	51	7.30	4.5
08/16/88			2.0	21.98	8.26	101.0	51	7.40	
08/16/88			5.0	21.90	8.18	99.9	51	7.53	
08/16/88			7.0	21.82	7.88	96.0	51	7.42	
08/16/88			8.9	21.48	4.46	54.0	51	6.85	
08/16/88	1030	#8 Mid	0.9	22.02	8.35	102.2	52	7.39	
08/16/88			2.0	22.05	8.35	102.2	52	7.44	
08/16/88	1035	#8 Left	0.9	22.08	8.46	103.6	51	7.46	
08/16/88	1044	P.F. Dam	0.8	22.06	8.18	100.2	52	7.44	
08/16/88			2.0	22.01	8.07	98.8	51	7.41	
08/16/88			5.0	21.89	7.82	95.5	52	7.26	
08/16/88			7.0	21.73	6.65	80.9	51	6.91	
08/16/88			10.0	21.12	3.13	37.6	51	6.63	
08/16/88			12.5	19.04	0.18	2.0	51	6.46	
08/16/88	1430	Lake Ent	1.1	21.74	7.56	92.1	49	7.21	
08/16/88			2.0	21.58	7.55	91.7	50	7.28	
08/16/88			5.0	21.23	7.62	91.9	49	7.36	
08/16/88	1437	#1 Right	1.0	21.34	8.29	100.1	49	7.56	
08/16/88			2.0	21.34	8.23	99.4	49	7.66	
08/16/88	1441	#1 Mid	1.0	21.42	8.16	98.7	49	7.48	
08/16/88			2.2	21.11	8.25	99.2	50	7.64	
08/16/88	1445	#1 Left	1.0	21.42	8.34	100.9	50	7.51	
08/16/88			3.3	21.03	8.42	101.2	50	7.68	
08/16/88	1452	#2 Right	1.0	21.33	8.09	97.7	59	7.22	
08/16/88			3.0	21.01	8.28	99.4	55	7.37	
08/16/88	1454	#2 Mid	1.0	21.16	8.27	99.5	51	7.44	
08/16/88			3.2	21.01	8.16	97.9	55	7.38	
08/16/88	1500	#2 Left	1.0	21.08	8.47	101.8	51	7.64	
08/16/88			2.0	21.01	8.40	100.8	51	7.67	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Sta loc	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/16/88	1506	#3 Right	1.0	21.45	8.33	100.9	54	7.21	
08/16/88			2.6	21.32	8.18	98.8	53	7.28	
08/16/88	1510	#3 Mid	1.0	21.37	8.34	100.8	53	7.28	
08/16/88			3.5	21.31	8.23	99.4	54	7.34	
08/16/88	1515	#3 Left	1.0	21.45	8.59	104.0	53	7.44	
08/16/88			2.2	21.38	8.28	100.1	53	7.36	
08/16/88	1520	#3A Right	1.0	21.79	8.00	97.4	53	7.11	
08/16/88			3.0	21.47	7.97	96.5	53	7.18	
08/16/88	1525	#3A Mid	1.0	21.79	8.33	101.5	53	7.27	
08/16/88			3.2	21.47	8.64	104.6	53	7.41	
08/16/88	1528	#3A Left	1.0	21.78	8.53	103.9	53	7.34	
08/16/88			2.5	21.49	8.80	106.5	53	7.34	
08/16/88	1536	#4 Right	1.0	22.14	8.46	103.8	53	7.27	
08/16/88			5.5	21.44	7.82	94.7	53	7.15	
08/16/88	1541	#4 Mid	1.0	22.19	8.60	105.6	54	7.36	
08/16/88			5.4	21.40	8.15	98.5	52	7.24	
08/16/88	1545	#4 Left	1.0	22.25	8.73	107.3	52	7.47	
08/16/88	1550	#4A Right	1.0	22.53	8.62	106.5	53	7.94	
08/16/88			1.7	22.21	8.64	106.1	53	7.95	
08/16/88	1557	#4A Mid	1.0	22.43	9.13	112.5	54	7.68	
08/16/88			6.7	21.80	7.63	93.0	53	7.37	
08/16/88	1603	#5 Right	1.0	22.86	8.82	109.6	53	7.57	
08/16/88			5.8	21.95	8.50	103.8	52	7.46	
08/16/88	1606	#5 Mid	1.0	22.78	8.73	108.3	53	7.68	
08/16/88			6.5	21.91	8.39	102.4	52	7.51	
08/16/88	1609	#5 Left	1.0	22.66	8.87	109.8	53	7.70	
08/16/88			3.1	22.10	8.81	108.0	52	7.72	
08/16/88	1615	#6 Right	1.0	22.57	8.71	107.7	52	7.61	
08/16/88			2.0	22.41	8.56	105.5	52	7.55	
08/16/88			5.0	22.02	8.44	103.3	51	7.39	
08/16/88			8.0	22.41	8.56	105.5	52	7.55	
08/16/88	1620	#6 Mid	1.0	22.50	8.71	107.5	53	7.59	
08/16/88			2.0	22.36	8.63	106.2	52	7.59	
08/16/88			5.0	22.05	8.46	103.6	52	7.61	
08/16/88			7.0	21.86	6.66	81.2	52	6.95	
08/16/88			10.0	21.09	4.43	53.3	52	6.69	
08/16/88			11.0	20.71	3.80	45.3	53	6.62	
08/16/88	1630	#6 Left	1.0	22.47	8.69	107.3	52	7.54	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Sta loc	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/16/88			2.0	22.33	8.59	105.7	52	7.63	
08/16/88			5.0	22.01	8.22	100.6	52	7.31	
08/16/88			8.9	21.46	4.64	56.2	53	6.78	
08/16/88	1645	#8 Right	1.0	22.67	8.52	105.5	51	7.47	
08/16/88			2.0	22.61	8.25	102.0	51	7.42	
08/16/88			5.0	22.07	8.30	101.6	51	7.40	
08/16/88			7.2	21.88	7.29	88.9	50	7.17	
08/16/88			10.0	21.45	2.35	28.5	52	6.54	
08/16/88	1650	#8 Mid	1.0	22.58	8.46	104.6	52	7.44	
08/16/88			2.0	22.46	8.36	103.1	52	7.41	
08/16/88	1656	#8 Left	1.0	22.47	8.67	106.9	52	7.71	
08/16/88	1700	P.F. Dam	1.0	22.68	8.20	101.6	53	7.44	
08/16/88			2.0	22.63	8.32	103.0	51	7.50	
08/16/88			5.0	22.03	8.19	100.3	51	7.44	
08/16/88			7.0	21.89	6.88	84.0	52	7.09	
08/16/88			10.0	21.06	2.13	25.6	52	6.56	
08/16/88			11.9	19.49	0.01	0.1	52	6.37	
08/17/88	630	#1 Right	1.0	20.59	7.93	94.5	49	7.47	3.4
08/17/88			2.8	20.53	7.88	93.7	48	7.44	
08/17/88	640	#1 Mid	1.0	20.60	7.81	93.1	49	7.41	
08/17/88			2.0	20.65	7.67	91.4	48	7.36	
08/17/88	646	#1 Left	1.0	20.63	7.53	89.7	48	7.30	
08/17/88			2.9	20.63	7.56	90.2	48	7.31	
08/17/88	656	#2 Right	1.0	20.85	7.88	94.3	58	7.30	
08/17/88			2.8	20.86	7.73	92.5	58	7.26	
08/17/88	700	#2 Mid	1.0	20.93	7.80	93.4	54	7.26	
08/17/88			2.9	20.66	7.89	94.1	54	7.44	
08/17/88	704	#2 Left	1.0	20.90	7.70	92.3	50	7.38	
08/17/88			2.2	20.75	7.83	93.6	50	7.46	
08/17/88	711	#3 Right	1.0	20.49	7.60	90.4	52	7.26	
08/17/88			3.0	20.47	7.46	88.7	52	7.23	
08/17/88	720	#3 Mid	1.0	20.54	7.88	93.7	52	7.34	4.1
08/17/88			3.7	20.56	7.75	92.2	52	7.29	
08/17/88	730	#3 Left	1.0	20.51	8.14	96.8	51	7.47	
08/17/88			2.6	20.48	7.89	93.7	51	7.41	
08/17/88	742	#3A Right	1.0	20.89	7.67	91.8	53	7.20	
08/17/88			3.3	20.80	7.72	92.3	53	7.20	
08/17/88	747	#3A Mid	1.0	20.94	7.50	89.9	53	7.15	
08/17/88			3.2	20.80	7.69	92.0	53	7.22	
08/17/88	750	#3A Left	1.0	20.93	7.53	90.2	53	7.15	
08/17/88			3.0	20.75	7.77	92.8	53	7.23	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/17/88	755	#4 Right	1.0	21.29	8.01	96.6	52	7.25	4.0
08/17/88			2.0	21.35	7.92	95.8	54	7.24	
08/17/88			5.0	21.32	7.92	95.6	53	7.23	
08/17/88	806	#4 Mid	1.0	21.36	8.05	97.2	53	7.27	3.9
08/17/88			2.0	21.37	7.96	96.2	53	7.15	
08/17/88			5.0	21.32	7.97	96.3	52	7.24	
08/17/88	814	#4 Left	1.0	21.32	8.24	99.5	52	7.32	
08/17/88			2.0	21.36	8.22	99.3	53	7.33	
08/17/88	823	#4A Right	1.0	21.42	8.71	105.4	52	7.47	
08/17/88			1.5	21.40	8.63	104.4	52	7.47	
08/17/88	827	#4A Mid	1.0	21.60	8.56	104.0	53	7.37	3.6
08/17/88			1.5	21.40	8.63	104.4	52	7.47	
08/17/88	831	#4A Left	1.0	21.63	8.52	103.5	53	7.34	
08/17/88			2.0	21.63	8.42	102.2	53	7.42	
08/17/88			5.0	21.63	8.39	101.9	53	7.45	
08/17/88			6.5	21.62	8.37	101.6	52	7.39	
08/17/88	840	#5 Right	1.0	21.73	8.44	102.7	52	7.38	3.5
08/17/88			2.0	21.78	8.30	101.0	53	7.34	
08/17/88			5.9	21.70	8.25	100.3	52	7.36	
08/17/88	847	#5 Mid	1.0	21.75	8.42	102.6	52	7.35	
08/17/88			2.0	21.78	8.38	102.1	53	7.38	
08/17/88			5.0	21.75	8.29	100.9	52	7.37	
08/17/88			6.1	21.72	8.25	100.4	52	7.35	
08/17/88	857	#5 Left	1.0	21.76	8.42	102.6	52	7.37	3.5
08/17/88			2.0	21.78	8.32	101.4	52	7.35	
08/17/88			5.0	21.72	8.33	101.4	52	7.40	
08/17/88			6.0	21.65	8.30	100.8	52	7.38	
08/17/88	905	#6 Right	1.0	21.81	8.20	100.0	52	7.38	3.7
08/17/88			2.0	21.83	8.17	99.6	52	7.38	
08/17/88			5.0	21.84	8.17	99.6	52	7.39	
08/17/88			7.0	21.83	8.10	98.8	52	7.38	
08/17/88			7.8	21.58	6.97	84.6	52	6.91	
08/17/88	915	#6 Mid	1.0	21.89	8.30	101.4	52	7.39	
08/17/88			2.0	21.89	8.23	100.5	52	7.43	
08/17/88			5.0	21.83	7.52	91.7	52	7.16	
08/17/88			7.0	21.79	7.54	91.8	52	7.11	
08/17/88			10.0	21.02	4.55	54.6	52	6.71	
08/17/88			12.8	19.87	1.81	21.2	52	6.47	
08/17/88	930	#6 Left	1.0	21.90	8.32	101.6	52	7.34	
08/17/88			2.0	21.90	8.28	101.0	52	7.41	
08/17/88			5.0	21.86	8.21	100.2	52	7.42	
08/17/88			7.5	21.83	7.86	95.8	52	7.23	
08/17/88			10.0	21.11	3.02	36.3	55	6.61	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/17/88	942	#8 Right	1.0	21.82	8.21	100.1	52	7.39	4.0
08/17/88			2.0	21.85	8.17	99.6	52	7.39	
08/17/88			5.0	21.83	8.02	97.7	52	7.38	
08/17/88			7.0	21.79	7.67	93.4	52	7.25	
08/17/88			10.0	21.38	2.79	33.7	51	6.60	
08/17/88	952	#8 Mid	1.0	21.88	8.22	100.3	52	7.20	
08/17/88			2.0	21.88	8.18	99.9	52	7.31	
08/17/88			5.0	21.85	8.17	99.6	51	7.35	
08/17/88			7.0	21.82	7.92	96.5	51	7.26	
08/17/88			8.0	21.75	6.94	84.5	51	6.96	
08/17/88	1002	#8 Left	1.0	21.78	8.30	101.1	52	7.37	
08/17/88	1008	P.F. Dam	1.0	21.91	7.94	97.0	52	7.26	
08/17/88			2.0	21.92	7.98	97.5	52	7.26	
08/17/88			5.0	21.88	7.79	95.0	52	7.21	
08/17/88			7.0	21.83	7.73	94.2	52	7.15	
08/17/88			10.0	21.19	1.63	19.6	52	6.54	
08/17/88			13.4	18.58	0.15	1.7	53	6.35	
08/17/88	1435	#1 Right	0.8	21.37	7.66	92.5	49	7.48	
08/17/88			2.8	21.34	7.59	91.7	49	7.35	
08/17/88	1440	#1 Mid	1.0	21.34	7.48	90.4	49	7.14	
08/17/88			2.8	21.32	7.43	89.8	49	7.18	
08/17/88	1445	#1 Left	1.0	21.63	6.77	82.2	49	8.20	
08/17/88			2.8	21.31	7.63	92.1	48	7.37	
08/17/88	1453	#2 Right	1.0	21.40	7.85	94.9	54	7.28	
08/17/88			2.5	21.14	7.82	94.1	52	7.33	
08/17/88	1458	#2 Mid	1.0	21.15	7.87	94.7	51	7.27	
08/17/88			3.0	21.13	7.92	95.2	51	7.36	
08/17/88	1502	#2 Left	1.0	21.19	8.02	96.6	51	7.44	
08/17/88			2.0	21.16	7.92	95.3	50	7.48	
08/17/88	1509	#3 Right	1.0	21.12	8.09	97.3	52	7.35	
08/17/88			2.6	21.05	8.18	98.3	52	7.46	
08/17/88	1512	#3 Mid	1.0	21.05	8.07	97.0	52	7.26	
08/17/88			3.1	21.00	8.18	98.2	53	7.43	
08/17/88	1516	#3 Left	1.0	21.04	8.43	101.3	52	7.46	
08/17/88			2.2	21.02	8.45	101.5	52	7.56	
08/17/88	1521	#3A Right	1.0	21.33	7.91	95.5	53	7.06	
08/17/88			3.0	21.09	7.92	95.2	53	7.22	
08/17/88	1528	#3A Mid	1.0	21.23	8.22	99.1	52	7.35	
08/17/88			2.8	20.99	8.47	101.7	53	7.64	
08/17/88	1532	#3A Left	1.0	21.15	8.73	105.1	52	7.36	
08/17/88			2.5	21.00	8.54	102.5	53	7.52	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/17/88	1541	#4 Right	1.0	22.33	8.54	105.0	54	7.34	3.8
08/17/88			4.8	21.30	8.17	98.6	53	7.57	
08/17/88	1545	#4 Mid	1.0	21.97	8.47	103.5	54	7.35	3.8
08/17/88			5.6	21.26	8.24	99.4	53	7.52	
08/17/88	1550	#4 Left	1.0	21.74	8.80	107.2	53	7.41	
08/17/88			3.0	21.58	8.58	104.1	53	7.48	
08/17/88	1555	#4A Right	1.0	22.26	9.08	111.6	53	7.69	
08/17/88			1.7	22.13	9.19	112.7	53	8.02	
08/17/88	1600	#4A Mid	1.0	22.30	8.93	109.9	53	7.64	3.8
08/17/88			2.0	22.07	8.88	108.7	53	7.66	
08/17/88			5.0	21.72	8.41	102.3	53	7.29	
08/17/88			7.1	21.67	8.17	99.4	52	7.25	
08/17/88	1610	#4A Left	1.0	22.37	8.85	109.0	53	7.61	
08/17/88			2.0	22.20	8.85	108.7	53	7.60	
08/17/88			5.0	21.72	8.31	101.1	53	7.52	
08/17/88	1617	#5 Right	1.0	22.47	8.91	109.9	53	7.66	
08/17/88			2.0	22.01	8.74	106.9	52	7.55	
08/17/88			5.0	21.85	8.19	99.9	53	7.47	
08/17/88	1623	#5 Mid	1.0	22.35	8.67	106.7	53	7.43	3.5
08/17/88			2.0	22.07	8.67	106.1	53	7.40	
08/17/88			5.7	21.81	8.10	98.7	52	7.50	
08/17/88	1629	#5 Left	1.0	22.44	9.04	111.4	53	7.70	
08/17/88			2.0	22.04	8.84	108.2	52	7.87	
08/17/88	1638	#6 Right	1.0	22.38	8.72	107.4	53	7.68	3.8
08/17/88			2.0	22.25	8.66	106.4	52	7.69	
08/17/88			5.0	21.93	8.37	102.2	52	7.77	
08/17/88			7.0	21.87	7.97	97.3	52	7.47	
08/17/88	1646	#6 Mid	1.0	22.50	8.43	104.1	52	7.47	
08/17/88			2.0	22.21	8.52	104.6	52	7.61	
08/17/88			5.0	21.95	8.35	102.0	52	7.60	
08/17/88			7.0	21.82	7.22	88.0	52	7.29	
08/17/88			10.0	21.14	4.40	52.9	53	6.71	
08/17/88			12.0	20.34	2.64	31.3	53	6.35	
08/17/88			15.6	18.90	0.08	1.0	54	6.39	
08/17/88	1700	#6 Left	1.0	22.56	8.45	104.5	52	7.52	
08/17/88			2.0	22.47	8.57	105.8	52	7.61	
08/17/88			5.0	21.94	8.46	103.4	52	7.45	
08/17/88			7.0	21.83	7.55	92.0	52	7.04	
08/17/88			10.0	21.13	2.97	35.8	53	6.48	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/17/88	1723	#8 Right	1.0	22.51	8.50	104.9	52	7.42	
08/17/88			2.0	22.14	8.38	102.7	52	7.55	
08/17/88			5.0	21.93	7.79	95.1	52	7.29	
08/17/88			7.0	21.87	7.59	92.6	52	7.20	
08/17/88			9.0	21.64	3.38	41.1	52	6.50	
08/17/88	1731	#8 Mid	1.0	22.51	8.41	103.8	52	7.41	
08/17/88			2.0	22.19	8.54	104.8	52	7.55	
08/17/88			5.0	21.96	7.55	92.3	51	7.25	
08/17/88	1738	#8 Left	1.0	22.60	8.88	109.8	52	7.64	
08/17/88	1740	P.F. Dam	1.0	22.16	8.03	98.5	53	7.30	
08/17/88			2.0	22.16	8.03	98.5	53	7.30	
08/17/88			5.0	21.92	7.65	93.4	52	7.40	
08/17/88			8.0	21.82	6.11	74.5	51	6.95	
08/17/88			10.0	21.45	3.88	47.0	51	6.57	
08/17/88			12.0	19.43	0.14	1.6	51	6.34	
08/18/88	630	#1 Right	1.1	20.27	8.04	95.1	49	7.75	
08/18/88			2.8	20.26	8.01	94.8	48	7.73	
08/18/88	637	#1 Mid	1.3	20.27	7.89	93.4	48	7.70	
08/18/88			2.0	20.33	7.73	91.6	49	7.52	
08/18/88	644	#1 Left	1.0	20.18	7.80	92.2	49	7.61	
08/18/88			2.6	20.20	7.64	90.3	48	7.52	
08/18/88	655	#2 Right	1.1	20.43	7.32	87.0	61	7.30	
08/18/88			3.1	20.39	7.28	86.3	61	7.22	
08/18/88	657	#2 Mid	1.1	20.41	7.38	87.6	55	7.36	
08/18/88			3.2	20.48	7.36	87.5	51	7.33	
08/18/88	700	#2 Left	1.1	20.16	7.70	91.0	49	7.42	
08/18/88			2.2	20.19	7.64	90.3	50	7.43	
08/18/88	706	#3 Right	1.1	20.67	7.75	92.4	55	7.37	
08/18/88			2.9	20.67	7.57	90.3	54	7.28	
08/18/88	714	#3 Mid	1.1	20.77	7.80	93.2	55	7.40	
08/18/88			3.5	20.79	7.68	91.9	54	7.38	
08/18/88	722	#3 Left	1.1	20.71	7.82	93.4	54	7.36	
08/18/88			2.4	20.70	7.72	92.2	54	7.28	
08/18/88	730	#3A Right	1.1	20.46	7.48	88.9	52	7.28	
08/18/88			3.0	20.50	7.36	87.5	52	7.47	
08/18/88	733	#3A Mid	1.1	20.47	7.94	94.4	52	7.34	
08/18/88			3.1	20.49	7.88	93.7	52	7.60	
08/18/88	736	#3A Left	1.1	20.43	7.94	94.3	53	7.32	
08/18/88			2.8	20.36	7.92	93.9	52	7.55	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/18/88	742	#4 Right	1.1	20.91	7.97	95.5	52	7.46	3.9
08/18/88			2.0	20.95	7.96	95.5	53	7.46	
08/18/88			5.1	20.93	7.98	95.7	53	7.47	
08/18/88	752	#4 Mid	1.1	20.91	8.17	97.8	53	7.44	4.0
08/18/88			2.4	20.93	8.09	97.0	53	7.44	
08/18/88			5.2	20.90	8.05	96.4	52	7.47	
08/18/88	758	#4 Left	1.1	20.99	8.16	97.9	53	7.39	
08/18/88	805	#4A Right	1.1	21.26	8.46	102.1	52	7.57	
08/18/88			1.8	21.26	8.42	101.6	52	7.51	
08/18/88	809	#4A Mid	1.1	21.48	8.32	100.8	53	7.50	
08/18/88			2.0	21.48	8.34	101.0	52	7.38	
08/18/88			5.9	21.41	8.42	101.9	51	7.61	
08/18/88	814	#4A Left	1.1	21.50	8.24	99.8	52	7.42	3.5
08/18/88			2.0	21.51	8.23	99.7	52	7.43	
08/18/88			5.2	21.50	8.21	99.5	52	7.49	
08/18/88	822	#5 Right	1.1	21.50	8.37	101.4	53	7.47	
08/18/88			2.0	21.54	8.32	100.9	53	7.47	
08/18/88			4.8	21.52	8.34	101.1	53	7.57	
08/18/88	828	#5 Mid	1.1	21.53	8.25	100.0	53	7.49	3.7
08/18/88			2.0	21.53	8.13	98.5	53	7.53	
08/18/88			5.0	21.47	8.10	98.1	52	7.55	
08/18/88			6.5	21.44	8.06	97.6	52	7.42	
08/18/88	834	#5 Left	1.0	21.56	8.34	101.2	53	7.52	
08/18/88			2.0	21.55	8.19	99.4	52	7.47	
08/18/88			5.0	21.47	8.17	98.9	52	7.55	
08/18/88	840	#6 Right	1.0	21.63	8.02	97.4	52	7.37	
08/18/88			2.0	21.66	7.97	96.9	52	7.41	
08/18/88			5.0	21.63	7.88	95.7	52	7.42	
08/18/88			6.2	21.62	7.75	94.1	53	7.31	
08/18/88	848	#6 Mid	1.0	21.67	7.91	96.1	52	7.34	3.8
08/18/88			2.0	21.67	7.88	95.8	52	7.42	
08/18/88			5.0	21.66	7.83	95.2	52	7.43	
08/18/88			7.0	21.30	7.63	92.1	52	6.73	
08/18/88			10.0	20.30	5.15	61.0	53	6.52	
08/18/88			12.0	20.39	2.50	29.7	55	6.38	
08/18/88			13.0	19.76	1.34	15.7	53	6.38	
08/18/88			15.0	18.96	0.11	1.3	54	6.37	
08/18/88			16.8	18.86	0.08	1.0	55	6.38	
08/18/88	900	#6 Left	1.0	21.64	7.99	97.1	52	7.30	
08/18/88			2.0	21.66	7.92	96.2	52	7.31	
08/18/88			5.0	21.64	7.81	94.9	52	7.37	
08/18/88			7.0	21.63	7.39	89.7	52	7.23	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/18/88	922	#8 Right	1.0	21.53	7.41	89.8	51	7.13	3.9
08/18/88			2.0	21.59	7.31	88.8	52	7.12	
08/18/88			5.0	21.56	7.52	91.2	51	7.25	
08/18/88			7.0	21.57	6.96	84.5	51	7.11	
08/18/88			8.7	21.56	7.16	86.8	51	7.16	
08/18/88	930	#8 Mid	1.0	21.69	7.68	93.4	52	7.24	
08/18/88			2.0	21.68	7.65	93.0	51	7.27	
08/18/88			4.4	21.60	8.05	97.8	51	7.41	
08/18/88	933	#8 Left	1.0	21.63	8.16	99.1	52	7.51	
08/18/88	940	P.F. Dam	1.0	21.70	7.34	89.3	51	7.10	
08/18/88			2.0	21.71	7.28	88.5	52	7.12	
08/18/88			5.0	21.64	7.19	87.4	52	7.18	
08/18/88			7.0	21.63	7.22	87.7	52	7.22	
08/18/88			10.0	21.56	6.28	76.1	53	6.80	
08/18/88	1448	#1 Right	1.0	21.03	8.07	97.0	49	7.43	
08/18/88			2.7	20.84	8.11	97.0	49	7.77	
08/18/88	1455	#1 Mid	1.0	20.91	7.96	95.4	49	7.53	
08/18/88			1.9	20.89	7.96	95.4	49	7.59	
08/18/88	1458	#1 Left	1.0	20.88	8.08	96.8	49	7.50	
08/18/88			2.6	20.75	8.05	96.1	49	7.56	
08/18/88	1507	#2 Right	1.0	21.08	7.93	95.4	53	7.27	
08/18/88			2.0	20.73	7.87	94.0	52	7.43	
08/18/88	1510	#2 Mid	1.0	20.80	7.87	94.1	50	7.27	
08/18/88			2.8	20.66	7.97	95.1	51	7.59	
08/18/88	1513	#2 Left	1.0	20.92	8.03	96.2	50	7.50	
08/18/88			2.2	20.77	7.99	95.5	51	7.59	
08/18/88	1521	#3 Right	1.0	21.11	7.91	95.1	54	7.34	
08/18/88			2.7	21.07	8.04	96.6	53	7.50	
08/18/88	1525	#3 Mid	1.0	21.07	7.84	94.2	53	7.23	
08/18/88			3.3	21.04	7.92	95.2	53	7.57	
08/18/88	1531	#3 Left	1.0	21.12	8.42	101.2	53	7.42	
08/18/88			1.5	21.15	8.47	102.0	53	7.54	
08/18/88	1537	#3A Right	1.0	21.10	7.55	90.8	52	7.12	
08/18/88			3.3	20.86	7.64	91.4	53	7.22	
08/18/88	1540	#3A Mid	1.0	21.10	8.00	96.2	53	7.16	
08/18/88			3.0	20.91	8.26	99.0	53	7.38	
08/18/88	1546	#3A Left	1.0	21.14	8.26	99.4	54	7.39	
08/18/88			2.8	20.92	8.75	104.9	53	7.85	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Sta loc	Depth m	Temp C	DO mg/L	% Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/18/88	1553	#4 Right	1.0	21.56	8.54	103.5	53	7.53	
08/18/88			2.0	21.41	8.47	102.5	52	7.65	
08/18/88			5.0	20.82	7.99	95.6	52	7.60	
08/18/88	1601	#4 Mid	1.0	21.53	8.40	101.8	53	7.59	3.9
08/18/88			2.0	21.45	8.39	101.5	53	7.62	
08/18/88			5.0	20.80	8.00	95.6	52	7.43	
08/18/88	1606	#4 Left	1.0	21.46	8.56	103.7	53	7.56	
08/18/88	1614	#4A Right	1.0	22.03	8.92	109.1	53	7.80	
08/18/88			2.0	21.80	8.94	109.0	53	7.94	
08/18/88	1617	#4A Mid	1.0	21.96	8.76	107.0	53	7.72	3.4
08/18/88			2.0	21.80	8.76	106.7	53	7.82	
08/18/88			5.0	21.48	8.34	101.0	53	7.48	
08/18/88			7.0	21.47	8.24	99.8	53	7.38	
08/18/88	1625	#4A Left	1.0	22.06	8.77	107.3	54	7.68	
08/18/88			2.0	21.99	8.71	106.5	53	7.81	
08/18/88			5.0	21.51	7.82	94.8	53	7.24	
08/18/88			6.2	21.50	7.84	95.0	53	7.20	
08/18/88	1634	#5 Right	1.0	21.92	8.87	108.3	53	7.99	3.7
08/18/88			4.2	21.62	8.33	101.2	53	7.55	
08/18/88	1637	#5 Mid	1.0	22.20	8.56	105.1	54	7.59	
08/18/88			2.0	21.85	8.56	104.4	53	7.68	
08/18/88			5.0	21.58	8.24	100.0	53	7.47	
08/18/88			7.0	21.51	8.01	97.0	53	7.26	
08/18/88	1645	#5 Left	1.0	22.31	8.55	105.2	53	7.77	
08/18/88			2.0	22.10	8.87	108.7	53	8.00	
08/18/88	1652	#6 Right	1.0	22.03	8.47	103.7	53	7.59	
08/18/88			2.0	21.99	8.44	103.2	53	7.65	
08/18/88			5.0	21.75	7.99	97.3	52	7.37	
08/18/88			6.1	21.70	7.79	94.7	52	7.21	
08/18/88	1659	#6 Mid	1.0	22.25	8.28	101.7	52	7.50	
08/18/88			2.0	22.25	8.27	101.6	53	7.58	
08/18/88			5.0	21.96	8.14	99.5	53	7.39	
08/18/88			7.0	21.70	7.83	95.3	52	7.20	
08/18/88			10.0	21.38	5.18	62.6	52	6.69	
08/18/88			13.4	19.93	1.38	16.2	52	6.30	
08/18/88	1708	#6 Left	1.0	22.32	8.24	101.4	52	7.45	3.7
08/18/88			2.0	22.30	8.21	101.0	53	7.48	
08/18/88			5.0	21.88	8.13	99.2	53	7.36	
08/18/88			7.0	21.71	7.80	94.9	52	7.17	
08/18/88			10.0	21.69	7.68	93.4	52	7.10	

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Table A-1. In-situ measurements of water quality in the Spokane River during the field study of August 16-18, 1988.

Date	Time h m	Station Location	Depth m	Temp C	DO mg/L	DO % Sat	Cond umho/cm	pH std units	Secchi Depth meters
08/18/88	1724	#8 Right	1.0	22.14	7.96	97.6	53	7.34	
08/18/88			2.0	21.88	8.12	99.1	52	7.42	
08/18/88			5.0	21.73	7.56	92.0	52	7.15	
08/18/88			7.0	21.68	7.23	87.9	52	7.03	
08/18/88			8.5	21.64	7.16	86.9	52	6.97	
08/18/88	1732	#8 Mid	1.0	22.29	7.80	95.9	52	7.22	
08/18/88			2.0	22.18	7.85	96.3	53	7.26	
08/18/88			5.0	21.74	7.40	90.0	52	7.04	
08/18/88	1736	#8 Left	1.0	22.32	8.11	99.8	52	7.43	
08/18/88	1739	P.F. Dam	1.0	22.03	7.78	95.2	53	7.20	
08/18/88			2.0	21.91	8.10	98.9	53	7.38	
08/18/88			5.0	21.81	7.87	95.9	52	7.28	
08/18/88			7.0	21.74	7.43	90.5	52	7.09	
08/18/88			10.0	21.51	4.72	57.2	52	6.58	
08/18/88			12.5	19.43	0.11	1.3	51	6.25	

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Table A-2. Laboratory measurements of water quality for receiving waters and point sources during August 16-18, 1988.

EPA Lab#	BOD5 mg/L	BOD10 mg/L	BOD15 mg/L	BOD20 mg/L	BOD60 mg/L
340300					
340301	8.00	17.60	114.00	74.00	
340304	5.60	29.60	90.40	98.00	
340307	12.40	27.60	72.80	86.80	
340302					
340303	8.40	38.60	23.60	15.40	
340305	8.60	36.80	8.20	17.60	
340306	12.20	47.20	24.00	21.60	
340311	0.73	0.59	0.96	0.95	1.75
340316	0.42	0.89	0.82	1.15	1.92
340321	0.44	0.79	1.09	1.21	
340312	0.89	1.14	1.43	1.91	2.89
340317	0.79	1.12	1.40	1.84	2.66
340322	0.78	1.47	1.94	2.34	
340313	1.28	1.48	1.87	2.07	3.09
340318	0.98	1.30	1.64	1.90	2.88
340323	1.04	1.55	1.75	2.03	
340314	1.25	1.67	2.01	2.16	3.54
340319	0.92	1.39	1.78	2.03	3.05
340324	1.27	1.83	2.20	2.30	
340315	1.70	1.96	2.28	2.48	3.35
340320	1.13	1.22	1.76	1.85	2.98
340325	1.08	1.50	2.10	2.25	
340326					

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Table A-2. Laboratory measurements of water quality for receiving waters and point sources during August 16-18, 1988.

EPA Lab#	NH3-N Total mg/l	NO2NO3-N Total mg/l	Kjel-N Total mg/l	Phos Total mg/l
340300	0.01U	0.01U	0.04U	0.01U
340301	16.000	1.65	22.50	7.000
340304	16.600	0.80	23.00	7.200
340307	14.700	1.24	21.50	6.800
340302	0.01U	0.01U	0.04U	0.01U
340303	0.055	25.00	1.92	9.900
340305	0.055	26.00	2.06	10.200
340306	0.058	25.50	2.50	10.200
340311	0.01U	0.01U	0.10	0.01M
340316	0.01U	0.01U	0.14	0.010
340321	0.01U	0.01U	0.12	0.010
340312	0.066	0.01	0.32	0.056
340317	0.052	0.01M	0.24	0.044
340322	0.120	0.01	0.34	0.066
340313	0.032	0.01U	0.26	0.064
340318	0.020	0.01U	0.22	0.044
340323	0.01U	0.01U	0.18	0.044
340314	0.01U	0.01U	0.26	0.040
340319	0.01U	0.01U	0.20	0.038
340324	0.01U	0.01U	0.18	0.040
340315	0.01U	0.01U	0.20	0.030
340320	0.01U	0.01U	0.16	0.030
340325	0.01U	0.01U	0.20	0.036
340326	0.01U	0.01U	0.06	0.010

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Table A-2. Laboratory measurements of water quality for receiving waters and point sources during August 16-18, 1988.

EPA Lab#	Arsenic As-Total ug/l	Mercury Hg-Total ug/l	Cadmium Tot-Rec ug/l	Chromium Tot-Rec ug/l	Lead Tot-Rec ug/l	Iron Tot-Rec ug/l	Zinc Tot-Rec ug/l
340300	0.6	0.08U	0.1U	0.5U	1U	7U	5U
340301	1.4	0.17	0.6	3.3	5		
340304	1.8	0.08U	1.0	3.1	7	253	51
340307	1.4	0.08U	0.5	4.0	4	216	42
340302	0.5U	0.08U	0.1U	0.7	1U	7U	5U
340303	3.7	0.21	0.2	1.3	2	102	43
340305	4.4	0.08U	2.0	0.9	1	105	38
340306	3.9	0.08U	0.2	0.9	1	109	40
340311	0.5U	0.44	0.7	0.5U	1	25	75
340316	0.5	0.45	0.4	0.7	1	22	63
340321	0.5	0.08U	0.6	0.5U	2	18	67
340312	0.6	0.25	0.7	1.2	2	27	66
340317	0.5U	0.13	0.4	1.7	2	24	62
340322	0.6	0.08U	0.4	0.5U	2	23	66
340313	0.8	0.30	0.3	1.8	1	34	56
340318	0.5	0.19	0.3	0.7	2	32	54
340323	0.6	0.08U	0.3	0.5U	2	34	56
340314	0.6	0.17	0.3	0.5U	1	28	53
340319	0.5	0.37	0.3	1.2	1	30	58
340324	0.7	0.08U	1.3	1.9	2	84	56
340315	0.5U	0.11	0.2	0.7	1	25	43
340320	0.7	0.15	0.3	0.7	1	28	47
340325	0.5U	0.08U	0.2	1.4	2	37	46
340326	0.5U	0.08U	0.1U	0.5U	1U	7U	5U

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Table A-2. Laboratory measurements of water quality for receiving waters and point sources during August 16-18, 1988.

EPA Lab#	Cond@25C Meter umho/cm	pH LAB Meter Std Unts	Alk-Tot CaCO3 mg/l	Hard-Tot CaCO3 mg/l
340300	1.5	4.40	0.1U	1.0U
340301	672.0	6.74	193.0	
340304	674.0	6.72	202.0	103.0
340307	677.0	6.74	196.0	110.0
340302	1.7	4.20	0.6	1.0U
340303	538.0	6.80	60.4	
340305	538.0	6.80	62.0	105.0
340306	538.0	6.74	60.0	103.0
340311	53.8	6.25	18.7	20.5
340316	53.8	5.95	19.0	21.5
340321	52.8	5.97	19.2	21.4
340312	57.6	6.30	19.3	21.8
340317	57.0	6.22	19.3	21.5
340322	58.3	6.17	20.1	21.9
340313	57.5	6.37	19.6	21.3
340318	57.8	6.27	19.9	22.3
340323	56.2	6.20	20.5	21.6
340314	56.9	6.35	20.2	22.0
340319	56.2	6.25	20.6	21.9
340324	56.6	6.30	19.9	21.9
340315	56.0	6.35	19.8	21.3
340320	55.3	6.34	19.5	21.4
340325	55.2	6.39	19.5	21.5
340326	1.8	4.28	1.5	1.0

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Table A-3. Index for location of laboratory samples for receiving waters and point sources during the field study of August 16-18, 1988.

EPA Lab#	Date	Time	Description	River mile
340300	88/08/16	0840	Coeur d'Alene STP effl blank	
340301	88/08/16	0845	Coeur d'Alene STP effl (G)	111.0
340304	88/08/17	0845	Coeur d'Alene STP effl (24)	111.0
340307	88/08/18	0940	Coeur d'Alene STP effl (24)	111.0
340302	88/08/16	0950	Hayden Lk STP effl blank	
340303	88/08/16	0955	Hayden Lk STP effl (G)	
340305	88/08/17	0930	Hayden Lk STP effl (24)	
340306	88/08/18	0835	Hayden Lk STP effl (24)	
340311	88/08/16	0630	Sta 1	111.1
340316	88/08/17	0630	Sta 1	111.1
340321	88/08/18	0630	Sta 1	111.1
340312	88/08/16	0740	Sta 3	108.6
340317	88/08/17	0715	Sta 3	108.6
340322	88/08/18	0710	Sta 3	108.6
340313	88/08/16	0835	Sta 4	106.5
340318	88/08/17	0800	Sta 4	106.5
340323	88/08/18	0745	Sta 4	106.5
340314	88/08/16	0920	Sta 5	104.4
340319	88/08/17	0845	Sta 5	104.4
340324	88/08/18	0820	Sta 5	104.4
340315	88/08/16	1020	Sta 8	102.0
340320	88/08/17	0945	Sta 8	102.0
340325	88/08/18	0920	Sta 8	102.0
340326	88/08/18		Transfer Blank	

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APPENDIX B

Method for Estimating
Cross-Sectional Averages
of
Water Quality

To compute the mean values by station for dissolved oxygen (DO) concentration, percent DO saturation, water temperature and conductivity, the receiving water data for these parameters were aggregated using areal average techniques. The data were depth-averaged for each section (right, middle, and and left) of each station.

Although DO, temperature, and conductivity were measured at increasing depths, these specific depths were not identical across sections or stations. Therefore, a method was sought that would produce estimates of parameter averages from the raw data. First, the river bed at each section was assumed to be 0.5 meters below the greatest depth where measurements were made (see Figs. B-1.1 and B-1.2). Next, simple linear equations (expressing parameter values as a function of water depth) were fit to each successive pair of measurements. Parameter values were assumed to be constant in the intervals between the surface and the first measurement and between the last measurement and the river bed (Fig. B-1.3). Parameter averages were then computed from the areas under the resulting line segments.

Assuming the section widths (right, middle, and left) were equal, the overall average for the station was computed by summing all of the areas, then dividing by the sum of the water depths. These data were further aggregated by summing over all the days on which measurements were made to obtain a station average of each parameter for the period of study. The results are presented as highly aggregated tranformations of the raw data.

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APPENDIX C

Measurements obtained from the
Citizens' Volunteer Monitoring Program

The State of Idaho's Department of Environmental Quality, working in cooperation with local volunteers, have implemented a sampling program in the Spokane River at three locations in the Spokane River between Coeur d'Alene and Post Falls, Idaho. Data obtained from this program is given in Tables C-1, C-2, and C-3.

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Table C-1. Water quality measurements in the Spokane River at the Cedars Site (approximate R.M. 111.1) obtained in the Citizen's Volunteer Monitoring Program supported by the State of Idaho's Department of Environmental Quality.

CVMP 1988						DEQ DUPE	
CEDARS SITE							
DATE	5/25/88	6/27/88	7/19/88	8/23/88	9/27/88	9/27/88	10/18/88
TIME	1100	1100	930	1000	1000	1000	1000
MAXIMUM DEPTH (M)	2.75	2.75	2.75	2.6	2.5	2.5	
SECCHI DEPTH (M)	2.75	2.75	2.75	2.6	2.5	2.5	
TEMPERATURE (C)@ 1M DEPTH	13.3	20	21	20	16	16	
TEMPERATURE (C)@ 1M OFF BOTTOM	12.2	21	20	20	16	16	
DISSOLVED OXYGEN (MG/L)@ 1M	12	4	8	7	9	9	
DISSOLVED OXYGEN (MG/L)@ 1M OFF	12	4	8	8	7	7	
TOTAL AMMONIA (MG/L)	0.013	0.014	0.05	0.007	0.018	0.021	0.007
TOTAL NO2+NO3 (MG/L)	0.014	0.008	0.018	0.02	0.02	0.016	0.012
TOTAL KJELDAHL (MG/L)	0.11	0.13	0.05	0.09	0.12	0.11	0.13
TOTAL PHOSPHORUS (MG/L)	0.011	0.009	0.008	0.009	0.007	0.008	0.008
ORTHOPHOSPHORUS (MG/L)		0.001	0.001	0.002	0.002	0.002	0.001
SPECIFIC CONDUCTANCE (UMHOS)	52	45	48	51	51	53	54
CHLOROPHYLL a (UG/L)		1.1	1.1	1.7	1	1	0.7
ZINC (UG/L)	90	220	60	30	59		50

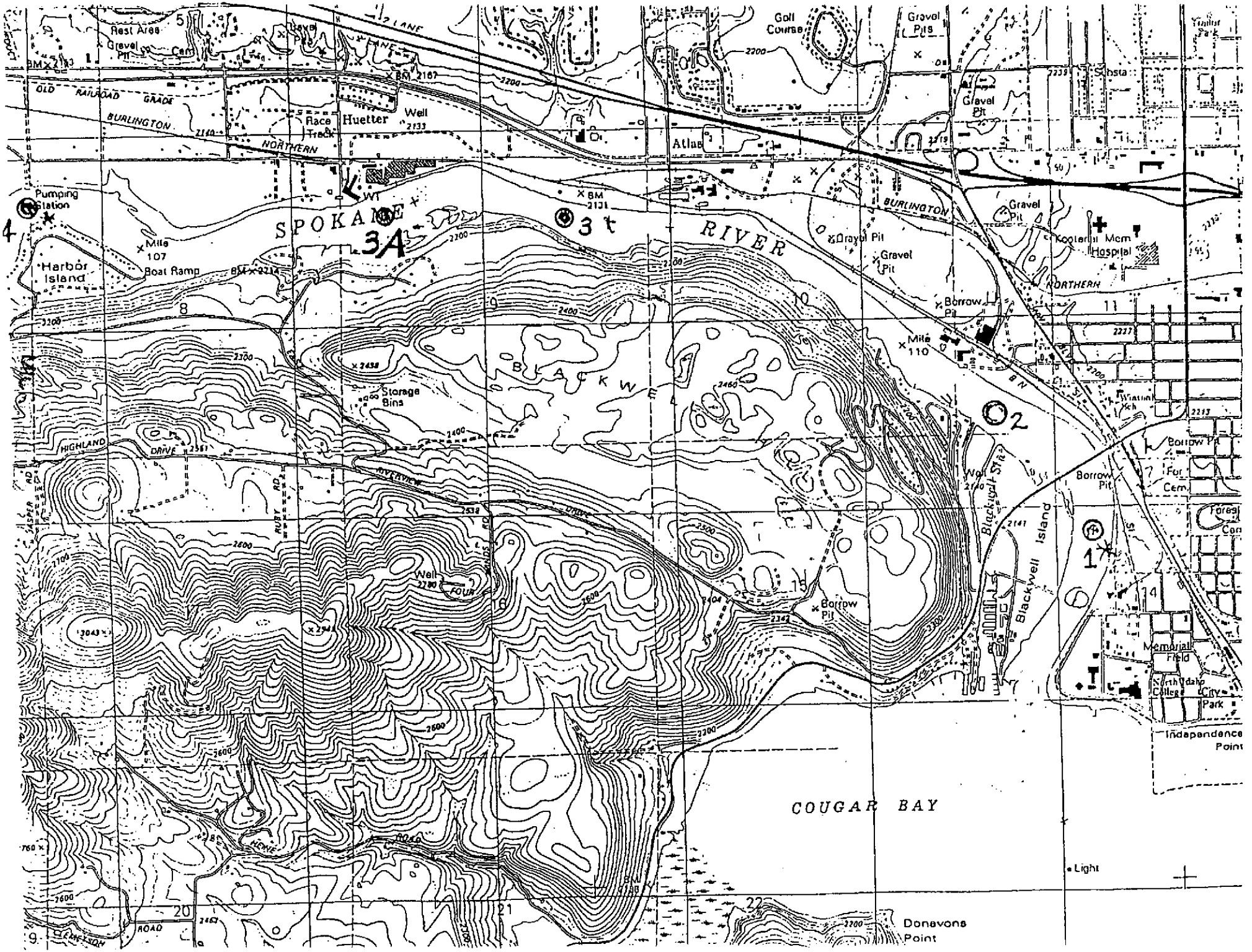
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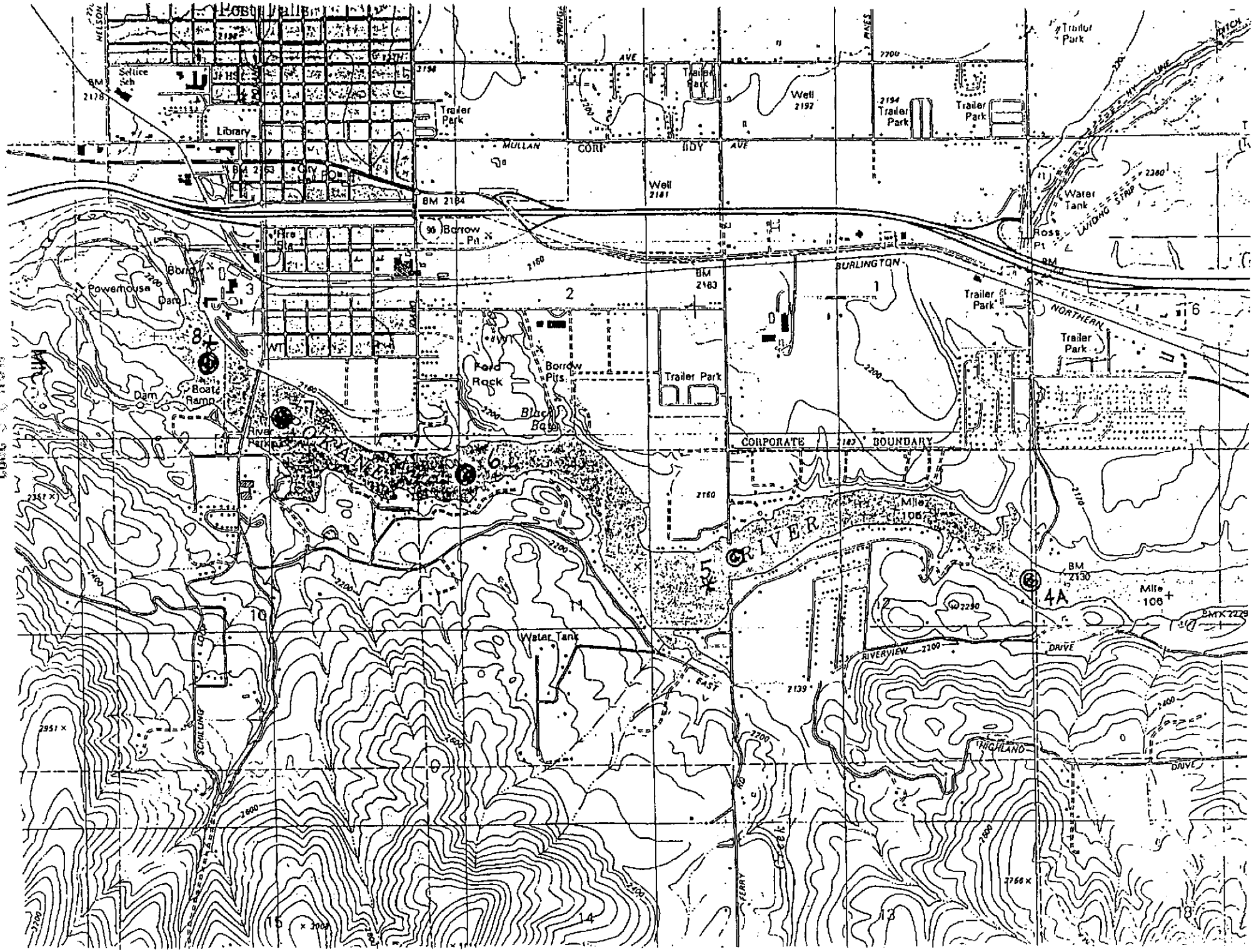
Table C-2. Water quality measurements in the Spokane River at Harbor Island (approximate R.M. 106.5) obtained in the Citizen's Volunteer Monitoring Program supported by the State of Idaho's Department of Environmental Quality.

SPOKANE RIVER CVMP 1988 HARBOR ISLAND						DEQ DUPE	
DATE	5/25/88	6/27/88	7/19/88	8/23/88	9/27/88	9/27/88	10/18/88
TIME	1300	1200	1100	1030	1140	1140	1000
MAXIMUM DEPTH (M)	5.75	5.75	5.75	5.8	5.8	5.8	
SECCHI DEPTH (M)	3.25	3.75	3.25	2.75	4.5	4.5	
TEMPERATURE (C)@ 1M DEPTH	13.3	20	21	21	15	15	
TEMPERATURE (C)@ 1M OFF BOTTOM	13.3	21	21	21	15	15	
DISSOLVED OXYGEN (MG/L)@ 1M	12	9	9	4	8	8	
DISSOLVED OXYGEN (MG/L)@ 1M OFF	12	9	6	8	9	9	
TOTAL AMMONIA (MG/L)	0.011	0.027	0.045	0.026	0.053	0.045	0.024
TOTAL NO2+NO3 (MG/L)	0.019	0.017	0.009	0.027	0.036	0.027	0.025
TOTAL KJELDAHL (MG/L)	0.14	0.13	0.12	0.19	0.17	0.14	0.13
TOTAL PHOSPHORUS (MG/L)	0.014	0.017	0.018	0.037	0.029	0.027	0.02
ORTHOPHOSPHORUS (MG/L)	0.001	0.007	0.003	0.022	0.017	0.018	0.013
SPECIFIC CONDUCTANCE (UMHOS)	50	46	50	55	53	53	56
CHLOROPHYLL a (UG/L)		1.6	1.7	6.5	0.8	1	0.6
ZINC (UG/L)	70	140	60	30	55		50
FECAL COLIFORM (#/100 ML)			10		10		

Table C-3. Water quality measurements in the Spokane River at Post Falls Bridge (approximate R.M. 101.8) obtained in the Citizen's Volunteer Monitoring Program supported by the State of Idaho's Department of Environmental Quality.

SPOKANE RIVER CVMP 1988 POST FALLS BRIDGE						DEQ DUPE	
DATE	5/25/88	6/27/88	7/19/88	8/23/88	9/27/88	9/27/88	10/18/88
TIME	1430	1200	1030	1115	1240	1240	
MAXIMUM DEPTH (M)	9	8.6	8.5	8.6	8.5	8.5	
SECCHI DEPTH (M)	3.25	3.5	2.75	4.75	4.75	4.75	
TEMPERATURE (C)@ 1M DEPTH	14	19.7	22.5	22	15	15	
TEMPERATURE (C)@ 1M OFF BOTTOM	13.4	21	21	22	15	15	
DISSOLVED OXYGEN (MG/L)@ 1M	13	5	9	10	8	8	
DISSOLVED OXYGEN (MG/L)@ 1M OFF	13	5	9	8	8	8	
TOTAL AMMONIA (MG/L)	0.013	0.019	0.028	0.01	0.035	0.038	0.024
TOTAL NO2+NO3 (MG/L)	0.017	0.021	0.003	0.016	0.033	0.034	0.018
TOTAL KJELDAHL (MG/L)	0.14	0.12	0.13	0.12	0.16	0.18	0.16
TOTAL PHOSPHORUS (MG/L)	0.014	0.016	0.017	0.028	0.027	0.027	0.023
ORTHOPHOSPHORUS (MG/L)		0.005	0.002	0.01	0.017	0.018	0.014
SPECIFIC CONDUCTANCE (UMHOS)	0.001	48	50	55	54	53	56
CHLOROPHYLL a (UG/L)	80	220	60	30	52	1	50
ZINC (UG/L)	70	140	60	30	55		50


Rest Area
Gravel Pit
Cem
BM 2167
OLD RAILROAD GRADE
BURLINGTON NORTHERN
Race Track
Huetter
Well
Golf Course
Gravel Pits
Atlas
Gravel Pit
Sbsta
Pumping Station
Mile 107
Boat Ramp
Harbor Island
SPOKANE RIVER
3A
3t
BM 2131
Gravel Pit
Kootenai Mem Hospital
NORTHERN
Borrow Pit
Mile 110
BLACKWELL
Storage Bins
HIGHLAND DRIVE
RIVERVIEW DRIVE
JASPER RD
RUBY RD
Well
FOUR
Borrow Pit
Blackwell Island
Blackwell Sta
Borrow Pit
Memorial Field
North Idaho College
City Park
Independence Point
COUGAR BAY
Light
Donavons Point
HOWARD ROAD


Library
City Pool
Trailer Park
Well
Water Tank
BM 2184
Borrow Pit
Fire Site
Powerhouse
Dam
Boat Ramp
River Park
Ford Rock
Borrow Pits
Black Bass
CORPORATE BOUNDARY
RIVER
Mile 106
BM 2130
Mile 106+
Water Tank
RIVERVIEW DRIVE
HIGHLAND DRIVE
BURLINGTON NORTHERN
LANDING STRIP
MULLAN
CORI
IDDY
AVE
SCHILLING
FERRY
Creek

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Comparison of Non-Point Source Phosphorus Loading to the Spokane River from Its Headwaters to Long Lake, WA with that Used in the Spokane River Phosphorus Attenuation Model

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as per
Agreement between the:

Washington State Department of Ecology, City of Spokane and Eastern Washington University

City of Spokane, Clerk's No. OPR93-236, Public Works File # 14099

Submitted: July 1993

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ABSTRACT

A computer program, the Spokane River Phosphorus Attenuation Model, was created to predict seasonal water quality conditions in Long Lake, WA, an impoundment of the river. The model was based on water quality information collected from 1972 through 1985 growing seasons and median flow conditions from the outlet of Lake Coeur d'Alene, ID. The Washington State Department of Ecology (WDOE) has been utilizing this model since 1989 as a management tool to regulate phosphorus loading from point and non-point sources to the Spokane River. The model is capable of predicting mean daily phosphorus loading to Long Lake and mean in-reservoir phosphorus levels for the growing season. The model also simulates other euphotic zone water quality parameters. The WDOE has determined a total maximum daily phosphorus load of 259 kg would be allowable and protective of Long Lake, WA water quality.

The primary objective of this study was to delineate the significance and controllability of non-point sources of TP loading to the Spokane River from its mouth to the upper end of Long Lake. Five non-point phosphorus sources to the Spokane River recognized in the model are Lake Coeur d'Alene, stormwater and combined sewage overflow contributions, Hangman Creek, the Little Spokane River and the Spokane Valley/Rathdrum Prairie Aquifer. The model predicted mean effective TP load to Long Lake from Lake Coeur d'Alene is 34.2 kg/day; however, the actual mean TP load was found to be 47.8 kg/day. The model predicted mean effective TP load to Long Lake from the Little Spokane River is 35.7 kg/day, while the actual mean TP load was 36.4 kg/day. The Spokane Valley/Rathdrum Prairie Aquifer is predicted to add 31.5 kg/day of TP to Long Lake by the model.

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More recent data for the aquifer does not exist for comparison with the model's prediction. The model predicted effective TP load to Long Lake from stormwater and combined sewage overflow contributions is 7.6 kg/day, but the calculated actual mean TP loads is determined to be 5.56 ($\pm$0.77) kg/day. Hangman Creek's predicted TP load was 5.1 kg/day; however, in 1991, the actual mean TP load was 2.6 kg/day.

The outlet of Lake Coeur d'Alene, the mouth of Hangman Creek and the mouth of the Little Spokane River should be monitored for TP concentration every two weeks during the growing season. The various stormwater and combined sewage overflow outfalls deliniated in the manuscript should also be monitored for TP concentration and volume during wet weather events. The Spokane Valley/Rathdrum Prairie Aquifer's TP load is very difficult to determine; however, quarterly monitoring of TP from the recommended wells along the aquifer course will allow for more accurate estimations of actual TP load contibutions from this source.

Rapid growth in the Inland Northwest is expected over the next ten years, which may quickly cause the total maximum daily phosphorus load of 259 kg to Long Lake to be exceeded. As growth takes place, non-point TP loading will probably increase, thus gathering the above information should provide data to determine the size and direction of change in non-point loads.

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INTRODUCTION AND BACKGROUND

Population growth in the Spokane River drainage basin has been accompanied by numerous issues of wastewater management. These issues have arisen, primarily because the drinking water source for much of the region in Idaho and Washington is the Spokane Valley/Rathdrum Prairie Aquifer (Molenaar, 1988). To minimize contamination of this sole source aquifer, Spokane and many communities upstream (i.e., Liberty Lake, WA; Post Falls, ID; Hayden Lake, ID; Coeur d'Alene, ID) are collecting and treating their wastewater and then discharge it to the Spokane River. The continued and expanded use of the river for wastewater disposal is also of equal concern to many groups and individuals downstream of such outfalls.

The Washington Department of Ecology (WDOE) has studied phosphorus loading from sources along the Idaho/Washington stretch of the Spokane River and determined that a total maximum daily phosphorus load of 259 (±43) kg would be allowable and protective of Long Lake, WA (an impoundment of the Spokane River). Long Lake (Lake Spokane) water quality today is managed by WDOE, in part, by controlling total phosphorus content in the Spokane River (WAC, 1990). Total phosphorus (TP) is regulated because:

- It is directly responsible for the identified water quality problems of low dissolved oxygen, excessive phytoplankton populations and poor water quality in Long Lake during the summer; and
- It can be related directly to upstream sources.

The WDOE's goal is to maintain Long Lake in a mesotrophic condition or better during the high use summer period. Therefore, with median flow

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(approximately 2970 cfs at the headwaters of the Spokane River or the outlet of Lake Coeur d'Alene), the seasonal June through October euphotic zone concentration of TP in Long Lake should be at or below an average of 25 µg/l (Patmont et al., 1987).

The relationships between influent TP concentration and key water quality variables in Long Lake have been assessed using simple regression and modeling methods (Patmont et al., 1987). The Spokane River Phosphorus Attenuation Model is a computer program which predicts mean daily TP loading to Long Lake, mean in-reservoir TP levels and other euphotic zone water quality parameters for the growing season based on upstream information entered. The model requires the outflow rate from Lake Coeur d'Alene during the growing season, the rate of discharge, the TP concentration, and the phosphorus removal efficiency for the point source dischargers and any miscellaneous sources of phosphorus loading. When the model was first introduced (Patmont et al., 1987), the point source dischargers were Coeur d'Alene's Advanced Wastewater Treatment Plant, Hayden Lake's Regional Sewage Treatment Plant, Post Falls' Sewage Treatment Plant, Rathdrum's Wastewater Treatment Plant, Liberty Lake's Sewage Treatment Plant, Spokane Industrial Park's Wastewater Treatment Plant, Kaiser's Wastewater Treatment Plant and coolant, Inland Empire's Wastewater Treatment Plant, Millwood's Sewage Treatment Plant, Spokane's Advanced Wastewater Treatment Plant and the Northwest Terrace Sewage Treatment Plant. As of 1993, the Rathdrum, Millwood and Northwest Terrace plants are no longer in use. Hayden Lake's Regional Sewage Treatment Plant does not discharge to the Spokane River during the growing season. Also as of this writing, no miscellaneous sources of phosphorus loading are accounted for and entered into model calculations made by

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WDOE (Merrill; pers. comm.). The non-point sources included in the model are the outflow from Lake Coeur d'Alene, stormwater from one outfall in the Spokane valley, Hangman Creek, City of Spokane's stormwater/combined sewer overflow (CSO) discharges, the mouth of the Little Spokane River and inputs from the Spokane Valley/Rathdrum Prarie Aquifer andatmospheric precipitation.

Using the entered data, the model calculates the TP load to the river from each point source and then gives the investigator the opportunity to modify the phosphorus load from the various point sources, as well as, four of the non-point sources (stormwater from the Spokane valley, Hangman Creek, Spokane's stormwater/CSO and the Little Spokane River). The TP load leaving Lake Coeur d'Alene is the intial boundary condition for water quality conditions in the head waters of the Spokane River. Once Lake Coeur d'Alene flow is entered, the only parameter that can be altered for outlet quality is TP concentration. The TP load produced by the model for the atmosphere/aquifer contribution to the Spokane River can not be altered.

As a managment tool, the model has been run using a median outflow of 2970 cfs from Lake Coeur d'Alene and an outflow TP concentration of 8.68 ($\pm$2.4) μg/l (Merrill, pers. comm.). By using the same TP concentration and flow at the outlet of Lake Coeur d'Alene, year after year, in effect causes the TP load from Lake Coeur d'Alene to the river to never change. In addition, the model adjusts the flow inputs of the Little Spokane River, Hangman Creek and the aquifer/atmosphere based on the magnitude of flow from the outlet of Lake Coeur d'Alene. The model also assumes a constant, but unique, TP concentration for each of the non-point sources. Hence, using the same Lake Coeur d'Alene discharge each year makes the TP loads to the Spokane River from the Little Spokane River, Hangman Creek

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and the aquifer/atmosphere constant. The other non-point sources (stormwater and CSO) are fixed values which are not weighted by the volume of the water leaving Lake Coeur d'Alene and do not change from year to year in the model's predictions.

The model divides the river into 16 reaches (Table 1). After the TP load from each point and non-point source has been calculated, the model goes through a series of computations taking into account phosphorus attenuation in each river reach, ultimately producing an effective TP load to Long Lake. Model output includes TP loading before attenuation, the percentage of the TP attenuated and the effective TP load to Long Lake for each source. The overall effective TP load to the reservoir is the sum of all point and non-point source loads.

There are also several known dischargers of wastewater into the Spokane River directly or indirectly that are not individually considered in the model. However, the potential TP load from most of these sources may be accounted for by the model's predicted load at the outlet of Lake Coeur d'Alene and at the mouths of Hangman Creek and the Little Spokane River. Lake Coeur d'Alene receives effluent from Mullan's Wastewater Treatment Plant (via the South Fork of the Coeur d'Alene River), Smelterville's Wastewater Treatment Plant (via the South Fork of the Coeur d'Alene River), Page's Wastewater Treatment Plant (via the South Fork of the Coeur d'Alene River), St. Maries' Wastewater Treatment Plant (via the St. Joe River), Santa Fernwood's Wastewater Treatment Plant (via the St. Maries River), Plummer's Wastewater Treatment Plant (via Plummer Creek) and wastewater from Potlatch Company's log storage runoff (via the St. Joe River; Cochrane, pers. comm.). In Washington, Hangman Creek receives wastewater from two of Spokane's CSO outfalls and Tekoa's Sewage

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Table 1. The reaches of the Spokane River from the oultet of Lake Coeur d'Alene, ID to Nine Mile, WA identified in the Spokane River Phosphorus Attenuation Model (Patmont et al., 1985; 1987).

Reach	River Miles	Description
1	111.7 - 106.6	Lake Coeur d'Alene to Harbor Island
2	106.6 - 101.7	Harbor Island to Post Falls Dam
3	101.7 - 96.0	Post Falls Dam to Stateline
4	96.0 - 93.0	Stateline to Harvard Road
5	93.0 - 90.4	Harvard Road to Barker Road
6	90.4 - 87.8	Barker Road to Sullivan Road
7	87.8 - 85.3	Sullivan Road to Trent Road
8	85.3 - 82.6	Trent Road to Argonne Road
9	82.6 - 79.8	Argonne Road to Upriver Dam
10	79.8 - 78.0	Upriver Dam to Greene Street
11	78.0 - 74.1	Greene Street to Post Street
12	74.1 - 69.8	Post Street to Fort Wright Bridge
13	69.8 - 67.6	Fort Wright Bridge to SAWTP*
14	67.6 - 64.6	SAWTP to Gun Club
15	64.6 - 62.0	Gun Club to Seven Mile Bridge
16	62.0 - 58.1	Seven Mile Bridge to Nine Mile Dam

*SAWTP = Spokane Advanced Wastewater Treatment Plant.

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Treatment Plant and indirectly from Cheney's Wastewater Treatment Plant (via Minnie Creek and Marshall Creek), Fairfield's Sewage Treatment Plant (via Rattler's Run Creek) and Rockford's Sewage Treatment Plant (via Rock Creek). The Little Spokane River receives wastewater from the Spokane Fish Hatchery. Medical Lake's Sewage Treatment Plant effluent probably reaches the Spokane River intermittently via Deep Creek. Imperial West Chemical Company and Washington Water Power Company (head quarters) also discharge wastewater into the Spokane River (Huffman, pers. comm.). The TP load, if any, is not known from the last three sources nor are they accounted for in the model.

For the 1990, 1991 and 1992 growing seasons, the point sources considered in the model contributed approximately 40 to 50 percent of the TP load to Long Lake, while non-point sources made up the remaining 50 to 60 percent (Soltero et al., 1993). Overall, there has been a decline in TP loading from monitored point sources since the model was introduced. Assuming TP loadings from monitored point sources are represenative and have declined, then non-point phosphorus loading has become more important as to the uncertainty in predicting the mean daily effective TP load to Long Lake.

The primary objective of this study was to delineate the significance of non-point sources of TP loading to the Spokane River from its mouth to the upper end of Long Lake. Other objectives were to identify where the Spokane River Phosphorus Attenuation Model may more accurately reflect actual TP loading to the river and thus Long Lake. Lastly, a monitoring program of the Spokane Valley/Rathdrum Priaire Aquifer and watershed is suggested to establish selected boundary conditions of TP loading.

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THE OUTFLOW FROM LAKE COEUR D'ALENE

The total phosphorus (TP) load leaving Lake Coeur d'Alene is the intial boundary for water quality conditions in the headwaters of the Spokane River. In order to determine the lake's TP load to the river, both the mean growing season outflow from Lake Coeur d'Alene into the river and the mean growing season TP concentration of the outflow must be known. The TP concentration for the outlet of Lake Coeur d'Alene is not routinely monitored; therefore, there is no commonly accepted TP concentration that can be used in load calculations from one year to the next.

As a managment tool, the model is typically run with a median outflow of 2970 cfs from Lake Coeur d'Alene and an outflow TP concentration of 8.68 (±2.4) µg/l of TP established by Patmont et al. (1987). The above flow and TP concentration produce a mean daily TP load from the outlet of Lake Coeur d'Alene of 63.07 (±17.04) kg/day (Appendix A).

In order to determine the actual TP load during the growing season, the actual mean daily discharge from Lake Coeur d'Alene is needed. Since the outflow from the outlet of Lake Coeur d'Alene is not routinely measured, it would be calculated by adjusting the flow leaving Post Falls Dam for irrigation withdrawals and point source discharges (Patmont et al., 1987). The mean daily outflow from Lake Coeur d'Alene for the 1990, 1991 and 1992 growing seasons was 4451 cfs, 3742 cfs and 1346 cfs, respectively (Soltero et al., 1993).

The TP concentration at the outlet of Lake Coeur d'Alene has been recently measured. One study sampled during both the 1990 and 1991 growing seasons, while the other sampled during the 1992 growing season

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Table 2. Total phosphorus (TP) concentrations at the outlet of Lake Coeur d'Alene, ID during the 1990, 1991 and 1992 growing seasons (Falter et al., 1991; McKeown et al., 1992).

1990		1991		1992	
Date	TP (µg/l)	Date	TP (µg/l)	Date	TP (µg/l)
6/29/90	19	6/4/91	12	8/19/92	10
7/9/90	31	6/18/91	12	8/26/92	25
7/23/90	<6	7/2/91	7	9/2/92	9
8/6/90	7	7/16/91	15	9/9/92	8
8/20/90	16	7/30/91	10	9/11/92	8
9/3/90	20	8/13/91	<6	9/14/92	13
9/17/90	11	8/27/91	13	9/16/92	16
10/1/90	10	9/10/91	<6	9/23/92	19
10/15/90	<6	9/9/91	9		
10/29/90	<6				

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(Falter et al., 1991; McKeown et al., 1992; Table 2). In 1990, mean growing season TP concentration at the outlet was 11.4 (±3.42) µg/l, while in 1991 it was 8.67 (±1.92) µg/l (Falter et al., 1991). In 1992, the mean growing season TP concentration at the outlet was 13.5 (±2.31) µg/l (McKeown et al., 1992).

The actual mean daily TP load to the Spokane River from Lake Coeur d'Alene for 1990 was calculated to be 124.14 (±37.26) kg/day (Soltero et al., 1993; Appendix B). The actual mean daily TP loads to the river for 1991 and 1992 were 79.46 (±17.61) kg/day and 44.56 (±7.61) kg/day, respectively (Soltero et al., 1993). The overall mean daily TP load to the river for all three years was 82.72 (±23.03) kg/day. The three year mean loading lies outside the predicted error of uncertainty for the model prediction of 63.07 (±17.04) kg/day at the outlet of Lake Coeur d'Alene (Soltero et al., 1993).

As mentioned earlier, there are seven point sources of TP loading via the major tributaries to Lake Coeur d'Alene. In addition to these point sources, there are a large number of dwellings along the lake's shoreline which contribute TP load from wastewater leachate. In 1977, there were 1688 occupied lots within one quarter mile of the lake's shore (Panhandle Health District I, 1977). Of these dwellings, 15 percent were occupied year round and 52 percent were within 300 feet of the lake's shore. This shoreline survey is seventeen years old and will be updated in the summer of 1993 by the Idaho Panhandle Health District I. At this time, it is suspected that the number of dwellings and the percentage occupied year round have increased significantly (Martindale, pers. comm.). The City of Coeur d'Alene has three stormwater pipes that drain directly into Lake Coeur d'Alene and two pipes that drain indirectly into Lake Coeur d'Alene via Fernan Lake. The potential TP load from the stormwater pipes directly or

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indirectly, should be accounted for by the model's predicted TP load from Lake Coeur d'Alene.

In 1991 and 1992, the U.S. Geological Survey sampled Lake Coeur d'Alene (Fig. 1). Sampling site 1 was approximately 1.3 miles southeast of Tubbs Hill, while sample site 6 was approximately 0.6 miles east of the lake's outlet and 0.2 miles northeast of Donavans Point. Site 1 yielded a mean growing season TP concentration of 5.29 (±0.73) µg/l and 2.00 (±0.58) µg/l for 1991 and 1992, respectively (Table 3). During 1991, site 6 had a mean growing season TP concentration of 3.14 (±0.76) µg/l (Table 3). The latter values are substantially lower than the growing season mean TP concentrations found at the lake's outlet for the same time period. Based on this limited information, it could be hypothesized that the known point and non-point sources to the main body of Lake Coeur d'Alene are not totally responsible for elevated mean TP levels at the outlet (8.64 to 13.5 µg/l). One possible explanation for elevated TP at the outlet is the resuspension of lake bottom sediment/organic matter by more forceful currents at the outlet. It is also likely that the large quanity of log storage contributes sediment and handling near the outlet and in the river contributes to phosphorus loading by direct leaching from exposed log surfaces as well as decaying bark and log deposits.

There appears to be little literature regarding phosphorus from logs. Schaumburg (1972) reported that leachable phosphorus probably did not occur in significant quantities in conifers; however, this report did not contain any phosphorus data. In a study on log holding ponds, adequate phosphate was released to support increased biological growth (Hoffbuhr et al., 1971). The leaching rate of orthophosphate has been studied for Douglas fir, grand fir, western red cedar and ponderosa pine (Stowell, 1976). In his

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Table 3. The U.S. Geological Survey total phosphorus (TP) data for Lake Coeur d'Alene, ID (Beckwith, pers. comm.).

Station 6		Station 1			
1991		1991		1992	
Date	TP (µg/l)	Date	TP (µg/l)	Date	TP (µg/l)
6/4/91	5	6/5/91	6	6/8/92	<1
6/26/91	6	6/26/91	7	6/29/92	3
7/16/91	2	7/17/91	4	7/20/92	3
8/5/91	1	8/5/91	7	8/13/92	4
8/28/91	4	8/27/91	2	8/31/92	2
9/16/91	2	9/16/91	6	9/23/92	1
10/8/91	2	10/8/91	5	10/10/92	1

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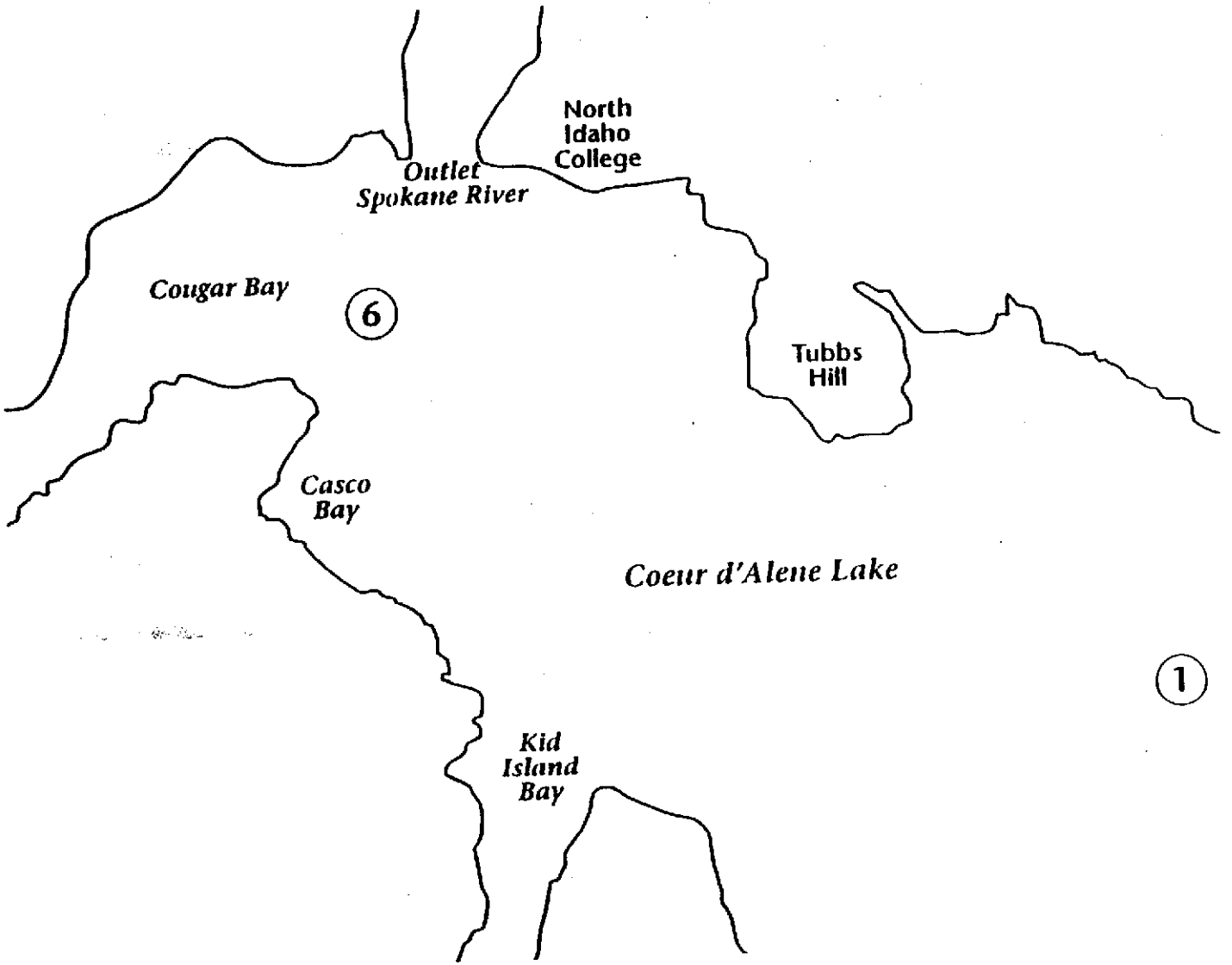


Figure 1. Location of the U.S. Geological Survey sample stations on Lake Coeur d'Alene, ID.

experiments, logs were leached over two thirty day periods using segments that had intact bark. Stowell (1976) even experimented with phosphorus leaching from logs with sealed ends versus not sealed. In the set of logs without the seals, orthophosphate leached at a rate of 9 mg/m^2 of exposed log surface. In the experiment with sealed log ends, the leachate rate was only 5 mg/m^2 of orthophosphate. Using an equation from Schaumburg (1972) and species specific data for ponderosa pine and Douglas fir trees, Stowell (1976) calculated that a log raft with 100,000 m^2 of log surface (if floating with only 1/2 of the log surface in contact with the water) would leach one kg/day of orthophosphate. If one were to assume that TP levels were as low as orthophosphorus concentrations, then the daily TP load from a log raft with 100,000 m^2 of surface area would be 0.33 kg (conversion to phosphorus = phosphate * 0.326). Dividing the 0.33 kg/day of TP by the 100,000 m^2 produces a daily TP load to the water column of 3.3 mg/m^2. The average exposed surface area for the logs stored near the outlet of Lake Coeur d'Alene during the growing season is not known. The length and diameter of the logs (thus the surface area) transported and stored in Lake Coeur d'Alene probably is known by local mills.

There is also not much literature regarding phosphorus release from bark; however, it has been reported that 2.5 to 10 cm depths of bark can have adverse effects on benthic organisms (EPA, 1992; Appendix C). On 11 February 1993 bark samples were collected along the Spokane River's edge between Coeur d'Alene's Advanced Wastewater Treatment Plant and the Idaho Forest Industries' lumber mill (Fredrickson, pers. comm.). On the same day, a sediment sample was taken in the same river reach at a depth of approximately one foot and at a point three feet from the river's edge. Both sediment and bark were dried and analyzed for total phosphorus by the City

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of Coeur d'Alene's Wastewater Laboratory, the North Idaho State Laboratory and Eastern Washington University. Coeur d'Alene's laboratory reported TP values of 377.8 and 613.5 mg/kg for the bark and sediment, respectively. The Idaho laboratory reported TP values of 469 and 618 mg/kg for the bark and sediment, respectively. Eastern Washington University reported 432 (bark) and 731 (sediment) mg/kg. The mean TP content for the bark was 426 (±32) mg/kg, while the mean TP quantity in sediment was 654 (±47) mg/kg. The quantity of bark avaliable for degradation and the percent of bark that actually under goes decomposition at or near the outlet during the growing season is unknown.

The TP load at the headwaters of the Spokane River as established by the model runs for the 1990 through 1992 growing seasons has averaged 16.7 percent of the total effective TP load to Long Lake (Table 4). When actual mean outlet flows and measured TP concentrations are used, Lake Coeur d'Alene contributed 19.5 percent of the total effective TP load to Long Lake (Table 5). The difference arises from the fact that when there is greater outflow from Lake Coeur d'Alene then there is less TP attenuation in the river before reaching the reservoir. The TP attenuation also increases with increased TP concentration at Lake Coeur d'Alene's outlet.

In order to more closely monitor outlet conditions of Lake Coeur d'Alene, the outlet should be sampled for TP every two weeks during the growing season. Flows from the outlet of Lake Coeur d'Alene can be calculated as previously discussed. The gathered data should be entered in the model to establish actual Lake Coeur d'Alene boundary conditions in place of using median flow and a constant TP concentration. However, existing model values should also be used in management/regulation of river

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Table 4. Comparison of total phosphorus daily load for the point and non-point sources entering the Spokane River from the outlet of Lake Coeur d'Alene, ID to Nine Mile, WA from 1990 through 1992. Data were generated from the Spokane River Phosphorus Attenuation Model assuming median flow and a constant total phosphorus concentration of 8.68 mg/l at the outlet of Lake Coeur d'Alene during the growing season.

Sources	TP - 1990		TP - 1991		TP - 1992		TP - 3 year mean	
	kg/day	percent	kg/day	percent	kg/day	percent	kg/day	percent
Lake Coeur d'Alene	34.7	15.2	34.0	17.8	34.0	17.2	34.2	16.7
Coeur d'Alene AWTP	33.5	14.6	5.7	3.0	4.9	2.5	14.7	6.7
Hayden Lake Regional STP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Post Falls STP	9.4	4.1	9.8	5.1	10.1	5.1	9.8	4.8
Rathdrum WTP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Liberty Lake STP	2.9	1.3	2.7	1.4	2.7	1.4	2.8	1.3
Spokane Industrial Park WTP	6.0	2.6	2.6	1.4	2.5	1.3	3.7	1.8
Kaiser WTP and coolant	0.6	0.3	0.6	0.3	1.5	0.8	0.9	0.4
Stormwater (Valley)	1.0	0.4	1.0	0.5	1.0	0.5	1.0	0.5
Inland Empire Paper WTP	4.3	1.9	2.8	1.5	3.3	1.7	3.5	1.7
Millwood STP	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.0
Hangman Creek	5.1	2.2	5.1	2.7	5.1	2.6	5.1	2.5
Spokane AWTP	58.1	25.4	52.2	27.4	58.2	29.4	56.2	27.4
Spokane CSO and stormwater	6.6	2.9	6.6	3.5	6.6	3.3	6.6	3.2
Northwest Terrace WTP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Little Spokane River	35.7	15.6	35.7	18.7	35.7	18.1	35.7	17.5
Aquifer/atmospheric	30.5	13.3	32.0	16.8	32.0	16.2	31.5	15.4
Total point sources	115.1	50.3	76.4	40.0	83.2	42.1	91.6	44.2
Total non-point sources	113.6	49.7	114.4	60.0	114.5	57.9	114.2	55.8
Grand total	228.7	100.0	190.8	100.0	197.7	100.0	205.7	100.0

water quality until actual data will allow for better refinement of predictions and more clearly point out trends.

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STORMWATER AND COMBINED SEWER OVERFLOW TO THE SPOKANE RIVER

Coeur d'Alene, ID

The City of Coeur d'Alene has four stormwater pipes that flow directly into the Spokane River (Frederickson, pers. comm.; Fig. 2) The volume and quality of these discharges are unknown. Therefore, the TP load can not be calculated and the significance of these sources is unknown. The Spokane River Phosphorus Attenuation Model does not account for these outfalls. There is an estimated 60.34 acres of impervious surface that drains in to the City of Coeur d'Alene's sewage system (Frederickson, pers. comm.). Any phosphorus that enters the sewage system would subsequently be treated by the Coeur d'Alene Advanced Wastewater Treatment Plant (CdAAWTP) and the resultant TP load to the river would be accounted for by the CdAAWTP TP load.

The practicality of controlling the TP load from the stormwater outfalls entering the river would depend on their magnitude. Probably the simplest solution to eliminate this TP load would be to use dry well injection for stormwater treatment, but the practicality of the dry wells in the area, pparticularly over the aquifer, is unknown. The flow and TP concentration at these outfalls should be monitored, particularly during wet weather events in order to determine the impact on river quality. Then, the mean daily TP load for the growing season can be computed and entered into the model as a miscellaneous source in the extreme upper reach of the river (which the model allows).

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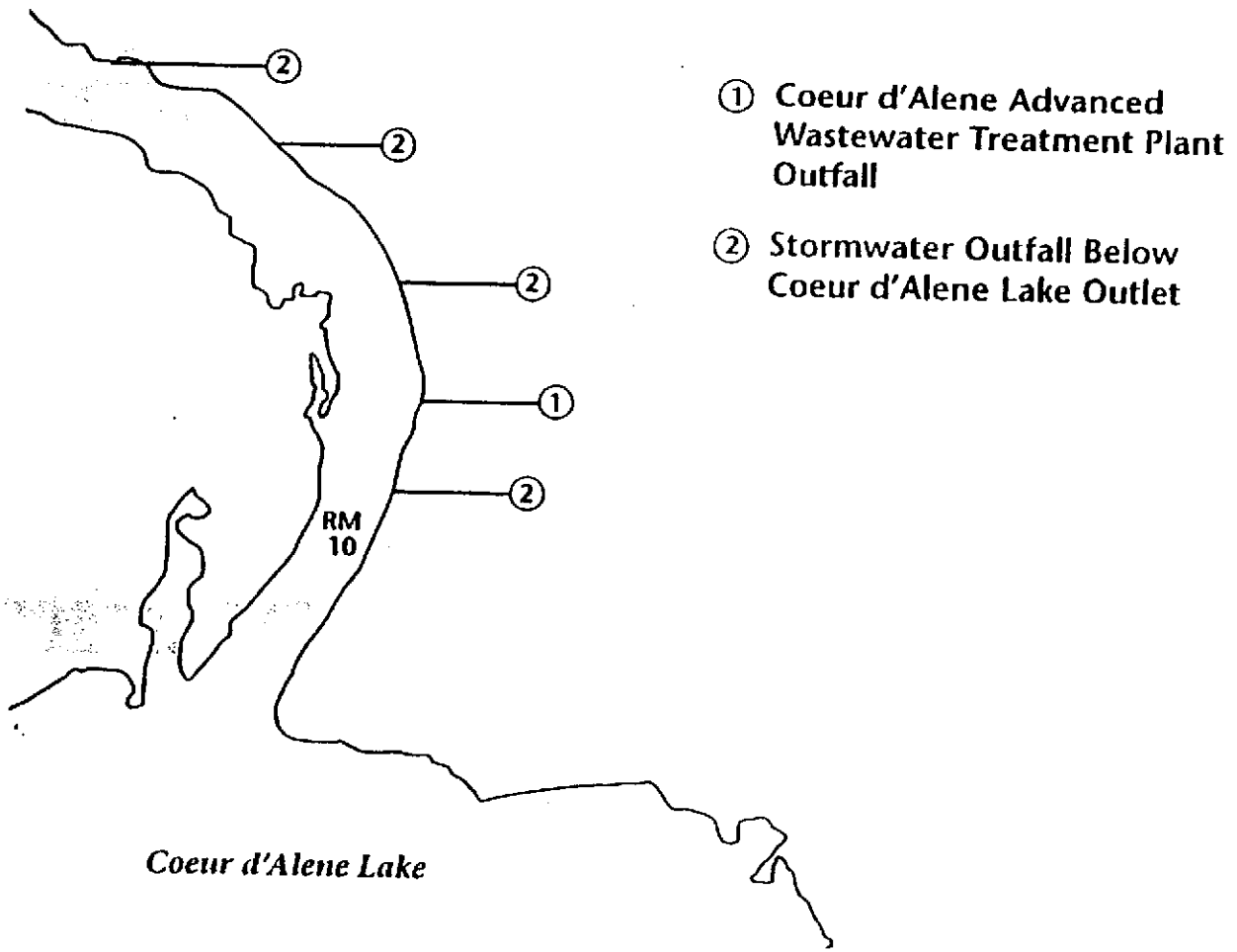


Figure 2. Locaton of the stormwater outfalls to the Spokane River from Coeur d'Alene, ID.

Post Falls, ID

The city of Post Falls has no stormwater pipes that drain into the Spokane River (Taccogna, pers. comm.). There is one stormwater pipe that drains into an old irrigation canal and the canal apparently does not drain into the Spokane River. Therefore, stormwater flows from Post Falls are probably not a significant source of TP loading to the Spokane River. Figure 3 shows the location of the Post Falls Sewage Treatment Plant outfall below Post Falls Dam.

Spokane Valley and Spokane, WA

It has been calculated that the Spokane metropolitan area has an estimated area of 8.7 (±2.1) square miles of impervious area that drains into the Spokane River (Corps of Engineers, 1976; URS, 1981; Patmont et al., 1987). Two-thirds of the of impervious area is within the city limits and one third is in the Spokane valley. The volume of runoff used in the Spokane River Phosphorus Attenuation Model is given by the following equation:

$$Q = PPT * RO * Area$$

where, PPT is average precipitation for the growing season (4.3 (±1.5) inches), RO is an estimated runoff coefficient (0.70 (±0.10)) and the area is the extent of impervious surface (mi^2 ; Patmont et al., 1987).

The City of Spokane's combined stormwater/sewage overflow system (CSO) has been undergoing modification to separate stormwater from sewage. At present, 86 percent of the CSO system has been separated (Gay, pers. comm.). Current CSO outfalls are shown in Figure 4 with location given in Table 6. Outfalls to the river that contain only stormwater are shown in Figures 5 and 6 with location given in Table 7.

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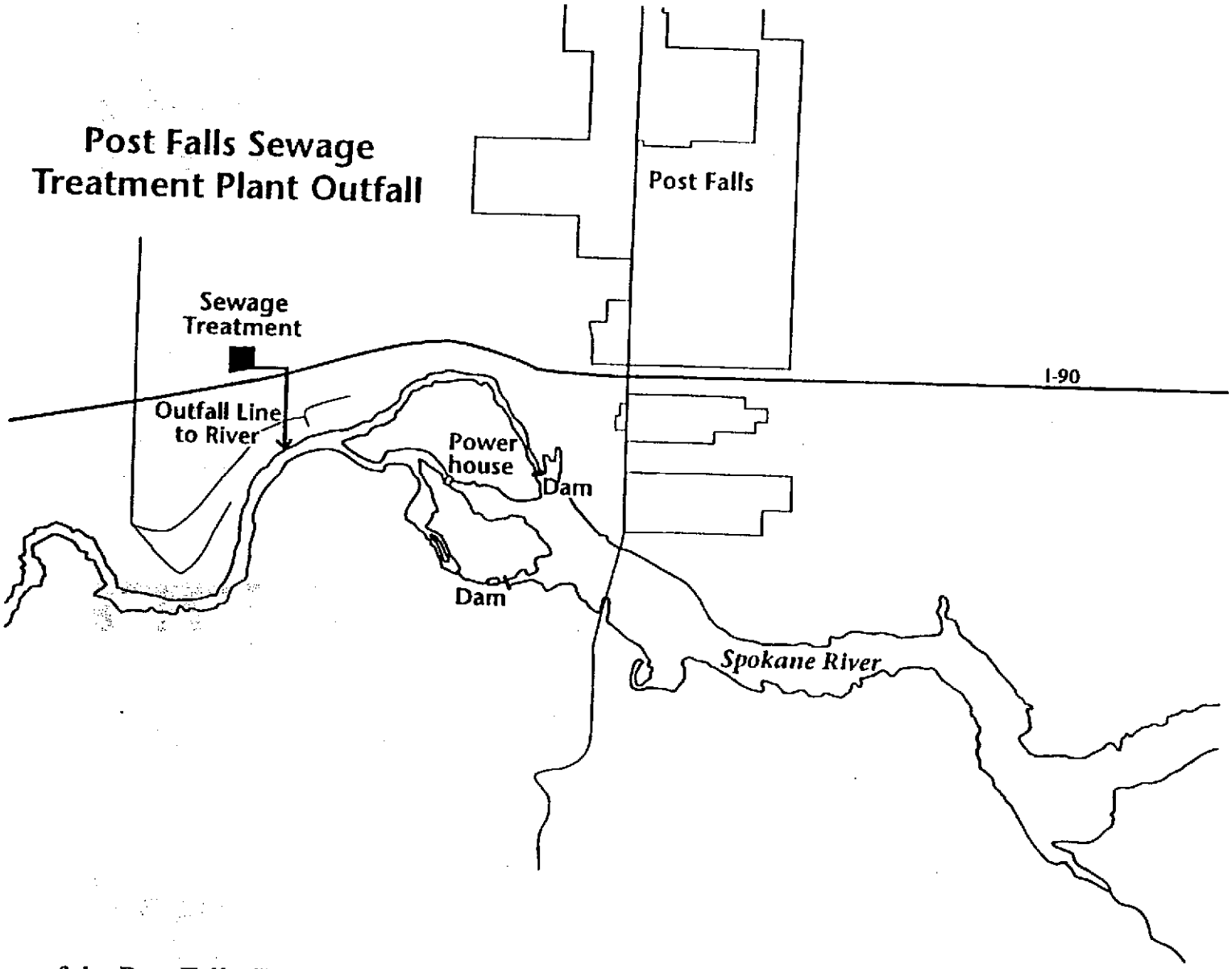


Figure 3. Location of the Post Falls, ID treatment plant outfall.

THE AQUIFER AND ATMOSPHERE

Investigation of water quantity and quality in the Spokane Valley /Rathdrum Prairie Aquifer system (SVRPA), that comprises a land area of about 408 mi^2 in northern Idaho and adjacent areas in Washington (Fig. 7), has resulted in a number of technical publications. Molenaar (1988) probably provides the best general overview of the system. One of the objectives of this investigation was to focus on the interaction and exchange of water between the SVRPA and the Spokane River from the mouth and lakeshore area of Lake Coeur d'Alene downstream (down gradient) to the Little Spokane River and Long Lake. A good understanding of the groundwater - surface water dynamics is imperative for the best possible selection of wells for future monitoring of aquifer TP concentrations. This data can then be used in the Spokane River Phosphorus Attenuation Model to more accurately represent actual conditions.

Idaho

In Idaho, the SVRPA, specifically in the reach from Lake Coeur d'Alene to Post Falls Dam, and downstream to the Washington state line, receives a significant quantity of recharge from the Spokane River. Figure 8 shows this portion of the SVRPA and its critical aquifer recharge areas. Researchers generally indicate that the Spokane River is entirely influent in this reach, that is, it loses water to the aquifer (Jones and Lustig, 1977; Seitz and Jones, 1981; Painter, 1991). Recharge to the SVRPA occurs in this area because the hydraulic gradient is away from the river and river stage is higher than the groundwater table surface. Any contamination introduced into the ground along the river in this reach and that vertically infiltrates

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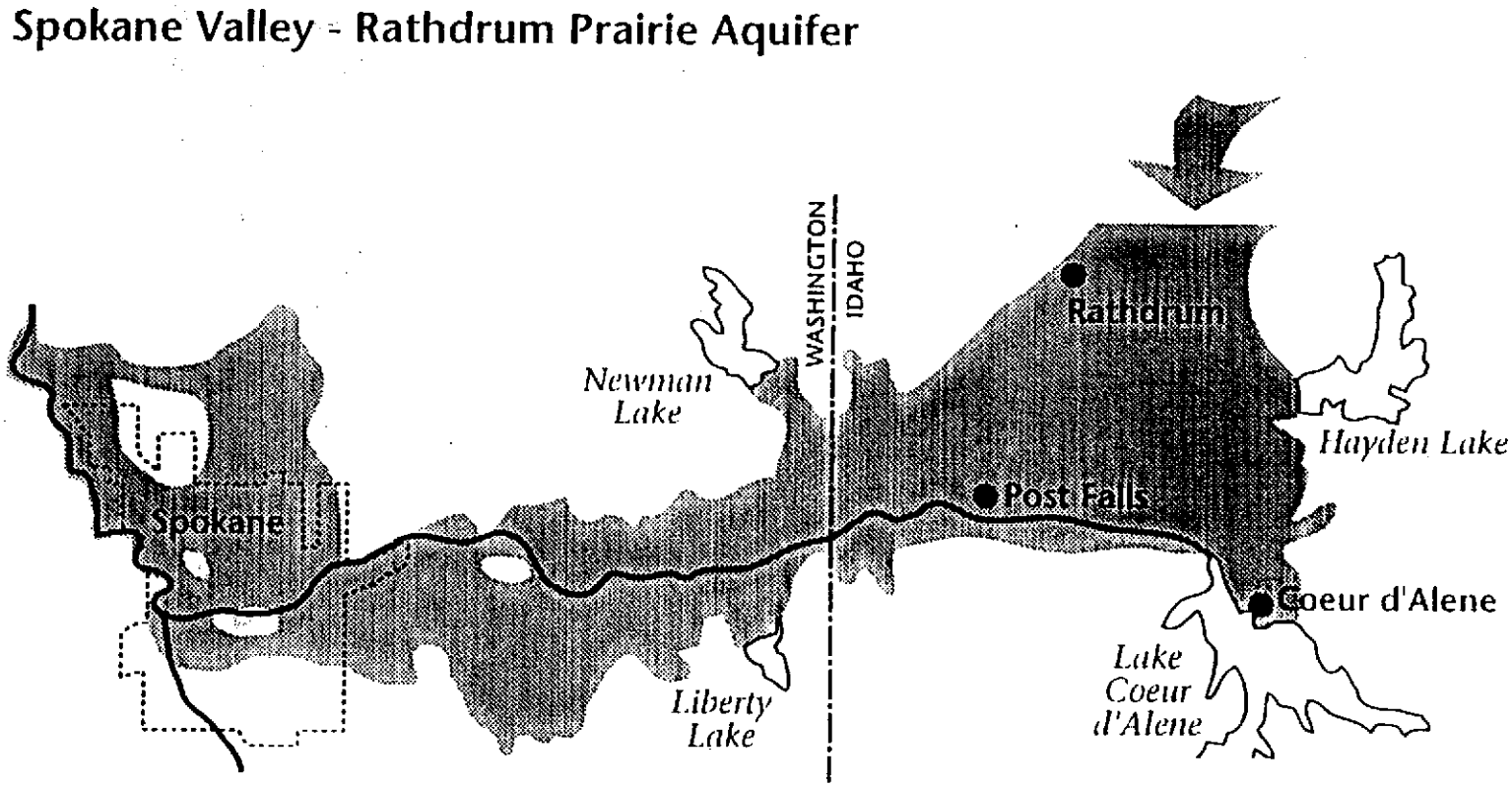


Figure 7. The Spokane Valley/Rathdrum Prairie Aquifer system.

through the soils to the groundwater table, from whatever source, will generally move away from the river and ultimately westward toward the Idaho/Washington stateline.

The most recent estimates on aquifer recharge rates from Lake Coeur d'Alene and the Spokane River by Painter (1991), in utilizing a mass balance approach with new data, shows that about 230 cubic feet per second (cfs) of water is lost from both the river and the lake into the aquifer along this reach. Pluhowski and Thomas (1968) determined, by using a water budget analysis, that seepage along this reach was about 250 cfs. Seitz and Jones (1981) attempted a similar calculation by actual flow measurement; however, they were unsuccessful.

It is important to note that Patmont et al. (1985) does not make any new estimates on the rate of seepage loss of the river to the aquifer above Post Falls Dam. In fact, Patmont et al. (1985; 1987) do not consider the volume loss to groundwater in this reach, and consequently, do not take into account the TP loading loss from the river to the aquifer. Patmont et al.'s (1985; 1987) phosphorus loading model only begins to consider seepage loss to the SVRPA below Post Falls Dam. However, downstream of Post Falls Dam, only volume loss due to seepage is considered, TP loss is not calculated by the model.

Recent work by Painter (1993, pers. comm.) has led to the development of a groundwater flow model based on the U.S. Geological Survey finite-difference code MODFLOW for the 283 mi^2 Rathdrum Prairie portion of the SVRPA in Kootenai and Bonner Counties. This model has been adapted by Buchanan (1993, ongoing work) to perform advective particle tracking to describe streamlines that illustrate both flow direction and time of travel through the aquifer system in this area. Figure 9

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illustrates the pathlines that 50 particles, placed at the Washington-Idaho state line, will follow as tracked backward through time to their source. Note that a large proportion of the streamlines, about one-third, emanate from Lake Coeur d'Alene and from the Spokane River, which corresponds with the 30.6 percent total aquifer recharge rate that Painter (1991) has calculated.

The groundwater flow pattern shown in Figure 9 is remarkably similar to the flow pattern envisioned by Jones and Lustig (1977) in their effort to delineate nitrate loading zones in the Rathdrum Prairie Aquifer in the area between Coeur d'Alene and the state line. Time series analysis of pathline data generated with the computer model through this region shows that particles introduced into the aquifer within the city of Coeur d'Alene will take about five to 14 years to reach the state line, whereas flow contributed to the aquifer from immediately above Post Falls Dam will take about one to two years to reach the state line.

Washington

In Washington, the hydraulic relationship between the SVRPA system and the Spokane River becomes more complex, as a number of researchers have shown that both influent (losing) and effluent (gaining) relationships are found through this reach. Figure 10 shows this portion of the SVRPA and its critical aquifer recharge areas. Broom (1951) and McDonald and Broom (1951) described two influent and two effluent reaches in the river from Post Falls Dam to Nine Mile Falls Dam, and also described the Little Spokane River from Dartford to its mouth as entirely effluent. Later work by Drost and Seitz (1978) and Esvelt (1978) reviewed the earlier work and did not gather any new direct data on the exchange of water between the

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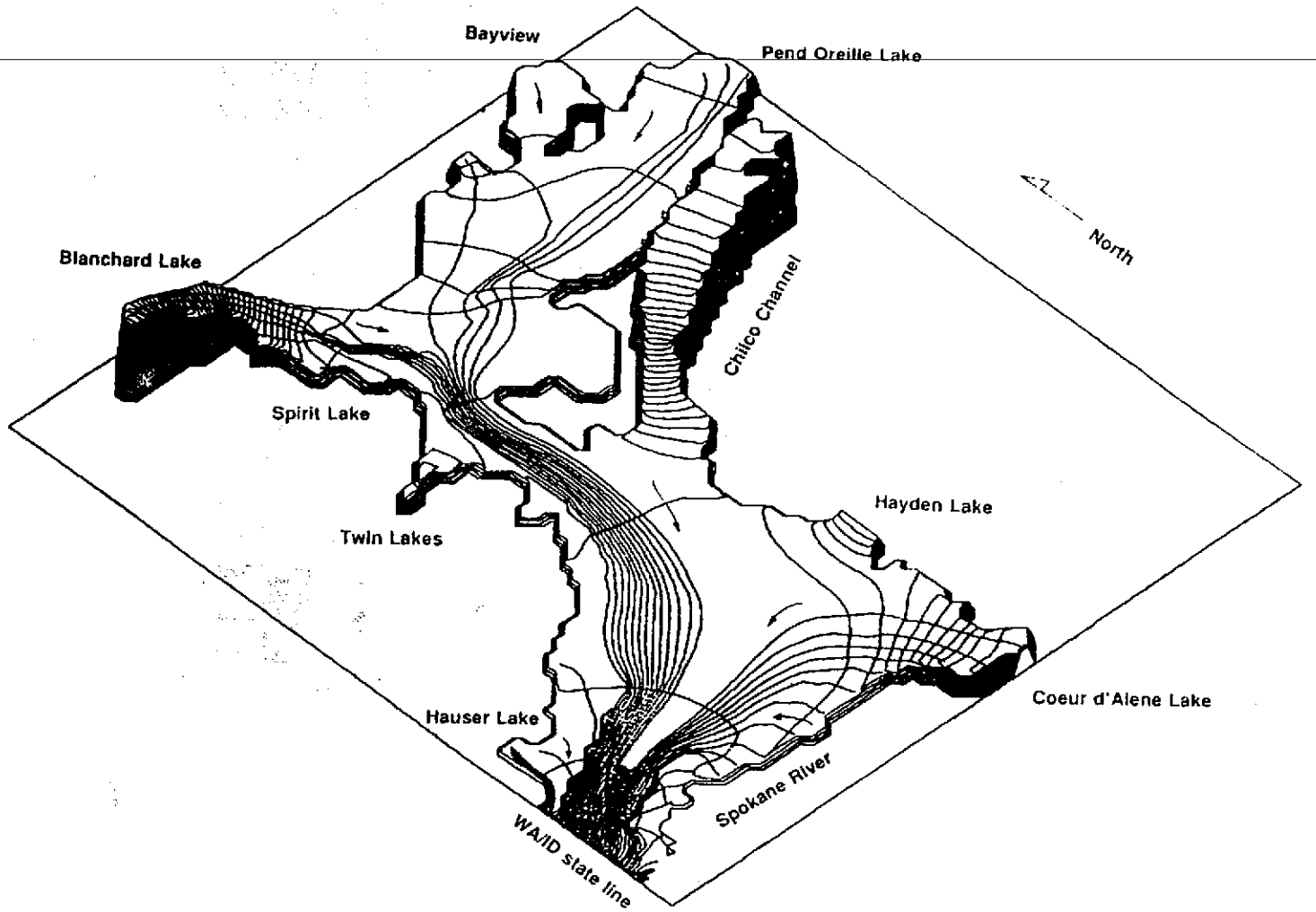


Figure 9. View to northeast (up-gradient) of the groundwater table map of the Rathdrum Prairie portion of the Spokane Valley /Rathdrum Prairie Aquifer system produced by computer simulation by utilizing MODFLOW (adapted by Buchanan from Painter, 1993, pers. comm.). Note the streamlines produced by back-tracking 50 particles placed at the state line toward their source. Arrows indicate direction of groundwater flow

river and the aquifer. A finite-element groundwater flow model constructed by Bolke and Vaccaro (1981) predicted similar relationships to the work by Broom (1951); however, they delineated five influent reaches and five effluent reaches based on model results (never field verified) in the Spokane River. Their model also predicted that the Little Spokane River is entirely effluent from Dartford to its mouth.

Patmont et al. (1985) has probably performed the best-to-date direct flow measurements of the Spokane River system that largely corroborates the predictions of the U.S. Geological Survey groundwater flow model of Bolke and Vaccaro (1981), especially in the area of the Spokane valley from the state line to the eastern city limits of Spokane. Patmont et al. (1985) showed that the Spokane River is effluent in six reaches (Table 8) between Post Falls and Long Lake.

Buchanan and Olness (1993) and Buchanan (1993, on-going work) have developed groundwater flow models for the Spokane valley area (state line to Havana Street) and for the region between Havana Street and the Little Spokane River also based on the U.S. Geological Survey finite-difference code MODFLOW. The groundwater model for the Spokane valley has been calibrated and predicts within several feet the configuration and elevation of the groundwater table of the SVRPA in this region. The model also supports the findings of Patmont et al. (1985, 1987) in regard to the exchange of water between the river and the SVRPA system, both in terms of location of the influent/effluent reaches, and in the direction and magnitude of the flux. Graphical output of the model (Fig. 11) as adapted to perform advective particle tracking shows clearly the pathlines that groundwater follows from the state line westward toward the city of

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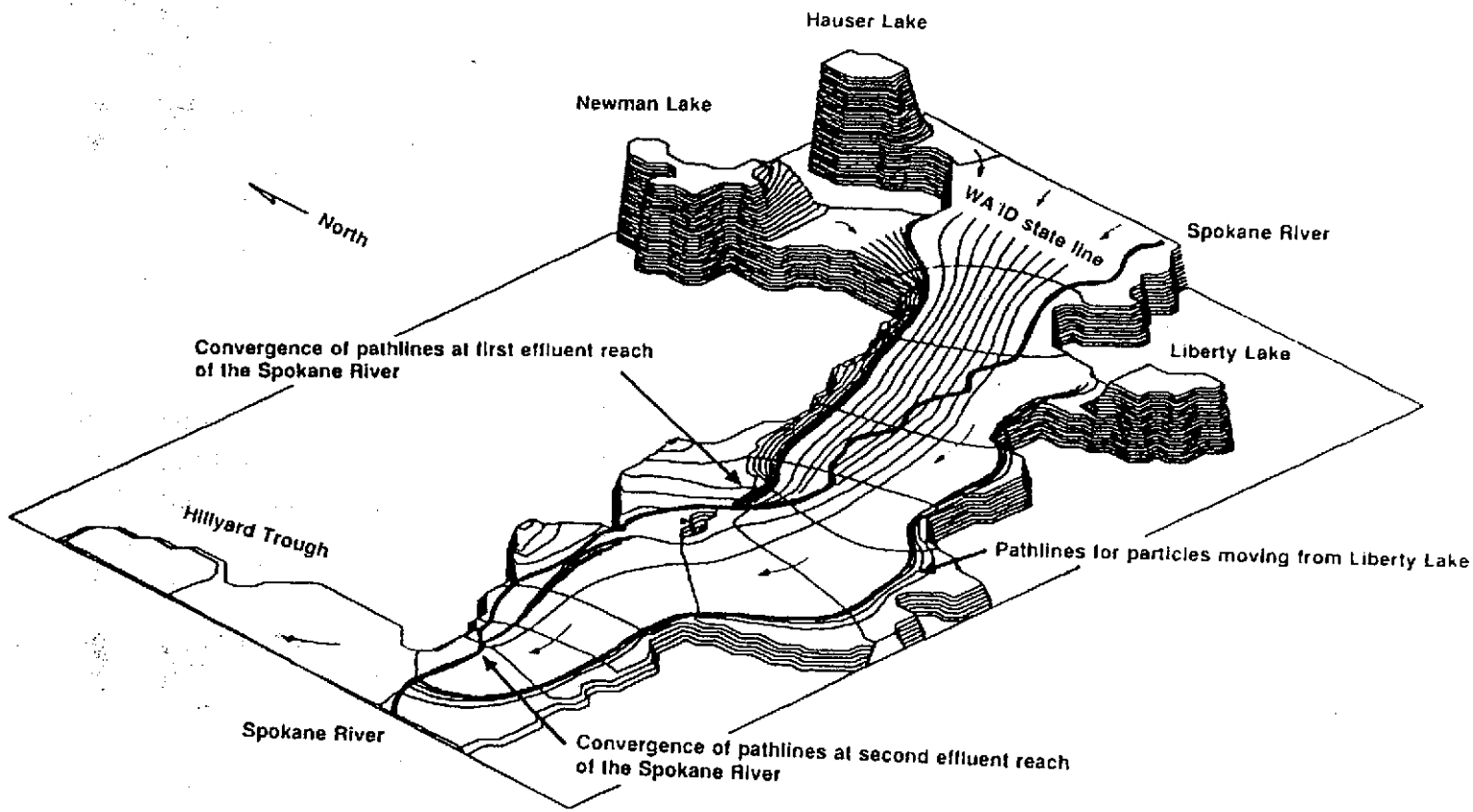


Figure 11. View to northeast (up-gradient) of the groundwater table map of the Spokane valley portion of the Spokane Valley/Rathdrum Prairie Aquifer system produced by computer simulation by utilizing MODFLOW (Buchanan and Olness, 1993). Note streamlines produced by forward-tracking 25 particles placed at the state line, Newman and Liberty Lakes, WA. Particles move toward effluent (gaining) reaches of the Spokane River, WA between Sullivan and Trent and just below Upriver Dam and Greene Street. Arrows indicate direction of groundwater flow.

Spokane. Note the convergence of pathlines in the area between Sullivan and Trent road, the first effluent reach of the Spokane River west of Post Falls Dam (Table 8). Travel time for particles introduced into the model at the state line, travelling forward through time along these pathlines toward the west, takes about three years to reach Sullivan and Trent, where the particles then enter the river. There is also convergence of flow lines below Upriver Dam and Greene Street (Fig. 11) in the second effluent reach considered by Patmont et al. (1985; Table 8). Particles introduced at the state line will require approximately six years to reach this discharge point and move into the river. Also note that surface water infiltrating the aquifer at Liberty Lake will enter the Spokane River in this area, taking about 14 years to travel the intervening distance.

The groundwater flow model for the area between Havana Street and the Little Spokane River has not been rigorously calibrated (Buchanan, on-going work), thus it can not be used to verify or confirm the Patmont et al. (1985; 1987) work. However, the model does reflect the general conditions in the SVRPA in this area, and can be utilized to graphically illustrate the pathlines that groundwater will travel in this portion of the system. Figure 12 shows the pathlines for particles introduced into the aquifer along the location of Havana Street as they travel to the north and northwest and discharge into the Little Spokane River. Travel time for particles introduced at Havana Street, and travelling northward through the Hillyard Trough corridor east of Five Mile Prairie, will require about 17 years to reach the Little Spokane River downstream of Dartford. Aquifer discharge to the Little Spokane River is through diffuse seepage and point sources such as Griffiths Spring and Waikiki Springs. Figure 12 shows that a small proportion of groundwater flows along the west side of Five Mile Prairie

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and toward the mouth of the Little Spokane River. Work done in this area of the SVRPA at the Northside Landfill by CH2M Hill (Grunenfelder, pers. comm.) corroborates this relationship. Travel time from Havana Street to the mouth of the Little Spokane River exceeds 30 to 50 years as predicted by the groundwater flow model.

Water Quality Monitoring of the Aquifer

The most comprehensive set of groundwater quality data that exists for the SVRPA in Washington was gathered during the '208' study (Esvelt, 1978). In a cooperative study with the U.S. Geological Survey (Vaccaro and Bolke, 1983) more than 150 locations were sampled four to twelve times during the year long study from the state line to the Little Spokane River (Fig. 13). Vertical variation in groundwater quality in the SVRPA was characterized by using a number of "depth selective" wells; however, no water quality samples were obtained from the aquifer at a depth more than 50 feet below the groundwater table.

Based on the results of this work, and on the modeling by Bolke and Vaccaro (1981), Patmont et al. (1985) concluded that the interaction between the aquifer and the Spokane River was well understood. Therefore, to account for non-point source aquifer loading rates to the Spokane River, Patmont et al. (1985) regularly sampled four wells in the identified aquifer discharge zones adjacent to the river (Patmont et al., 1985). Three of the wells utilized by Patmont et al. (1985; Trentwood Progress, Orchard #1 and Walsh City Landfill) were part of the '208' program (Fig. 13). The Knorr Brothers (Mielke) well was also monitored to characterize the seepage at Upriver Dam, but it could not been located during this review.

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Furthermore, Patmont et al. (1985) used data from an additional 24 wells to understand the phosphorus distribution in the SVRPA, but the authors did not describe the locations or name them.

Given the understanding of the SVRPA system as revealed through the modeling work by Buchanan and Olness (1993) and this investigation, Patmont et al. (1985) sampling was inadequate to fully characterized aquifer non-point source phosphorus loading to the Spokane and Little Spokane rivers. The four wells regularly sampled by Patmont et al. (1985) may not accurately reflect phosphorus concentrations in the aquifer that are entering the Spokane River in the effluent reaches. The Trentwood Progress well (Fig. 13) is too close to the northern edge of the SVRPA system and is probably not representive of water quality in the main flow of the groundwater moving from up gradient and recharge zones in Idaho. The Orchard #1 well sampling site is probably an acceptable monitoring point for groundwater travelling toward the effluent reach of the Spokane River below Upriver Dam, and the Landfill well near the Northside Landfill site may also be adequate to monitor water quality in this region of the SVRPA (Fig. 13). Construction details of these wells were not investigated during this review, so comment on their appropriateness for monitoring vertical variation in groundwater quality beneath the groundwater table is not possible. Again, the location of the Knorr Brothers well in the vicinity of Upriver Dam is unknown.

The Hillyard Trough area was left unmonitored by Patmont et al. (1985) since it was only considering non-point source phosphorus loading to the Spokane River. However, this area of the SVRPA is very important to phosphorus loading to the Little Spokane River given that a significant

volume of groundwater is moving northward through this area as indicated in Figure 12.

More data on the variation of groundwater quality with depth in the aquifer is important and additional investigation is necessary. The limited data presented by Esvelt (1978) and Vaccaro and Bolke (1983) from three depth selective wells shows that there are significant changes (reduction) in water quality parameters with increasing distance beneath the groundwater table. Vertically infiltrating septic plumes, for example, driven downward through the soils by seasonal rainfall, have approximately neutral density when they encounter the water table. As a result the plumes no longer descend, and the highest concentrations of various compounds occurs at or near the water table as the '208' program data suggests (Esvelt, 1978). Data from other sand aquifers also supports this relationship (Robertson et al., 1991). Significant stratification can occur in the upper 50 feet of the SVRPA, where these compounds move horizontally and probably transported at rapid rates toward discharge points. That is, the highest concentrations of TP may occur in the portion of the aquifer that most strongly interacts with the river system. As a side note, many people that are opposed to sewering the Spokane valley incorrectly assume that the wastewater infiltrating from septic systems will mix with the entire volume of water in the SVRPA system, diluting it to concentrations that are well below concern. However, the data exists to the contrary that strongly indicates that little vertical mixing and attenuation occurs in the aquifer, and that the highest concentration groundwaters are transported horizontally, and at rapid rates, toward the effluent reaches of the Spokane River. Therefore, source control continues to be an important method to reduce TP loading to

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the aquifer, and consequently the Spokane River, rather than relying on a dilution mechanism.

Spokane River Phosphorus Attenuation Model and Future Work

The effective TP load to Long Lake from aquifer/atmosphere inputs generated by the phosphorus attenuation model is a summation of several variables and multiple fixed values. The mean daily TP load from the atmosphere is set in the model at 0.4 kg/day (Table 9). Therefore, most of the mean daily TP load is from the aquifer and is a composite of the six areas where the aquifer flows into the Spokane River plus an additional region of residual ground water inflow (Table 9). The model adjusts aquifer inflow along given river reaches based on the magnitude of flow from the outlet of Lake Coeur d'Alene. The TP concentration for the various aquifer inflows is constant and unique. River reaches, volumes of aquifer inflow and mean daily TP load for each reach are also given in Table 9. If the same flow for each year is assumed, then TP load to the Spokane River during the growing season from the aquifer/atmosphere remains unchanged. Under median flow conditions, the model estimates that the aquifer/atmosphere contributes 31.5 kg/day of total phosphorus to the river. If the actual mean TP concentrations in the various reaches of the aquifer were at the lower limit of their respective standard errors of the mean, then the aquifer/atmosphere would contribute 25.0 kg/day of TP (Appendix D). With lower aquifer TP concentration, the resultant total effective TP load to Long Lake in 1992 would have been 190.9 (±19.2) kg/day. However, if the actual mean TP concentration were at the upper limit of their respective standard errors, then the aquifer/atmosphere would contribute 39.0 kg/day of TP (Appendix E). With higher TP aquifer concentration, the total

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resultant effective TP load to Long Lake in 1992 would have been 204.9 (±19.8) kg/day.

In 1992, the overall effective TP load to Long Lake was 197.7 (±19.5) kg/day using the mean TP concentration for the aquifer (Soltero et al., 1993). The difference between the high estimate and the low estimate was 14.0 kg/day of TP. This range of error appears to significantly enough to substantiate further investigation of TP concentrations for various aquifer inflows to the Spokane and Little Spokane rivers.

To better characterize non-point source TP loading to the surface water system and to assess overall the water quality in the SVRPA system, additional groundwater monitoring sites are needed at specific sites within the aquifer, as well as better vertical discretization of data gathered during any new monitoring effort. In order to more completely monitor the TP loading from the SVRPA system to the Spokane and Little Spokane rivers, quarterly sampling of four existing '208' wells is recommended. Figure 13 shows the general locations of the wells. The C.P.M. Sullivan Road well will monitor aquifer flow into the first gaining reach of the Spokane River in the valley as well as monitor any industrial impact on the aquifer in this area. The '208' SCC well will similarly monitor the aquifer contribution to the second effluent reach immediately below Upriver Dam (Figure 11). The '208' Arlington School well can provide intermediate monitoring of TP concentrations in the aquifer in the Hillyard Trough area, while the Whitworth Test well will monitor a major portion of the aquifer contribution to the Little Spokane River.

Such a program will also enable assessment of the changes in groundwater quality as a result of sewering and other land use management practices, and allow comparison to the baseline data gathered during the

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'208' monitoring program. Future work should utilize selected '208' wells, with a more frequent and continuous sampling schedule. Additional new wells may be needed in the SVRPA at the state line, in the Spokane valley area and in the Hillyard Trough area because the existing network of '208' wells do not appear to be adequately located, both areally and vertically, to assess TP concentrations in the aquifer. These new monitoring wells should be completed at various depths so that water quality stratification can be delineated.

Work on the aquifer model from Havana Street, down gradient to the discharge points along the Little Spokane River needs to continue (Buchanan, on-going work), with a calibrated groundwater flow model as the result. The exchange of groundwater between the river and the SVRPA in this area remains poorly characterized, and the flow model will allow better understanding of this relationship. Coupling this flow model with work done in the Spokane valley (Buchanan and Olness, 1993) and that in Idaho by Painter (pers. comm.) will give planners/managers an important tool to assess the impact that urban growth, increased pumping and changing land use practices will have on the SVRPA.

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Table 16. Output from the Spokane River Phosphorus Loading Attenuation Model using calculated flows and measured total phosphorus concentrations at the outlet of Lake Coeur d'Alene, ID.

1990, flow = 4451, conc = 11.9

1990

========== SUMMARY OF INPUT VALUES FOR SURFACE SOURCES ==========

SOURCE	NET Q (MGD)	TP REMOVAL (%)	TP (KgP/Day)	REACH(I,J)
LAKE CDA	2876.756	NA	124.1392	0 , 1
CDA STP	5.25	33.05599	60.96001	1 , 1
Hayden L	0	10	0	2 , 1
Post Fal	.3	32.13069	14.88	3 , 1
Rath STP	0	10	0	4 , 2
Liberty	.35	35.43289	4.260001	5 , 1
SIP WTP	.6	-34.69283	8.520001	7 , 1
Kaiser	.2	0	.92	7 , 2
Stormwat	1.053496	0	1.395732	8 , 1
Inland E	2.95	0	5.9	9 , 1
Millwood	.018405	10	.0396342	9 , 2
Hangman	22.95193	0	8.1365	12 , 1
Spokane	34.92	89.15584	60.05996	14 , 1
CSO/Strm	3.535353	0	6.829546	14 , 2
NW Terr	0	10	0	15 , 1
L SPOK R	286.5979	NA	40.23489	17 , 1

WOULD YOU LIKE TO EDIT A SOURCE VALUE? (Y/N)
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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Cadmium, Lead, and Zinc in the Spokane River

Recommendations for Total Maximum Daily Loads and Waste Load Allocations

by
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Abstract

The Spokane River regularly violates water quality standards for zinc. Standards for lead and cadmium are also exceeded frequently, especially at higher flows. A procedure for determining Waste Load Allocations (WLAs) for all NPDES point source discharges to the Spokane River was developed based on meeting aquatic life criteria in the effluent. Permit limits for NPDES dischargers will be developed in the future for each individual discharger under Ecology's current schedule for permit cycles. Effluent limits for cadmium, lead, and zinc will be determined by comparing existing concentrations of metals in effluent, where adequate data exist, with the water quality criteria associated with the effluent hardness. Whichever results in the lower permit limits will be chosen.

This method should not result in any unreasonable compliance issues and minimizes the addition of metals to a system that is already exceeding the criteria. It is also an alternative to developing very stringent water quality-based effluent limits that are severely restricted due to excessive upstream and out-of-state metal sources. This approach is consistent with the intent of the anti-degradation policy of the federal Clean Water Act and the policy enunciated in the Washington State Water Pollution Control Act (RCW 90.48) requiring "... all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state ...(AKART)".

Waste Load Allocations are established as a maximum discharge concentration (micrograms per liter) rather than a discharge loading (pounds per day). The federal Clean Water Act allows for the use of allocations in mass per time or other appropriate measure. In this case, a concentration measure is appropriate, because the relationship between the effluent-based criterion and receiving water quality holds for all effluent and river flow rates.

The Spokane River at the state line is the upstream boundary for the present Total Maximum Daily Load (TMDL) in Washington. The proposed TMDL and analysis to address point source discharges and other sources of metals in the Spokane River requires that the Spokane River will meet Washington state's water quality standards, at a point where the river enters Washington State, within a reasonable period of time. The ultimate success and appropriateness of this TMDL/WLA depends solely on whether the Idaho Department of Environmental Quality or EPA develops and implements an adequate TMDL/WLA and management plan that will result in meeting Washington's water quality standards at the upstream end of the Spokane River.

Introduction

Objective

The Spokane River regularly has elevated levels of zinc, and frequently has elevated levels of lead and cadmium. The river does not meet water quality standards for these metals. The Washington State Department of Ecology, Idaho's Division of Environmental Quality (IDEQ), and the U. S. Environmental Protection Agency (EPA) are evaluating regulatory actions to address this issue. The various entities that are permitted under NPDES to discharge to the Spokane River have also been active in proposing approaches to regulate water quality in the Spokane River.

The objective of this report is to propose an approach for regulating point source dischargers in Washington under a Total Maximum Daily Load (TMDL), instead of developing unreasonably stringent water quality-based effluent limits on a case-by-case basis when upstream concentrations of metals already exceed criteria. At the same time, Idaho and EPA are developing a TMDL to control pollution sources in Idaho. One of the necessary objectives of the Idaho and EPA TMDLs is to meet Washington's water quality criteria in the Spokane River. This TMDL by Ecology addresses NPDES discharges in Washington, and uses an approach that will preferably be similar to EPA's proposed regulation of NPDES dischargers in Idaho.

Spokane River Dischargers and Hydrology

The source of the Spokane River is Lake Coeur d'Alene located in Idaho (Figure 1). The river flows in a westerly direction from Lake Coeur d'Alene, across the state line, to the city of Spokane. From Spokane, the river flows in a northwesterly direction to its confluence with the Columbia River. In Idaho, the following wastewater treatment plants (in order proceeding downstream from the river source) are permitted to discharge to the river:

- City of Coeur d'Alene Advanced Wastewater Treatment Plant (AWTP)
- Hayden Area Regional Sewer Board (HARSB) Publicly-owned Treatment Works (POTW)
- City of Post Falls POTW (also serves the City of Rathdrum)

Continuing downstream, the dischargers in Washington are as follows:

- Liberty Lake POTW
- Kaiser Aluminum Industrial Wastewater Treatment Plant (IWTP)
- Inland Empire Paper Company IWTP
- City of Spokane AWTP

The current and projected effluent design flows from the NPDES dischargers are presented in Table 1 (SRDG, 1997).

Substantial inflows of groundwater enter the river beginning downstream from the Liberty Lake outfall. The groundwater inflows significantly increase the river flow rate, especially when surface water flows are low. Table 2 presents the equations used to estimate the aquifer inflow and outflow to the river based on the compilation of data used for the phosphorus attenuation model of the basin (Patmont *et al.*, 1985; Patmont *et al.*, 1987).

Aquifer inflows and outflows were assumed to be correlated to river flows up to a flow of 4,000 cfs from Lake Coeur d'Alene based on the evaluations by Patmont *et al.* The total net aquifer inflows range between about 500 to 800 cfs depending on river flow. For comparison, the combined effluent flow from all current NPDES dischargers is about 128 cfs. The *lowest* 7-day average flow with a 10-year recurrence for the Spokane River at the upstream end near Post Falls (river mile 100.7) is approximately 187 cfs; the *highest* 7-day average flow with a 10-year recurrence is approximately 36,000 cfs; and the annual average flow is approximately 6,300 cfs.

A recent groundwater modeling study by CH2M-Hill suggests that aquifer exchange may be less than previous estimates (CH2M-Hill, 1998). However, the results of the CH2M-Hill study were not used for this study because their reach definitions were not as detailed, and their findings are still under review. Also, if future review of the aquifer exchange rates results in confirmation of CH2M-Hill estimates, then the recommended effluent limits to meet criteria for cadmium, lead, and zinc will not change because the concentrations of metals in the aquifer are much lower than water quality standards, and therefore the recommended effluent limits do not depend on the aquifer exchange rates. However, for future evaluations of limits for other constituents that are a function of available dilution (*e.g.* ammonia), it may be preferable to use the revised aquifer exchange rates by CH2M-Hill.

TMDL Boundaries

Cadmium, lead, and zinc concentrations in the Spokane River at the state line often exceed water quality standards. The Bunker Hill Superfund site is the largest source to discharge heavy metals in the Idaho sub-basin (IDEQ, 1998). More than a century of deep-shaft mining activities for sulfide-based heavy metals has elevated levels of cadmium, lead, arsenic, and zinc in the South Fork Coeur d'Alene River, which discharges into Lake Coeur d'Alene. Although measures have been taken to dramatically reduce loading to the South Fork, existing concentrations of some metals are still above those in most surface waters of the nation.

IDEQ is currently developing a TMDL for metals and is initiating projects to further reduce metals loads to the South Fork. That TMDL also must have the objective of eventually meeting Washington's water quality standards in the Spokane River. The EPA is working closely with the IDEQ to ensure that progress in reducing loads of metals continues in Idaho.

Ecology is also monitoring the trend in water quality at the state line to detect expected decreases in metals concentrations.

The outlet of Lake Coeur d'Alene is a logical upstream boundary for a separate TMDL analysis to address point source discharges and other sources of metals in the Spokane River, provided that IDEQ develops an adequate TMDL and management plan to meet Washington's water quality standards at the border. However, delays in TMDL development in Idaho have caused Washington State to proceed with a TMDL/WLA which begins with the upstream reach of the Spokane River beginning at the Idaho-Washington state line, and the downstream boundary located below the outfall for the City of Spokane's AWTP. Spokane is the most downstream NPDES discharger, and is therefore considered to be the most downstream potential contributor of significant concentrations of cadmium, lead, and zinc.

Data Analysis and Modeling

Water Quality Criteria for Cadmium, Lead, and Zinc

Water quality criteria to protect aquatic life (established in WAC 173-201A-040) apply to the dissolved fraction for cadmium, lead, and zinc and are calculated with the following equations for chronic (4-day average concentration in micrograms per liter not to be exceeded more than once every three years) and acute (one-hour average concentration in micrograms per liter not to be exceeded more than once every three years based on hardness in milligrams per liter as $CaCO_3$):

Dissolved Cadmium

Chronic ≤ (1.101672-((LN(hardness))*(0.041838)))*EXP(0.7852*(LN(hardness))-3.49)
Acute ≤ (1.136672-((LN(hardness))*(0.041838)))*EXP(1.128*(LN(hardness))-3.828)

Dissolved Lead

Chronic ≤ (1.46203-((LN(hardness))*(0.145712)))*EXP(1.273*(LN(hardness))-4.705)
Acute ≤ (1.46203-((LN(hardness))*(0.145712)))*EXP(1.273*(LN(hardness))-1.46)

Dissolved Zinc

Chronic ≤ 0.986*EXP(0.8473*(LN(hardness))+0.7614)
Acute ≤ 0.978*EXP 0.8473*(LN(hardness))+0.8604)

Figures 2 and 3 depict two hypothetical waters in relation to the water quality criterion curve for cadmium, lead and zinc. If one were to mix the two waters, the resulting mixed concentration of metals and hardness would always fall on a straight line between the two points. Assuming Point A is the Spokane River, meeting the water quality criteria as it exits Lake Coeur d'Alene, a discharge (Point B) at or below the effluent-based criterion would result in a mixture that falls below the criterion curve. Because of the concave shape (bending downward) of the cadmium and zinc criteria curves, any combination of cadmium, zinc, and hardness for the discharge that falls below the curve will mix with river water (A) to form a mixture that also falls below the curve. Therefore, in this situation, the effluent-based criterion approach is protective of state water quality standards.

However, for lead, the criterion curve is convex, or bending upward, leaving open the possibility that a mixture could exceed the criterion even when the waters individually fall below the criterion (a straight line between two points on the criterion curve will fall above the curve). If discharges do not exceed the lead concentration on the tangent line associated with the effluent hardness, the lead criterion will not be exceeded in the mixture of effluent and river water (Figure 3 and Appendix A). This approach is recommended to assure that limits are protective of state water quality standards.

If other sources of water with greater hardness than the river are also added to the mixture, for example groundwater or tributaries, then the resulting mixture including these multiple sources would also meet the criteria provided that no single source exceeds the criteria for cadmium or zinc, or exceeds the tangent line for lead. If the effluent concentrations of metals are below aquatic life criteria, then the metal toxicity in the river below the outfall is reduced by the hardness affect, which allows the river to either be closer to meeting the water quality standard or creates a small safety buffer.

Effluent Data

Typical effluent data are presented in Appendix B. The Spokane River Dischargers Group (SRDG) is currently collecting samples to characterize effluent quality. Appendix B presents preliminary results from the November-December 1997 sampling, as well as sampling by the City of Spokane AWTP from July 1996 through April 1998. All samples of effluent from all dischargers have been found to meet the chronic aquatic life criteria for cadmium, lead, and zinc at the effluent hardness. Effluent lead has also been consistently below the tangent equation for lead shown in Figure 3.

River Modeling

A mass-balance model of the Spokane River was developed to evaluate the effect of different effluent loading on metals and hardness. The model includes a flow balance that accounts for inflow of water from the outlet of Lake Coeur d'Alene, inflow from NPDES dischargers, and inflow/outflow from the aquifer and Hangman Creek. The model divides the river into reaches

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as shown in Table 2. For each reach, the flow balance is calculated from the following equation:

$$Q_{down} = Q_{up} + Q_{npdes} + Q_{aquifer}$$

where:

Q_{down} = flow at the downstream end of the reach (cfs)
Q_{up} = flow at the upstream end of the reach (cfs)
Q_{npdes} = flow from NPDES dischargers (Table 1) (cfs)
$Q_{aquifer}$ = flow from or to the aquifer or tributary (Table 2) (cfs)

The mass balance for hardness was calculated from the following equation:

$$H_{down} = [\, Q_{up} H_{up} + Q_{npdes} H_{npdes} + Q_{aquifer} H_{aquifer} \,] / Q_{down}$$

where:

H_{down} = hardness (mg/L as $CaCO_3$) at the downstream end of the reach
H_{up} = hardness at the upstream end (assumed to be H_{down} from previous reach)
H_{npdes} = hardness of NPDES effluent
$H_{aquifer}$ = hardness of aquifer (if aquifer inflow) or H_{up} (if aquifer outflow)

For metals, the mass balance was as follows:

$$M_{dis,down} = F_{down} [\, Q_{up} M_{trec,up} + Q_{npdes} M_{trec,npdes} + Q_{aquifer} M_{trec,aquifer} \,] / Q_{down}$$

where:

$M_{dis,down}$ = dissolved metals (ug/L) at the downstream end of the reach
F_{down} = fraction of dissolved/total recoverable metals at downstream end of reach
$M_{trec,up}$ = total recoverable metals at upstream end of reach ($=M_{dis,down} / F_{down}$ from previous reach)
$M_{trec,npdes}$ = total recoverable metals of NPDES effluent
$M_{trec,aquifer}$ = total recoverable metals of aquifer (if aquifer inflow) or $M_{dis,up}$ (if aquifer outflow)

The fraction of dissolved/total recoverable metals was estimated to equal the conversion factor used to convert the total recoverable criteria to the dissolved criteria (EPA, 1996). It was not considered necessary to use site-specific ratios of dissolved/total recoverable metals because the conversion factors generally represent a worse-case scenario of higher fractions of dissolved metals, and the use of site-specific ratios was not expected to result in different conclusions provided that all sources meet water quality criteria at their respective hardness. Aquifer inflow of total recoverable metals to the river was assumed to equal the dissolved metals concentration estimated during model calibration.

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Model Calibration

Calibration of the model to actual conditions in the river involved estimation of aquifer hardness and metals to match observed concentrations in the river. All other inputs in the flow and mass balance equations were directly estimated from available data:

- The effluent flow rates were assumed to be the current flows presented in Table 1.
- Aquifer inflow/outflow rates were estimated as presented in Table 2.
- Outflow from Lake Coeur d'Alene was assumed to be various values between the normal range of 300 to 20,000 cfs.
- Effluent hardness was assumed to be approximately 145 mg/L as $CaCO_3$ based on the 10th percentile hardness for the Spokane AWTP (CH2M-Hill, 1997). Effluent hardness from Kaiser IWTP was assumed to be a lower value of 120 mg/L as $CaCO_3$ based on the mixture of river and groundwater used for the production process.
- Effluent total recoverable cadmium, lead, and zinc were assumed to be approximate maximum values reported by the SRDG (0.3 ug/L cadmium, 2.5 ug/L lead, and 100 ug/L zinc).
- The ratio of dissolved/total recoverable metals was assumed to equal the conversion factor for the chronic criteria evaluated at the hardness of the river water. The effluent was assumed to partition at the same ratio of dissolved/total recoverable metals as the river at the mixing zone boundaries and after completely mixing with river water.
- The hardness for the outflow from Lake Coeur d'Alene was assumed to be 20 mg/L as $CaCO_3$. This represents the seasonal 10th percentiles for the low flow (July-February) and high flow (March-June) seasons (Pelletier, 1994), and also the 5th percentile of hardness from all seasons. Hardness was not found to be correlated with flow at the upstream end of the Spokane River (Appendix C).
- The hardness at river mile 85.3 and 66 was assumed to equal the 10% prediction limits from the regression equations with flow presented in Appendix C.
- The dissolved cadmium, lead, and zinc in the outlet of Lake Coeur d'Alene was assumed to equal the upper 90% prediction limit from the regression equations with flow presented in Appendix C for river mile 96-100.7.
- The dissolved cadmium, lead, and zinc at river mile 63.5-69.9 was assumed to equal the upper 90% prediction limit from the regression equations with flow presented in Appendix C.

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Relationships between hardness, metals, and flow are known at various locations in the Spokane River based on long-term ambient monitoring data (Appendix C). The model was calibrated for hardness by starting with the known upstream hardness and trying various values for groundwater hardness until the mass balance model predicted the observed downstream hardness. After the hardness was calibrated, the same approach was used to estimate the dissolved cadmium, lead, and zinc of the aquifer/tributary inflow. Appendix C presents the results of model calibration of aquifer hardness and metals.

Model Application to Various Scenarios of Effluent and River Flows

The calibrated mass balance model was next used to estimate concentrations of metals in the river for a variety of river flows and effluent flows (Appendix D). The model was used to evaluate whether water quality standards would be violated in the river if the effluent meets end-of-pipe limits based on effluent hardness. The following assumptions were made:

- The hardness for the outflow from Lake Coeur d'Alene was assumed to equal 20 mg/L as $CaCO_3$.

- The dissolved cadmium, lead, and zinc in the outlet of Lake Coeur d'Alene were assumed to equal the chronic criteria for protection of aquatic life at the hardness of the river.

- The dissolved cadmium and zinc in the effluent from NPDES dischargers were assumed to equal the chronic criteria for protection of aquatic life for the hardness of the effluent (Figure 2).

- The ratio of dissolved/total recoverable cadmium and zinc was assumed to equal the conversion factor for the chronic criteria evaluated at the hardness of the effluent or river water. The ratio of dissolved/total recoverable metals in the effluent was used to test whether criteria were met in the effluent. The effluent was assumed to partition at the same ratio of dissolved/total recoverable metals as the river at the mixing zone boundaries and after completely mixing with river water.

- For lead, the convex shape of the criterion curve precludes the use of the conversion factor as a default translators to a total recoverable lead limit. Appendix E presents a spreadsheet illustrating the problem. Two hypothetical waters are mixed, and total recoverable lead is tracked. The use of the default translation causes the effluent to exceed the water quality criterion at certain dilutions. Therefore, the total recoverable lead in the effluent from NPDES dischargers was assumed to equal the value predicted from the tangent line for the chronic criteria for total recoverable lead shown in Figure 3. Appendix E presents a comparison of alternative methods for estimating the WLA for total recoverable lead.

- Aquifer inflow/outflow rates were estimated as presented in Table 2.

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- Effluent hardness and aquifer hardness, dissolved cadmium, lead, and zinc were as estimated during calibration.

Various combinations of effluent and river flows were evaluated as follows:

- Current effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs.

- 20-year projected effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs (this scenario was run for zinc only because the conclusions for zinc were expected to be representative of cadmium and lead also).

- 50-year projected effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs (this scenario was run for zinc only because the conclusions for Zinc were expected to be representative of cadmium and lead also).

- 20-times current effluent flows combined with outlet flows from Lake Coeur d'Alene of 300, 2,000, and 20,000 cfs. This scenario was chosen to show the potential effect of extremely high flow rates from NPDES dischargers.

The results of the model runs (Appendix D) show that the water quality standards for cadmium and zinc would not be exceeded in the river if the effluent meets end-of-pipe limits based on effluent hardness. The water quality criteria for lead would not be violated if the maximum concentration of total recoverable lead in the effluent does not exceed the value predicted from the tangent line for the equation for the chronic criteria for total recoverable lead shown in Figure 3. The relationship between effluent-based criteria and receiving water quality holds for all river and effluent flow rates.

Proposed TMDL Approach

Permit limits for all point source discharges to the Spokane River will be established by comparing potential limits based on meeting aquatic life criteria at effluent hardness with AKART limits based on maintaining existing concentrations of metals in effluent, where adequate data exist. Whichever method results in lower limits will be selected for the permit. AKART based limits would be reevaluated at each permit re-issuance. These limits may change over time, but could never exceed the aquatic life criteria based limits. This method should not result in any unreasonable compliance issues and minimizes the addition of metals to a system already exceeding the criteria due to pollutant loading from an upstream state. This is consistent with the intent of anti-degradation policy of the federal Clean Water Act and the policy enunciated in the Washington State Water Pollution Control Act (RCW 90.48) requiring "... all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the state ...".

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The use of effluent hardness in the criteria equations to determine the potential limits will be termed the "effluent-based criterion" approach. There are several ways to illustrate the effect of effluent hardness on river metals conditions. In simple terms, applying the effluent-based criterion is analogous to treating the effluent discharge as if it were a tributary that has higher hardness levels than the river. The tributary would be allowed to achieve less stringent (*i.e.*, higher) metals criteria by virtue of its elevated hardness levels. Similarly, the criteria applied to protect the mainstem would be more stringent due to its lower hardness levels. The focus of concern then becomes the point of mixing between the tributary and river.

The analogy to a tributary can be extended to selection of a load allocation (LA) for a tributary or a WLA for a point source. The LA for a tributary to a water quality-limited river would be the existing concentration in the tributary if it is lower than the criteria at the hardness of the tributary. Similarly, the permit limits for the NPDES dischargers will be either the potential limits based on meeting criteria at effluent hardness, or the potential limits based on maintaining existing concentrations (performance-based), whichever is more restrictive.

Waste load allocations (WLAs) are established as a maximum discharge concentration (micrograms per liter, or ug/L) rather than a discharge loading (pounds per day). TMDL regulations allow for the use of allocations in mass per time or "other appropriate measure" (40 CFR 130.2). In this case, a concentration measure is appropriate because the relationship between the effluent-based criterion and receiving water quality holds for all effluent flow rates. The use of effluent flow to establish a loading limit would not only be unnecessary, but also could be misconstrued to represent a restriction on effluent flow. Also, a loading limit could require unnecessary TMDL and permit modifications to change loading limits as communities grow and flows increase.

Waste Load Allocations (based on meeting the aquatic life criteria at effluent hardness)

For cadmium and zinc, potential limits based on aquatic life criteria for all point source discharges to the Spokane River are estimated from the water quality criteria associated with the effluent hardness. For lead, limits based on aquatic life criteria are estimated from the point on a line tangent to the lead criterion curve (intersecting the curve at the river hardness value) associated with the effluent hardness. Figure 4 shows the recommended equations for each metal.

The chronic aquatic life criteria are expressed as 4-day-average dissolved metal concentrations. The 5th percentile value of the effluent hardness for each facility should be used by permit writers to establish aquatic life criteria at effluent hardness for derivation of potential limits. Permit writers will also translate the dissolved criteria into total recoverable metal limitations pursuant to the NPDES regulations and Ecology's Permit Writer's Manual.

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The hardness of the wastewater effluent is significantly higher than the hardness of the Spokane River. The metals criteria for protection of aquatic life are based on hardness, because the toxicity of metals to aquatic life decreases as hardness increases. Thus, as the Spokane River flows downstream, its loading capacity (its total maximum daily load) for metals increases due to inflows of higher hardness water (mainly groundwater and to a lesser extent effluent discharges). While the loading capacity changes are relatively minor on the Idaho stretch of the river, changes in river hardness and flow due to groundwater inflows and effluent discharges result in significant loading capacity increases in Washington.

Because of the concave shape (bending downward) of the cadmium and zinc criteria curves (Figure 2), any combination of cadmium, zinc, and hardness for the discharge that falls below the curve will mix with river water to form a mixture that also falls below the curve. Therefore, in this situation, the effluent-based criterion approach is protective of state water quality standards. However, for lead, the criterion curve is convex, or bending upward, leaving open the possibility that a mixture could exceed the criterion even when the waters individually fall below the criterion (a straight line between two points on the criterion curve will fall above the curve). If discharges do not exceed the lead concentration on the tangent line associated with the effluent hardness, the lead criterion will not be exceeded in the mixture of effluent and river water (Figure 3).

The criterion curve for lead also affects the options available for translating a dissolved lead WLA into a total recoverable lead WLA for NPDES permitting. This issue is discussed later in this document in the "Example Calculations" section.

Potential Limits (based on performance)

Washington State law (RCW 90.48) requires that dischargers use all known available and reasonable methods to prevent and control the pollution of the waters of the state (AKART). A performance-based assessment of existing condition in the effluent is a good measure of what can be reasonably achieved using the existing technology. Performance-based limits would be established using the statistical methods in Ecology's Permit Writer's Manual (Ecology, 1998) and EPA's Technical Support Document (EPA, 1991). These performance-based limits would be reevaluated during each permit re-issuance.

Since many dischargers do not have adequate data to estimate the effluent concentration of metals, a monitoring program will need to be established. Ecology's Permit Writer's Manual recommends that greater than 10 samples are required to estimate effluent variability. Therefore, the recommended minimum sampling frequency is monthly sampling for at least 12 months to provide sufficient data to estimate effluent quality of metals. The sampling and analysis methods should be conducted under a Quality Assurance/Quality Control Project Plan (QAPP) that describes the methods to be used. EPA's 1600-series methods (EPA, 1995) are recommended for sampling trace metal concentrations that are less than detection limits for the usual 40 CFR Part 136 methods, unless the QAPP demonstrates that alternative methods are sufficient the measure the expected concentrations.

Implementation of WLAs in NPDES Permits

The WLAs will be implemented as permit limits in the NPDES permits for each facility. Using statistical permitting procedures, Ecology will determine whichever potential limits are more restrictive based on comparison of:

- Potential limits based on meeting aquatic life criteria at effluent hardness, or
- Potential limits based on maintaining existing concentrations of metals in effluent (AKART), where adequate data exist.

Whichever method results in lower limits will be selected for the permit limit.

Example Calculations: WLAs for the Spokane AWTP

The following calculations are provided as an example of the waste load allocation method for each facility. The example calculation is performed for the City of Spokane Advanced Wastewater Treatment Plant (SAWTP). During permit development, similar calculations would be performed for each facility, based on the effluent hardness and metals data available to the permit writers.

A Microsoft Excel spreadsheet was developed to perform the calculations (Appendix F). The equations used in the spreadsheet are presented in Appendix G. Appendices F and G should be consulted to follow the calculations presented in this example.

The equations that were used in the spreadsheet to calculate permit limits were taken from the EPA Technical Support Document for Water Quality-based Toxics Control (EPA, 1991), and have been widely used in the Ecology NPDES program (Ecology, 1998; *e.g.*, Ecology's PWSPREAD and TSDCALC7 spreadsheets).

WLAs (based on meeting the aquatic life criteria at effluent hardness)

1. *Estimated 5th percentile hardness*

   SAWTP has collected 234 samples of effluent hardness between 6/25/96 and 2/18/98. The 5th percentile hardness for this sample set is estimated to be 138 mg/L.

2. *Chronic aquatic life criteria*

   The following calculations were performed to establish the chronic aquatic life criteria (ALC) for cadmium, lead, and zinc for the SAWTP facility.

- Chronic ALC for dissolved cadmium = (1.101672-[ln(hardness)(.041838)]) * ($e^{(.7852[\ln(\text{hardness})]-3.49)}$) = 1.31 ug/L

- Chronic ALC for dissolved lead = 0.02378(hardness) - 0.05505 = 3.23 ug/L dissolved Lead

- Chronic ALC for dissolved zinc = $.986e^{(.8473[\ln(\text{hardness})]+.7614)}$ = 137 ug/L

3. *Ratio of total recoverable/dissolved metals, and*

4. *Chronic aquatic life criteria for total recoverable metals*

For cadmium and zinc, default conversion factors in the federal criteria can be used to translate dissolved criteria to total recoverable metals. The conversion factors are 1/(1.101672-[ln(hardness)*(.041838)]) for cadmium, and 1/.986 for zinc. For the SAWTP facility, with a hardness of 138 mg/L $CaCO_3$, the default translators are 1.12 for cadmium and 1.01 for zinc.

Development of effluent-specific translators is also allowable, using parallel total recoverable and dissolved effluent samples to derive a conservative ratio of total recoverable-to-dissolved metals. Translators based on ratios in the river should be used if they are more restrictive than ratios for effluent.
The chronic aquatic life criteria, in terms of total recoverable cadmium and zinc, for the SAWTP example are as follows:

- Chronic ALC for total recoverable cadmium = 1.46 ug/L
- Chronic ALC for total recoverable zinc = 139 ug/L

For lead, the convex shape of the criterion curve precludes the use of the conversion factor as a default translator to a total recoverable lead limit. The use of the default translation causes the effluent to exceed the water quality criterion at certain dilutions (Appendix E).

As with cadmium and zinc, an effluent-specific translator is allowable. Development of this translator will require characterization of total recoverable and dissolved concentrations at a number of points between 0 and 100% effluent (diluted with ambient water, sampled at the same time) to ensure that the translator is protective of the dissolved criterion at all points of mixing.

Another option for developing total recoverable lead limits is to convert the dissolved criterion curve to the associated total recoverable criterion curve using the default conversion factor (see Figure 3). Then a tangent line to this curve at the river hardness value is used as the chronic aquatic life criterion for total recoverable lead, rather than using the dissolved criterion tangent (Figure 4) and an effluent-specific translator.

Using this approach and Figure 3 in the SAWTP example, the chronic aquatic life criterion for total recoverable Lead is:

- Chronic ALC for total recoverable lead = 3.49 ug/L total recoverable lead

5. *Number of samples (n2) required per month for compliance monitoring*

For the SAWTP example, 2 samples per month were assumed as a requirement for compliance monitoring. This number could be changed to any reasonable value between once per month and daily sampling.

6. *Coefficient of variation for effluent metals*

Effluent samples for metals were collected by SAWTP between 7/12/96 and 4/2/98. The coefficients of variation for cadmium, lead, and zinc were estimated from the 31 samples collected:

- CV for total recoverable cadmium = 0.431
- CV for total recoverable lead = 0.335
- CV for total recoverable zinc = 0.283

7. *Calculate maximum daily and average monthly permit limits from the aquatic life criteria*

The statistical method for calculating permit limits from the aquatic life criteria is presented in the EPA's Technical Support Document for Water Quality-based Toxics Control (EPA, 1991). A spreadsheet was developed to simplify the calculation procedure (Appendix F). Equations for the spreadsheet are presented in Appendix G.

The first step is to back-calculate a long-term average (LTA) concentration of metals that corresponds to the chronic aquatic life criteria (ALC). The LTAs for cadmium, lead, and zinc are as follows:

- LTA for total recoverable cadmium = 0.91 ug/L
- LTA for total recoverable lead = 2.4 ug/L
- LTA for total recoverable zinc = 101 ug/L

The next step is to calculate the maximum daily limit (MDL). The maximum daily limits (MDLs) for cadmium, lead, and zinc are as follows:

- MDL for total recoverable cadmium = 2.2 ug/L
- MDL for total recoverable lead = 4.9 ug/L
- MDL for total recoverable zinc = 186 ug/L

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The last step is to calculate the average monthly limits (AML). The average monthly limits (AMLs) for cadmium, lead, and zinc are as follows:

- AML for total recoverable cadmium = 1.4 ug/L
- AML for total recoverable lead = 3.4 ug/L
- AML for total recoverable zinc = 138 ug/L

Potential Limits Based on Performance

A performance-based assessment of the existing condition in the effluent is a good measure of what can be reasonably achieved using the existing technology. Performance-based limits would be established using the statistical methods in Ecology's Permit Writer's Manual (Ecology, 1998) and EPA's Technical Support Document (EPA, 1991). This evaluation would occur during each permit re-issuance cycle and would be documented in the Fact Sheet. The Fact Sheet is the basis document for each permit. While these performance-based limits may change over time they could never exceed the aquatic life criteria based limits.

Since many dischargers do not have adequate data to estimate the effluent concentration of metals, a monitoring program will need to be established. Ecology's Permit Writer's Manual recommends that greater than 10 samples are required to estimate effluent variability. Therefore, the recommended minimum sampling frequency is monthly sampling for at least 12 months to provide sufficient data to estimate effluent quality of metals.

Waste Load Allocations (the most restrictive of limits based on aquatic life criteria or performance)

The last step is to assign permit limits in terms of maximum daily and average monthly limits for the NPDES permits. The potential limits based on steps I and II above will be compared, and the most restrictive values will be chosen. This would be documented in the Fact Sheet during each permit re-issuance cycle.

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Figures

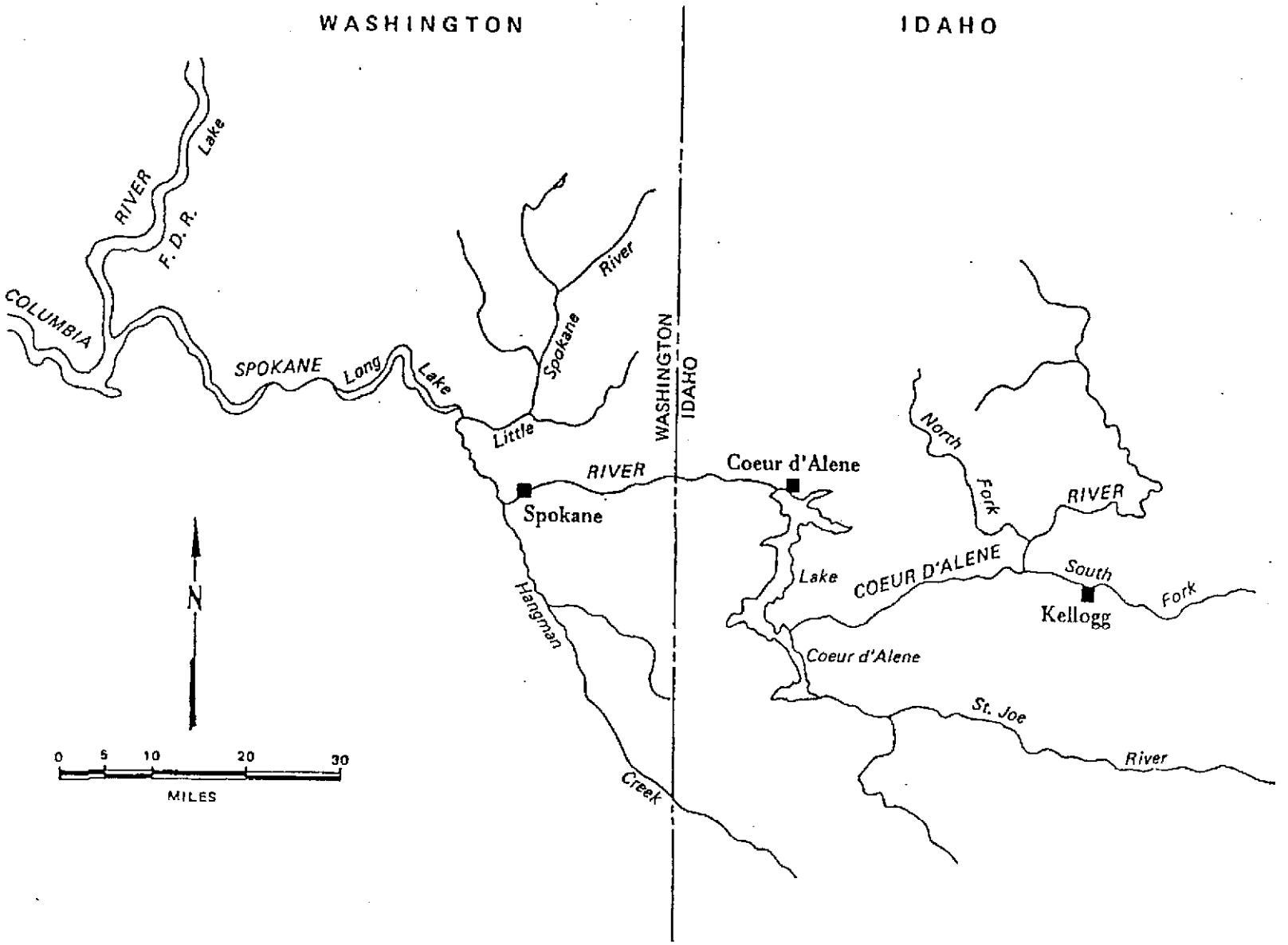


Figure 1. SPOKANE RIVER DRAINAGE SYSTEM

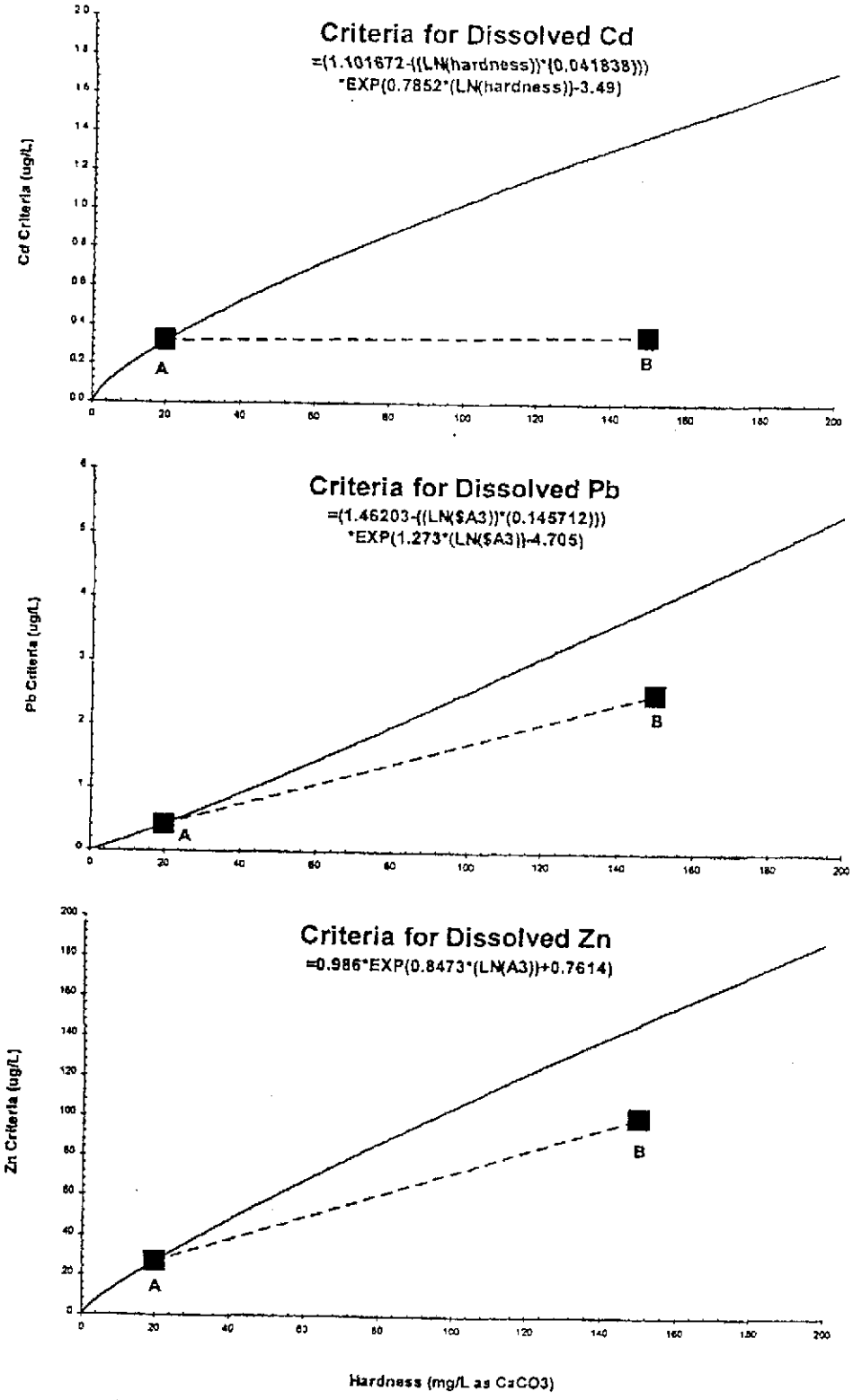


Figure 2. Chronic aquatic life criteria for dissolved Cd, Pb, and Zn.

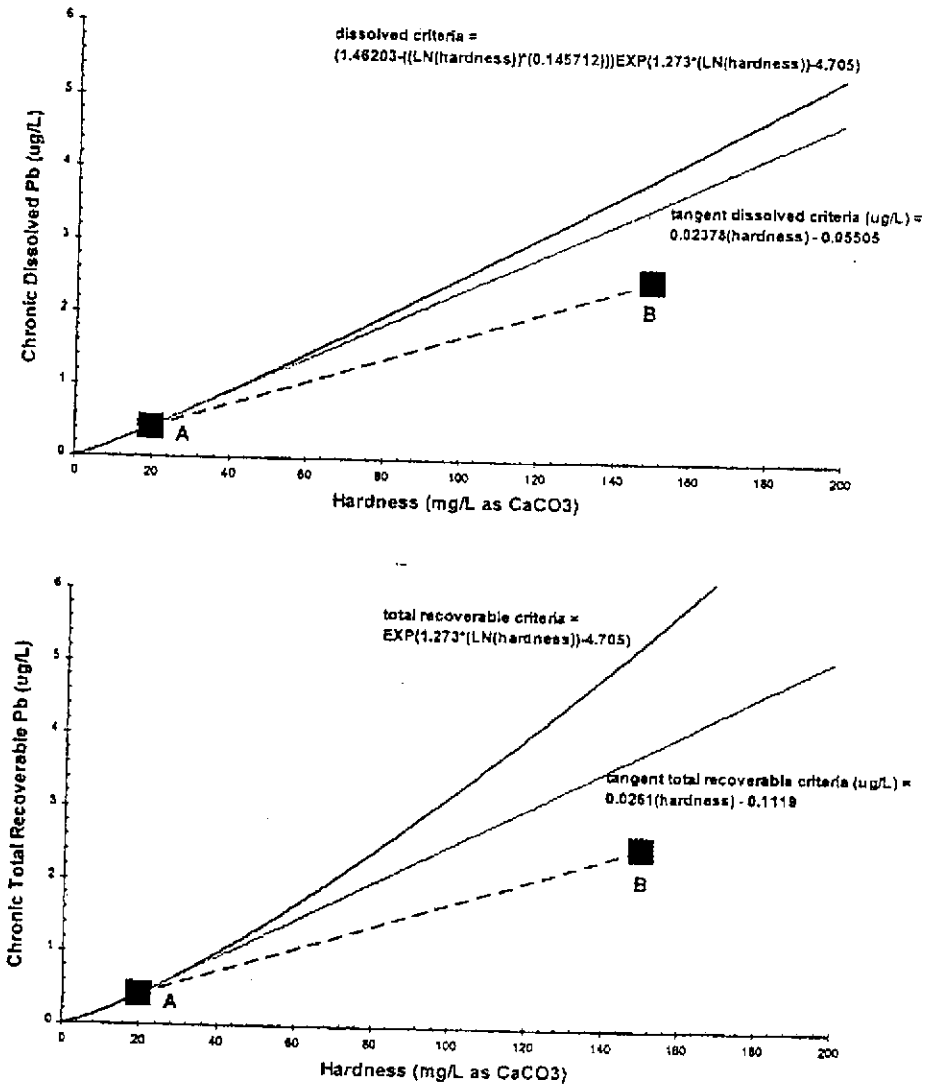


Figure 3. Chronic aquatic life criteria for dissolved Pb and total recoverable Pb (assuming the translator equals the conversion factor).

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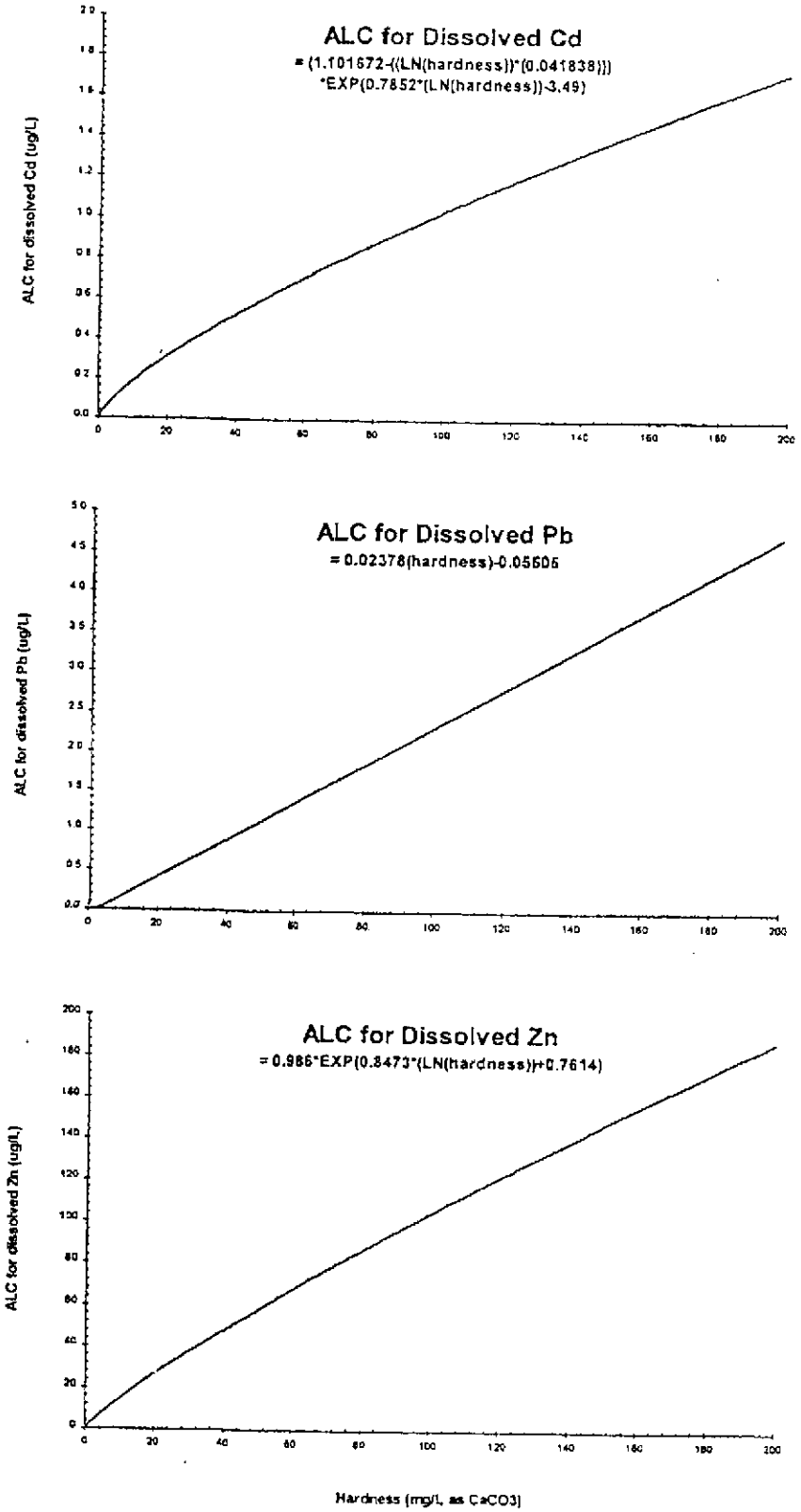


Figure 4. Recommended aquatic life criteria (ALC) for effluent dissolved Cd, Pb, and Zn for calculation of permit limits.

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Tables

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BEFORE THE BOARD OF COUNTY COMMISSIONERS OF KOOTENAI COUNTY, IDAHO

IN THE MATTER OF THE APPLICATION OF BLACK ROCK INVESTMENTS FOR APPROVAL OF THE CLUB AT BLACK ROCK, A PLANNED UNIT DEVELOPMENT ON 674 ACRES OF LAND IN THE RURAL AND RESTRICTED RESIDENTIAL ZONES	**CASE NO. PUD-037-99, FINDINGS OF FACT, COMPREHENSIVE PLAN ANALYSIS, CONCLUSIONS OF LAW AND ORDER OF DECISION**

I COURSE OF PROCEEDINGS

1.01 The Planning Department issued a notice of Public Hearing on this application (PUD-037-99) to be held December 13, 1999. Public notice requirements set forth in *Idaho Code* have been met. On November 26, 1999, notice was published in the *Coeur d'Alene Press*. On December 6, 1999, notice was posted at the site. It is the Applicant's responsibility to notify all property owners within 300 feet of the project site. Based on the signed affidavit, the requirements for public notification have been met.

1.02 The Planning Commission heard this request at a public hearing on December 13, 1999. At said hearing, persons were asked for testimony relative to the request. The hearing was continued to a date certain of January 19, 2000.

1.03 The Planning Commission reconvened on January 19, 2000. With four members present, the Commission voted unanimously to recommend that the request for Case No. PUD-037-99 be approved.

1.04 The Planning Department issued a notice of Public Hearing on this application (PUD-037-99) to be held on March 1, 2000. Public notice requirements set forth in *Idaho Code* have been met. On February 15, 2000, notice was published in the *Coeur d'Alene Press*. On February 23, 2000, notice was posted at the site. It is the Applicant's responsibility to notify all property owners within 300 feet of the project site. Based on the signed affidavit, the requirements for public notification have been met.

1.05 The Board of County Commissioners heard this request at a public hearing on March 1, 2000. At said hearing, the Board received a recommendation from the Planning Commission to approve Case No. PUD-037-99, and persons were asked for testimony relative to the request.

1.06 A legally noticed site visit was conducted by the Board of County Commissioners on March 20, 2000.

1.07 At their deliberations on March 29, 2000, the Board of County Commissioners further considered the case. Upon review of all files, exhibits, and testimony of current record regarding said application, the Board makes the follow Findings of Fact and Conclusions.

1.08 Files and exhibits relative to this application are available for review in the Kootenai County Planning Department.

II FINDINGS OF FACT

2.01 **Applicant(s).** The Applicant is Black Rock Investments, Inc., P.O. Box 977, Wheat Ridge, Colorado 80034.

2.02 **Owner(s).** The property owner is CAG Investments L.L.C., P.O. Box 977, Wheat Ridge, Colorado 80034.

2.03 **Proposal.** The Applicant is proposing to construct an 18 hole public golf course, clubhouse/restaurant, pro shop/grill, equestrian center, recreational center with swimming pool and tennis courts, convenience store, leasing office, and other related structures and uses along with a maximum of 204 single family dwellings and a maximum of 177 high-density residential units, to be platted through the County's subdivision process. The high-density homes may consist of zero lot line homes, condominiums, timeshares and/or pooled units.

2.04 **Phasing.** The Applicant's narrative states that the proposal has been divided into 2 Phases, to be completed as follows:

Phase One: Site disturbance will begin in the spring of 2000. Development of the golf course is anticipated to begin in the spring of 2001, and it will take approximately two years for the seeding of the fairways and greens to be complete. During this phase, Clubhouse Drive will be constructed and underground sewer and water lines will be installed. Successive roadways will be constructed and paved as they are developed to accommodate residential construction. Heavy truck traffic is anticipated during construction, therefore improvements to Loffs Bay Road and Rockford Bay Road are proposed to be completed once the golf course opens. The construction of the fire station will be concurrent with the clubhouse. The sales office and maintenance building will also be constructed during this phase.

The overall project density is approximately 1.8 acres per home site using the calculation of 381 living units and 674 acres.

Phase Two: Residential development will begin in Phase Two. The Applicant's narrative states that 20 to 50 residential units will be constructed each year for 7- 10 years. The convenience store is expected to be completed during this phase. The recreation center and the equestrian center will also be included in this phase.

2.05 **Existing Structures.** There are no existing structures at the site.

2.06 **Location and Legal Description.** The site is described as an area of land situated on the north side of Rockford Bay, Lake Coeur d'Alene, which includes portions of Sections 8, 9, 16, and 17, all in Township 48 North, Range 4 West. B.M., Kootenai County, Idaho. The site is located off of Loffs Bay Road, approximately 1 mile east of its intersection with Rockford Bay Road and extends to the intersection of Black Rock Road and is bordered by Rockford Bay Road to the south. The individual parcel numbers for the land subject to this request are:

48N04W-08-6800	Section 8	Township 48 North	Range 4 West	40.00 acres
48N04W-08-8000	Section 8	Township 48 North	Range 4 West	167.08
48N04W-08-8600	Section 8	Township 48 North	Range 4 West	40.00
48N04W-08-9200	Section 8	Township 48 North	Range 4 West	50.00
48N04W-09-3970	Section 9	Township 48 North	Range 4 West	83.45
48N04W-09-4600	Section 9	Township 48 North	Range 4 West	67.63
48N04W-09-5800	Section 9	Township 48 North	Range 4 West	10.00
48N04W-09-6800	Section 9	Township 48 North	Range 4 West	80.00
48N04W-16-0900	Section 16	Township 48 North	Range 4 West	2.29
48N04W-16-2800	Section 16	Township 48 North	Range 4 West	79.40
48N04W-16-3650	Section 16	Township 48 North	Range 4 West	34.27
48N04W-17-0050	Section 17	Township 48 North	Range 4 West	10.00
48N04W-17-0075	Section 17	Township 48 North	Range 4 West	10.00
			Total:	674.12 gross acres

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2.07 **Zoning.** The site and surrounding area is zoned both Rural and Restricted Residential. Of the total 674 acres at the project site, 538 acres are zoned Rural while the remaining 136 acres are zoned Restricted Residential.

The Zoning Ordinance, using calculations for both the Rural and Restricted Residential zones, will allow up to 704 single-family residences on the site, under the current zoning.

Minimum lot size requirements within a planned unit development can be redistributed. Section 15.04 of the Zoning Ordinance states, "The distribution of dwellings or other land uses within the Planned Unit Development shall not be affected by the zoning district boundaries."

2.08 **Physical Characteristics.** Most of the site is a gently rolling area, although the south side slopes off rapidly to Rockford Bay Road. The highest point is a grassy knoll in the middle of the property. Much of the site adjacent to Loffs Bay Road is an unforested, open field, partially cultivated with wheat. The rest of the site is forested. Interspersed throughout the site are steep drainage channels and wetland areas. The total relief (high point to low point) at the site is 500 feet.

The Soil Survey of Kootenai County Idaho identifies eight prevalent soil types on site. The open field areas contain mostly Santa silt loam and Taney silt loam, soils well suited to Douglas fir, ponderosa pine, western larch, lodgepole pine and western white pine. The available water capacity is moderate; permeability can be slow, resulting in a perched water table in the spring. Depending on the slope, runoff is medium to rapid; the hazard of erosion moderate to high. Limitations for home sites are the slow permeability of the soil and the seasonal perched water table. The primary limitations for the construction of roads are potential frost action damage and the inherent low support strength of the soil.

Lacy-Bobbitt association and Lacy-Rock outcrop complex soils are found in the steeper areas and are soils typically found in canyon areas and along escarpments. Limitations for homesites and roads are depth to rock, slope, and stoniness.

Blinn stony loam soil is found along the shoreline and has a high hazard of erosion. The Applicant will be working with the Idaho Department of Lands, Navigable Waters Division, to apply for an encroachment permit in an effort to protect and enhance shoreline development.

Shallow depth to rock and the presence of wetlands prohibit subsurface disposal of wastewater at the site.

The Applicant's environmental report states that previous development efforts in the 1980s included grading activities that resulted in recontoured areas with exposed subsoil and stockpiled topsoil. These areas have several deep and eroding gullies that are minimally vegetated.

2.09 **Noxious Weeds.** The site was visited in August 1999 by Sandy Daniel, Superintendent of Kootenai County Noxious Weed Control. Her site evaluation confirmed the presence of Canada thistle, Dalmatian toadflax and spotted knapweed. Ms. Daniel states that the current weed infestation is light considering the vastness of the site. Her recommendation is that treatment be required along the roadway during the development of the golf course and clubhouse to prevent the spread of spotted knapweed to other areas.

2.10 **Stormwater Plans and Review.** All site disturbing activity must be in compliance with Site Disturbance Ordinance No. 283. The Applicant's engineer has filed a preliminary stormwater drainage plan with the Planning Department.

Rand Wichman, Senior Planner, reviewed the stormwater plan. His comments are outlined in a memorandum dated November 18, 1999. He states that due to the sensitive nature of the soils at the site, a complete site disturbance plan will be required prior to any earthwork or construction being performed

at the site. The stormwater system will be required to be sized to treat runoff from the anticipated impervious areas on all lots within the development. He recommended that the Planning Commission consider requiring treatment of runoff from all irrigated areas of the golf course. In addition, an extensive geotechnical engineering evaluation will be necessary to address the seasonal high groundwater and the slope stability for the steeper portions of the site.

The Applicant responded in a letter dated November 24, 1999. The letter addresses the concerns raised by Mr. Wichman and states that a specific, detailed site disturbance plan that includes a geotechnical review and stormwater management plan will be prepared and submitted for review by the Planning Department after receiving preliminary approval of the planned unit development master plan. On November 5, 1999, the Applicant filed a Notice of Intent for Storm Water Discharges Associated with Construction Activity under a NPDES General permit with the U.S. Environmental Protection Agency.

2.11 **Lakes, Rivers and Streams.** The site is located on Rockford Bay on the southwest side of Lake Coeur d'Alene. The site is located on the Coeur d'Alene Indian Reservation and is not included in the area mapped by the Federal Emergency Management Agency for flood zone purposes.

2.12 **Wetlands.** The Clean Water Act of 1975 was established to maintain and restore the physical and biological integrity of the waters of the United States. Section 404 of the Clean Water Act authorizes the Army Corps of Engineers to issue permits for the discharge of dredged or fill material into the waters of the U.S., which includes wetlands.

The Applicant requested a wetlands study to be done by Selkirk Environmental for the purpose of providing a detailed determination and delineation of the project area. This study has been completed and is a part of the file marked as Exhibit A19.

Selkirk identified twenty-two jurisdictional wetland areas at the site. Seven channelized drainages were identified and delineated as waters of the U.S.

On December 7, 1999, The Planning Department spoke with Gregg Raynor, Regulatory Project Manager, Army Corps of Engineers. He stated that the Applicant has filed some initial permits for wetland fills with the Corps. A letter outlining the recommendations and requirements from the Corps were available at the hearing and entered as an exhibit.

2.13 **Wildlife Habitat.** The site supports a diverse stand of wildlife, including a wide variety of birds. In a letter dated November 4, 1999, the Idaho Fish and Game Department states that while the proposal includes retention of open space and some natural cover, development of the site will clearly result in a reduction in the numbers and kinds of wildlife presently found. Also, the potential for human/wildlife conflicts will increase. The Department makes the following recommendations to help reduce the impact to wildlife:

- Maximize the retention of open, undeveloped space through clustering. A minimum ratio of 80% open space to 20% developed area.
- Avoid development in or adjacent to wetlands, stands of mature timber, stream corridors and waterfront areas.
- Maintain travel corridors for wildlife, particularly from upland areas to the lake. Any fences used should be designed to not limit movement of wildlife.
- Retain large trees at or near waterfront sites for use by bald eagles, ospreys, and other raptors.

The Department also expressed concern with regard to the production of sediment and increased stormwater runoff effecting water quality in the lake.

2.14 **Significant Historical and Cultural Sites.** This site is located within the boundaries of the Coeur d'Alene Reservation and is under the jurisdiction of the Coeur d'Alene Tribe. In a letter dated June 4, 1999, Ernest Stensgar, Chairman of the Tribe stated that the Tribe has no opposition to the project as proposed. In a subsequent telephone conversation with Alfred Nomee on November 8, 1999, the Tribe requested that any development activity at the site that should result in uncovering any archeological artifacts, temporarily cease and the Tribe be notified by phone.

In 1985, the University of Idaho completed an archeological reconnaissance of the proposed site. Their conclusions are included in a letter that states, in short, that it remains possible, but unlikely, that a subsurface cultural feature, such as a burial, may exist in the area.

2.15 **Comprehensive Plan Designation.** The Kootenai County Future Land Use Map designates the site and immediate area as Rural and Rural Residential land as well as a Surface Water Resource Area. The purpose of this designation is to provide a "country like" setting for residences with agricultural, timber, or open space environments, and to prevent the financial burden of providing infrastructure where it would be least beneficial. A Rural Area is defined as a sparsely settled area usually related to farming, forest management, or open space, that is distinct from settled communities. This designation may have some agriculture or timber production. The Rural designation is given to areas of the County which are not close to population centers and in areas where continued sparse settlement is encouraged due to the difficulty of providing services. Services and infrastructure are not expected to be improved in the near future.

Residential designations are given to areas where the primary use is residential. These residential areas are outside of a city's boundaries, but may have some of the services and amenities of a city. These locations often have distinguishable neighborhoods with community or homeowners' associations. Development in these areas requires improved infrastructure and services. The residential designations encourage a wide variety of residential uses within three density ranges: Rural Residential, Suburban Residential and Urban Residential. The Rural Residential areas commonly border Rural areas and may actually be Rural in appearance. Distinguishing these areas from those areas designated as Rural is the size of the existing parcels and the level of police and fire protection that can be provided.

The Future Land Use Map is not an attempt to define exact boundaries, but instead a general outline of areas of suitable projected land uses. There are no sharp breaks between boundaries, rather transitions that should be considered approximately ¼ mile wide.

The Future Land Use Map is intentionally general. Designations should be given to broad areas, not to individual sites. For most of the County, the minimum area to be considered for a separate designation should be approximately ½ square mile (320 acres).

2.16 **Surrounding Land Use.** Surrounding the proposed site, is an area that is open and sparsely populated. The majority of the parcels that lie to the north and east of the site are approximately 10 acres in size. Larger, unplatted 20 acre and larger parcels lie to the northeast; south of the site, along the shores of the lake and south of Rockford Bay Road, homesites are smaller, platted lots, most under an acre in size. The area is rural in nature, with few homes along Loffs Bay Road in view. Along Rockford Bay Road, the land use is typical of summer, lakeside homes.

2.17 **Area of City Impact.** The parcel is not located within an Area of City Impact.

2.18 **Distance to Services.** The nearest services are within 5 miles of the site, at the Rockford Bay Store and the Fighting Creek Store.

2.19 **Sewage Disposal.** The Applicant proposes that at completion, the development will be served by a Septic Tank Effluent Pumping (STEP) wastewater system. This system consists of individual septic tanks, wet wells and lift stations, four recirculating sand filters, an outside storage pond, and a 30-acre land application irrigation system.

Each lot owner will be responsible for individual septic pumping. Effluent from each septic tank will be gravity fed/ pumped with the aid of lift stations to a large collection or dosing tank. The effluent is then circulated three to four times through a 24-inch deep sand filter. The effluent is contained within the sand filter by a HDPE membrane and concrete floor. The effluent is then chlorinated and pumped to an outside pond for storage. The pond will be lined with a 60-mil thick liner, fenced, and designed to hold 12 million gallons of treated wastewater. Odor will be removed through the use of a vent pipe. Residual odors are routed to a biofilter, filled with natural substances such as peat or soil. The system is being designed to accommodate 397 equivalent residence connections (ERs) at an average flow of 250 gallons per day for each.

During the winter months, the effluent will remain in the pond. In the spring of each year, DEQ will determine when land application may begin. It is anticipated that land application will be carried out from April through October through drip and spray irrigation.

It is projected that the treated effluent will reach disinfection levels of < 2.2 organisms per 100 ml. This will allow minimum 50 foot buffer zones for drip irrigation, and 100 foot minimum buffer zones for spray irrigation.

However, during Phase One, the Applicant states that temporary wastewater disposal facilities will provide service for sewage generated by the maintenance building, clubhouse, fire station and sales office. This may include some or all of the components of the STEP system. Land application is not anticipated during this phase, rather the effluent will remain in the pond. The Applicant has stated that they intend to use septic tanks and drainfields during Phase 1.

2.20 **Water.** The development is proposed to be served by a community water system. Domestic water and fire flow water will be supplied by wells located in the north area of the project. Two test wells have been drilled with a capacity in excess of 100 gallons per minute; additional wells will be added as the need arises. Water from the wells will be pumped into two 150,000-gallon reservoirs equipped with booster pumps to pressurize the distribution system.

Irrigation water will be provided by pumping water from Lake Coeur d'Alene to the ponds on the golf course. Dual irrigation pumps will be installed in the existing 12 inch casings at the lake frontage lot. Water will be pumped to the golf course ponds by an 8 inch distribution line.

The Department of Environmental Quality has approved sites for four drinking water wells. DEQ recommends:

Storage capacity at 800 gallons per connection
Total daily use without separate irrigation provisions – 1500 gallons per residence
Total daily use with separate irrigation provisions – 800 gallons per residence
Maximum instantaneous demand – 300 gpm
Pressure tanks with a gross volume 10 times the capacity of the largest pump used to prevent pumps from cycling excessively

Since groundwater can be scarce, the use of potable water for irrigation should be discouraged

The Applicant is proposing that the water and sewer systems shall be maintained by the Association, authorized to act as a Water and Sewer System Control Committee.

The Applicant has applied for and been granted assignment of a permit to appropriate water from the lake through the Department of Water Resources.

Concerns regarding the static levels of adjacent wells were raised at both public hearings and in public comment received during the application process. In an effort to mitigate those concerns, the Applicant has agreed to spend a maximum of $10,000 to complete a baseline study of all wells located within 300 feet of the subject property. The details of this offer are outlined in a March 1, 2000 letter from the Applicant that is a part of the file.

2.21 **Air and Water Quality.** The Applicant is providing funding to the Worley Highway District to improve and pave approximately 2.25 miles of Loffs Bay Road. Loffs Bay Road is currently gravel. Roads within the Planned Unit Development will also be paved.

Water quality impacts can be reduced through the requirements of the Site Disturbance, the Army Corps of Engineers and the NPDES permit processes.

2.22 **Hazardous Areas.** This site was assessed by Budinger and Associates, a geotechnical engineering firm in Spokane. In a letter dated May 22, 1998, the firm reported that they had completed a Level I Environmental Site Assessment of the property. The letter states they did not find any evidence of adverse environmental conditions including heavy metal contamination.

Thirty-one of the 104 soil types in the County have inherently low support strength and are susceptible to slippage. Two of these soils, Santa and Taney (slope range from 5 – 20% and 3 – 25% respectively) are found at the site. With low support strength soils, the steeper the slopes, the greater the hazard of slippage. In their natural state, such soils are often stabilized by vegetation.

2.23 **Access and Transportation.** The site is primarily accessed off of Loffs Bay Road and is under the jurisdiction of the Worley Highway District. Three approaches into the development will exist on the south side of Loffs Bay Road. There will be a main approach to the clubhouse and golf course, a northwest subdivision entrance and an entrance to the parking lot for the wastewater treatment facility. Three approaches lie to the north of the road - one to the convenience store, one to the mini-storage, and one to the fire station. Two secondary approaches exist on Rockford Bay Road. One ingress/egress into the southern portion of the subdivision and one to the south of Rockford Bay Road, to the lake access portion of the parcel. In a letter dated August 10, 1999 the District states that the Board of Highway Commissioners will require all of the approaches to be professionally designed to safely accommodate the projected traffic.

According to their letter, the Highway District Commissioners will require that 1.2 miles of Rockford Bay Road and 2.25 miles of Loffs Bay Road be reconstructed to the current Highway Standards for Associated Highway Districts, Kootenai County, Idaho. A variance from the standards on the width of the travel surface from 28 feet to 24 feet will be granted, although two-foot shoulders will still be required. Pavement will be a requirement on both roadways. The District will administer the design and construction of the project.

The District proposes two separate contracts for the improvements. The first contract would be for the improvements to Loffs Bay Road, minus the pavement. The second contract would be for the improvements to Rockford Bay Road, including pavement and paving of Loffs Bay Road.

Clubhouse Drive will be built to highway district standards and with a 28 foot width; other roads within the development will be built to highway district standards with exception for the width, which is proposed to be 24 feet. The road to the lake side portion of the site will also meet highway district

standards with the exception of width (20 feet) and a grade of 10%. All roads will be privately maintained by the Board of Directors of the Association.

The Idaho Transportation Department has been notified of the proposal and to date no letter of comment has been received. ITD has plans to reconstruct the intersection of Rockford Bay Road and Highway 95. Those plans include turn lanes at that intersection.

2.24 **Fire Protection.** The area is under the protection and jurisdiction of the Worley Fire District. In a letter dated August 12, 1999, the District states that the development will have 300,000 gallons of domestic water storage for firefighting use. The hydrant system capable of supplying this water will be capable of flowing 2500 gpm for 120 minutes. According to the Applicant's engineer, hydrants will be set as the roads are developed.

Access roads within the development will meet or exceed the District's standards for width, surface and grade. Cul-de-sacs must meet a 70 foot diameter and all buildings must be no higher than two stories above ground.

The Applicant has agreed to convey by deed a lot within the subdivision which will house a new fire station, complete with parking areas, all utilities and a payment of $150,000 to be used to purchase and equip the new station. The Applicant has agreed that construction of the fire station shall commence concurrently with the clubhouse. Conveyance by deed requires that the Applicant file a subdivision application with the Planning Department, contingent upon approval by the Board of County Commissioners.

2.25 **Schools.** This subdivision will be served by Coeur d'Alene School District #271. On July 1,1999, the District commented on the proposal with a projected build out of 300 homes. Their letter outlines the major concerns of the District which include design considerations that provide safe places for children to walk, ride and wait for school buses. They stated that designated school bus stops should be incorporated into the design of the development and delineated on the master plan. The Applicant has stated that the master plan will be revised to replace the trash compound with a bus stop at the commercial portion of the site indicated for a trash compound.

2.26 **Solid Waste.** Property owners in Kootenai County are responsible for providing solid waste pickup for a project both during and after construction. The original master plan for the entire project includes an area designated as a trash compound site, although the Applicant has recently indicated to the Planning Department a preference for trash pick-up service at each individual building. If the compound were built, it would consist of dumpsters for trash and roll off containers for recyclables, the size and number to be determined by the demands of the development.

The master development plan indicates that the compound area will be located just east of the intersection of Loffs Bay Road and Black Rock Road. This area lies within the 6.92-acre site that is under consideration for a zone change from Rural to Commercial.

In a letter dated October 12, 1999, the Kootenai County Solid Waste Department) gives their recommendations for waste disposal. These recommendations include the proper disposal of construction and land clearing debris as well as garbage disposal once residential construction begins. They also request that the Applicant provide containers for recycling.

2.27. **Landscaping and Design Standards.** The Zoning Ordinance has specific standards for landscaping, parking, and screening of all commercial and community use structures. Proposals are reviewed against these standards at the building permit stage.

2.28 **Lighting.** The Zoning Ordinance requires that a Conditional Use Permit be applied for and granted prior to erecting any outdoor lighting for recreational facilities. The Planning Department has provided lighting standards obtained from The Illuminating Engineering Society of North America as requirements to be used by the Applicant in designing a lighting plan for the development.

2.29 **Signage.** Signs are prohibited in the Rural and Restricted Residential zones. The Applicant has proposed signage for the development. All signs requested must be included in the exhibits entered at the public hearings.

2.30 **Lake Access.** The lakeside portion of the parcel is proposed to be for day use by boaters and picnickers. There will be a dock, but no boat slips. The closest boat launch is at the Rockford Bay Marina, southwest of the site. A sales and leasing office will be located at this site.

III APPLICABLE LEGAL STANDARDS

3.01 Kootenai County Subdivision Ordinance No. 26-B
3.02 Kootenai County Zoning Ordinance No. 159, as amended
Article 15, Planned Unit Development
3.03 Kootenai County Building Ordinance No. 221-A
3.04 Kootenai County 1994 Comprehensive Plan
3.05 Kootenai County Site Disturbance Ordinance No. 283
3.06 Kootenai County Road Naming and Addressing Ordinance No. 229-B

IV COMPREHENSIVE PLAN ANALYSIS

Goal 1: Maintain and improve air quality

- While development of any kind will generate more pollutants into the air as traffic increases, the paving requirements of the Highway District will reduce dust and particulate matter now being generated by local traffic on gravel and dirt roads.

Goal 2: Maintain the existing high quality of groundwaters in Kootenai County

- Development at the site will undoubtedly have an impact on the existing groundwaters. However, development that includes a geotechnical review and stormwater management plan will assist in lessening the negative impacts on groundwater quality. A wastewater treatment facility in lieu of individual drainfields lessens the impact to groundwater supplies.

Goal 3: Ensure that demand of groundwater resources does not exceed sustainable yield

- The use of lake water rather than potable water for irrigation will help to conserve groundwater supplies. Clustered housing conserves water used for irrigation purposes.

Goal 4: Preserve, protect, and enhance the water quality and quantity of lakes, streams, rivers, and wetlands

- Mitigation through the implementation of erosion control and on-site stormwater treatment will help to limit the flow of untreated stormwater into the lake.
- Development in wetlands must be restricted to ensure that wetlands continue to function as filters/purifiers to groundwaters, as recharge areas to surface and groundwaters, and are allowed to retain their ability to reduce the adverse effects of flooding.
- Designating environmentally sensitive areas and requiring safeguards for these areas will ensure development will occur in areas less susceptible to contamination.
- The use of greenbelts provide buffer strips that protect surface waters and wetlands.

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Goal 5: Encourage the preservation, protection and enhancement of native vegetation

- Noxious weeds are injurious to crops, livestock, and public health. In an effort to protect the environment and promote sensible development, the Planning Department works in conjunction with the Kootenai County Noxious Weed Department to ensure that noxious weed mitigation be a consideration in all current land use applications. The Applicant has stated intent to maintain native vegetation and will be working with the Noxious Weed Department to eliminate noxious weeds at the site.

Goal 6: Encourage the preservation, protection, and enhancement of fish and wildlife habitat

- The Applicant's narrative lists a variety of wildlife and fowl habitats at the site: grasslands, woodlands, wetlands. Development requirements set forth by the Board of County Commissioners will include coordination efforts with wildlife management agencies. In addition, provisions for setbacks from riparian areas will protect fish habitats. Fish and Game have identified specific areas as that are most likely to provide shelter for the area's wildlife. A commitment to providing and protecting these areas will support this goal.

Goal 7: Prevent or limit development activity in hazardous areas

- The Applicant's geotechnical report will include soils and slopes not conducive to development. Restricting development in these areas and requiring a site disturbance plan to control erosion will ensure that Goal 7 is met.

Goal 9: Develop land use regulations that protect property rights, maintain quality of life, provide adequate land for development, buffer non-compatible land uses, and protect the environment

- The soils, topography, and climate in this area have, in the past, allowed for sustainable farming practices. However, farming in the area has declined, population centers are shifting and citizens are looking for more housing and recreational areas.

Goal 10: Guide population growth to allow for inevitable expansion without sacrificing the environment or the quality of life which currently characterizes Kootenai County

- A large scale development, such as is proposed, in the Loffs Bay - Black Rock area will indelibly change the character and living style of the residents now living there. That change must be accomplished without sacrificing the quality of life in the area.
- A maximum number of living units will be established with the approval of the PUD master plan. The number recommended by the Planning Commission and adopted by the Board of County Commissioners reflect a genuine interest in balancing the Applicant's request with the desire of the community and neighborhood.
- In an effort to control over illumination at the site, recommendations for lighting standards set by The Illuminating Engineering Society of North America have been incorporated into this Order of Decision.

Goal 11: Provide safe, adequate, and affordable housing for people of all income levels

- The proposal presents a range of home styles and prices built to a standardized Building Code.

Goal 12: Promote a diversified, safe, and stable economic base in an environmentally responsible manner

- The project will provide opportunities for economic benefits to the area in the form of increased employment and revenues generated through the construction of the development.

Goal 13: Maintain viable agricultural, forestry and mining land uses

- Farming practices at the site have been abandoned for the past decade.

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Goal 14: Provide for the efficient, safe and cost-effective movement of people and goods

- The Worley Highway District has reviewed the Applicant's request and responded with requirements that are expected to support this goal. The Idaho Transportation Department has recognized the need for turn lanes and widening of Highway 95, even before this proposal was submitted. This request encourages the development of public roads. Approaches will be limited to what is indicated on the plat.

Goal 16: Provide efficient, convenient, and effective government services

- A portion of the site will house a fire station and provide funds for equipment for the Worley Fire District. The Fire District and the Applicant have agreed that the fire station is to also be used for community purposes, on a permission-first basis from the District. A community use facility would support the Comprehensive Plan's objective of optimizing public investment and providing direct, coordinated services to the public.

Goal 17: Ensure efficient and effective police, fire, and emergency services

- Adequate water supplies shall be provided for fire suppression

Goal 18: Assist in the efficient and orderly expansion and improvements of public utilities and services

- An additional fire station in the area will maximize a public investment as it provides a service to all homes/citizens in the area.

Goal 19: Ensure the availability and affordability of energy-related services while protecting the environment

- The Kootenai County Building Department will ensure all structures are built to be Northwest Energy Code compliant.

Goal 20: Protect water quality to ensure adequate quantity and quality of drinking water to meet the current and future needs in the County

- See Goals 2 and 3.

Goal 21: Provide environmentally sound, efficient, and cost effective management of wastes

- Since the placement of all construction debris is prohibited in the County's rural collection system, arrangements will need to be made for the disposal and recycling of all construction and land clearing debris. The operation of the planned unit development will generate refuse and recyclables that will need to be separated for proper pickup and disposal. Environmental protection from unsafe solid waste disposal practices can be accomplished by the Applicant through working with the Kootenai County Solid Waste Department. Recycling of all land clearing and construction debris, aluminum, newspapers and cardboard is a step towards an environmentally sound development

Goal 22: Provide for school representatives to participate in the community planning process

- The Coeur d'Alene School District has been given the opportunity to provide comments regarding the increase in the numbers of school children expected at the time of full build-out. The safety of school children is a serious consideration in a development the size of this one. In order to ensure a safe place for children to wait for the school bus, a bus stop shall be incorporated into the development plan and delineated on the final PUD master plan. The Planning Director and School District 271 shall approve this bus stop.

Goal 23: Develop quality County parks, greenbelts, and recreational facilities to meet the diverse needs of a growing population

- The central theme of the Applicant's proposal is an 18-hole golf course. Shoreline development will include a day use picnic area.

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Goal 24: Secure waterfront and near-shore areas for beneficial public uses and enhance public enjoyment of county waterways

- The proposal includes development of a lakeside public area, which includes a dock.

Goal 25: Encourage the preservation, protection, and enhancement of areas that are historically and culturally significant

- The State Historical Preservation Office and the Coeur d'Alene Tribe record all artifacts that are unearthed during excavation/construction both inside and outside the boundaries of the Coeur d'Alene Reservation. The Applicant has contacted the Coeur d'Alene Tribe and has agreed to notification in the event of the discovery of any historical or culturally significant items.

Goal 26: Foster growth in a manner that does not compromise the visual qualities of Kootenai County

- Deliberate placement of structures within building envelopes make the best possible use of the topography at the site.

Goal 27: Preserve, protect, and enhance natural landmarks and areas of scenic beauty, such as waterways and unique landscapes

- The developer has made a commitment to incorporate the unique landscape of the site into the design of the golf course and subdivision. CC&Rs to be recorded with the PUD master plan can help assure adherence to this commitment. In addition, the Covenants and CC&Rs can protect the landscape from the visual pollution caused by unnatural color schemes.

Goals 8 and 15 are not applicable.

V CONCLUSIONS OF LAW

5.01 Article 15 of Kootenai County Zoning No. 159, as amended, specifies the General Provisions and Procedures for reviewing requests for Planned Unit Developments. Based on the analysis and findings herein, it is concluded that the request is in harmony with the purpose and intent of the Zoning Ordinance and is in conformance with the specific requirements of Idaho Code and the Zoning Ordinance, as well as the intent of the 1994 Comprehensive Plan. The project is in the public interest and will not adversely effect the public interest.

5.02 The construction and operation of the project will satisfy the performance standards set forth in the Zoning Ordinance (Article 15 and Article 17) and Site Disturbance Ordinance No. 283. The zoning at the site is in accordance with the request. Full consideration has been given to the proximity of adjacent uses and the effect of the proposal on adjacent property. The construction and operation of the project will also be required to conform to all other applicable regulatory requirements, including those of the Panhandle Health District, the Division of Environmental Quality, the Worley Highway District, the Worley Fire District and the Idaho Transportation Department prior to issuance of certificates of occupancy or commencement of operations.

5.03 The public convenience and necessity will be served by the project with the improvements made to the road system, the addition of a fire station, the increase in jobs in the area and the enhancement of bare, unimproved land through landscaping and a viable stormwater plan.

5.04 The proposal is in conformance with the goals, objectives and policies of the 1994 Kootenai County Comprehensive Plan, as discussed more fully herein.

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5.05 The future land use designations were chosen and defined in consideration of both the environmental conditions and the goals of the 1994 Comprehensive Plan. This proposal has been found to be in conformance with the Comprehensive Plan and the Future Land Use Map.

5.06 The Kootenai County Board of County Commissioners finds this request meets the requirements of Idaho's Local Land Use Planning Act.

5.07 These conclusions are based on a thorough analysis of the applicable legal standards contained in Section III of this Order and all of the evidence and testimony presented in these proceedings.

ORDER OF DECISION

Based upon the Findings of Fact and Conclusions of Law set forth in this document, the Kootenai County Board of County Commissioners hereby recommends that Case No. PUD-037-99, a request by Black Rock Investments for a Planned Unit Development be **APPROVED** with the following conditions:

VI CONDITIONS OF APPROVAL

6.01 In the event that any artifacts are found during excavation or construction, all work efforts at the immediate site shall cease and the Coeur d'Alene Tribe Office shall be notified within 24 hours.

6.02 Prior to recordation of the PUD master plan, the Applicant shall provide:

- A letter from the Planning Department stating approval of a stormwater management plan sized to meet the needs of the development at full build out;
- An engineered geotechnical evaluation of the site, particularly addressing the seasonal high groundwater table and slope stability;
- A contract with a solid waste source that addresses the disposal of all construction and land clearing debris. This contract will include provisions for recycling all debris that is eligible. The Applicant may choose between a private hauler or make arrangements to drop off their refuse at the Kootenai County Solid Waste Department;
- Design and delineation on the PUD master plan with acceptance by the Planning Director and School District 271 of a bus stop for school children;
- Construction drawing approval from the appropriate agencies.

6.03 Prior to the Planning Department's signature on the Certificate of Occupancy for the clubhouse, the Applicant shall provide:

- A contract that includes the disposal and recycling of all refuse generated as a result of normal day to day operations within the planned unit development. If a trash compound site is designated, this contract shall include recommendations with regard to the number of dumpsters, roll off containers and frequency of pickup service. Roll off containers for aluminum, newspaper, cardboard and magazines shall be permanently located at the trash compound. All containers must have tight fitting lids to prevent scattering and scavenging. The trash compound shall be screened with a 6 foot high sight obscuring fence that meets the architectural control style outlined in the Architectural Control Rules and Regulations, Item 2.5. A building permit indicating Planning Department approval shall be required prior to the placement of the fence. In the event of individual garbage pickup service,

a letter from a service provider that a contract has been entered into which includes recycling provisions;

- A letter confirming that a contract has been entered into with the Noxious Weed Department or that treatment has been applied to the areas infested with knapweed along the roadway;
- A letter of approval from the Worley Fire District stating that the District's requirements have been met, including the construction of a new fire station, funds to equip that station, and the existence of adequate water supplies for fire suppression;
- A letter from the Worley Highway District stating that the District's requirements have been met, including the paving of Loffs Bay Road and the improvements to Rockford Bay Road;
- Clubhouse Drive shall be paved;
- Construction and release of all bonding for infrastructure improvements for Phase One.

6.04 A monument sign consisting of natural materials shall be allowed at the main entrance to the development. The sign shall meet the setbacks indicated on the site plan. The lighting for the sign shall be included in the overall lighting plan provided by the Applicant to the Planning Director. The Applicant shall obtain approval from the Planning Director prior to the application for a building permit and shall comply with all UBC requirements for signage.

6.05 Phase 1 of the development shall commence upon recordation of the final master plan and after receiving any necessary permits including Army Corp of Engineers permits. Phase 1 and all related structures shall be completed no later than December 31, 2003. Phase 2 construction of structures shall commence upon recordation of the subdivision mylar and after receiving any necessary permits. Planting and infrastructure developments for Phase 2 shall be completed by December 31, 2010. One, 1-year extension for a subdivision application may be requested by the Applicant upon demonstrating just cause.

6.06 All retail sales within the clubhouse, recreational center and concession located at lake front, are limited to small ticket items and confectioneries directly associated with the facilities' use in which they are located.

6.07 The following structures shall be restricted to the maximum size, location and appearance as depicted in the master plan and the exhibits submitted at the public hearing, except that the convenience store shall be located south of Loffs Bay Road and within the visual perimeter of the PUD:

- Clubhouse/Restaurant
- Pro-shop/grill
- Recreational facility
- Convenience store
- Maintenance facilities
- Fire station
- Equestrian center
- Sales office

6.08 Any proposed changes to the associational by-laws, covenants, conditions and restrictions, and architectural rules and regulations shall require the approval of the Planning Director and shall be recorded with the Kootenai County Recorder's office.

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6.09 Specific standards for parking, lighting, landscaping and screening will be applied, as required in Article 17 of the Zoning Ordinance, at the time the building permit for any structure is applied for. In addition, all public-parking areas not associated with a building must be paved.

6.10 A Conditional Use Permit shall be applied for and approved prior to the placement of any recreational lighting. Any outdoor lighting proposed, including streetlights, shall be delineated in a lighting plan and approved by the Planning Director prior to placement and use.

6.11 The Applicant shall be in full compliance with all development requirements set forth in this document for the planned unit development prior to the first application submitted for preliminary subdivision approval.

6.12 Prior to Board approval of the master plan, all requirements as outlined in Article 15 for a planned unit development must be fulfilled.

6.13 All design restrictions set forth in Section 2 of the Architectural Control Rules and Regulations shall be adhered to or as otherwise amended.

6.14 All commercial and residential structures shall obtain a Certificate of Occupancy from the Kootenai County Building Department prior to occupancy.

6.15 All roads inside the project area will be built to highway district standards as provided in Section 2.23 of this Order, except for width. The roads may be constructed in their respective residential phases.

6.16 Signs shall be limited to a monument sign incorporated into the design of the main entrance, as indicated on the master site plan. No signs shall be allowed except for any aforementioned or any approved at the public hearings as a part of the exhibits submitted. Directional signs are excluded from this requirement. Directional signs are unlighted, less than 8 square feet in area and are provided for directional rather than advertising purposes only.

6.17 All amendments to the PUD or subsequent applications for subdivision applications shall be governed by the ordinance(s) in effect at the time of the application.

6.18 Any site disturbance within the delineated wetland areas or within any of the drainage channels on the site shall require approval from the Army Corps of Engineers. This includes enhancement of the wetland areas.

6.19 The Applicant shall, at all stages of the project, minimize construction development in or adjacent to wetlands, stands of mature timber, stream corridors and waterfront areas. In addition, the project will maintain travel corridors for wildlife, particularly from upland areas to the lake. Any fences used should be designed to not limit movement of wildlife. The Applicant shall retain all large trees at or near waterfront sites for use by bald eagles, ospreys, and other raptors.

6.20 In designing the water system(s) for the development, the Applicant shall comply with the recommendations in the Department of Environmental Quality's April 30, 1999 letter that is a part of the file.

6.21 All structures shall be no higher than two stories and cul-de-sacs design must meet the requirements of the fire district.

6.22 Recordation of the master plan must take place within 120 days of the Board of County Commissioners' approval of the master plan.

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6.23 The project's 2.29 acre lakeside portion of the proposal (parcel number 48N04W-16-0900) depicted on the master plan as the location of the sales and leasing office and beachfront recreation area shall be fenced on north, east and west sides and have a security gate off of Rockford Bay Road that will allow controlled access to the site. Activity at the site shall be limited to the hours of 6:00 a.m. to 9:00 p.m.

DATED this 10th day of May, 2000

BY ORDER OF THE KOOTENAI COUNTY BOARD OF COMMISSIONERS

Richard Panabaker, Chairman

Dick Compton, Commissioner

Ronald D. Rankin, Commissioner

ATTEST:
DANIEL J. ENGLISH, CLERK

BY: Deputy Clerk

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MAY 2 6 2000

REFERENCE:

COEUR D'ALENE TRIBE

850 A STREET
P.O. BOX 408
PLUMMER, IDAHO 83851
(208) 686-1800 • Fax (208) 686-1182

RECEIVED
AUG 28 2000
Department of Water Resources

August 25, 2000
Mr. L. Glen Saxton, P.E.
Chief, Water Allocation Bureau
Department of Water Resources
1301 North Orchard Street, P.O. Box 83720
Boise, ID 83720-0098

Subject: Application for permit number 95-09045 in the name of CAG Investments, LLC

Dear Mr. Saxton:

I have enclosed a copy of the Coeur d'Alene Tribe's Environmental Action Plan (EAP) Project's *EAP Assessment of Environmental Concerns on and near the Coeur d'Alene Reservation* Executive Summary (July 2000) to be included in the documents that will be reviewed in reference to the above permit application.

Please take a close look at the introduction to the *EAP Assessment*, especially the risk rankings table on page 11. The risk rankings are applied to 25 environmental concerns and the scale that is used is low, medium, high or extreme. As you will see, "Human population growth and development patterns" is ranked as an EXTREME risk and "Non-point source surface water pollution" is ranked as a HIGH risk.

The Historical Atlas section (pp.21-48) contains information on changes in land use over time in the Tribe's aboriginal territory and the Reservation. This and other sections of the report explains why the Tribe is concerned about sprawl development, especially development adjacent to Lake Coeur d'Alene. The Tribe maintains that water allocation is directly related to enabling this type of development and all of these impacts should be considered in the decision on whether to grant a permit to appropriate water. Please read pages 91-92, the general summary of the Ecology report in the *EAP Assessment*. I also encourage you to read pages 119-120, the introduction and conclusions of "The Importance of Natural and Environmental Resources in the Economy of the Coeur d'Alene Reservation" by Dr. Thomas Power of the University of Montana in Missoula. Please read as much of the *EAP Assessment* as time permits. If you would like more detail, the complete report is an 800+ page document in two volumes and I could send it to you upon request.

I am sending a copy of this letter and a copy of the *EAP Assessment* Executive Summary to the applicant and to Kootenai Environmental Alliance (Mr. Mike Mihelich) as you requested in your letter to me dated August 22nd, 2000. Thank you for the opportunity to provide the Tribe's *EAP Assessment* report.

Sincerely,

Tiffany Allgood

Tiffany Allgood
EAP Coordinator

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NOV 2 8 2000

Coeur d'Alene Tribe
Environmental Action Plan
(EAP) Project

EAP Assessment of Environmental Concerns on and near the Coeur d'Alene Reservation July 2000

Prepared by
The Coeur d'Alene Tribe,
the EAP Steering Committee
and
EAP Technical Workgroup

Funding Provided by United States Environmental Protection Agency



Executive Summary
Volume 1

MICROFILMED Entire Book
NOV 2 6 2003

The Coeur d'Alene Tribe
Environmental Action Plan (EAP) Project

EAP Assessment of Environmental Concerns on and near the Coeur d'Alene Reservation Executive Summary Volume 1 July 2000

Tribal Natural Resource Department
P.O. Box 408, 850 "A" Street
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Public Outreach and Administrative Assistant

John Bottelli
Graduate Student Assistant

Student Interns:
Antoine George
Leia McJoe
Mandy Morrell
John Tsawklai
James Twoteeth
Audra Vincent

The Coeur d'Alene Tribe would like to say thank you, "limlemtsh", and acknowledge all of the EAP volunteers and the public that gave their time and input to identify and inform others about environmental concerns on and near the Coeur d'Alene Reservation. Over 150 people contributed to this report at EAP meetings during the past two years.

Consultant assistance provided by
Ridolfi Engineers, Seattle, WA
and
Advanced Forest Systems
Coeur d'Alene, ID

Technical Assistance provided by
The Western Center for Environmental Decision-Making
Boulder, CO

All photos, unless otherwise noted, were taken by
Worley photographer, Alison Meyer (208-686-1936).

Editing provided by
Integrated Composition Systems, Spokane, WA

This document printed on paper which contains a minimum of 30% post-consumer material.
Binding coils contain 100% post-consumer material.

DEDICATION

This Environmental Assessment Report
is Dedicated to Tribal Elders
Lawrence Aripa and Henry SiJohn

LAWRENCE STANISLAUS ARIPA
Born in DeSmet, Idaho on March 26, 1926
Passed Away on October 11, 1998

An Elder, A Tribal Leader, An Artist, A Storyteller

HENRY JOSEPH SIJOHN
Born in Lovell Valley on August 6, 1917
Passed Away on February 9, 1999

An Elder, A Tribal Leader, A Tireless Caretaker of the Environment

This environmental report is the result
of the vision, dedication and commitment of people
such as
Lawrence Aripa and Henry SiJohn

Poem Dedicated to EAP
March 17, 1998

Thanks to Tribal members for asking us to play
a variety of roles in what happens here today.

We'll put our heads together, use some expertise,
recognize some problems, on the future take a lease.

Sitting where we Bingo, talking E.A.P
wading through a wetland, walking 'round a tree.

Thinking of environment, looking up the past,
speaking to the future, planning things that last.

Getting down on paper steps to get things done,
planning for a system, to get objectives won.

If we work together, charting out a map,
avoiding duplication, not falling in the trap

of backing to our corner, thinking just of ME,
instead to hold our hands out joined in thoughts of WE.

Ray Lubben
Tensed, Idaho

List of EAP Participants

*(Those who served on committees are listed in the appopriate sub-group. Former members are marked with an *.)*

Steering Committee

Richard Mullen – Cd'A Tribal Council/Cultural
Tiffany Allgood – Cd'A Tribe Natural Resource *(EAP Coordinator - ad-hoc)*
Ruth Rathbun – St. Maries Community-at-Large
Nancy A. Wolff – St. Maries City Council
Virginia Nigh – City of Worley
Dale Bates – Benewah Medical Center
Felix Aripa – Cd'A Tribe Natural Resource Committee
* Bob Singleton – Superintendent of Worley/Plummer
George Asan – Plummer/Worley Schools
Dave Johnson – Benewah County
Alfred Nomee – Cd'A Tribe Natural Resource Director
Henrietta Brown – Cd'A Tribe Development Board
* Ron Rankin – Kootenai County Commissioner
* Cheri Howell – Kootenai County (alternate)
* Scott Kuhta – Kootenai County (alternate)
Rand Wichman – Kootenai County
* Charles Finan – Kootenai County (alternate)
Michael George –Tribal Community-at-Large
Charlotte Nilson – Cd'A Tribe Planning & Development Corporation
A.F. Corky Booth – City of Plummer
Michael Reid – City of Tensed
* Mariane Hurley – Mayor of Tensed
P. Frank SiJohn – Cd'A Tribe TERO
* Dave Peters – Cd'A Tribal School
John Anderson – Cd'A Tribal School (alternate)
* Henry SiJohn – Cd'A Tribal Council/Cultural
* Megan Harding – Benewah Medical Center
Janette Taylor – Cd'A Tribe Department of Education
* Dixie Saxon Stensgar – Cd'A Tribe Education
Perry Kitt – DeSmet Community Representative
Martha Youckton – Cd'A Tribal Housing Authority
* Gino White – Cd'A Tribe Housing
Margaret José – Cd'A Tribe Social Service
Silvia Baheza – Cd'A Tribe Social Service (alternate)
* Norm Campbell – Cd'A Tribal Council
Marcia Stearns – Cd'A Tribe Human Resources
* Sharon Johnson – Cd'A Tribe Personnel
* Matthew Stensgar – Benewah Medical Center
* Lawrence Aripa – Cd'A Tribe Council

* Tom Moss – St. Maries City Council
* Merle SiJohn – Tribal Community–at–Large
Charles Matheson – Cd'A Tribal Council
* Pete Mahoney – City of Plummer

Human Health Sub-Group Members

George Asan – Plummer/Worley School District (EAP Steering Committee)
Rick Barlow – Panhandle Health District – *co-chair*
Dale Bates – Benewah Medical Center (EAP Steering Committee) – *co-chair*
Paul Daman – Tensed Ambulance
Robert Flagor – Kootenai Environmental Alliance
Patricia Hoffman – Save our Summers
* Donna Hollister – Kootenai Environmental Alliance
John Kennison – Tensed Community
Perry Kitt – Cd'A Tribe Natural Resource - GIS (EAP Steering Committee)
Larry LaSarte – Cd'A Tribe Natural Resource (Forestry)
Ron LaSarte – Cd'A Tribe Natural Resource (Forestry)
Martha Little Crow – Cd'A Tribe Natural Resource (ANA Programs)
Kat Goodwin – Cd'A Tribe Natural Resource (ANA Programs)
Rich Morrison – Farmer
Virginia Nigh – City of Worley (EAP Steering Committee)
Camille Scott – Benewah Community Hospital
Susan Spalinger – University of Idaho Graduate Student
Paul Stearns – Cd'A Tribe Smoke Management Committee
Margrit Von Braun and students – University of Idaho, Environmental Science
Ida Curley – Cd'A Tribe Head Start

Ecological Sub-Group Members

Angelo Vitale – Cd'A Tribe Natural Resource (Fish, Water & Wildlife) – *co-chair*
Bernie Wilmarth – Potlatch Corporation – *co-chair*
Robert Matt – Cd'A Tribe Natural Resource (Fish, Water & Wildlife)
* Eric Johnson – Washington Water Power
Dale Pierce – Rayonier
Jack Bowlin – Community Member
Barb Scaroni – Cd'A Tribe Natural Resource (Forestry)
Don Patterson – Bennett Lumber
* Brad Burmark – US Forest Service St. Joe District
Bryan Helmich – Idaho Fish & Game
* Eric Krueger – Cd'A Tribe Natural Resource (Fish, Water & Wildlife)
Mark Addy – NRCS Plummer
Ed Tulloch – Idaho DEQ
Francis SiJohn – Cd'A Tribe Natural Resource (Air Quality), now Planning Corp.
* Buell Hollister – Kootenai Environmental Alliance
John Bentley – Kootenai Environmental Alliance (alternate)
Terry Baune – Farmer- FSA
Lester Higgins – Cd'A Tribe Natural Resource (Pesticide)

* David Neighbor – (formerly) Cd'A Tribe Natural Resource (Fish, Water & Wildlife)
Jim Colla – Idaho Department of Lands
Tom Pakootas – Cd'A Tribe Natural Resource (Fire Management)
Charles Hatch – University of Idaho
Ken Paulson – Heyburn State Park
George Bain – US Forest Service, St. Maries
* Kevin McHail – Potlatch Corporation
Waverly Reeves – Potlatch Corporation
John Bottelli – Cd'A Tribe EAP

Quality of Life Sub-Group Members

Rodney Frey – University of Idaho *(chair)*
* Gardner Cromwell – Retired Environmental Law Professor *(co-chair)*
Laura Ackerman – Washington Environmental Council
David A. Asher – Cenex Supply & Marketing (Worley)
A.F. Corky Booth – City of Plummer (EAP Steering Committee)
Larry Bruce – Golden Hill Resource – Bennet Lumber
Kathy Canfield-Davis – University of Idaho – IWRRI
Christine Crawford – Benewah S&WCD
* Matt Drechsel – Farmer
Robert Flagor – Kootenai Environmental Alliance (Human Health Member)
Kim Golden – Panhandle Lakes RC&D
Eric Granlund – Cd'A Tribe Natural Resource (Land Services)
Mike Hemkin – Farmer
Jim Linskey – Cenex Supply & Marketing (Spokane)
Richard Mullen – Cd'A Tribal Council
Charlotte Nilsen – Cd'A Tribe Planning & Development Corporation (EAP Steering)
* Ronald Peters – Cd'A Tribe Natural Resource (Fish, Water & Wildlife)
Dee Ann Bailey – Cd'A Tribe Natural Resources (Fish, Water & Wildlife)
Lee Provance – City of St. Maries (Public Works)
Ruth Rathbun – St. Joe Development (EAP Steering Committee)
Dixie Saxon Stensgar – Cd'A Tribe Education (EAP Steering Committee)
Jannette Taylor – Cd'A Tribe Education

Others Attending:

Ashley Martens – University of Idaho
Vardahi Petrosyah – University of Idaho
Lindsay Wichars – University of Idaho
Rhonda Rushing – Guest (Tiffany's Mother)
Pat Patterson – Community Member
Alieene "Boom" George – Cd'A Tribe EAP
Bill Beckley – Ridolfi Engineers
Greg Glass – Ridolfi Engineers
Charles Johnson – Advanced Forest System
Mandy Morrell – Cd'A Tribe EAP Student Intern
James Twoteeth – Cd'A Tribe EAP Student Intern

Kate Kramer – WCED
Raven C. George – Tribal Member (Youth)
Gary Greenwell – Economist (Contractor for Cd'A Tribe ANA)
Mary Bell Austin – U.S. EPA, Seattle (Air Quality)
Arlene Boss – U.S. EPA, Boise (Tribal Liaison)
Doug Cole – U.S. EPA, Boise (Tribal Programs)
John Emery – Potlatch Corporation
Kathy Hill – EPA, Seattle (former Director, Tribal Office)
Gabriella Lombardi – EPA, Washington, D.C.
Debora Martin – EPA, Washington, D.C.
Kurt Mettler – Cd'A Tribe Forestry
Susan Morales – EPA, Seattle (Environmental Justice)
Ken Sherwood – Cd'A Tribe Older Americans
Jim Webster – Western Center for Environmental Decision-Making
Anthony Garcia – Cd'A Tribe Social Services Intern
John Tsawklai – Cd'A Tribe EAP Student Intern
Bingo SiJohn – Cd'A Tribe Cultural Committee Member
Skip Skanen – Cd'A Tribe Elders Board
Terry Hendrickx – Cd'A Tribe Natural Resource Committee
Isaac SiJohn – Cd'A Tribe Natural Resource Committee
Kelly Lillengreen – Cd'A Tribe Natural Resource (Fish & Wildlife)
Chris Hardy – (formerly) Cd'A Tribe Natural Resource (Water)
Dave Barr – (formerly) Cd'A Tribe Natural Resource (Pesticide)
Janel McCurdy – Cd'A Tribe Natural Resource (Forestry Manager)
Norma Jean Louie – Cd'A Tribe Natural Resource (Land Service Manager)
Sydney Green – Advanced Forest Systems
Andrea Lewis – Heyburn State Park
Tamara Walsh – Heyburn State Park
Gerald Green – Cd'A Tribe Natural Resource (Fish, Water & Wildlife)
Leia McJoe – Cd'A Tribe EAP Student Intern
Veronica Torpey – Cd'A Tribe Land Services

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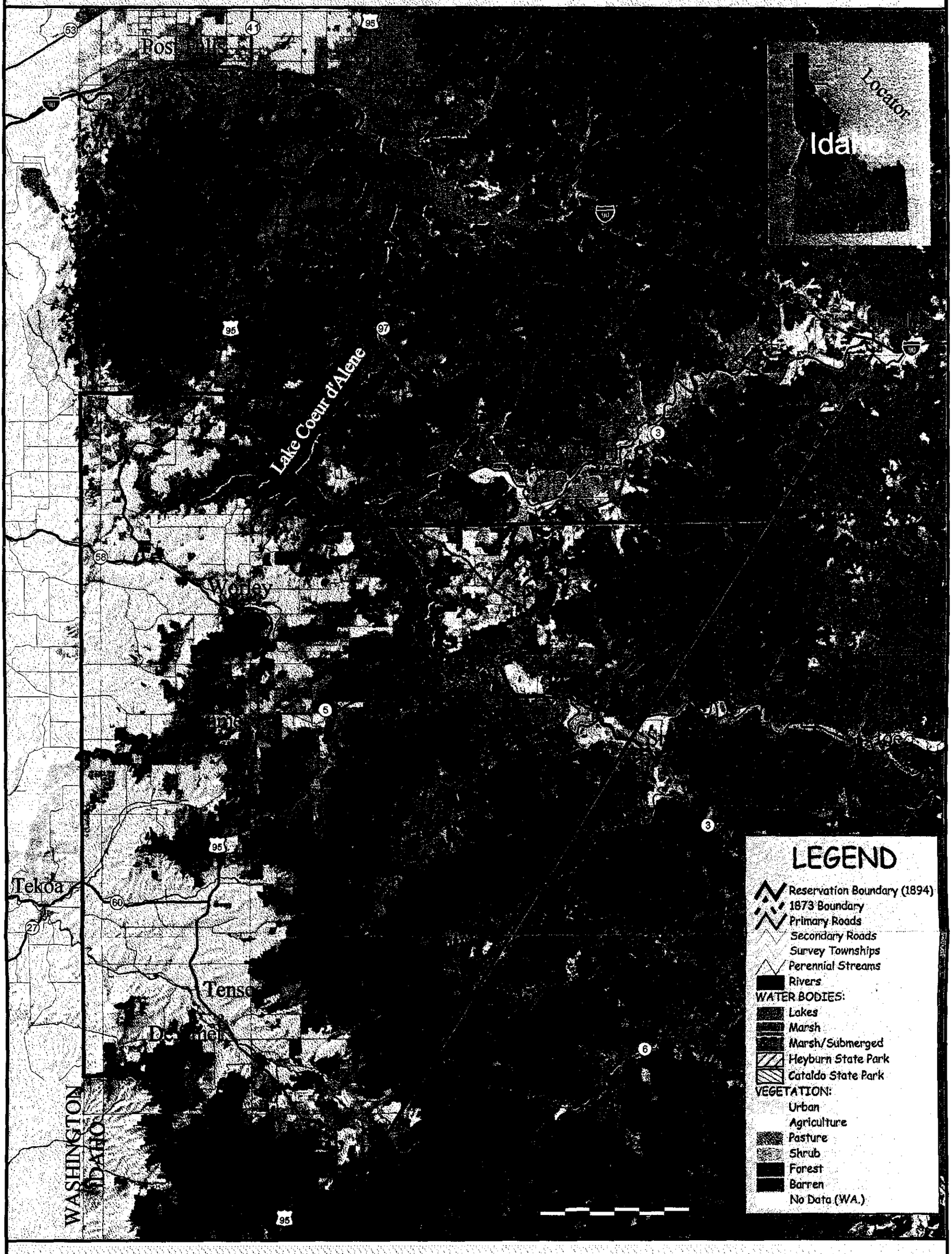
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EXECUTIVE SUMMARY



of the EAP Assessment

Coeur d'Alene Reservation



Coeur d'Alene Tribe Environmental Action Plan Project, J. Bottelli, Cd'A Tribe GIS, 5/31/99

Introduction

The Coeur d'Alene Tribe has prepared an Assessment of Environmental Concerns on and near the Coeur d'Alene Reservation as part of its broader Environmental Action Plan (EAP) Project.

- The EAP Project's main objective is to develop and implement a Coeur d'Alene Tribal Environmental Action Plan

The preliminary goals of the EAP Project are to:

- Improve local environmental conditions to benefit human health, ecology and quality of life
- Involve the public throughout the planning process
- Provide tools for Tribal and community environmental planning and action
- Increase communication and cooperation to improve environmental management

There are three phases of the EAP Project:

- Phase I – Assessment of Environmental Concerns
- Phase II – Development of an Environmental Management Plan
- Phase III – Implementation of the Environmental Management Plan

The Assessment report that follows is Phase I of the EAP, including the Risk Ranking of the 25 EAP environmental concerns. The Tribe's Assessment of Environmental Concerns on and near the Coeur d'Alene Reservation has been prepared to provide information about the natural environment to the Tribe, Tribal members, Reservation residents and other interested parties. This is the first time that the Tribe, or any agency or group, has researched comprehensive environmental concerns on the Coeur d'Alene Reservation. This Assessment should be viewed as a *beginning* in the compilation and understanding of information relating to the natural environment. The EAP Assessment does not assess the impact of historic mining and/or milling activities on natural resources on and/or near the Coeur d'Alene Reservation (i.e. including the Coeur d'Alene River). The Natural Resource Damage Assessment being undertaken by the Tribe and the United States is addressing mining and/or milling-related resource impacts independent of the EAP. In a few instances, the human-influenced environment is also addressed.

The Assessment reflects the work and involvement of over 150 people, Tribal and non-Tribal. It has taken over three years of active involvement from the participants to produce this report. With all of this interest and dedication, it is the Tribe's desire that the results of the Assessment will yield a greater understanding of the world around us.

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The following tables summarize the environmental concerns identified by those involved in the planning process, the criteria used by the sub-groups for assessment of risks, the topics addressed by each of the sub-groups, and the final risk rankings completed by the EAP Steering Committee and approved by the Tribal Council.

EAP Environmental Concerns List

Environmental Concerns	Including But Not Limited To the Following Items
LAND	
Agricultural chemicals	Pesticides, fertilizers, rodenticides, home/yard chemical use
Energy production and consumption	Environmental outcomes of local energy production and consumption such as wood burning stoves (except Post Falls dam)
Food contamination	Restaurant and public facility food safety, etc.
Tribal cultural food and medicines contamination	Most contaminants that affect traditional foods: heavy metals (other than mining), bacteria, animals eating chemicals on plants, etc.
Forest health	Pests, disease, species conversion, clear cutting, over-harvest, roads, fire suppression, loss of old-growth ponderosa pine, white pine, larch stands
Hazardous waste	Unremediated underground storage tanks, old fuel tanks in Lake, and accidental releases, etc.
Human population growth and development patterns	Local effects of population growth and how new developments affect natural resources
Roads	Safety, high density, effects on wildlife, hydrology, fisheries, dust
Solid waste generation and disposal	Smell at Kootenai County Farm Landfill, litter along roads, status of recycling options
AIR	
Indoor air pollution	Second-hand smoke, radon, mold, dust, toxic building materials, drift of agricultural chemicals into homes
Outdoor air pollution	Vehicles, co-generation, grass burning (including tradeoffs with water quality and erosion if burning was stopped), fugitive dust from roads, wood smoke, slash burning, etc.
Localized effects of atmospheric changes	Global climate change, ozone depletion
Localized effects of Hanford Nuclear Reservation	Thyroid problems, contamination of migratory species
WATER	
Drinking water quality and contamination	Wells, iron, inadequate treatment systems
Ground water contamination	Nitrates, ground water depletion/recharge rate, bacteria, etc.
Hydrologic changes	Flooding, reduction of surface water quantity, etc.
Non-point source surface water pollution	Storm water runoff, accidental sewer releases, road runoff, sediment
Point source surface water pollution	Abandoned vehicles leaking hazardous waste into water, sewage overflows, industrial discharges

MULTI-MEDIA	
Wetlands	Nutrient loading, loss of wetlands, change in quality of wetlands
Native plant and animal populations and species diversity	Tribal and non-Tribal harvest pressure-especially on migratory species, threatened and endangered species and sensitive species, effects of monoculture farming
Tribal culturally-important species' populations and diversity	Harvest pressure on wildlife, non-native plant species out-competing natives, pesticide use, habitat conversion to other uses
Native wildlife and fisheries habitat	Farming to creek edges, habitat fragmentation and destruction, lack of travel corridors in riparian areas, human-made barriers to migration, other human development, stream and lake temperatures (including wetland water temperatures.)
Non-native plant and animal species	Noxious weeds, competition and hybridizing between native and non-native fish species, diseases associated with non-natives
Soil productivity	Forest and agricultural soils, soil erosion (economic losses and impacts of new construction and farming, etc.), loss of farm production, boat wakes eroding banks of St. Joe River
Tribal cultural sites	Archaeological, spiritual, grave – impacts to these sites

It is important to note that the list of environmental concerns is broken into 25 broad categories and that this does not reflect the fact that the environment is one seamless or whole system. The EAP Project is breaking the concerns into categories only for the purpose of managing the assessment. It is the Project's hope that, once the 25 concerns are analyzed, a picture of the state of the environment as a whole environment as it affects the entire community, Tribal and non-Tribal, human and natural, will begin to emerge.

Criteria Used for Ranking/Evaluating Environmental Concerns

Criteria
HUMAN HEALTH
1. health effect and severity
2. population exposed
3. degree of uncertainty
4. identifiable trends
5. potential impacts to future generations
6. fairness and equity
ECOLOGICAL HEALTH
1. changes since settlement
2. magnitude of impacts
3. severity of impacts
4. reversibility of impacts
5. degree of uncertainty
6. current trends
7. impact to future generations
8. fairness/equity of impacts
QUALITY OF LIFE
1. economy and/or subsistence
2. spiritual and/or moral well-being
3. aesthetics
4. community well-being
5. personal well-being
6. impacts on Tribal culture
7. degree of uncertainty
8. identifiable trends
9. seasonal differences in severity of impacts
10. impacts on future generations
11. fairness/equity of impacts

Environmental Concern Categories Reviewed by EAP Sub-Groups

Environmental Concerns	Human Health	Ecology	Quality of Life
LAND			
Agricultural chemicals	X	X	X
Energy production and consumption		X	X
Food contamination	X		X
Tribal cultural food and medicines contamination	X		X
Forest health		X	X
Hazardous waste	X	X	X
Human population growth and development patterns	X	X	X
Roads	X	X	X
Solid waste generation and disposal	X	X	X
AIR			
Indoor air pollution	X		X
Outdoor air pollution	X	X	X
Localized effects of atmospheric changes	X	X	X
Localized effects of Hanford Nuclear Res.	X	X	X
WATER			
Drinking water quality and contamination	X		X
Ground water contamination	X	X	X
Hydrologic changes	X	X	X
Non-point source surface water pollution	X	X	X
Point source surface water pollution	X	X	X
MULTI-MEDIA			
Wetlands		X	X
Native plant and animal populations and species diversity		X	X
Tribal culturally-important species' populations and diversity		X	X
Native wildlife and fisheries habitat		X	X
Non-native plant and animal species		X	X
Soil productivity		X	X
Tribal cultural sites			X
TOTALS	**16**	**20**	**25**

Summary of Risk Rankings Completed by the EAP Steering Committee and Approved by the Coeur d'Alene Tribal Council

Final Risk Rankings of EAP Environmental Concerns - June 2000

Please note that, for the most part, the risk rankings are based upon conditions on and near the Coeur d'Alene Reservation and are not a comparison between the Reservation and other areas in the United States or the world. Also note that concern number 22 Native Wildlife and Fisheries Habitat has been broken into 22A Native Wildlife Habitat and 22B Native Fisheries Habitat because the Steering Committee thinks that wildlife habitat is at a medium risk while fisheries habitat is at an extreme risk.

Environmental Concerns	EAP Steering Committee Rankings
LAND	
1. Agricultural chemicals	8 MEDIUM/ 3 HIGH
2. Energy production and consumption	MEDIUM
3. Food contamination	MEDIUM
4. Tribal cultural food and medicines contamination	EXTREME
5. Forest health	HIGH
6. Hazardous waste	MEDIUM
7. Human population growth and development patterns	EXTREME
8. Roads	HIGH
9. Solid waste generation and disposal	MEDIUM
AIR	
10. Indoor air pollution	MEDIUM
11. Outdoor air pollution	MEDIUM
12. Localized effects of atmospheric changes	LOW
13. Localized effects of Hanford Nuclear Reservation	HIGH
WATER	
14. Drinking water quality and contamination	HIGH
15. Groundwater contamination	HIGH
16. Hydrologic changes	HIGH
17. Non-point source surface water pollution	HIGH
18. Point source surface water pollution	MEDIUM
MULTI-MEDIA	
19. Wetlands	6 MEDIUM/ 6 EXTREME
20. Native plant and animal populations and species diversity	HIGH
21. Tribal culturally-important species' populations and diversity	EXTREME
22A. Native wildlife habitat	MEDIUM
22B. Native fisheries habitat	EXTREME
23. Non-native plant and animal species	HIGH
24. Soil productivity	HIGH
25. Tribal cultural sites	EXTREME



Trails such as this are found in forests throughout the Coeur d'Alene Tribe's traditional territory. Scenes like this emphasize the importance of protecting the environment for all people.

Purpose of the Assessment of Environmental Concerns

The Coeur d'Alene Tribe's Natural Resource Department (NRD) began the Environmental Action Plan (EAP) Project in response to Tribal members' and Tribal Council's request for the NRD's goals. The Tribe's NRD was established and grew quickly between 1992 and 1996. Recognizing that an integrated or holistic approach to environmental management was needed due to the size and diversity of the Department, the NRD Director determined that a Reservation-wide environmental management plan was needed.

- The purpose of the Assessment or Phase I of the EAP Project is to collect and analyze existing information on a comprehensive set of potential environmental concerns on and near the Coeur d'Alene Reservation

The information contained in the Assessment report was used to rank the severity of the 25 broad environmental concerns that were identified. It will also be used to assist in developing goals for the Tribe's environmental management plan, Phase II of the EAP Project. Additional uses may include developing environmental education curricula for local schools, sharing it as a reference document to orient new employees of the Tribe's NRD and for general education.

What the Assessment of Environmental Concerns IS and IS NOT

The Tribe's Assessment of Environmental Concerns **IS**:

- an information tool
- a gathering of existing information on the Reservation's natural environment
- an analysis of existing information combined with "Best Professional and Community Judgment" to determine potential environmental concerns and rank the risks that they pose
- a beginning, a place to start in understanding the human-induced changes in the natural environment

The Tribe's Assessment of Environmental Concerns **IS NOT**:

- designed to set environmental management priorities by itself
- able to address the entirety of the Tribe's aboriginal territory and all Tribal resources due to time and funding constraints

How to Read the Assessment of Environmental Concerns

The Executive Summary (Volume 1) is the place to start if the reader would like a shorter version of the complete Assessment report.

If the reader is interested in details of the report, the complete report (Volume 2 and Volume 3) is broken into the following sections and subsections:

Volume 2:

- **Coeur d'Alene Tribe Historical Atlas** – thirteen maps comparing the present land uses with past land uses and landscape of the Coeur d'Alene Tribe
- **Human Health Effects Report** – describes how human health may be adversely affected by environmental concerns
- **Ecological Impacts Report** – describes how the ecology of the Reservation may be adversely affected by environmental concerns. It also compares the present condition with what is known about the past condition of the natural environment

Volume 3:

- **Quality of Life Impacts** – summarizes a sampling of local people's understanding about what is important to create a "good quality of life", in what ways the elements of a good quality of life might relate to the natural environment and what impacts the list of EAP environmental concerns might have on the quality of life
    - *The Importance of Natural and Environmental Resources in the Economy of the Coeur d'Alene Reservation* – a report that discusses the relationship between the economy of the Reservation and its natural and environmental resources
    - Summaries and full text of Quality of Life "focus group" sessions
    - Summary of Interviews Supplemental to Focus Group Information
    - Compilation of Quality of Life community questionnaires filled out at two local community events
- **Appendices to the EAP Assessment report**
    - Risk Ranking Reports
    - Summary of Public Involvement
    - Tribal Council resolutions for EAP Assessment

Methods Used to Develop the Assessment of Environmental Concerns

The method that was chosen to develop the Coeur d'Alene Tribe's Assessment of Environmental Concerns is called "Comparative Risk Assessment". The Tribe utilized

the United States Environmental Protection Agency's (EPA) information on Comparative Risk Assessment as a model, recognizing that all models require modification to fit a particular place or community. Some excellent references are:

- A Guidebook to Comparing Risks and Setting Environmental Priorities, US EPA 230-B-93-003, September 1993
- Public Involvement in Comparative Risk Projects: Principles and Best Practices – A Sourcebook for Project Managers, Western Center for Environmental Decision-Making, Boulder, CO, January 1997

The steps that were used to develop the EAP Assessment of Environmental Concerns are as follows:

Laying the EAP Project Groundwork (January 1997 to November 1997)

- Obtained US EPA funding for the Natural Resource Department
- Hired a Program Manager to coordinate the EAP Project
- Facilitated internal Tribal government discussions with Tribal leadership, Tribal Administration and staff from the various Tribal departments on environmental planning and management to use in developing the EAP Project
- Formed an EAP Steering Committee, composed of Tribal and non-Tribal people living on and near the Coeur d'Alene Reservation
- Developed a "Scope of Work" with the EAP Steering Committee
- Obtained Tribal Council approval for Steering Committee and Scope of Work
- Developed and obtained Tribal Council approval for a "Public Involvement Strategy" for use during the EAP Project
- Hosted an EAP Project "Kick-Off" Event to announce the EAP Project to the public and begin to recruit volunteers

Comparative Risk Assessment (July 2000)

- Began past and future visioning work – began the past vision in the form of the Atlas of Historical Maps
- Formulated draft environmental concern list based on existing information
- Involved the community with developing the environmental concern list and criteria to evaluate the concerns – two rounds of public meetings were held
- Finalized EAP List of Environmental Concerns

- Developed EAP Ranking Criteria to evaluate the EAP Environmental Concerns – a criteria addressing human health, ecology, quality of life and cross-cutting-categories
- Obtained Tribal Council approval of EAP Environmental Concerns List and Ranking Criteria
- Formed a Technical Workgroup to collect and analyze information on EAP List of Environmental Concerns
- Summarized information and analysis about List of Environmental Concerns in the EAP Assessment report
- Presented proposed final Assessment report to EAP Steering Committee for recommendation to go to Tribal Council
- Obtained Tribal Council approval to share EAP Assessment findings with the public
- Held third round of public meetings to share EAP Assessment findings and obtain input on the risk ranking of the EAP Environmental Concerns
- Ranked the Environmental Concerns for their risk to human health, ecology, quality of life and cross-cutting issues using the EAP Risk Ranking Criteria
- Obtained Tribal Council approval of the EAP Steering Committee's Risk Ranking of Environmental Concerns
- Inserted ranking results and all other modifications into the EAP Assessment of Environmental Concerns
- Obtained Tribal Council approval of EAP Assessment report

Scope of the EAP Assessment of Environmental Concerns

Geographic The Assessment's geographic boundary is the Reservation boundary for all of the reports, which currently includes 334,471 acres, not including Tribal submerged lands. There are a few exceptions. For some of the issues, the entire town of St. Maries was included, even though only half of it lies within the Reservation boundary. Additionally, for fisheries and water issues in the Ecological Impacts section of the report, 6 sub-watersheds were identified and some portion of 4 of the watersheds fall outside of the Reservation boundary.

The ownership of the Coeur d'Alene Tribe's waters and submerged lands has not been judicially determined in full. The federal court has ruled that the Tribe owns most of the waters and submerged lands within the current Coeur d'Alene Reservation. The court has not judicially established ownership for the waters claimed by both the Tribe and the state within Heyburn Park, Lake Coeur d'Alene north of Harrison, the Coeur d'Alene River and related lateral lakes downstream from Cataldo, and the southern half of the

Spokane river in Idaho. As such, the maps in this document do not show a Reservation boundary line crossing Lake Coeur d'Alene at Harrison.

The Tribe maintains an active interest in its aboriginal territory and nothing in this report is meant to limit the Tribe's rights and responsibilities to the entire aboriginal territory. Due to limitations of staff and funding, the Tribe, at this time, chose to begin the EAP Assessment process investigating the Reservation's natural environment. However, the scale of this report is still large enough that smaller scale assessments may yield additional details for particular watersheds or species. In other words, it is not possible that all impacts to Tribal resources are identified in this report at this time.

Temporal The temporal scope of the EAP Assessment begins approximately at the time of non-Indian settlement of the Reservation area. A date of 1850 was chosen to represent the beginning of settlement. One of the evaluation criteria for the Risk Ranking is "Changes Since Settlement". The EAP Assessment itself is a current picture of the Reservation environment when compared with changes since settlement. Then, another Risk Ranking evaluation criteria is "Impacts to Future Generations" and the projection is 100 years into the future. The Tribe feels that it is important to address the past, present and future when considering the natural environment due to the immense changes that have occurred and are expected to continue occurring due to human activities.

Topical Only two main topics were deliberately excluded from consideration: Heavy metals contamination from mining, including the transportation of mined materials, and impacts from the Post Falls Dam. The topics of heavy metals contamination and impacts of the Post Falls Dam are currently the subject of litigation and/or negotiation. As such, they are already identified as potential risks and top priorities of the Tribe.

All other topics were available to the public, EAP participants and the Tribe to include in the List of Environmental Concerns. In fact, the goal was to assemble a *comprehensive* environmental concerns list. However, it is probable that potential environmental concerns were missed.

Impacts to Coeur d'Alene Tribal Culture from Environmental Concerns

There is no doubt that the environmental concerns identified in the EAP Assessment have had a monumental impact upon Coeur d'Alene Tribal culture. Yet it is difficult to even define what "Coeur d'Alene Tribal culture" is or was or will be. One Tribal member thought that this phrase could be broken into three areas: 1) traditional Tribal culture, 2) current Tribal culture, and 3) Reservation culture.

Three of the EAP Environmental concerns, "Tribal Food and Medicines Contamination", "Tribal Culturally-Important Species" and "Tribal Cultural Sites", have incorporated the idea that there is *Tribal culture*. However, for the most part, the EAP Assessment decided not to attempt to evaluate impacts to Tribal culture. Tribal culture is, however, alluded to in the Historical Atlas in the map entitled, "Landscape of the

Schitsu'umsh (Coeur d'Alene Tribe)". Impacts to Tribal culture were also discussed in the focus group sessions that made up the Quality of Life Impacts section of the Assessment. In the case of the Quality of Life section, a small number of Tribal members shared general ideas on how the environmental concerns may impact Tribal culture. Therefore, it must be viewed as an incomplete discussion of Tribal culture as it relates to environmental concerns primarily in the natural world.

Several themes have emerged during the time that Coeur d'Alene Tribal culture was discussed by Tribal members in the EAP Assessment process. Some of these themes have also been identified in *The World of the Coeur d'Alene Indians: Landscape Traveled by Crane and Coyote*, the manuscript based on interviews with Coeur d'Alene Tribal members and prepared by Dr. Rodney Frey (who also chaired the EAP Quality of Life sub-group). These themes can be summarized as follows:

- Non-humans are included in traditional Tribal familial relationships, as close and immediate relatives
- Tribal culture is different for each individual and each family in the Tribe
- It is more difficult than it used to be to find Tribal foods and medicines in the landscape on the Reservation (i.e. camas, water potato, huckleberry, grouse, etc.)

There is undoubtedly an extremely close relationship between the natural environment and traditional Tribal culture. Impacts to the natural environment have had corresponding impacts upon Tribal culture. This report will not attempt to describe details associated with those impacts due to the intricacy and sensitivity of the task.

Summary of Public Involvement in the EAP Assessment Phase

By involving Tribal and non-Tribal members on Environmental Action Plan (EAP) committees, public involvement has been built into the structure of the EAP Assessment process. In addition, a number of opportunities were created for additional public involvement which are summarized below:

- **EAP Project Kick-Off**: invitations were sent to over 200 mailing addresses for agencies, church groups, media, environmental and community organizations and others to attend the EAP Kick-Off held on **Tuesday, October 14th, 1997**. Over 100 people signed in and many of these people became members of the EAP Technical Workgroup as volunteers. Newspaper articles and a television news story resulted.
- **First Round of EAP Public Meetings**: 4 public meetings were held in **January and February of 1998** in Worley, Plummer, St. Maries and Tensed in the evenings to introduce the EAP Project and to obtain the public's environmental concerns for the EAP List of Environmental Concerns. Over 50 people attended the public meetings and provided valuable input to the EAP Project. Meetings were advertised in the St. Maries Gazette, Coeur d'Alene Press, Spokesman-Review, radio announcements and fliers. Follow-up newspaper articles resulted.
- **EAP Technical Workgroup formed in February 1998:** this Workgroup was broken into 3 sub-groups (Human Health, Ecology and Quality of Life). All people who indicated an interest in being on the EAP Technical Workgroup at the EAP Kick-Off meeting were invited to become volunteer members.
- **Second Round of EAP Public Meetings**: Four public meetings and one Tribal/Native American meeting were held in **May and June of 1998** to obtain input on the draft EAP Environmental Concerns List and draft Risk Ranking Criteria. A total of 55 people attended. However, 29 people were already participating in the EAP process. Of the 26 people who attended the meetings who were not participating in the EAP process, 18 attended the Tribal member/Native American meeting. However, valuable input was obtained at the public meetings and used to finalize the EAP List of Environmental Concerns and Risk Ranking Criteria. Meetings were advertised through local newspaper and radio announcements, as before. Fliers were also distributed locally.
- **Invitation letters to all participants in the First and Second Round of EAP Public Meetings were sent in July 1998**: invitations were sent to solicit additional community volunteers for the EAP Technical Workgroup/sub-groups.
- **Third Round of EAP Public Meetings**: Four public meetings and one Tribal/Native American meeting were held in February and March 2000. The proposed final draft EAP Assessment report was shared for comment and risk ranking questionnaires were distributed. A total of 75 people attended the meetings and 132 questionnaires were returned by the public and EAP participants. Changes have also been made to the EAP Assessment report in response to public comment, and the EAP Steering Committee reviewed the questionnaire results to prepare for their risk ranking sessions.

Report Findings

Executive summaries are presented for each of the four main sections of the EAP Assessment. The complete reports, along with supporting supplemental material, are contained in Volumes II and III for each of these areas:

- Coeur d'Alene Tribe Historical Atlas
- Human Health Effects Report
- Ecological Impacts Report
- Quality of Life Impacts Report



Wheat fields after harvest. Agriculture on the Coeur d'Alene Reservation has many economic and environmental impacts.

Coeur d'Alene Tribe
Historical Atlas
Executive Summary

Introduction

The Coeur d'Alene Tribe Historical Atlas attempts to use historical information to produce maps showing changes that have occurred in the local environment over the past 150 years. A total of 13 maps were produced for the Historical Atlas. The benefit of looking to the past is that context can be gained for interpreting the conditions of the present. While it is not possible to go back to some correct "starting point" (since any snapshot in time is just one moment in a continual flow of change), by looking back as far as possible there can be some yardstick from which to measure change.

Methods

Historic maps, documents, survey records, soil reports and inventory data were acquired from various sources including Libraries, Archives, Government Agencies, collections of private individuals and the Coeur d'Alene Tribe. These materials were evaluated for their descriptive potential and entered into the Tribe's Geographical Information System (GIS). More than a dozen new GIS layers were created and over 500 aerial photographs from 1933 and 1946 were saved in digital format for future analysis. The project also produced a large inventory of historical documents and maps which have been indexed and catalogued for future use by the Tribe.

Description of Maps

Maps 1 & 2: Landscape of the *Schitsu'umsh*; Landform / Habitat Regions: Coeur d'Alene Tribe's Aboriginal Territory

The first two maps in the Atlas show the area of the Tribe's Aboriginal Territory. The first presents the general layout of the landscape and the second is an interpretive map that speaks to the composition of the landscape, showing landforms and discussing their history and origins. The remaining maps in the Atlas demonstrate changes in the cultural and natural landscapes on the Coeur d'Alene Reservation.

Map 3: History of Reservation Boundaries

This map shows changes in land ownership over time which have influenced the patterns of land use affecting the Reservation environment. From the 1873 Reservation that was negotiated from an aboriginal territory that spanned millions of acres, Tribal land

ownership today amounts to a percentage of the current 334,471 acre (not including Tribal submerged lands) Reservation.

Map 4: Locations of Allotments and Areas "Opened" for the 1910 Lottery

All lands within the negotiated Reservation boundaries consistently remained Coeur d'Alene Tribal territory until the General Allotment Act was implemented on the Coeur d'Alene Reservation in stages between 1906 and 1910. That year, more than two-thirds of the lands on the Reservation were "sold" to non-Indian settlers in a nation-wide lottery. The U.S. government took this action unilaterally, over Tribal objection, and in violation of its 1889 agreement with the Coeur d'Alene Tribe.

Map 5: Locations of Forest Land and Agricultural/Grasslands in 1906

This map was created from the original field notes of Harold Rands, who conducted the survey and subdivision of the Reservation in 1905-1906 in preparation for allotment.

- At least 84,000 acres of forest have been cleared from the Reservation for agricultural and other land uses since 1906.

Map 6: Estimated Pre-Settlement and Current Wetlands Compared with Land Use

The locations of potential pre-settlement upland wetlands were identified using information contained in soil surveys.

- More than 20,000 acres – over 80% – of the estimated original wetlands have been potentially lost to mainly agricultural uses in the last 150 years.

Map 7: Proportion of Cultivated Land by Section in 1935 and Today

This map highlights the dramatic increase in agricultural activity that characterizes the western half of the Reservation. Some areas such as Benewah Creek show a reduction in cultivated land since 1935.

Maps 8 & 9: Roads: Coeur d'Alene Reservation circa 1939; Roads: Coeur d'Alene Reservation Today

The road data show two groups of findings:

- Paved roads on the Reservation increased from 49 miles to 284 miles from 1939 to the present day; gravel roads increased from 88 to 477 miles; dirt & 4wd roads increased from 508 to 2058 miles. The increase in total miles of road on the Reservation from 1939 to the present day was from 645 to 2855.

- Changes in *road surface (i.e. paved, gravel, etc.)* characterize the agricultural areas in the western half of the Reservation, while *new road construction* has been concentrated in the mountains.

Map 10: 1933 Forest Survey Data: Size Class of Timber Stands

- 25% of the mapped stands were sawlogs in 1933, the remaining 75% were pole trees or saplings.
- 80% of sawlog stands were 160-200+ years old; the majority of pole stands and seedling stands (78% and 97%) were classed as 0-80 years old.

Map 11: 1933 Forest Survey Data: Potential Old Growth Stands

There were more than 24,000 acres of *potential* old growth forest still standing on the Reservation in 1933, nearly 75% of which was Ponderosa Pine in the Hangman Creek watershed.

Map 12: 1933 Forest Survey Data: Economic Timber Stands

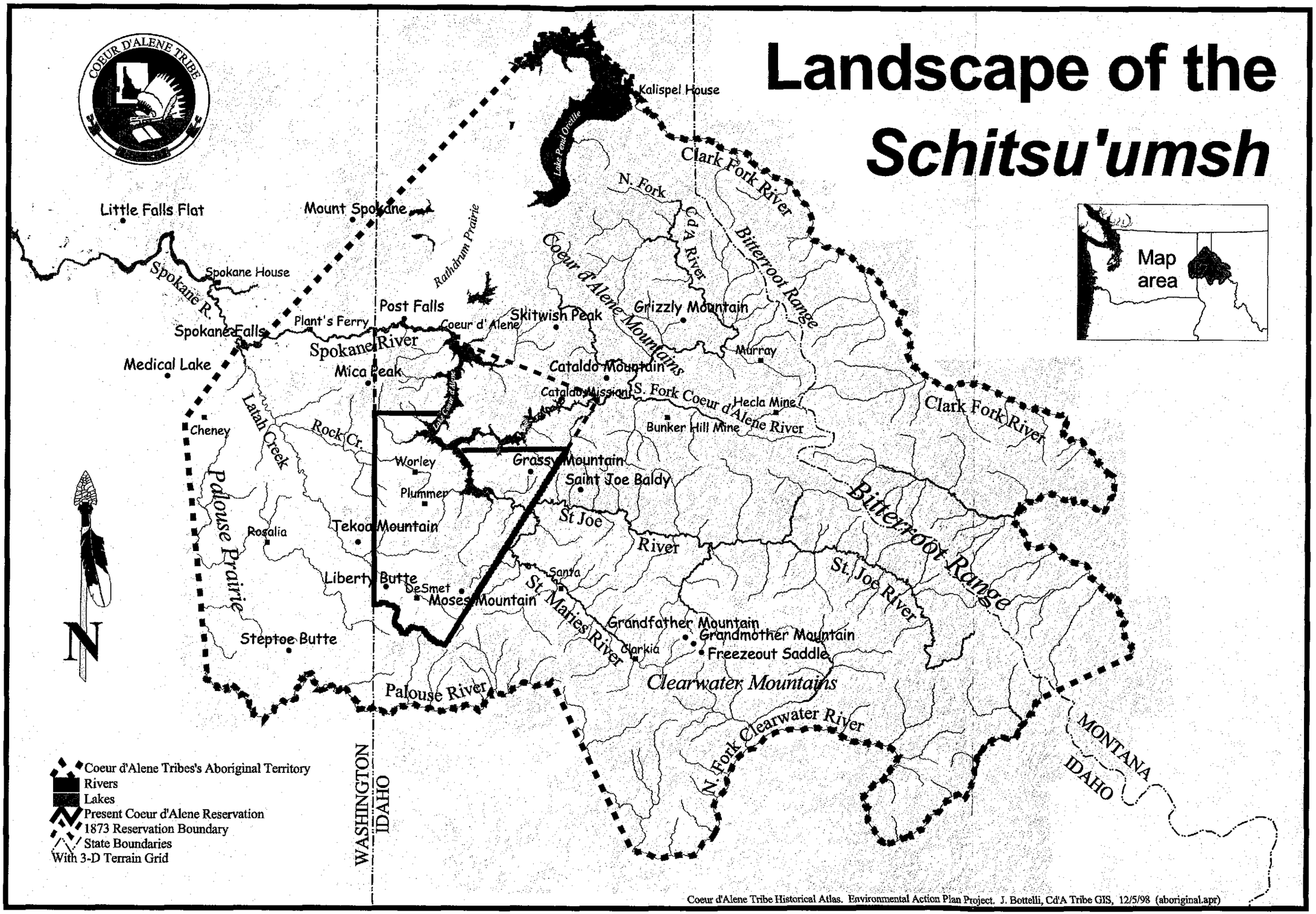
This map shows the species types of the mapped timber stands on the Reservation.

- In 1933, ponderosa pine, western white pine, and larch-Douglas-fir comprised the major stand types within the mapped area, accounting for 36%, 13% and 18% of the total area respectively.

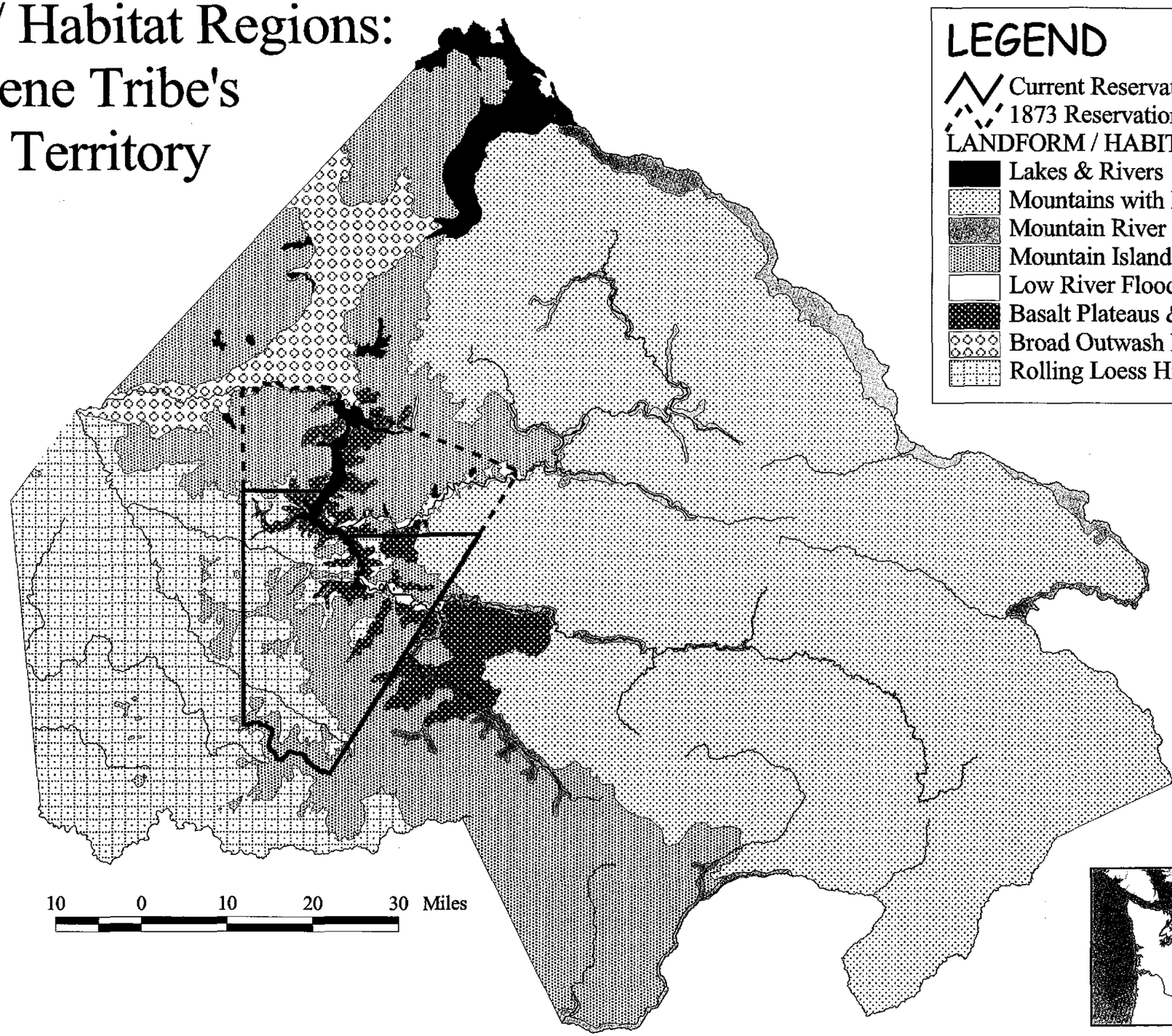
Map 13: Current Satellite Land Cover Data: Cover Types Grouped into 1933 Timber Stand Classifications

This map shows current forest types on the Reservation within the same area that was mapped in 1933. The modern cover types were re-classified according to the stand definitions used for the 1933 data. Overlay analysis of the two data sets suggest potential changes in species composition on the Reservation that would need to be checked with ground data to determine their accuracy.

- Ponderosa pine, western white pine, and larch/Douglas-fir types have been greatly reduced and fragmented, or eliminated altogether. Ponderosa pine accounts for 15% today (down from 36%), and western white pine no longer exists as a dominant type on the Reservation.
- Grand fir/western hemlock/western red cedar types now account for 40% of the mapped area, an enormous increase (up from 3.0% in 1933).
- Agriculture/pasture now accounts for 19% of the area (up from 13% in 1933).


Landscape of the
Schitsu'umsh
COEUR D'ALENE TRIBE
Kalispel House
Lake Pend Oreille
Clark Fork River
N. Fork
Cd'A River
Bitterroot Range
Little Falls Flat
Mount Spokane
Rathdrum Prairie
Coeur d'Alene Mountains
Spokane House
Spokane R.
Post Falls
Plant's Ferry
Coeur d' Alene
Skitwish Peak
Grizzly Mountain
Spokane Falls
Spokane River
Murray
Medical Lake
Mica Peak
Cataldo Mountain
Cataldo Mission
S. Fork Coeur d'Alene River
Hecla Mine
Bunker Hill Mine
Clark Fork River
Latah Creek
Rock Cr.
Cheney
Worley
Grassy Mountain
Saint Joe Baldy
Plummer
Palouse Prairie
St Joe River
Bitterroot Range
Rosalia
Tekoa Mountain
Liberty Butte
DeSmet
Moses Mountain
Santa
St. Maries River
St. Joe River
Grandfather Mountain
Grandmother Mountain
Clarkia
Freezeout Saddle
Steptoe Butte
Clearwater Mountains
Palouse River
N. Fork Clearwater River
MONTANA
IDAHO
WASHINGTON
IDAHO
Map area
N
Coeur d'Alene Tribes's Aboriginal Territory
Rivers
Lakes
Present Coeur d'Alene Reservation
1873 Reservation Boundary
State Boundaries
With 3-D Terrain Grid
Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/5/98 (aboriginal.apr)

Landform / Habitat Regions: Coeur d'Alene Tribe's Aboriginal Territory



LEGEND

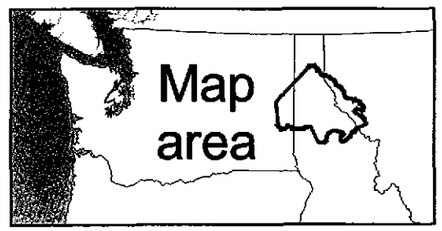
- Current Reservation Boundary
- 1873 Reservation Boundary

LANDFORM / HABITAT REGIONS:

- Lakes & Rivers
- Mountains with Deep River Canyons
- Mountain River Valley Bottoms
- Mountain Islands & Footslopes
- Low River Floodplains
- Basalt Plateaus & Escarpments
- Broad Outwash Plains
- Rolling Loess Hills

N

10 0 10 20 30 Miles

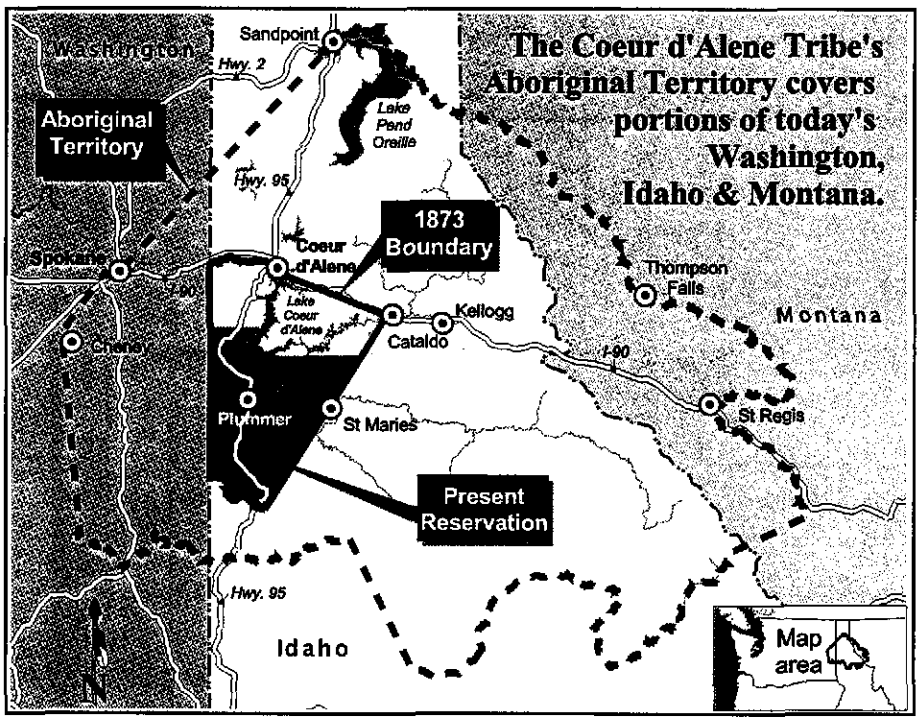


The information depicted on this map is the result of digital analyses performed on a database consisting of information from a variety of governmental and other credible sources. The accuracy of the information presented is limited to the collective accuracy of the database on the date of the analysis. The information is believed accurate and reasonable efforts have been made to ensure the accuracy of the map. However, the Coeur d'Alene Tribe expressly disclaims responsibility for damages or liability that may arise from use of this map. This product is the property of the Coeur d'Alene Tribe and its use is thereby restricted.

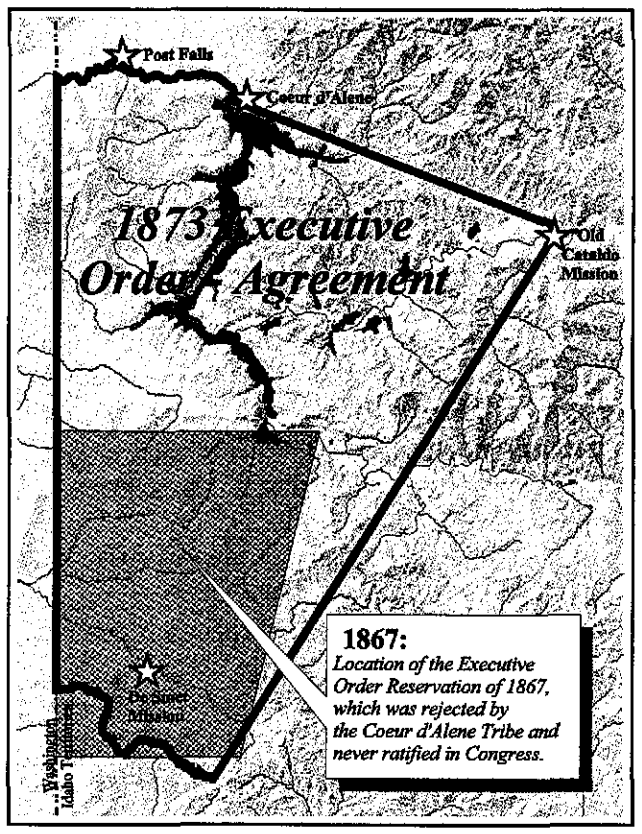
Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 1/24/99 (physmap.apr)

History of Reservation Boundaries

OVERVIEW



1873



1891

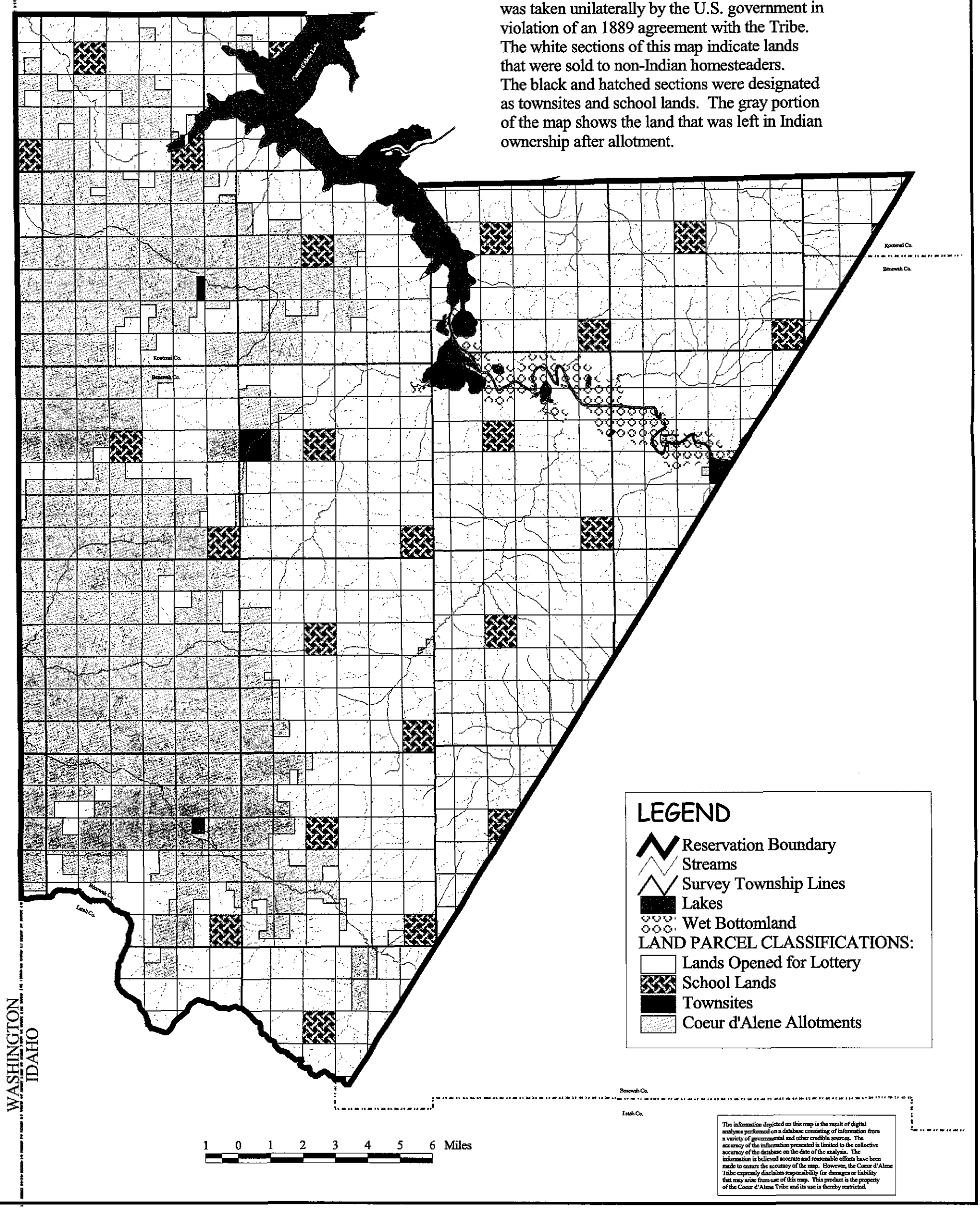
1894

1910

1999

Lands "Opened" for the 1910 Homestead Lottery on the Coeur d'Alene Reservation

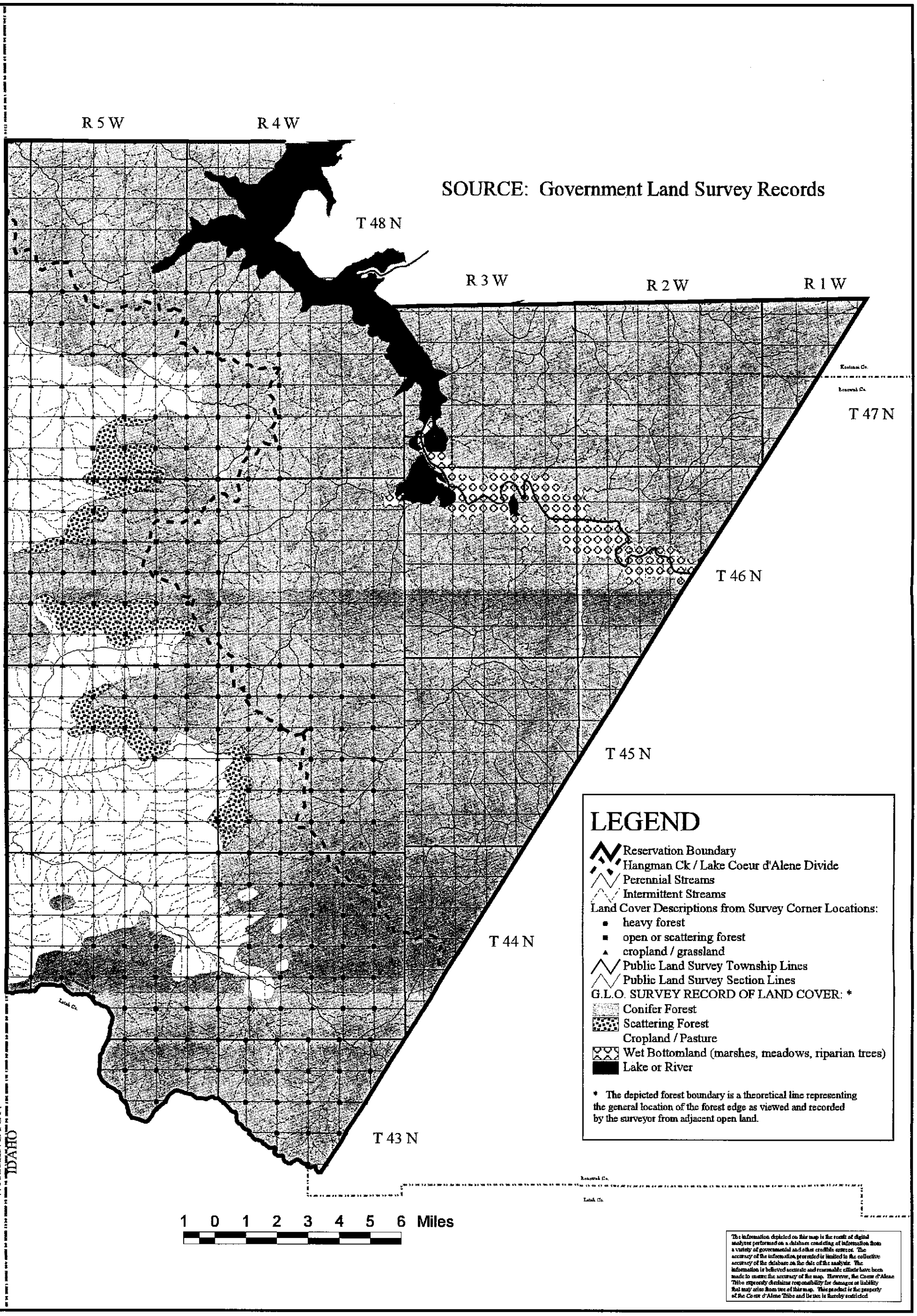
In 1910, more than two-thirds of the land on the Coeur d'Alene Reservation was taken without Tribal consent and sold through the General Land Office in a nation-wide lottery. This action was taken unilaterally by the U.S. government in violation of an 1889 agreement with the Tribe. The white sections of this map indicate lands that were sold to non-Indian homesteaders. The black and hatched sections were designated as townsites and school lands. The gray portion of the map shows the land that was left in Indian ownership after allotment.



The information depicted on this map is the result of digital analysis performed on a database consisting of information from a variety of governmental and other credible sources. The accuracy of the information presented is limited to the collective accuracy of the database on the date of the analysis. The information is believed accurate and reasonable efforts have been made to ensure the accuracy of the map. However, the Coeur d'Alene Tribe expressly disclaims responsibility for damages or liability that may arise from use of this map. This product is the property of the Coeur d'Alene Tribe and its use is thereby restricted.

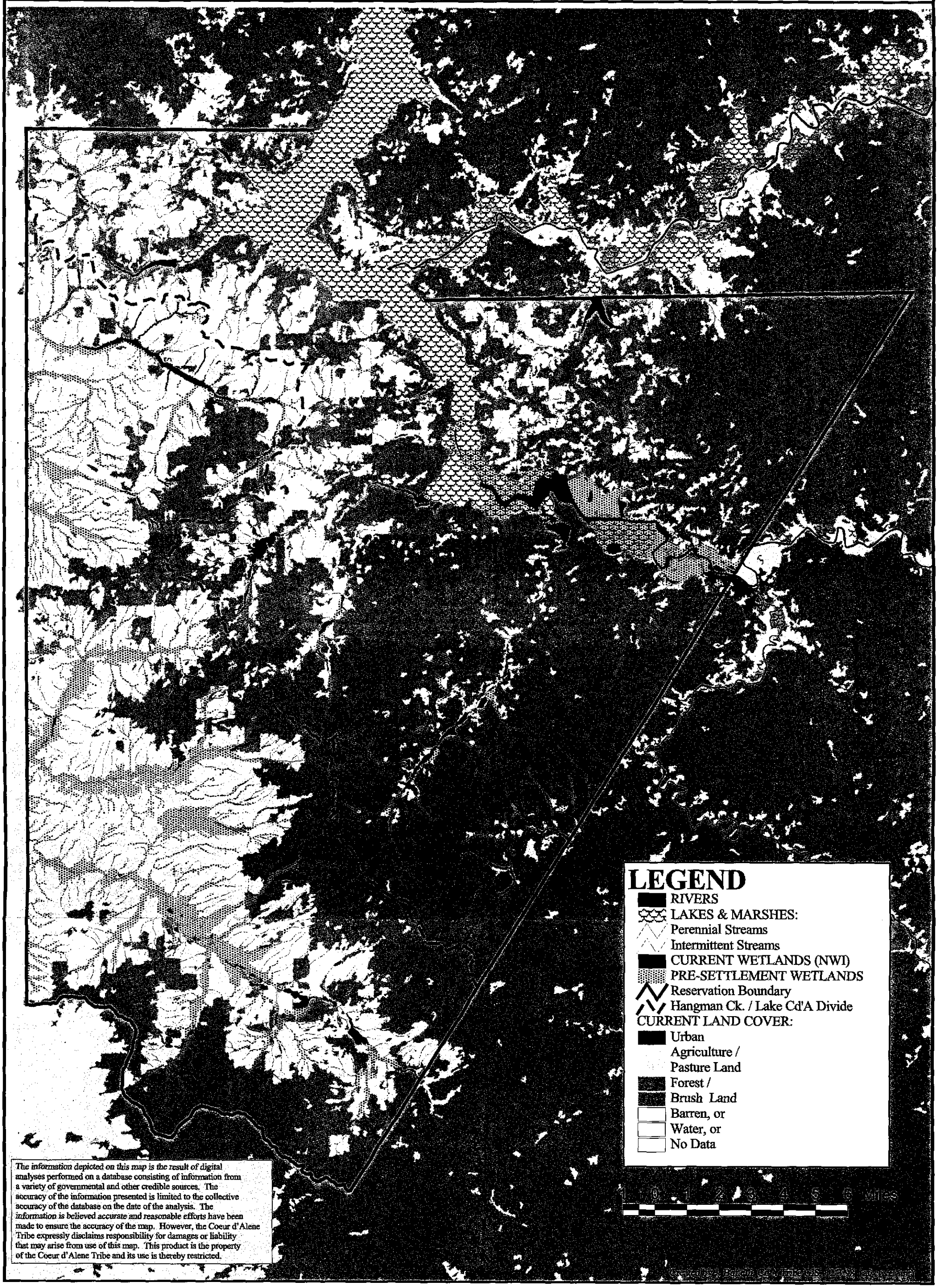
Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/4/98 (allotments.apr)

Locations of Forest Land and Agricultural/Grasslands in 1906



Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/4/98 (corners1905.apr)

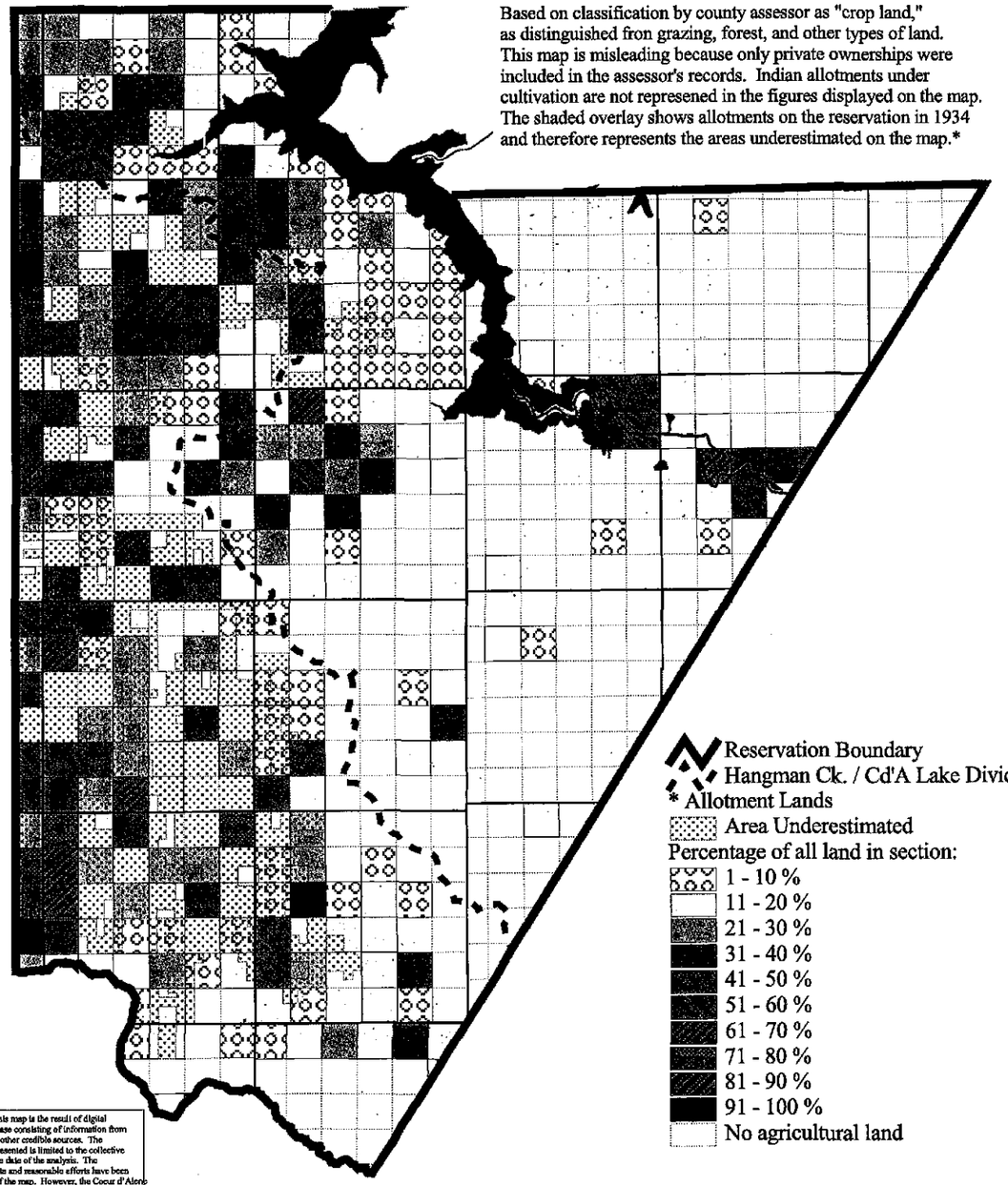
Estimated Pre-Settlement Wetlands Compared with Current Land Cover



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Proportion of Cultivated Land

Percentage of land in Agriculture in 1933

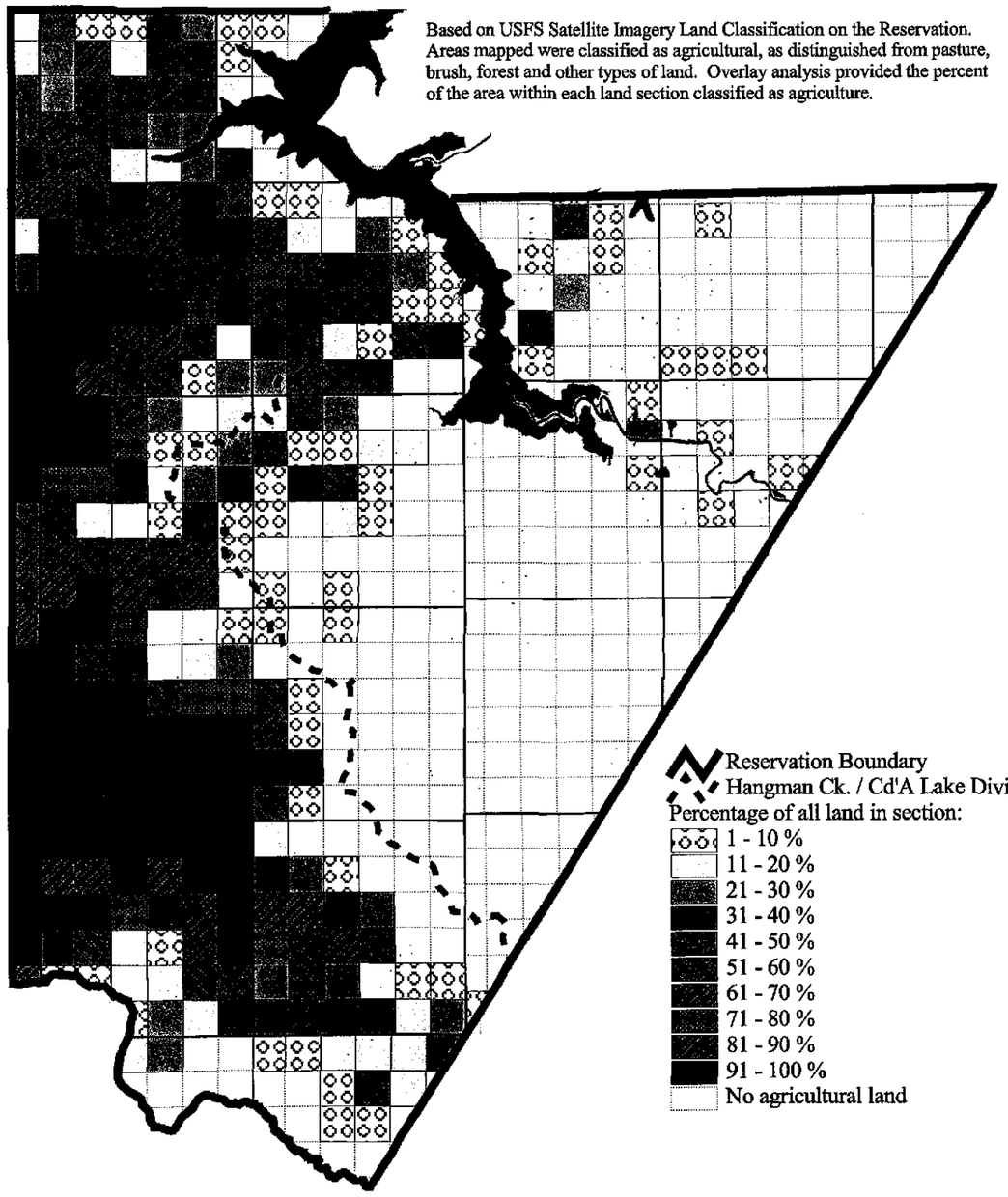


Based on classification by county assessor as "crop land," as distinguished fron grazing, forest, and other types of land. This map is misleading because only private ownerships were included in the assessor's records. Indian allotments under cultivation are not represened in the figures displayed on the map. The shaded overlay shows allotments on the reservation in 1934 and therefore represents the areas underestimated on the map.*

Reservation Boundary
Hangman Ck. / Cd'A Lake Divide
* Allotment Lands
Area Underestimated
Percentage of all land in section:
1 - 10 %
11 - 20 %
21 - 30 %
31 - 40 %
41 - 50 %
51 - 60 %
61 - 70 %
71 - 80 %
81 - 90 %
91 - 100 %
No agricultural land

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Percentage of Agricultural Land Today

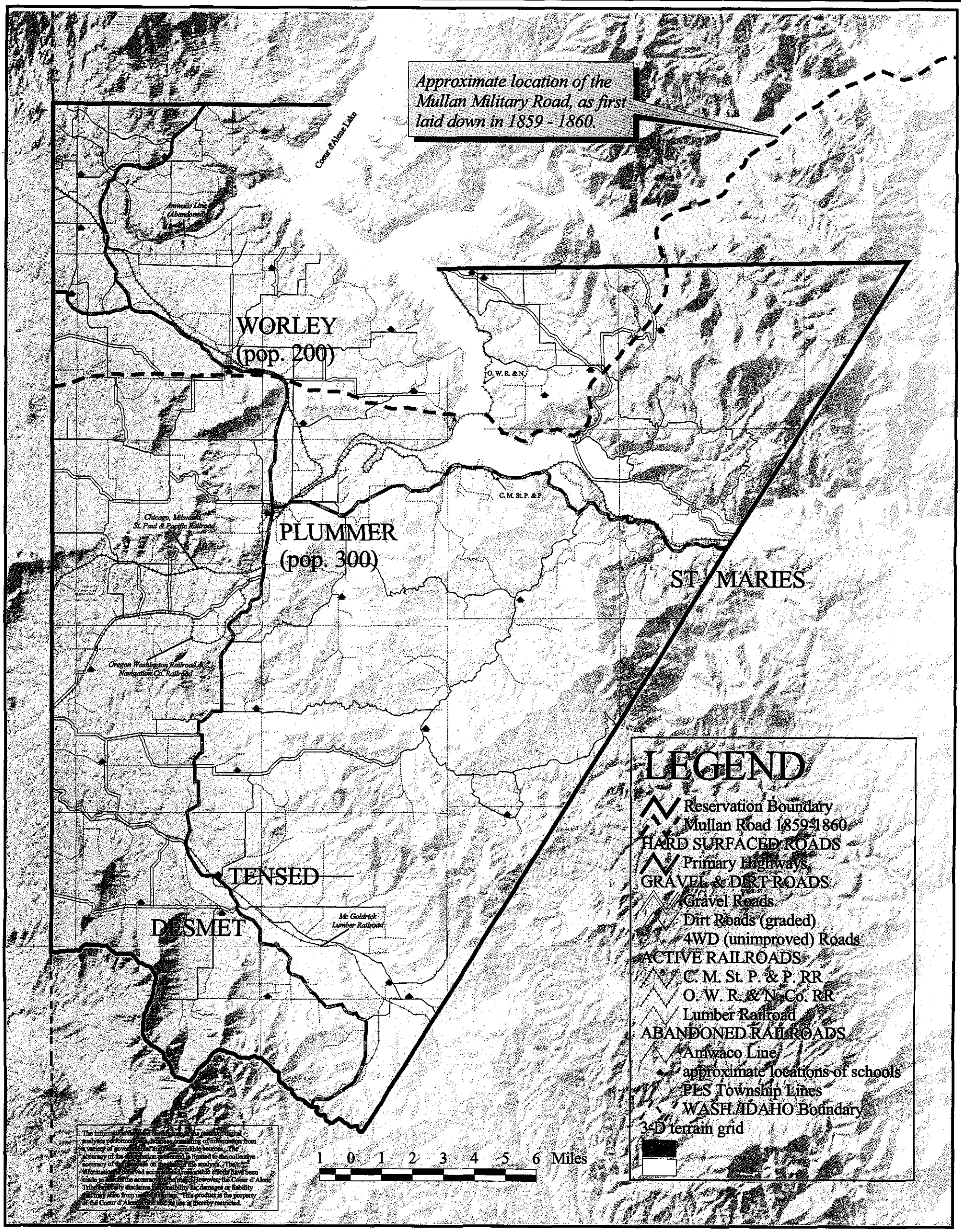


Based on USFS Satellite Imagery Land Classification on the Reservation. Areas mapped were classified as agricultural, as distinguished from pasture, brush, forest and other types of land. Overlay analysis provided the percent of the area within each land section classified as agriculture.

Reservation Boundary
Hangman Ck. / Cd'A Lake Divide
Percentage of all land in section:
1 - 10 %
11 - 20 %
21 - 30 %
31 - 40 %
41 - 50 %
51 - 60 %
61 - 70 %
71 - 80 %
81 - 90 %
91 - 100 %
No agricultural land

Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/4/98 (agstats.apr)

ROADS: Coeur d'Alene Reservation circa 1939



The information contained herein is the product of digital analyses performed on a database consisting of information from a variety of governmental and public, credible sources. The accuracy of the information presented is limited to the collective accuracy of the databases on which the analysis. The information has received accompanied reasonable efforts have been made to maximize the accuracy of the data. However, the Coeur d'Alene Tribe specifically disclaims any responsibility for damages or liability arising from use of this map. This product is the property of the Coeur d'Alene Tribe and its use is thereby restricted.

Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/5/98 (roads_old.apr)

ROADS: Coeur d'Alene Reservation Today

Approximate location of the Mullan Military Road, as first laid down in 1859 - 1860.

Coeur d'Alene Lake

WORLEY

PLUMMER

ST. MARIES

TENSED

DESMET

WASHINGTON

IDAHO

LEGEND

PAVED ROADS:
- Primary Highways
- Secondary Roads

NATIVE SURFACE ROADS:
- Gravel Roads
- Dirt & 4WD Roads
- Railroads
- Abandoned Railroads
- Reservation Boundary
- PLS Township Lines

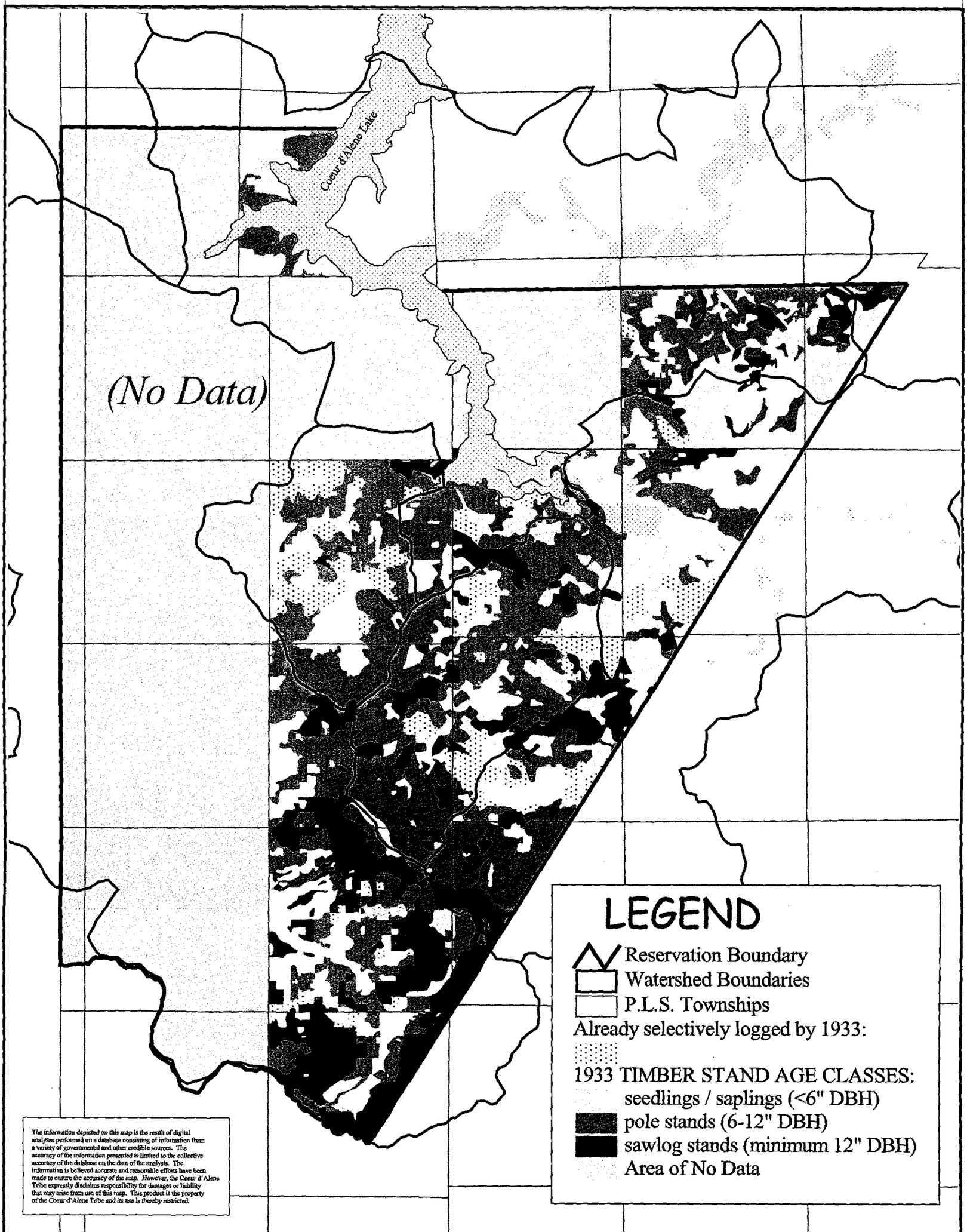
3-D terrain grid

1 0 1 2 3 4 5 6 Miles

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Coeur d'Alene Tribe Historical Atlas. Environmental Action Plan Project. J. Bottelli, Cd'A Tribe GIS, 12/5/98 (roads_old.apr)

1933 Forest Survey Data: Size Class of Timber Stands



LEGEND

- Reservation Boundary
- Watershed Boundaries
- P.L.S. Townships

Already selectively logged by 1933:

1933 TIMBER STAND AGE CLASSES:

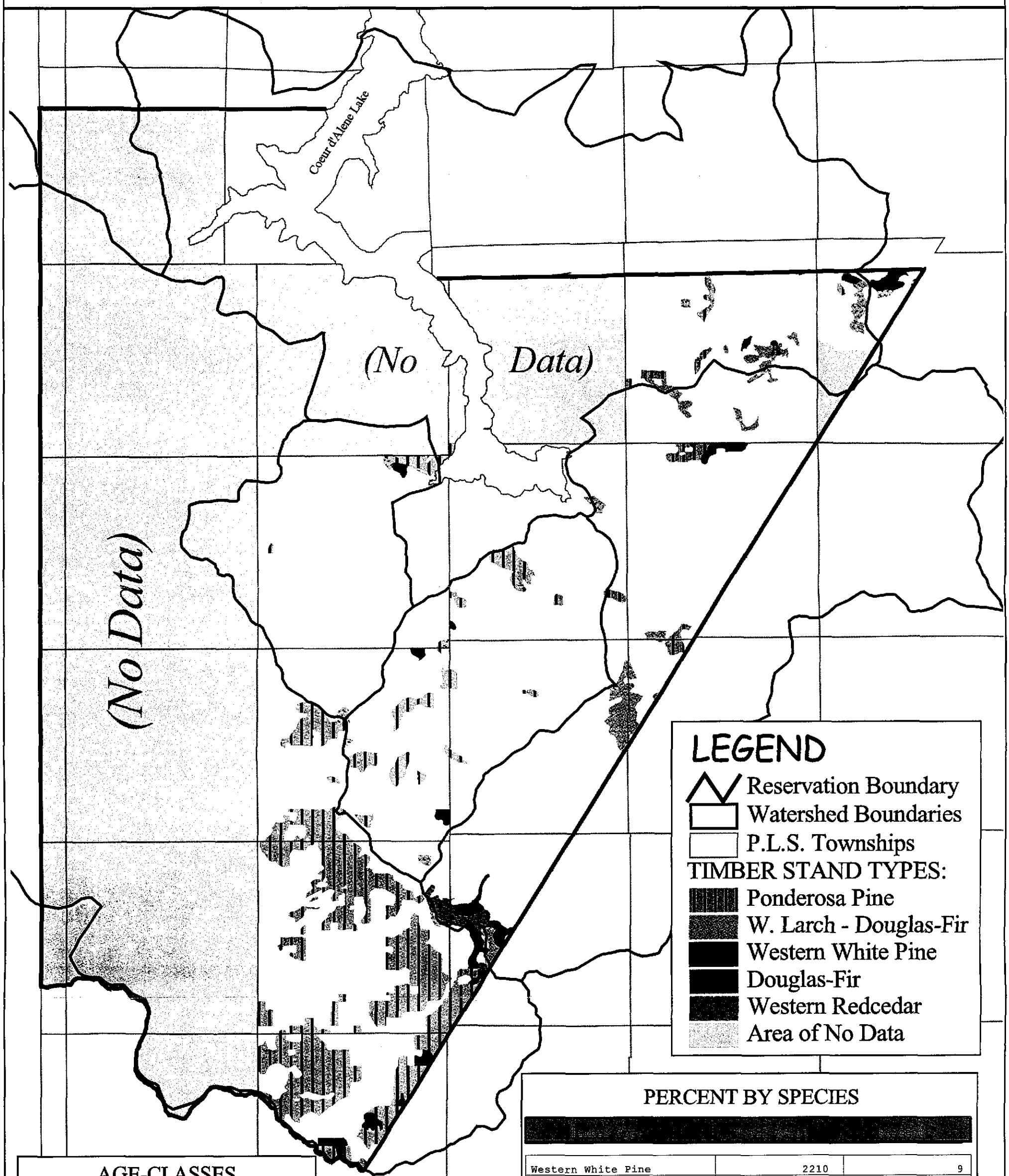
- seedlings / saplings (<6" DBH)
- pole stands (6-12" DBH)
- sawlog stands (minimum 12" DBH)
- Area of No Data

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Coeur d'Alene Tribe Historical Atlas. J. Bottelli, Cd'A Tribe GIS, 1/25/99 (forests33.apr)

1933 Forest Survey Data: Potential Old Growth Stands

* Unmanaged Pole and Sawlog Stands that were identified as 160-200 or 200+ years old in 1933.



AGE-CLASSES

161-200	1848	8
200+	22602	92

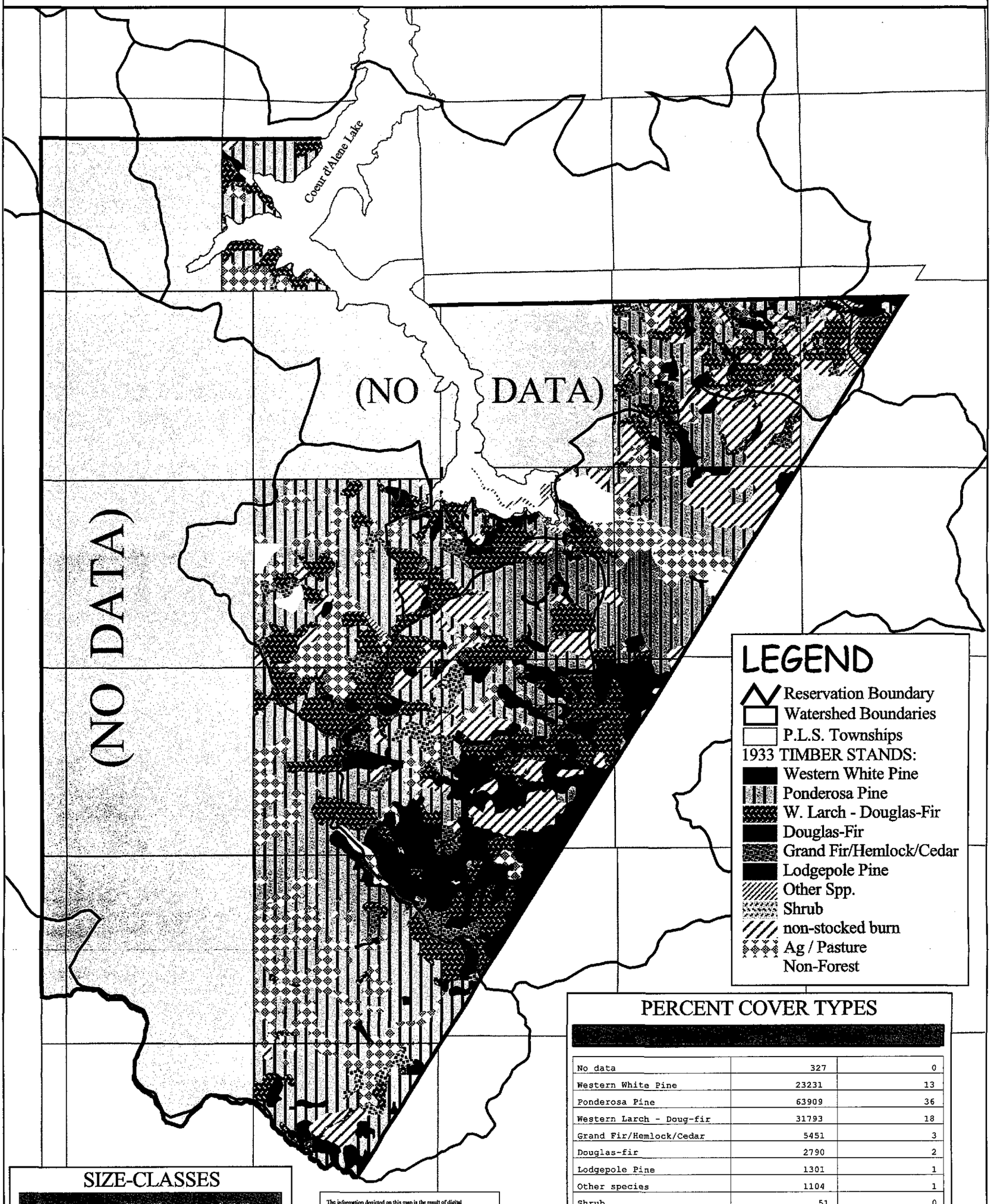
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PERCENT BY SPECIES

Western White Pine	2210	9
Ponderosa Pine	18282	75
Western Larch - Doug-fir	3058	13
Douglas-fir	143	1
Western Redcedar	755	3

Coeur d'Alene Tribe Historical Atlas. J. Bottelli, Cd'A Tribe GIS, 1/25/99 (forests33.apr)

1933 Forest Survey Data: Economic Timber Stand Types



PERCENT COVER TYPES

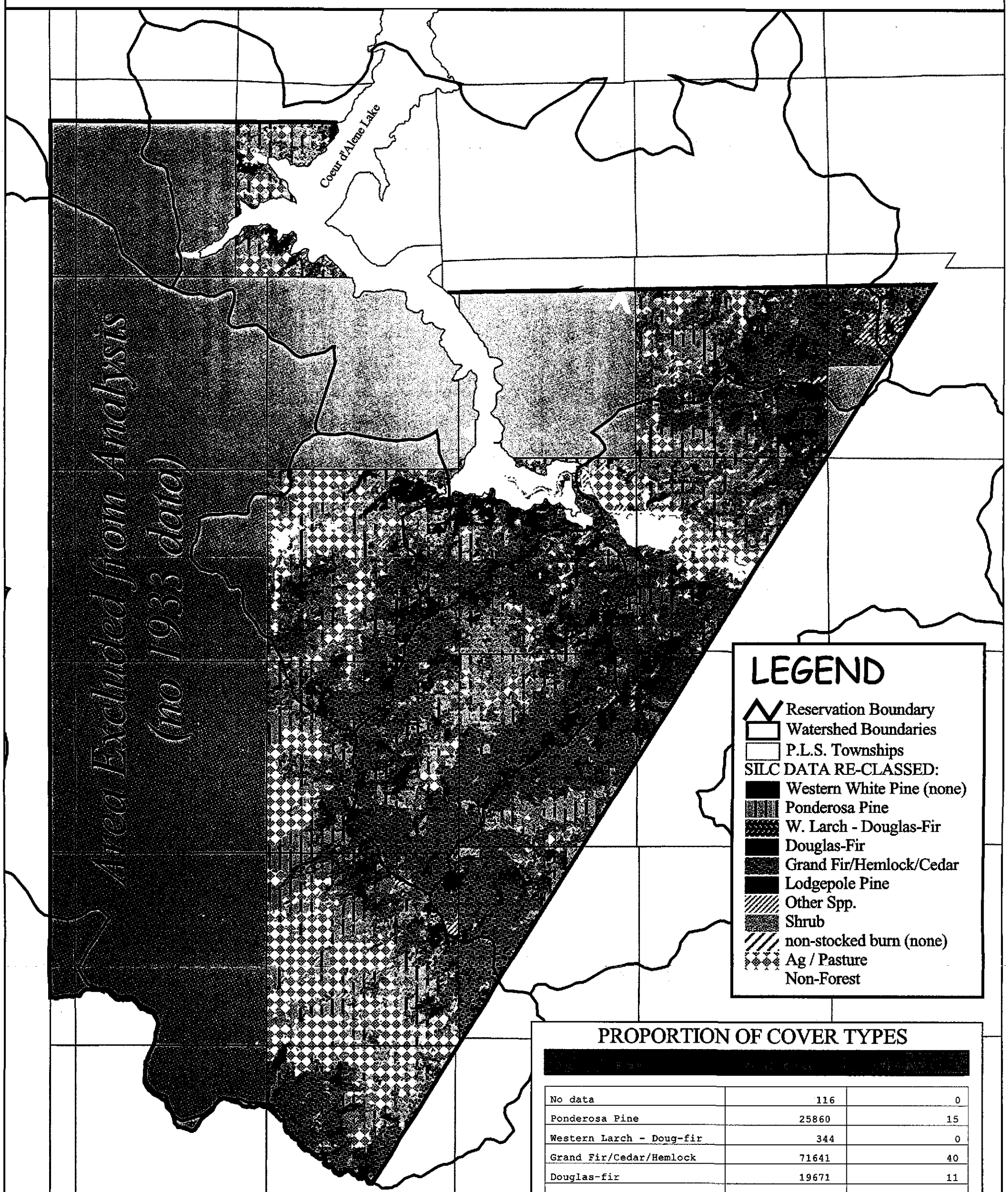
No data	327	0
Western White Pine	23231	13
Ponderosa Pine	63909	36
Western Larch - Doug-fir	31793	18
Grand Fir/Hemlock/Cedar	5451	3
Douglas-fir	2790	2
Lodgepole Pine	1301	1
Other species	1104	1
Shrub	51	0
Non-stocked Burned Land	18460	10
Agriculture / Pasture	22937	13
Non-forest	5756	3

SIZE-CLASSES

Saplings	28856	25
Poles	55128	48
Sawlogs	31438	27

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Current Satellite Land Cover Data: SILC Cover Types Grouped into 1933 Timber Stand Classifications



LEGEND

- Reservation Boundary
- Watershed Boundaries
- P.L.S. Townships

SILC DATA RE-CLASSED:

- Western White Pine (none)
- Ponderosa Pine
- W. Larch - Douglas-Fir
- Douglas-Fir
- Grand Fir/Hemlock/Cedar
- Lodgepole Pine
- Other Spp.
- Shrub
- non-stocked burn (none)
- Ag / Pasture
- Non-Forest

PROPORTION OF COVER TYPES

No data	116	0
Ponderosa Pine	25860	15
Western Larch - Doug-fir	344	0
Grand Fir/Cedar/Hemlock	71641	40
Douglas-fir	19671	11
Lodgepole Pine	3507	2
Other species	1939	1
Shrub	16612	9
Agriculture / Pasture	32968	19
Non-forest	4452	3

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Coeur d'Alene Tribe Historical Atlas. J. Bottelli, Cd'A Tribe GIS, 1/25/99 (forests33.apr)

Human Health Effects Report
Executive Summary

Introduction

This chapter describes and evaluates those environmental issues, developed by the EAP Human Health Sub-Group of the EAP Technical Workgroup, and through public participation, that may pose threats to human health on the Coeur d'Alene Reservation. Environmental health risks, which are the subject of this chapter, are a subset of overall public health risks and typically involve the interactions of people with environmental media such as air, ground water, surface water, soil, vegetation, and foods. Many of these interactions may involve exposure to chemical or radiological contamination. Following is a brief discussion of public health risks and environmental health risks, both in general and specific to the Reservation.

Public Health Risks Human health risks arise in many ways, and many causes of these risks are familiar. A partial list of some of the familiar types of human health threats include the following:

- motor vehicle accidents
- diet (e.g., high fat and high salt intake, obesity)
- lifestyle choices including smoking, alcohol consumption, recreational activities involving risk of injury or death
- accidents during typical daily activities
- infectious diseases
- congenital birth defects and disabilities
- occupational risks
- violent crime
- depression and suicide attempts
- exposures to chemical contamination

Statistical summaries for the leading causes of death or injury, causes for hospitalization, reasons for lost days of work, or life expectancies provide useful overviews of public health status.

A number of public health concerns have been identified on or near the Coeur d'Alene Reservation. A 1996 Health Needs Assessment for the State of Idaho provided statistical summaries for a number of different causes of death or injury for all counties in the state.

Based on average annual rates, Benewah County, where the majority of the Reservation population resides, experienced some of the highest death rates in the state, from 1992 through 1994, for:

- chronic liver disease and cirrhosis (1st in the state)
- colorectal cancer (1st in the state)
- motor vehicle injury (1st in the state)
- accidents, including vehicle injuries, falls, drownings, and poisonings (2nd in the state)
- lung cancer (2nd in the state)
- malignant neoplasms (3rd in the state)

According to statistics from the Benewah Medical Center, the most common reasons for clinic visits include depressive disorders, diabetes, acute upper respiratory illnesses, hypertension, head lice, and ear, nose, and throat infections.

The magnitude of many risks can be estimated directly. For example, based on statistics of highway traffic fatalities in the U.S., the lifetime risk of dying in a motor vehicle accident is on the order of 1 in 100. Our level of recognition of and concern for health risks is, however, affected by factors other than simple magnitude or probability. Characteristics such as whether the risks are familiar or unfamiliar, a result of voluntary or involuntary actions, or a result of activities conveying benefits as well as risks are very important to our perceptions of human health threats.

Environmental Health Risks As noted above, environmental health risks are a subset of the larger universe of public health risks. The list of issues in the following list, which was approved by the Human Health Sub-Group, defines the scope of environmental risks being addressed by this report.

- Agricultural chemicals
- Food contamination
- Tribal cultural food and medicines contamination
- Hazardous waste
- Human population growth and development patterns
- Roads
- Solid waste generation and disposal
- Indoor air pollution
- Outdoor air pollution
- Localized effects of atmospheric changes
- Localized effects of Hanford Nuclear Reservation
- Drinking water quality and contamination

- Ground water contamination
- Hydrologic changes
- Non-point source surface water pollution
- Point source surface water pollution

Most of these issues are readily seen to involve the interactions of people with environmental media (e.g., air, ground water, surface water, soil, vegetation, food), and many involve exposure to chemical or radiological contamination.

According to a 1990 report by the Environmental Protection Agency's Science Advisory Board, the four environmental health risks that have the greatest impact on public health in the U.S. are:

- outdoor air pollutants
- hazardous substances in indoor air
- contaminated drinking water
- on-the-job exposures to hazardous substances

The characteristics of these environmental threats (often perceived as involuntary, unfamiliar, not easily detectable, and providing little or no benefit) generally result in acceptable risk levels that may be quite small in comparison with risks that are tolerated for familiar, everyday activities such as driving or normal diets. The relative importance of environmental risks in comparison with other more familiar, higher magnitude risks has been widely debated. **The assumption for this report is that information is required to support a comparative risk assessment within the list of environmental risk issues, not between environmental risks and other types of risks. Therefore, the evaluations of human health threats in this report are limited to the list of environmental issues approved by the Human Health Sub-Group.**

Methods Used to Develop the Human Health Effects Report

In cooperation with the Human Health Sub-Group, a methodology and format were developed for evaluation of the selected environmental concerns. Following this methodology, an assessment was made of the ***potential sources of contamination***, the ***potential for exposure to the contaminants***, and the ***potential health consequences resulting from exposure***. Based on this information, potential human health risks were characterized with respect to the following criteria:

- health effect and severity
- population exposed
- degree of uncertainty
- identifiable trends

- potential impacts to future generations
- fairness and equity

An evaluation of these criteria is presented to provide the EAP Steering Committee a basis for performing a risk ranking of environmental concerns, in combination with ecological and quality of life information that will be provided in other chapters of the EAP report.

The basis for this assessment is generally qualitative in cases where site-specific quantitative data are limited. Existing local information was obtained from Tribal, local, state, and federal agency staff; from a number of individual members of the Human Health sub-group; and through interviews with area health professionals. Information was also compiled through a literature search at local libraries, universities, and on the Internet. Where local information does not exist, regional or national data were used.

Based on existing information and current scientific knowledge, potential health risks associated with each of the environmental concerns were assessed. A risk characterization of each of the concerns considered, and an attempt to describe the severity of local impacts, is provided in this chapter.

Environmental Concerns

The following section summarizes information related to sources of contamination, potential exposure, and potential health consequences for each of the environmental concerns. Items in bold print were thought to be particularly noteworthy.

Agricultural Chemicals

Agricultural chemicals, including herbicides, pesticides, and fertilizers, are widely used across the Reservation. The majority of chemical use occurs on commercial agricultural lands, although chemicals are also used in forest management activities, to control vegetation along transportation and utility corridors, and for indoor and outdoor residential use.

Key Findings

1. Most commercial agricultural chemicals currently used on the Reservation are classified as slightly to moderately toxic, and most break down quickly in the environment, normally in hours to weeks.
2. Health effects resulting from exposure to these chemicals are generally short-term and reversible, and may include skin, eye, or respiratory irritation. However, long-term repeated exposure to some chemicals may potentially result in chronic health effects such as chronic dermatitis (skin rashes or increased sun sensitivity), kidney or liver effects, or reproductive effects.
3. Two chemicals, Bronate and Weedar, are suspected carcinogens. Both these chemicals are primarily used on wheat crops, primarily in the fall.
4. Based on exposure information from Washington State pesticide incident tracking surveys and case-by-case analysis by the Idaho Department of Agriculture, pesticide exposure is most likely to occur as a result of:
    - mixing and loading of chemicals
    - inappropriate application or disposal (including aerial drift)
    - contact with contaminated media such as surface water, ground water, or foods
5. For the majority of Reservation residents, the greatest risks from commercial agricultural pesticide contamination may be from exposure to residual contamination from historically-used banned chemicals, such as DDT, which persist in the environment.
6. Based on other comparative risk projects, the principal human exposure to pesticides occurs in the home. Statistics compiled by Washington State indicate that home exposures account for 75 percent of all pesticide-related injuries and emergency room visits.
7. In a US Geological Survey water quality assessment conducted in the Palouse region between 1993 and 1995, none of the pesticides commonly used for dryland farming of wheat and small grains in the Palouse region were detected in ground water, but 10 were detected in surface water. A number of these pesticides, including Far-Go, Bucktril, 2,4-D-based, and MCPA-based pesticides, are also used on the Reservation under similar conditions and using similar agricultural practices.

Risk characterization of agricultural chemicals in commercial use.

Agricultural Chemicals - Commercial Use	
Criteria	**Evaluation**
Health Effect/Severity	Most likely health effects include skin, eye, or respiratory irritation. Potential for increased cancer risks associated with some chemicals. Chronic, non-cancer risks may include chronic dermatitis, kidney or liver effects, and reproductive effects. Mildest forms of skin irritations may be considered nuisance effects.
Population Exposed	Mixers, applicators, and transporters of pesticides and other agricultural workers are most likely to be exposed. Residents adjacent to farmlands where chemicals are used may be exposed depending on extent of drift. Individuals who use affected resources (e.g., ground water or fish) may be exposed. Children may be especially sensitive to exposure.
Uncertainty	Frequency and occurrence of aerial drift is unknown. Extent and location of exposed population is unknown. Completeness of health reporting is uncertain. Historical chemical use is uncertain.
Trends	Continuing risk from persistent chemicals. General trend toward less chemical use, biological controls, and integrated pest management. General trend toward improving packaging, less handling.
Potential Impacts to Future Generations	Cross-generational impacts from endocrine disruptors (uncertainty). Persistent chemicals may remain in environment. Potential for long-term ground water contamination.
Fairness/Equity	Non-farming community may bear impacts from chemicals without receiving associated economic benefits from farming.

Risk characterization of agricultural chemicals in residential use.

Agricultural Chemicals - Residential Use	
Criteria	**Evaluation**
Health Effect/Severity	Effects range from severe, systemic effects due to poisoning to mild effects such as skin, eye, or throat irritation.
Population Exposed	Majority of residents are likely to have chemicals in home or in neighboring homes. Home pesticide poisonings are most common among young children.
Uncertainty	Unknown types and quantities in homes. Unknown storage or usage practices. Lack of toxicity characterization. Lack of incident reporting and tracking.
Trends	Possible trend toward less toxic chemicals. Possible trend toward better education of residential users.
Potential Impacts to Future Generations	Possible exposure to endocrine disruptors.
Fairness/Equity	No apparent issues.

Food Contamination

Despite increased attention and improvements in food handling, the safety of food served in restaurants and other public facilities continues to be a health concern throughout the country. A number of outbreaks of food-borne illness have occurred locally and regionally just within the past year. It is estimated that food-borne illnesses such as E. coli, hepatitis A, and salmonella contribute to 9,000 deaths and as many as 33 million illnesses in the United States each year.

Key Findings

1. The following four factors contributed to most food-borne illness outbreaks:
   - improper holding temperatures—this factor contributes to most outbreaks
   - poor personal hygiene—this is the second leading cause of outbreaks
   - inadequate cooking—all E. coli outbreaks involving meats could have been prevented by proper cooking
   - contaminated equipment and cross-contamination
2. Populations especially vulnerable to food-borne illness include:
   - senior citizens
   - pregnant women and very young children
   - people with weakened immune systems suffering from chronic illnesses such as cancer, diabetes, liver diseases, and AIDS
3. Health symptoms from most common food-borne illnesses are typically temporary, and often are flu-like in nature. However, in sensitive individuals, especially young children, some food-borne illnesses can be fatal.

Risk characterization of food contamination.

Food Contamination	
Criteria	**Evaluation**
Health Effect/Severity	Symptoms are typically temporary. Most common symptoms are similar to the flu and can include fatigue, nausea, vomiting, liver pain, and fever (hepatitis A); or diarrhea and abdominal cramps (E. coli). E. coli may cause hemolytic uremic syndrome (HUS) in some people, leading to possible kidney failure. Most people recover from HUS, but it may be fatal.
Population Exposed	Anyone who eats at food-serving facilities may be exposed. Vulnerable populations include elderly, pregnant women, very young children, and people with weakened immune systems. Local and non-local populations may be exposed on the Reservation, and Reservation residents may be exposed either on or off the Reservation.
Uncertainty	Lack of reporting or tracking. Number of people actually exposed to food-borne contaminants.
Trends	Due to recent outbreaks, trend may be toward more stringent regulation, better training for food handlers, and greater access to vaccinations.
Potential Impacts to Future Generations	None apparent.
Fairness/Equity	Areas with few resources for regular food safety inspections may be at greater risk.

Tribal Cultural Foods and Medicines Contamination

The Coeur d'Alene Tribe has traditionally relied upon the natural resources of the Reservation and surrounding lands and waters as a source of foods and medicines to sustain themselves and their culture. Lakes and streams provide fish; forested lands provide elk, moose, and deer; mountains and meadows provide huckleberries and camas roots; and wetlands provide waterfowl and water potatoes. Contamination of these and other traditional foods and medicines may be a potential source of health effects.

Over the last century the loss or contamination of traditional food sources, in addition to other lifestyle changes, has resulted in significant dietary changes among most native peoples. Today, chronic diseases have replaced infectious diseases as the major causes of death among Native Americans, and **at least four of the 10 leading causes of American Indian and Alaska Native deaths are nutrition-related**, including heart disease, cancer, cirrhosis, and diabetes. Native Americans appear to be more vulnerable to nutrition-related health conditions than the general U.S. population.

Although nutrition-related health effects may be an overriding concern among Tribal members, the scope of this assessment was focused on potential exposure to contaminants through collecting and using traditional food and medicines.

Key Findings

1. The most likely sources of contamination of cultural foods and medicines on the Reservation are toxic chemicals and bacteriological sources.
2. Commercial agricultural pesticide use is the most widespread source of potentially toxic chemicals on the Reservation.
3. Other potential sources of contamination include:
    - persistent pesticides, such as DDT, still in the environment from historic use
    - accidental releases of hazardous chemicals
    - improperly disposed agricultural chemicals
    - leaking septic systems or sewage lagoons
    - leaking underground storage tanks (USTs)
    - air-deposited contaminants from non-local sources
4. Populations most likely to be exposed include those who rely most heavily on traditional cultural foods for a significant part of their diet. Tribal members are most likely to be affected by changes to a "westernized" diet.

Risk characterization of Tribal cultural foods and medicines contamination.

Tribal Cultural Foods and Medicines Contamination	
Criteria	**Evaluation**
Health Effect/Severity	Health effects are most likely to be from chronic, long-term exposures. Potential cancer effects from some pesticides. May be extremely difficult to distinguish specific cause of chronic health effects. Bacteriological contamination may result in short-term, reversible gastrointestinal effects.
Population Exposed	Tribal members who regularly collect and consume traditional foods and medicines. Residents who rely on native plants or animals for a significant portion of their diet.
Uncertainty	Lack of monitoring of cultural foods and medicines. Population utilizing foods and medicines is uncertain. Quantities of foods and medicines consumed is uncertain.
Trends	Uncertain. See Agricultural Chemicals trends.
Potential Impacts to Future Generations	Most likely future effects of contamination are from persistent chemicals remaining in the environment.
Fairness/Equity	Impacts are generally the result of non-traditional, non-Tribal activities. Impacts disproportionately affect Tribal members.

Hazardous Waste

Hazardous waste is typically defined as waste material that is ignitable (i.e., burns readily), corrosive, or reactive (e.g., explosive) and may be solid, semi-solid, or liquid. Known or suspected hazardous waste sites are regulated by the Resource Conservation and Recovery Act (active sites), or the Comprehensive Environmental Response, Compensation, and Liability Act, also known as "Superfund" (inactive or abandoned sites). Hazardous wastes related to mining activities in the Coeur d'Alene Basin are not discussed in this report.

Key Findings

The number of identified hazardous waste generators on the Reservation is small. The federal database for tracking active hazardous waste sites includes five facilities on the Reservation that may be generators, transporters, treaters, storers, or disposers of hazardous waste. Three facilities; an auto dealership, a State Department of Lands facility, and a county landfill; are located in St. Maries. The other two facilities, one in Worley and one in Tensed, handle agricultural chemicals. A log yard facility in St. Maries has been identified as a source of hazardous wastes from wood treatment activities which may be migrating into surface or ground water.

Risk characterization of hazardous waste.

Hazardous Waste	
Criteria	**Evaluation**
Health Effect/Severity	Effects may range from mild to severe depending on a number of factors.
Population Exposed	People who live near dump sites. People who live near roads or facilities where there may be spills or fires.
Uncertainty	Very limited knowledge of unreported generators on Reservation. Completeness of inventory of generators or waste sites is uncertain. Historic dumping and disposal practices are unknown.
Trends	Increased industry could generate more hazardous waste.
Potential Impacts to Future Generations	Potential presence of persistent contaminants from historic practices.
Fairness/Equity	Unknown.

Human Population Growth and Development Patterns

Nearly all environmental concerns affecting human health are directly tied to population growth and development patterns on or adjacent to the Reservation. Population growth affects the sources of contamination, through increased rural, urban, commercial, and industrial development, as well as the number of people exposed to those contaminants. Population growth and development can dramatically affect the availability of traditional foods and medicines and other natural resources, and can potentially affect mental well-being by eliminating open spaces and natural resources that provide cultural, spiritual, and recreational opportunities.

The current Reservation population is estimated to be 9,168, approximately 17 percent being Native American . By the year 2008 it is estimated that the population will be 12,652.

Key Findings

1. Increasing population and development on the Reservation may increase the number and magnitude of pollution sources, and may increase the population potentially exposed to environmental pollutants. Effects may include:
   - Increased vehicle traffic, leading to increased air pollution and increased safety hazards.
   - Increased use of synthetic building materials leading to increased indoor air pollution.
   - Increased demand on drinking water supply systems leading to increased stress on the delivery system and potential contamination.
   - Increased stormwater runoff from construction and urbanization.
   - Increased waste generation and disposal.
   - Increased sewage disposal.
   - Increased land development, resulting in decreased availability of Tribal cultural foods and medicines.
2. Expansion of development may place a larger population in proximity to areas where agricultural chemicals are used.
3. Increasing development of tourism facilities, including restaurants, could increase the population potentially exposed to food contamination or drinking water contamination.
4. It is estimated that the Reservation population will increase by 38 percent over the next 10 years, with the most significant rate of population growth continuing to occur within the rural area of Kootenai County.

Risk characterization of human population growth and development patterns.

Human Population Growth and Development Patterns	
Criteria	**Evaluation**
Health Effect/Severity	Increased development may increase the potential severity of health effects by increasing existing sources of contamination or introducing new contamination sources.
Population Exposed	Increased population may expose a larger number of people to sources of contamination.
Uncertainty	The magnitude, location, and types of development are uncertain.
Trends	Census data from 1990 to 1994 indicate increasing population trends in all Reservation towns. The Reservation population is estimated to grow by 38 percent by the year 2008.
Potential Impacts to Future Generations	Increasing population growth and development, especially poorly planned development, may increase the potential for impacts to future generations. Increasing development at this time may limit environmental protection and restoration options for future generations.
Fairness/Equity	Larger property owners will likely have the greatest economic benefit from increased growth and development. Tribal members and others who depend on access to natural resources may be disproportionately affected.

Roads

Roads on the Reservation pose a health concern for two primary reasons: 1) as a source of fugitive dust; and 2) as a public safety concern. Health effects from fugitive dust are discussed in the outdoor air pollution section of this report, and this section focuses on the public safety risks posed by roads on the Reservation.

Statistics for specific roads and road sections are available for a fee from the Idaho Transportation Department, but were not used in this assessment.

Key Findings

1. According to State statistics, Benewah County had the highest average annual rate in the State of Idaho between 1992 and 1994 for deaths due to motor vehicle accidents. The county's average annual death rate of 80.3 deaths per 100,000 population (based on 20 actual fatalities from 1992 through 1994) was nearly four times the overall average for the state (22.0) and nearly five times the 1994 national average of 16.2. Kootenai County ranked 38th out of 44 Idaho counties in this statistic.
2. In 1994, the leading factors contributing to traffic deaths on Idaho roads were:
   - speeding (22 percent)
   - alcohol or drug use (6 percent)
   - inattention (6 percent)
   - failure to yield (5 percent)
3. Between 1992 and 1994, one-fourth of all motor vehicle deaths occurred to Idahoans between the ages of 15 and 24.

Risk characterization of roads.

Roads	
Criteria	**Evaluation**
Health Effect/Severity	Health effects range from minor injury to death.
Population Exposed	Anyone who travels in a motor vehicle may be exposed to adverse health effects.
Uncertainty	Environmental component causing high accident rate is highly uncertain, that is, it is difficult to determine what percentage of risk is due driving habits, and what percentage is due to unsafe road conditions.
Trends	None apparent from available information.
Potential Impacts to Future Generations	Impacts may continue into the future unless addressed.
Fairness/Equity	No apparent issues.

Solid Waste Generation and Disposal

Concerns which were identified during the EAP process relating to solid waste disposal included odor and potential water quality impacts from the Kootenai County Farm Landfill, litter along the roads, open dumping in forested areas, and the status of recycling options. Because no information was obtained on the types, amounts, or locations of solid waste outside of existing landfills, this assessment focused on potential health effects associated with the Kootenai County Farm Landfill.

Key Findings

1. The primary environmental risks associated with municipal landfills are due to the leachate and gases produced from the interaction of waste materials, rain, and organic degradation. Rain water filtering through the waste produces a solution (leachate) that is typically high in heavy metals and volatile organic compounds (VOCs). The microbial decomposition of organic material produces a landfill gas comprised primarily of methane and carbon dioxide.
2. In 1997, a consultant for the Tribe conducted an assessment of noxious odors from the Kootenai County Farm Landfill, which have been the source of numerous complaints from residents adjacent to or downwind of the landfill. This assessment indicated that odors from the landfill were related to landfill gas not collected by the landfill's gas extraction system and to septic conditions that occasionally existed in the leachate treatment ponds.
3. Based on the results of the assessment of noxious odors at the Kootenai County Farm Landfill, and on conversations with officials from the Panhandle Health District, ***the odor from the landfill appears most likely to have "nuisance" effects rather than identifiable health effects.***
4. Because of increasingly stringent regulation of existing landfills, unknown materials in unregulated or abandoned waste disposal sites may pose a greater health risk than materials or conditions at existing landfills.
5. Waste handlers are the group most likely to be exposed to contaminants associated with solid wastes, especially if household or other hazardous wastes are not segregated from solid wastes.

Risk characterization of solid waste generation and disposal.

Solid Waste Generation and Disposal	
Criteria	**Evaluation**
Health Effect/Severity	Nuisance effects from landfill odors. Potential health effects from handling of co-mingled solid and hazardous waste.
Population Exposed	People in vicinity of current landfill may be exposed to impacts. People in vicinity of historic dump sites may be exposed to impacts. Solid waste handlers may be most likely to be exposed to impacts.
Uncertainty	Past practices, including historic dumping or burning are uncertain. Solid waste disposal practices outside urban areas is not known. Degree of possible co-mingling of solid and hazardous waste is unknown. Handling of special categories of wastes, like tires or appliances, is unknown. Solid waste handling practices are unknown. Past importation of waste onto Reservation is unknown. Presence/abundance of disease carriers (vectors) is unknown.
Trends	General trend toward better handling and separation of wastes. General trend toward better disposal practices resulting in less potential for environmental exposures.
Potential Impacts to Future Generations	Possible impacts from historic practices. Potential failure of current containment practices could result in future environmental releases.
Fairness/Equity	Unknown.

Indoor Air Pollution

Despite the fact that most people spend the vast majority of their time indoors, very little information exists on indoor air quality. However, a number of known sources of indoor air pollution exist on the Reservation, including wood stoves, gas furnaces, second-hand tobacco smoke, synthetic building materials, and molds and bacteria. A number of indoor air pollutants may be carcinogenic.

Key Findings

1. All comparative risk studies previously conducted in the United States have determined that indoor air pollution is one of the largest sources of both cancer and non-cancer health risks because of the significant indoor sources and concentrations of air pollutants and the large percentage of time people spend indoors.
2. Indoor air contamination consistently yields a high health-risk ranking, despite the fact that uncertainty regarding exposure to the array of potential pollutants is vast.
3. Major sources of indoor air contamination include:
   - environmental tobacco smoke
   - combustion products from wood, oil, and gas heating sources
   - biological agents, including mites, molds, and bacteria
   - vapors from synthetic building materials; vapors from paints, glues, and cleaning products
   - pesticides
   - indoor radon
4. Nearly 4,000 chemical compounds are found in tobacco smoke; more than 50 are known or suspected human carcinogens.
5. Smoke from wood-burning stoves and fireplaces has been shown to contain 17 priority pollutants and up to 14 carcinogens.
6. Radon is a natural source of radiation that can become concentrated indoors and is an indoor air concern in many areas. Based on results of 1998 radon testing on the Reservation, about 7 percent of a total of 169 tests exceeded the federal "action level".
7. Based on other comparative risk projects, the next highest cancer risks in indoor air after radon and environmental tobacco smoke are attributed to volatile organic compounds, especially formaldehyde. The principal indoor sources of formaldehyde are pressed wood (particle board), urea formaldehyde foam insulation, and household cleaning agents.

8. Sub-populations who may be more sensitive to air contaminants than the general population include children, the elderly, and individuals with asthma or other respiratory problems.

Risk characterization of indoor air pollution.

Indoor Air Pollution	
Criteria	**Evaluation**
Health Effect/Severity	Most common effects include respiratory irritation. Numerous cancer risks exist from exposure to environmental tobacco smoke, wood smoke, radon, and volatile organics. Neurological effects may occur from exposure to high concentrations of carbon monoxide.
Population Exposed	Everyone is potentially exposed to indoor air pollution. Exposures may be frequent and long-term.
Uncertainty	Lack of data on indoor air quality, potential sources, and lifestyle information.
Trends	General trend toward increasing indoor air quality problems due to increasingly air-tight homes and increased use of synthetic materials.
Potential Impacts to Future Generations	Potential future exposure from current construction practices and building materials.
Fairness/Equity	No apparent issues.

Outdoor Air Pollution

Outdoor air pollution is regulated under the federal Clean Air Act. To measure outdoor air quality, regulators use six "criteria pollutants" as indicators of air quality, and the Environmental Protection Agency has established maximum concentrations for each of them above which effects to human health may occur. The six criteria pollutants include:

- particulate matter (PM_{10} and $PM_{2.5}$)
- carbon monoxide (CO)
- ozone (O_3)
- sulfur dioxide (SO_2)
- lead (Pb)
- nitrogen dioxide (NO_2)

The EPA has recently divided the particulate matter criterion into two separate criteria: "PM_{10}", which was previously the only particulate criterion, and which includes particulates less than 10 but greater than 2.5 microns in diameter; and "$PM_{2.5}$", which is a new criterion and which includes all particulates less than 2.5 microns in diameter. A micron is one-millionth of a meter. The new $PM_{2.5}$ standard is in response to recent studies that show the very fine particles from combustion-related sources (such as vehicle emissions, power plants, wood burning, agricultural burning and other industrial and residential sources) cause greater health effects than the larger PM_{10}, which may include road and agricultural dust.

Key Findings

1. Based on several years of monitoring, Spokane County, which borders the Reservation to the west, has determined the primary causes of air quality degradation in the county include *wood burning, field burning*, and *road dust*.
2. Although monitoring of outdoor air quality on the Reservation is limited, wood burning, field burning, and road dust also appear to be the primary causes of air quality problems on the Reservation. Particulate matter, the catch-all term for everything non-gaseous found in the air, is the criteria pollutant most commonly associated with all of these air pollution sources.
3. In Spokane County, particulate matter comes mostly from wood burning and dust from unpaved and paved roads. During the months of August and September, however, 50 to 75 percent of particulates in Spokane come from the burning of bluegrass in eastern Washington and northern Idaho. Burning of wheat stubble is also conducted during this period.
4. During 1997, the Tribe conducted particulate matter monitoring throughout the Reservation. No air quality exceedances for PM_{10} were observed during this period. However, some information indicates that the greatest air quality threat to health may be posed by peaks of pollution occurring for short periods which may not be reflected in the 24-hour average concentrations typically reported. While the Tribe has initiated monitoring for $PM_{2.5}$, results of that monitoring are not yet available.
5. Forty-seven to 70 percent of polycyclic aromatic hydrocarbons (PAHs) in grass smoke are contained in the fraction of particulates less than 2.0 microns. A number of PAHs may be carcinogenic.
6. During a significant portion of the year, residential wood burning may be the largest source of outdoor air pollution on the Reservation.
7. According to a US Department of Energy report, residential wood-burning emissions are considered to be "a potential major threat to public health because of their highly respirable nature, the hazardous chemicals they contain, the available information relating these emissions, chemicals, etc. to health related problems, the fact that they are emitted in residential areas, and that the emissions are increasing".
8. Particulate matter from dust and smoke may cause eye and nose irritation, coughing, decreased lung function, and premature mortality. Exposure to particulate matter, especially very fine particulate matter, has been linked to severe health effects and even death among people with existing respiratory illnesses. Some information suggests that these adverse health effects may occur at levels below existing PM standards.

Risk characterization of outdoor air pollution.

Outdoor Air Pollution	
Criteria	**Evaluation**
Health Effect/Severity	Particulate matter from dust and smoke may cause eye and nose irritation, coughing, decreased lung function, and premature mortality. Particulate matter exposure has been linked to severe health effects and even death among people with existing respiratory illnesses. Carbon monoxide from vehicle emissions and smoke may affect blood's ability to transport oxygen and may cause headaches, dizziness, and flu-like symptoms. At extreme exposure, may be fatal. Some chemicals in both wood smoke and grass smoke may cause cancer. Many common health effects may be temporary.
Population Exposed	The majority of the population is exposed to particulate matter throughout the year. Exposure to grass smoke may occur during one to two months each fall. Exposure to wood smoke may occur for up to five or six months per year, and exposure may be concentrated in residential areas.
Uncertainty	Lack of air quality data. Lack of exposure data. Difficult to separate effects from indoor and outdoor air exposures.
Trends	Grass burning may be decreasing on adjacent lands in Washington. Grass burning may be decreasing on the Reservation over the next 10 years. Burning of other agricultural crops (wheat stubble) may increase in the future.
Potential Impacts to Future Generations	None apparent.
Fairness/Equity	Agricultural burning may commonly have effects on non-agricultural community.

Localized Effects of Atmospheric Change

According to some forecasters, adverse impacts to human health may result from human-induced climate change. An increase in "greenhouse" gases, resulting primarily from combustion of fossil fuels and large-scale deforestation, may result in rising global temperatures and depletion of the protective ozone layer in the earth's upper atmosphere.

Key Findings

1. Based on a federal report, released in 1999, Idaho's winter snowpack is expected to decrease by about 30 percent in the next 80 years due to global warming. The reduced snowpack could have devastating impacts on water resources including the operation of dams, fish habitat, ski resorts, and farming.
2. Assuming carbon dioxide levels double in the next 80 years, as many experts predict, modeling indicates that in the year 2080 there will be:
   - a significant decrease in snow cover over the northwest
   - an increase in winter precipitation in the form of rain
   - an average increase in winter temperatures of 3 to 5 degrees
   - an average increase in summer temperatures of 2 degrees
3. A local or regional increase in average temperature may be sufficient to cause migration of certain plant or animal species who require specific climatic or habitat conditions, affecting the availability of native food sources.
4. Depletion of stratospheric ozone is expected to lead to greater numbers of skin cancers, especially among fair-skinned people in temperate climates (which includes northern Idaho) where the ozone layer is thinner.
5. On a world-wide basis, rising global temperatures will continue to bring more extreme and erratic weather, with greater incidence of droughts, floods, and hurricanes, which in turn will increase rates of death, injury, and infectious diseases due to proliferation of pests. Other major diseases likely to spread with global warming are cholera, filariasis, and sleeping sickness. Vulnerable populations will likely include children, elderly people, and people in areas where disease epidemics could spread.

Risk characterization of localized effects of atmospheric change.

Localized Effects of Atmospheric Change	
Criteria	**Evaluation**
Health Effect/Severity	Increased potential for heat stress or heat-related death. Increased potential for flood-related or other extreme weather-related injury or death. Increased occurrence of infectious disease. Increased potential for skin cancer.
Population Exposed	All residents would be exposed to climatic effects. On a world-wide basis, vulnerable populations would likely include children, elderly people, and people in areas where disease epidemics could spread.
Uncertainty	Potential local or regional effects are highly uncertain. Timing and duration of effects are highly uncertain.
Trends	Overall global temperature is generally trending upward.
Potential Impacts to Future Generations	All impacts would be to future generations.
Fairness/Equity	Impacts may be felt in areas where local activities are not contributing to climate change.

Localized Effects of the Hanford Nuclear Reservation

From 1944 to 1988, the U.S. Government made plutonium for nuclear weapons at the Hanford Nuclear Reservation in southeast Washington State. Activities at Hanford resulted in the release of large amounts of radiation into the air, water and soil of the Northwest over several decades. In an effort to estimate radiation doses the public may have received as a result of these releases, a scientific study known as the Hanford Environmental Dose Reconstruction (HEDR) project began in 1987.

The purpose of the HEDR project was to estimate radiation exposure, and was not intended to address potential health effects. However, a thyroid disease study was undertaken and a final report from that study was released in January 1999.

Key Findings

1. Scientists believe iodine-131 accounted for more than 90 percent of radiation doses to residents of the HEDR study area, which included the Coeur d'Alene Reservation. However, other radioactive materials, including cerium-144, ruthenium-103, ruthenium-106, strontium-90, and plutonium-239, were also contributors to doses from the air.

2. According to the HEDR project estimates, the most important radiation exposure pathway for iodine-131 was milk produced by cows on irrigated pasture downwind of Hanford; iodine-131 transmitted through milk products and leafy vegetables accounted for as much as 99 percent of air pathway doses in 1945. A large number of dairies were located in Spokane County near the Reservation between 1945 and 1947.

3. The largest doses of iodine-131 were released between December 1944 and December 1947. In all, an estimated 740,000 curies of radioactive iodine-131 were released to the air. The largest intentional release of radiation at Hanford occurred in 1949, and is known as the "Green Run". Recently declassified documents show that Hanford released 8,000 curies of radioactive iodine on December 2, 1949. For comparison, the Three Mile Island nuclear plant accident in 1979 released between 15 and 24 curies of radioactive iodine, and nearby residents were evacuated.

4. In addition to the HEDR project, the federal government sponsored a second study, the Hanford Thyroid Disease Study (HTDS). The HTDS investigated whether thyroid disease, including thyroid cancer, was increased among people exposed to iodine-131 from Hanford. In previous studies of other populations, exposure to radiation has been shown to cause thyroid disease, including cancerous and non-cancerous thyroid growth.

5. The HTDS final report, which was released in January 1999, found no correlation between exposure to iodine-131 released from Hanford and the incidence of thyroid disease in those who were living nearby. The HTDS study group did not include residents from Spokane County or counties on the Reservation, although it did include individuals who lived in closer proximity to Hanford releases.

6. An earlier study, commissioned as part of the Hanford "downwinders" lawsuit, showed that there was a much higher incidence of thyroid disease and cancer in downwinders than would normally be expected.

Risk characterization of localized effects of the Hanford Nuclear Reservation.

Localized Effects of the Hanford Nuclear Reservation	
Criteria	**Evaluation**
Health Effect/Severity	Thyroid disease. Thyroid or other types of cancer.
Population Exposed	Individuals who lived downwind during times of releases. Most sensitive population includes individuals who lived downwind and were children during times of releases.
Uncertainty	Lack of medical monitoring. Long latency period for cancers. Lack of specific causal information. Uncertainty of individual doses.
Trends	Decreasing with time. Exposures are historic and not ongoing.
Potential Impacts to Future Generations	None apparent.
Fairness/Equity	Exposed populations had no responsibility for, control over, or knowledge of releases.

Drinking Water Quality and Contamination

Most Reservation residents receive their drinking water through public supply systems or small private wells. Other than the City of St. Maries water supply, which lies outside of the Reservation, nearly all drinking water is derived from ground water sources. This assessment focused on recorded public and private systems. However, there may be private wells or surface water withdrawals that are not recorded and where no information was available.

Key Findings

1. The vast majority of public and private wells on the Reservation are between 250 and 400 feet deep. Because of the depth of most wells, and because of the presence of relatively low-permeability layers of clay or metamorphic rock between the surface and most drinking water sources, drinking water sources in most areas appear to be well protected from potential sources of contamination.
2. There are areas of the Reservation, including the Tensed area, where some relatively shallow wells (less than 100 feet) exist, and shallower wells may be more vulnerable to contamination from surrounding land uses.
3. Historical information indicates that in the late 1970s there were shallow wells and poorly constructed deep wells that were a health hazard due to seepage from septic tanks. This problem was believed to be most serious in the Tensed area. It is not known if the same conditions exist today.
4. Available monitoring data and other information indicate that most drinking water quality violations are likely the result of contamination in the delivery system, either from water delivery pipes or home plumbing.
5. Drinking water violations for lead and copper on the Reservation were very infrequent and, in some cases, samples appear to have been taken from water taps that were not normally used for drinking water consumption. These violations appear to result from the corrosion of pipes or other plumbing fixtures.
6. Drinking water violations for total coliform were the most common, and were most frequently observed in the City of Plummer water supply system.
7. Total coliform bacteria is the most widely used indicator organism for drinking water, and the presence of these bacteria may indicate possible contamination by a number of other bacteria that may cause illness. They have been most frequently present in systems when there are leaks in water mains or when a system is otherwise "open" for repairs, construction, or maintenance. Data do not indicate the presence of fecal coliform in association with total coliform in any of the public supply systems.
8. Iron and manganese drinking water violations in nine private wells were for exceedance of secondary drinking water standards. These metals are believed to have only aesthetic effects, such as taste, color, or odor.

9. In wells for which monitoring data are available, no agricultural chemicals or organic compounds were detected.
10. Water quality, condition, and vulnerability of most private wells appear to be largely unknown.
11. Infants and children are exposed to more waterborne contaminants relative to their size than are adults. One-year-olds drink more than twice as much water relative to their size as do adults.
12. Based on the available information, drinking water supplies that appear to be most vulnerable to contamination are:
    - shallow wells, if they are near potential contamination sources
    - poorly constructed or poorly maintained wells
    - supply systems that are frequently "open" due to breaks or construction
    - public or private systems using highly corrosive water, especially older systems

Risk characterization of drinking water quality and contamination.

Drinking Water Quality and Contamination	
Criteria	**Evaluation**
Health Effect/Severity	Potential for gastrointestinal effects and flu-like symptoms from bacteria, generally short-term and temporary. Potential for cognitive, behavioral, or neurological effects from childhood lead exposure, possibly long-term and non-reversible. Possible long-term cancer risks from disinfectant by-products in chlorinated systems. Primarily nuisance effects from iron and manganese.
Population Exposed	Most of population potentially exposed to lead from distribution system, plumbing, and faucets. Populations using public systems potentially exposed to disinfection by-products. Populations using public systems potentially vulnerable to bacterial contamination (total coliform). Populations using shallow or poorly constructed private systems potentially vulnerable to bacterial contamination (fecal coliform). Sensitive populations include infants and children, especially infants using drinking water in formula, elderly, and those with compromised immune systems.
Uncertainty	Only limited monitoring, especially in private wells. No known wellhead protection programs. Construction/maintenance of wells. Lack of epidemiological connection between contamination and health incidence.
Trends	Lead exposure may be reduced through awareness and education. Source appears stable. Growing trend toward alternatives to chlorine for disinfection.
Potential Impacts to Future Generations	Contamination of ground water may be impossible to treat or reverse. Potential for lead transfer from mother to fetus or infant.
Fairness/Equity	None apparent.

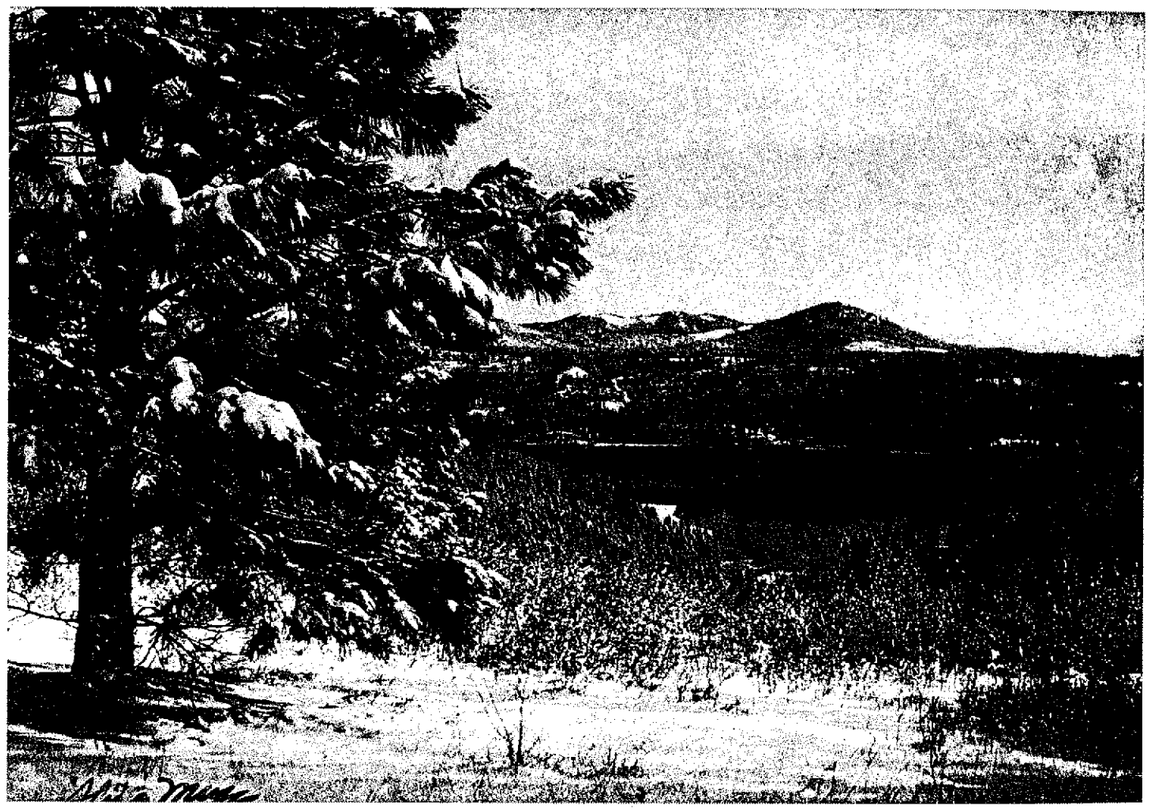
Ground Water Contamination

The assessment of this concern focused on potential sources of ground water contamination. Exposure to ground water contamination is likely to be through drinking water use or through contact with surface waters which receive discharge of contaminated ground water. The health effects and risk characterizations associated with these exposure routes are discussed in their respective sections. **Therefore, no risk characterization table was prepared for this topic.**

Key Findings

1. The quality of ground water is most commonly affected by waste disposal and land use.
2. Above-ground sources of ground water contamination include:
    - infiltration of contaminated surface water
    - land disposal of solid and liquid waste materials
    - stockpiles, tailings, and spoils
    - dumps
    - disposal of sewage and sludge from water treatment plants
    - animal feedlots
    - leaching of fertilizers and pesticides
    - accidental spills
    - surface impoundments (e.g., unlined sewage lagoons)
3. Below-ground sources of ground water contamination include:
    - septic tanks
    - landfills
    - waste disposal in excavations
    - leaking underground storage tanks (USTs)
    - leaking underground pipelines
    - sumps and dry wells
4. The overall leachability, or the likelihood of pesticides used on the Reservation to migrate to ground water, appears to be low to medium.
5. According to 1998 UST inventory information provided by the Tribe, a total of 97 tanks existed on the Reservation, 68 of which have been closed or removed, leaving 29 USTs which have not been closed or removed. Based on EPA inspections in 1993, three USTs, one in Worley, one in St. Maries, and one in Tensed, were on the leaking underground storage tank (LUST) list.

6. Ammonia was detected in ground water monitoring wells at the Kootenai County Farm Landfill, but was detected upgradient, and therefore may not be related to landfill activities. Ammonia was not detected in nearby residential wells.
7. Chromium and other metals were also detected in monitoring wells at the Kootenai County Farm Landfill, both upgradient and downgradient from the landfill site.



Lake Coeur d'Alene in winter. Both the snow and the lake are important components of the Reservation's water resources.

Hydrologic Change

Hydrologic change relates to changes in the quantity and timing of surface water runoff. Human health effects related to hydrologic change on the Reservation are most likely to be associated with increased peak flows and associated flooding, but may also be related to decreased base flows which may lessen the ability of surface waters to dilute pollutant discharges.

Key Findings

1. Sources of contamination associated with flooding on the Reservation are most likely to include bacterial contamination from overflowing sewage treatment plants, lagoons, or septic systems, and agricultural or industrial contaminants.
2. Other sources of physical injury may include swiftly flowing water or deep standing water, and damaged electrical systems, natural gas, or propane tanks.
3. Individuals may be exposed to contaminants in flood waters through ingestion, through skin contact, especially in cuts or open sores, and through inhalation of airborne bacteria, mold, or viruses.
4. Individuals living in frequently flooded areas are most likely to be affected, especially those living immediately downstream from pollutant sources where concentrations of contaminants may be the highest.
5. Although skin contact with water does not, by itself, pose a serious health risk, there is some risk of disease from eating or drinking anything contaminated with flood water. Inhalation of airborne bacteria, molds, or viruses may cause disease or trigger allergic reactions. There may also be health risks related to physical hazards like fires, explosions, or electrical hazards.
6. Outbreaks of infectious diseases that were not present in the community before the flood are not usually a problem. However, the rates of diseases that were present before the flood may increase because of decreased sanitation or overcrowding among displaced persons.

Risk characterization of hydrologic change.

Hydrologic Change	
Criteria	**Evaluation**
Health Effect/Severity	Increased incidence of disease. Respiratory effects or allergic reactions from airborne contaminants. Physical injury or death by drowning, fire, or electrocution.
Population Exposed	Populations within floodplain, especially in lower portion of watersheds are most likely to be affected. Elderly, very young, and those with immune deficiencies are most likely to be affected.
Uncertainty	Little information was available on the extent of flooding and associated impacts.
Trends	Increasing development is likely to increase flood potential, both in frequency and severity.
Potential Impacts to Future Generations	Poorly planned development and increased land clearing may increase flood potential for future generations.
Fairness/Equity	Residents in lower watersheds or downstream from pollutant sources may be disproportionately affected.

Non-Point Source Surface Water Pollution

Non-point sources of surface water pollution include diffuse sources, such as agricultural or urban runoff, and do not normally require a permit. However, non-point sources are not allowed to cause violations of water quality standards, and activities responsible for contributing non-point source pollution are to be conducted using "best management practices" (BMPs). The common categories of non-point source pollution are: agriculture, including livestock management, forestry, urban, mining, construction, dams and channels, and land disposal.

Key Findings

1. Surface water pollution on the Reservation is primarily the result of non-point source, as opposed to point source, pollution.
2. Non-point sources of pollution on the Reservation are believed to primarily include:
   - runoff from agricultural lands
   - forest practices
   - runoff from construction sites
   - runoff from roads and urban areas
   - runoff from solid or hazardous waste disposal sites
   - leaking septic systems
   - leaking USTs
   - runoff from log yards
3. The contaminants on the Reservation most likely to be sources of health effects include:
   - bacteria
   - pesticides
   - metals
   - nutrients (especially nitrates)
   - hydrocarbons
4. Between 1992 and 1995 the United States Geological Survey (USGS) conducted a water quality assessment of the Central Columbia Plateau in Washington State. The assessment included an investigation of the potential effects of dryland farming of wheat and small grains on water quality in the Palouse region, which borders the southwestern portion of the Reservation.

   The following is a summary of the major findings of the water quality assessment.

- Thirty-one surface water sites representing agricultural land use with different crops and agricultural practices were sampled for pesticides. **Pesticides were detected in samples from all sites except for the Palouse River at Laird Park, a headwaters site in a forested area.**
- Many pesticides were detected in surface waters at very low concentrations. Concentrations of six pesticides in one or more surface water samples exceeded freshwater-chronic criteria for the protection of aquatic life. Of 226 samples, 3 percent of the samples contained Far-Go (Triallate) in concentrations exceeding the freshwater chronic criterion for aquatic life. Far-Go is an herbicide commonly used on the Reservation.
- In the Palouse Subunit, pesticides were detected in 97 percent of surface water samples.
- Ten pesticides commonly used in the Palouse Subunit were detected in surface waters, and four of these were detected in concentrations exceeding freshwater-chronic criteria for the protection of aquatic life. A number of these pesticides, including Far-Go, Bucktril, and 2,4-D-based pesticides, are also used on the Reservation under similar conditions and using similar agricultural practices.
- No pesticide concentrations in surface waters exceeded drinking water standards.

Risk characterization of non-point source surface water pollution.

Non-Point Source Surface Water Pollution	
Criteria	**Evaluation**
Health Effect/Severity	Potential for gastrointestinal effects and flu-like symptoms from bacteria, generally temporary and reversible. Potential for chronic effects from long-term, low dose exposure to pesticides.
Population Exposed	Primary exposure pathway is ingestion. People using surface water as a drinking water source most likely to be exposed. Potential exposure from contact or incidental ingestion during recreational or cultural activities in or around surface waters.
Uncertainty	Incomplete water quality data. Pesticides and VOCs are not typically monitored on Reservation. Potentially exposed population is uncertain.
Trends	General trend toward improved agricultural practices. Increasing population and development trends could increase pollution in localized areas.
Potential Impacts to Future Generations	Potential for some persistent chemicals to remain in environment.
Fairness/Equity	Agricultural activities may disproportionately impact non-agricultural community.

Point Source Surface Water Pollution

Point source water pollution, as defined in the Clean Water Act, is a "discernible, confined, and discrete conveyance from which pollutants are, or may be, discharged". Most often point sources are discharged from pipes. The Clean Water Act does not consider agricultural runoff, runoff from small municipalities or other developed lands, or flood-related overflow of sewage lagoons to be point sources. These sources are regulated as "non-point sources". Point sources, which typically include industrial or wastewater discharges, must be permitted under the National Pollutant Discharge Elimination System (NPDES). The Environmental Protection Agency is currently responsible for issuing NPDES permits to dischargers on the Reservation.

Key Findings

1. The primary point sources of surface water pollution on the Reservation are wastewater treatment plant discharges, and the related health effects are most likely to result from bacteriological contamination.
2. Point sources of pollution on the Reservation are believed to include:
   - wastewater treatment plants (St. Maries, Plummer, Worley, Tensed)
   - industrial discharges (Potlatch at St. Maries, Rayonier at Plummer)
3. Exposure to bacterial contamination may result in gastrointestinal effects and flu-like symptoms which are generally temporary and reversible.

Risk characterization of point source surface water pollution.

Point Source Surface Water Pollution	
Criteria	**Evaluation**
Health Effect/Severity	Potential for gastrointestinal effects and flu-like symptoms from bacteria, generally temporary and reversible.
Population Exposed	Primary exposure pathway is ingestion. People using surface water as a drinking water source most likely to be exposed. Potential exposure from contact or incidental ingestion during recreational or cultural activities in or around surface waters.
Uncertainty	Incomplete water quality data. Potentially exposed population is uncertain.
Trends	General trend toward improved wastewater treatment. Increasing population and development trends could increase pollution in localized areas.
Potential Impacts to Future Generations	Potential for some persistent chemicals, such as metals in wastewater effluent, to remain in environment.
Fairness/Equity	Impacts and resource burden for cleanup of commercial discharges may disproportionately affect the public, rather than the discharger.

Environmental Concerns and Mental Health Effects

As part of the evaluation of health effects of environmental concerns on the Reservation, a cursory effort was made to identify information connecting environmental conditions with mental health effects.

Key Findings

1. Health officials from both the Benewah Medical Center and Benewah Community Hospital identified conditions related to mental well-being as the most common reasons for visits to Reservation health facilities. These conditions include depression, alcoholism, substance abuse, low self-esteem, and other related conditions. These effects were noted among both Tribal and non-Tribal people throughout the Reservation.
2. While there may be a number of social or economic factors involved in producing these conditions, Tribal values and lifestyle are so intimately connected to the environment that environmental degradation may be disproportionately affecting Tribal mental health.
3. According to researchers, there is a distinct relationship between culture loss and mental health. One researcher, working with the Ojibwa Tribe, noted that the social/economic context of Ojibwa society has been so greatly altered by colonization that individual and group characteristics which were once functional are no longer. He suggested that traditional lifeways are now gone, and the once functional traditional value of passive dependence on Nature has been transferred to a passive dependence on Welfare, which promotes low self-esteem.
4. Another researcher working on the Yakama Reservation in Washington State studied epidemiological transitions and mortality on the Yakama Reservation between 1888 and 1964. He concluded that Native Americans living on the Reservation were, in fact, in jeopardy as a result of the "reservation system". Not only did this alien and artificial culture radically alter traditional ways of life, but sanitation methods, housing, hospitals, public education, medicine, and medical personnel affiliated with the reservation system all proved inadequate, and each in its own way contributed significantly to high Yakama death rates.
5. The University of Oregon Health Sciences Center maintains a "Bibliography of North American Indian Mental Health", whose purpose is to make accessible the storehouse of information pertinent to the study of North American aboriginal mental health.



Plummer Butte rises over agricultural lands and forest. Such areas are rich in the many plant and animal species found on the Coeur d'Alene Reservation.

Ecology Report
Executive Summary

Introduction

The Ecology Chapter documents the results of one of several assessments conducted to characterize the environmental health of the Coeur d'Alene Reservation. The areas studied include human health, ecological health and quality of life. The Ecology Chapter documents existing information regarding the ecological health of the Coeur d'Alene Reservation. The primary objectives of the analysis used to develop the ecology chapter included:

- Identify each major environmental stressor, for each of the environmental concerns identified through public input.
- Characterize the effects, or environmental risks, associated with each stressor.
- Describe the severity of the ecological impacts, in terms of the ecological health and evaluation criteria, identified through public involvement.

Methods Used to Develop the Ecological Assessment

Environmental concerns were identified during a series of public meetings by the EAP Steering Committee, EAP Technical Workgroup and Tribal Natural Resources staff. A total of 25 concerns were identified for detailed evaluation. Of these, 5 concerns were determined to be primarily human health or quality of life issues. Therefore, this chapter deals only with the 20 concerns involving ecological health which are listed below.

20 Environmental Concerns Addressed in the Ecology Chapter

1. Agricultural Chemicals
2. Energy Production and Consumption
3. Forest Health
4. Hazardous Waste
5. Human Population Growth and Development Patterns
6. Roads
7. Solid Waste Generation and Disposal
8. Outdoor Air Pollution
9. Localized Effects of Atmospheric Changes
10. Localized Effects of Hanford Nuclear Reservation
11. Ground Water Contamination
12. Hydrologic Changes
13. Non-Point Source Surface Water Pollution

14. Point Source Surface Water Pollution
15. Wetlands
16. Native Plant and Animal Populations and Species Diversity
17. Tribal Culturally Important Species Populations and Diversity
18. Native Fish and Wildlife Habitat
19. Non-Native Plant and Animal Populations
20. Soil Productivity

The first step of the assessment process was to identify the various environmental elements, or ecosystem components and the sources of stress on those elements. Sources of stress were grouped into ten major categories, while environmental elements were grouped into nine types as identified in the following table. These groupings are referred to as "stressor categories" and "environmental elements" throughout the Ecology Chapter.

Environmental Elements and Stressors Evaluated in the Ecology Chapter

Environmental Elements	***Stressor Categories***
Air	Agricultural Practices
Surface Water	Forestry Practices
Ground Water	Recreation Practices
Soils	Mining Practices
Grasslands	Human Habitation
Forest Lands	Wildlife Practices
Wetlands	Transportation Systems
Wildlife	Waste Systems
Fisheries	Energy Systems
	Water Systems

Each stressor and element was then evaluated to determine if a significant cause/effect relationship existed between them. The determination of a cause/effect relationship was based on best professional and community judgment. This evaluation was used to focus research efforts. For example, forestry practices were identified as having an effect on non-point surface water quality and quantity, but not on ground water quantity or quality. Therefore, no effort was made to quantify impacts of forestry on ground water.

The next step was to determine the appropriate assessment boundaries, given the project goals, budget, and time constraints. It was recognized that given the time and budget allocated, it would not be possible to evaluate the Tribe's aboriginal territory or even an area large enough to capture the entire "ecosystem" which influences, and is influenced by the Coeur d'Alene Reservation. Such an area would probably include the entire Coeur d'Alene and St. Joe River drainages, and the entire Hangman Creek

watershed at a minimum. Therefore, the assessment area was limited to the current Reservation boundary, although a limited number of areas outside the Reservation boundaries were included since fish and water reporting areas were assessed on a watershed basis.

Five major ecosystem types, or reporting units, were selected to describe the general nature of the changes to the ecology of the Reservation. These included: 1) Lakes, 2) Rivers and Streams, 3) Wetlands, 4) Agricultural Lands, and 4) Forest Lands.

Six major watershed groups were identified which would be used as fish and water reporting areas to document cumulative effects. These groups include rivers and streams which are wholly or partially on the Reservation. The following is a brief description of each of the six groups.

Hangman Creek: The Hangman Creek watershed, which includes the Rock Creek watershed.

Lake Creek: The Lake Creek watershed.

Plummer Creek: The Plummer Creek watershed.

Benewah Creek: The Benewah Creek watershed.

St. Maries/St. Joe Rivers: All streams draining into the St. Maries or St. Joe rivers, including Alder Creek.

Lake Coeur d'Alene Tributaries: Other streams draining into Coeur d'Alene Lake and the Coeur d'Alene River, including Fighting, Bellgrove, Cave Bay, Unnamed Cave Bay, Aberdeen Bay, Cotton Bay, O'Gara Bay, Shingle Bay, Black, Willow, and Evans Creeks.

Summary of Ecological Conditions on the Reservation

General Summary

The environmental impacts of a growing human population, development, changes in land use and a multitude of other environmental stressors have led to large changes in the ecology of the Coeur d'Alene Reservation. In many cases, degraded habitat has reduced plant, wildlife and fish populations and species diversity. Human inhabitants have affected all parts of the Reservation.

Since European settlement, 114,411 acres of forest, grassland and shrub habitat types have been converted to agricultural and pasture land. In addition to this, an estimated 21,417 acres of wetland have been converted to agricultural and other uses. This represents a loss of approximately 83% of the original Palustrine wetlands on the Reservation. In addition to this an undetermined amount of wetlands associated with Coeur d'Alene Lake and the St. Joe River have been altered due to dikes, levees, nutrient and sediment loading from upstream sources and other impacts. Roads and urban development have converted another 2,245 acres of land to impermeable surfaces. The

vast amount of old growth forest existing in 1850 has been virtually eliminated. Today, approximately 193,465 acres remain forested on the Reservation, most of which has been impacted by timber harvest, exclusion of fire, and introduction of exotic species.

The loss and alteration of wetlands due to agriculture, forestry, exotic species, human development and energy resource development has resulted in decreased wetland function for flood prevention, nutrient uptake, sediment trapping, ground water recharge, shoreline protection and habitat for native plants, water fowl, fur bearers and other species.

Lake systems on the Reservation have been impacted by increased sedimentation and nutrients, introduction of exotic species and altered hydrology. All of these have led to degraded water quality, and/or changes in fish populations and species diversity. Rivers and streams have also been greatly impacted on the Reservation due to non-point and point sources of pollution, sedimentation, decreased canopy cover, channelization, introduction of exotics species and hydrologic changes induced by altered land cover. Fisheries in streams and rivers on the Reservation have all been altered to varying degrees. In may cases certain native species no longer exist in portions of, or entire streams, that had once been inhabited.

Forests once dominated by an old growth overstory of shade intolerant species, such as ponderosa pine, white pine, and western larch, have been converted to fairly even-aged stands dominated by smaller, more dense, and younger shade tolerant species, such as Douglas-fir and grand fir. This change poses an increased risk of insect, disease, and fire losses in the future.

Characterization of Effects by Ecological Concern

The following pages summarize the major findings and conclusions for each of the 20 areas of concern detailed in this section. The individual areas of concern are identified as either an element of the environment or a stressor to the environment.

Agricultural Chemicals (stressor) Specific stressor types include herbicides, fertilizers, fungicides, and insecticides. These types of chemicals are used on most of the estimated 135,828 acres of agricultural land and about 100 acres of forest land within the Reservation each year. Levels used in and around homes and gardens is not known. Chemicals can be injurious to mammals, birds, fish, and insects, especially if transported off of the application site. Bioaccumulation of some chemicals (such as DDT, which is now banned) may have occurred and could potentially persist for decades in the environment. Neither the levels of contamination or specific environmental impacts to the ecology have been studied on the Reservation.

Agricultural Chemicals

Criteria	Evaluation
Changes Since Settlement	Use of agricultural chemicals did not exist prior to European settlement. The use of chemicals, and the impacts associated with them, have become greater since World War II.
Magnitude of Impacts	Herbicides, fertilizers and insecticides are used on most, if not all, of the estimated 135,828 acres of agricultural land each year. Chemicals are used on about 100 acres of forest land each year. Domestic use is unknown, but probably occurs throughout the Reservation annually. Potential impacts exist throughout the Reservation, where ever chemicals are used.
Severity of Impacts	No studies of impacts of chemicals on ecological elements have been completed, specific to the Reservation. Impacts to exposed species are usually quite severe, causing death or significant changes in growth. Toxicity and frequent use make chemicals an inherent threat. Certain insecticides, herbicides and fertilizers, known to be used on the Reservation, can be toxic to fish, wildlife, aquatic invertebrates, birds and bees.
Reversibility of Impacts	Use of chemicals can stop at any time. Most residual chemicals in the environment would degrade a year after use is halted. Stopping use would eliminate impacts to plants and animals caused by direct exposure. It is not known if cumulative effects of past use exist, and thus if they could be reversed. Some chemicals used in the past, such as DDT, can accumulate in wildlife, and persist for decades in the environment.

Degree of Uncertainty	No studies of environmental impacts caused by use of agricultural chemicals have been completed for lands on the Reservation. The extent, amount, and type of home and garden chemicals used on the Reservation is unknown.
Current Trends	There is a trend towards use of more selective pesticides and herbicides. Current use, and thus associated impacts, may be stable at this time. Forestry use may increase in the future. Increased impacts could occur in the future, if chemicals are accumulating in the environment.
Impact to Future Generations	The impacts of long term use of agricultural chemicals are not known at this time. The risk associated with chemical use will probably persist due to increasing global demand for food and fiber.
Fairness/Equity of Impacts	Impacts are most severe on lands where chemicals are used, especially on target species. Species located on, or adjacent to, agricultural lands have greater risk of exposure. Impacts to species on forest lands are much lower, due to the limited amount of chemicals used at this time. Because of potential for chemical contamination from runoff and leaching, threat to aquatic species may be greater in the long term.

Energy Production and Consumption (stressor) Specific stressor types include the hydroelectric dams on the Columbia River, the co-generation plant at Plummer (which is not currently in operation), and use of wood stoves. Energy consumption has increased in proportion to increases in human population and more consumptive lifestyles. Hydro-electric dams on the Columbia River system effectively eliminated the migration of salmon and steelhead to the Hangman Creek drainage. The co-generation facility has been associated with impacts to air and water quality. This could in turn affect wildlife and fisheries. Cutting of firewood for home heating impacts wildlife by removing live trees, dead trees, and downed logs used by grouse and cavity-dwelling animals. With increasing human population in the region, energy demand and consumption is likely to increase.

Energy Production and Consumption	
Criteria	**Evaluation**
Changes Since Settlement	Much of the wood and coal burning on the Reservation has been replaced by hydroelectric sources. However, wood remains a major energy source. Hydroelectric dams were constructed on the Columbia River system. A co-generation plant was constructed on the Reservation. Energy consumption, and associated impacts have increased on the Reservation, and in the Region.
Magnitude of Impacts	Dams on the Columbia have impacted anadromous fish in the Hangman Creek watershed. The co-generation plant, when in operation, reduced air quality in local low

	lying areas such as Plummer and Worley, and contributed to impacts to Plummer Creek and Coeur d'Alene Lake. Use of wood for heating continues throughout the Reservation.
Severity of Impacts	The Hangman Creek sub-species of salmon and steelhead are extinct due to elimination of migration routes to the ocean. Wood cutting directly eliminates live trees, dead trees and logs used as wildlife habitat.
Reversibility of Impacts	Salmon and steelhead could be returned to the Hangman Creek watershed. However, these would not be the native populations which once existed there. Air and water quality impacts caused by the co-generation plant are likely reversible. Loss of live trees, snags and down woody material is reversible to the extent large enough green trees exist to replace this component.
Degree of Uncertainty	The ability of Hangman Creek to support lost anadromous fish populations is unknown. Impacts to water quality and associated habitat due to the co-generation plant have not been determined. Ecological impacts caused by air pollution from the co-generation plant, and wood-stoves have not been studied on the Reservation.
Current Trends	Population growth on the Reservation and in the surrounding areas will result in increased energy demands. It is unlikely that the co-generation plant will re-open in the near future.
Impact to Future Generations	Increased demand for energy may have future impacts on the Reservation.
Fairness/Equity of Impacts	Salmon and steelhead populations in Hangman Creek have been impacted more than any other environmental element.

Forest Health (element) The forest conditions thought to be present in 1850 no longer exist today. Fire suppression, timber harvest, conversion to agriculture and other uses, and the introduction of non-native diseases (white pine blister rust), non-native plants (noxious weeds), and non-native insects (larch casebearer) have cumulatively altered the structure and function of the forest lands. Current forests consist of dense stands of relatively young, shade-tolerant species as opposed to the mosaic of shade tolerant old growth and younger age classes that existed before European influence. For example, a portion of the Reservation was inventoried in 1933. This resulted in identifying several forest cover types. Ponderosa pine and white pine cover types accounted for 49% of the sampled area in 1933 but comprised only about 15% of the same area in 1996. Western larch/Douglas-fir also declined from 18% of the area to 11%, while hemlock/grand fir/cedar cover types increased from 3% to 40% of the area. With the exception of the white pine types, the size and structure of the pre-settlement forests can be recovered, but ecological function is irreversibly altered by the introduced non-native species. Blister rust has permanently altered the structure and function of stands in the white pine type, as white pine will not be a major overstory component as it once was.

Forest Health	
Criteria	**Evaluation**
Changes Since Settlement	Introduction of agriculture and modern development practices have reduced the amount of forest lands on the Reservation. Partial cutting, and fire suppression have altered species composition, stocking, and size and age class distribution. White pine has been greatly reduced from those forest types where it once was a dominant overstory tree.
Magnitude of Impacts	About 114,411 acres of forested lands supporting open forest, shrub and grassland vegetation has been cleared and converted to non-forest uses. The remaining 193,465 acres of Reservation forest has been impacted by logging, non-native species and/or fire suppression.
Severity of Impacts	Clearing for agriculture and other uses has eliminated the forest vegetation and forest related functions in the area impacted. Agriculture, forestry, blister rust, and other development have eliminated the old-growth (200 years and older) forests on the Reservation. White pine, ponderosa pine, and western larch have been greatly reduced in terms of relative abundance. Absence of fire in the eastern mountain forests have resulted in a build up of woody fuels. Blister rust has eliminated much of the white pine, and will prevent this tree from being a major overstory component in future old growth stands.
Reversibility of Impacts	Eradicating non-native species, such as blister rust, is not possible. The loss of white pine as a major old growth component, and associated changes in forest succession and function cannot be recovered. Converted forest lands can be recovered. However, non-native species make returning these forests to pre-settlement conditions impossible. Old growth stand conditions, and old growth trees can be recovered to the extent management guidelines favor these conditions.
Degree of Uncertainty	Pre-settlement forest conditions are unknown, and therefore precise changes in forest conditions since settlement cannot be identified without detailed study. Information on stocking conditions of private lands on the Reservation is not available. Impacts to forest health cannot be determined without data on all forest lands on the Reservation.
Current Trends	Additional conversion of forest land to agricultural land is likely to be limited if it occurs at all. Some marginal agricultural land is being converted back to forest. Home site development is occurring in forested areas. Forest practices on private lands currently favor development of younger, more even-aged stands.

Impact to Future Generations	Impacts associated with non-native species will continue to stress the forest. Loss of white pine and associated forest functions will continue to exist. Impacts associated with conversion of forest land remain for decades or centuries. Increases in shade tolerant species and tree densities will create greater risk of disease, insect and fire losses to the forest in the future.
Fairness/Equity of Impacts	The plants and animals dependent on the forests which were converted to non-forest uses, and those dependent on old growth forest conditions or white pine have been more severely affected. Western white pine has been more impacted than any other species due to attack by an exotic disease for which there is no control. Ponderosa pine and western larch have also been greatly reduced in abundance.

Hazardous Waste (stressor) Specific types of waste evaluated included metals, chemicals and biological materials. Evaluation of metals contamination did not include sources from mining activities within the Coeur d'Alene Basin. Various chemicals and metals have been introduced to the soil and waters of the Reservation. However, petroleum products and agricultural chemicals are the most abundant contaminants. The full extent and severity of impacts associated with hazardous wastes on the Reservation have not been identified. These contaminants have the potential to destroy both aquatic and terrestrial plant life and aquatic biota (e.g. invertebrates and fish).

Hazardous Waste	
Criteria	**Evaluation**
Changes Since Settlement	Hazardous materials have been introduced to the water and soil of the Reservation. These substances did not exist prior to settlement on the Reservation.
Magnitude of Impacts	Impacts of hazardous wastes appear to be focused within the lakes, rivers and streams. Sources include underground storage tanks, agricultural chemicals, various industrial facilities, automobiles, and boats.
Severity of Impacts	Severity of impacts due to hazardous wastes have not been studied on the Reservation.
Reversibility of Impacts	Impacts of hazardous wastes are reversible to the extent that they can be removed. There is the possibility of a legacy effect in some species due to hazardous wastes.
Degree of Uncertainty	Little is known about the extent and magnitude of abandoned automobiles on the Reservation. There is little site specific data about contaminant concentrations in streams, lakes, and wetlands. The specific ecological impacts from hazardous wastes have not been studied on the Reservation.
Current Trends	Trends cannot be determined due to lack of site specific information regarding impacts.

Impact to Future Generations	Bioaccumulated effects of hazardous wastes could manifest themselves in the future. Increased use of hazardous chemicals would increase risk of contamination.
Fairness/Equity of Impacts	Species associated with wetlands, lakes, rivers and streams appear to be at greater risk from hazardous waste contamination.

Human Population Growth and Development Patterns (stressor) The combined population of Kootenai and Benewah counties, in 1998, was 114,745 people, with 9,168 of these people living on the Reservation. Population on the Reservation increased about 51 percent (3,100 people) from 1989. Most development on the Reservation associated with this population is in the forested rural areas, especially in the northern portion of the Reservation. Impacts associated with population growth and development include degradation of water quality and stream banks, wildlife displacement and habitat loss, predation on wildlife by domestic pets, introduction of non-native plant species, and conversion of lands from forest and agriculture to other uses.

Human Population Growth and Development Patterns

Criteria	Evaluation
Changes Since Settlement	Population of Coeur d'Alene Tribal Members has declined from an estimated 3-5,000 to approximately 1,600. The Tribe's land base has been reduced from millions of acres to thousands of acres. Total population on the Reservation has increased to an estimated 9,168 people. Total population in Kootenai and Benewah Counties has increased to 114,745.
Magnitude of Impacts	Roads and other urban areas cover an estimated 2,245 acres. Growth and associated development is mostly in rural areas, and thus affects most of the Reservation.
Severity of Impacts	Development has led to degraded fisheries habitat and water quality. The severity of current human impacts on the ecology of the Reservation can only be understood when reading all of the sections of this report together.
Reversibility of Impacts	Human population growth can be reduced but probably not eliminated on the Reservation. Impacts of paved surfaces cannot be reversed unless impermeable surfaces are removed with contour and vegetation restored. Other impacts, such as sediment loading, can be reversed.
Degree of Uncertainty	No studies exist that predict specific impacts of population growth and associated development on the ecology of the Reservation.
Current Trends	Reservation growth is greatest in the rural areas of Kootenai County. This is expected to continue, along with all associated impacts.
Impact to Future Generations	Population on the Reservation is expected to continue to increase in the future. If population increases there may be greater impacts to natural resources.
Fairness/Equity of Impacts	Forest lands, wetlands, and their associated species have been more impacted by development in the past. Areas along existing main transportation corridors may be more impacted by development than others.

Roads (stressor) Approximately 284 miles of paved road and 2,571 miles of gravel or native surface roads have been constructed on the Reservation with more construction anticipated. Presence of roads can affect the environment by eroding and delivering sediment to streams, disrupting wildlife behavior patterns, increasing disturbance and predation by humans, contaminating soil and water by petrochemicals leaking from vehicles, and reducing air quality due to dust and vehicle emissions. Limited site specific data exists regarding the impacts of roads on the plants and animals on the Reservation. Sediment related impacts to fisheries is known, but site specific contributions of roads to sediment and increased peak flows has not been determined.

Roads

Criteria	Evaluation
Changes Since Settlement	Approximately 284 miles of paved and 2,571 miles of native surface roads have been constructed on the Reservation.
Magnitude of Impacts	Roads affect every watershed and ecosystem on the Reservation to varying degrees.
Severity of Impacts	Road systems contribute approximately 1.3% to 3% of sediment loading to Plummer and Lake Creeks respectively. Native surface roads contribute to sedimentation more than paved roads. Roads can fragment wildlife habitat by increasing human disturbance of animals.
Reversibility of Impacts	Sedimentation from roads can be reduced but not eliminated altogether without removing the roads. All impacts to all wildlife habitat can be reduced but not eliminated without removing the roads.
Degree of Uncertainty	The exact amount of sediment produced from roads on the Reservation is not known. Specific impacts to wildlife habitat, native species, forest health, and wetlands have not been quantified.
Current Trends	Road mileage on the Reservation is increasing. Modern road construction practices are reducing sediment contributions. Improvements to Highway 95 are planned for the near future.
Impact to Future Generations	Impacts of roads will continue to affect future generations.
Fairness/Equity of Impacts	Impacts to wildlife, water and fish have been greater than other ecosystem components.

Solid Waste Generation and Disposal (stressor) 101,000 tons of solid waste, generated each year in Kootenai County, is deposited in the Kootenai County Farm Landfill immediately north of the Reservation. This landfill is expected to be full between 2006 and 2010, at which time a landfill extension or re-siting will be needed. The Kootenai County facility has impacted water quality in the past, and poses a long term environmental risk.

A transfer station and closed landfill are located just outside of the town of St. Maries overlooking the St. Maries River valley. This landfill was operated until 1993 when it

was closed per Federal subtitle D regulations. After closure the site was sealed with a 6-inch impermeable clay cap. This clay seal has not yet been certified and a vegetative cover has not yet been established to meet state and federal landfill regulations. Improper capping and/or failing to complete the cap with a proper vegetative cover can compromise the integrity of the barrier and lead to increased leachate generation. There is insufficient data to evaluate the increased risk that leachate will be generated and become fugitive. The County is currently assessing the condition of the landfill cap and will supplement it to mitigate risks to sub-surface flow. The site is now operated exclusively as a transfer station for Benewah County waste. Garbage that comes to this facility is hauled to Missoula, Montana for permanent disposal.

Presence of a landfill can affect the environment by increasing scavenger populations, direct land conversion, contamination of water by leachates, and releasing odorous or toxic gasses into the atmosphere. Retired landfills pose a risk of contamination to surface and ground water, and subsequent impacts on fish and wildlife.

Solid Waste Generation and Disposal	
Criteria	**Evaluation**
Changes Since Settlement	Consumption and generation of waste products has increased on the Reservation and general area. 43 acres of agricultural land were converted into barren landfill in the Fighting Creek Watershed just north of the Reservation boundary. St. Maries Landfill was constructed and closed down.
Magnitude of Impacts	There are illegal dump sites on the Reservation. There are no major landfills on the Reservation. The St. Maries and Kootenai County Farm Landfills affect primarily the area around the landfill, although down stream impacts to the Reservation are possible.
Severity of Impacts	Since completion of storm water treatment systems, there have been no reported releases to surface or ground water from the Kootenai County site. Impacts from solid waste related processes are believed to be minor.
Reversibility of Impacts	Retired landfills will continue to pose a threat to surface and ground water quality.
Degree of Uncertainty	A complete list of landfill leachate constituents was not obtained for this project. The plans to deal with future Kootenai and Benewah County solid waste are still being developed. The severity of ground and surface water run-off from the St. Maries landfill is unknown.
Current Trends	Increasing populations in both Kootenai and Benewah counties have increased the demand on local landfills. Future landfill development or expansion of the Kootenai County Farm Landfill site is forthcoming. Benewah County also needs to address long term solid waste disposal.
Impact to Future Generations	The Kootenai County Farm Landfill is projected to last until 2006-2010. Sites for future landfills include, among other areas, locations on the Reservation. If chosen, these sites, or other sites located upstream of the Reservation, could impact future generations. Leachate from the Kootenai County Farm Landfill will be burned in the near future. However, the Kootenai County and St. Maries landfills may pose a long term hazard.
Fairness/Equity of Impacts	Waste disposal facilities are often located in rural areas, so impacts are greater in these areas. Long term, aquatic resources may face the greater impact, due to increased risk of leachate reaching streams and lakes.

Outdoor Air Pollution (stressor) The entire Reservation is affected by air pollution, primarily smoke and dust associated with agriculture, forestry, wildfires, roads and wood burning stoves. The impacts of outdoor air pollution to the ecosystems of the Reservation have not been studied.

Outdoor Air Pollution	
Criteria	**Evaluation**
Changes Since Settlement	The amount of chemical pollutants has obviously increased substantially since European settlement. All human made chemicals were not on the Reservation prior to settlement. Reductions in wild fires, and use of wood and coal as a primary fuel source, have reduced smoke emissions since European settlement.
Magnitude of Impacts	The entire Reservation is affected by air pollution.
Severity of Impacts	The impact of air pollution on the environment of the Reservation has not been studied at this time.
Reversibility of Impacts	With the exception of soil contamination caused by airborne pollutants, the known effects of air pollution are reversible.
Degree of Uncertainty	There is considerable uncertainty about the effects of air pollution on the ecology on the Reservation.
Current Trends	Burning blue grass in the late summer months is expected to continue for the next several years, and could increase if grass seed production is favored by growers over other crops. Smoke from forest practices appears to be stable. Smoke from wildfires could increase in the future. Smoke from wood stoves, and pollutants from automobiles and boats will more than likely increase.
Impact to Future Generations	Current impacts are unknown and thus there is no known impact to future generations resulting from impacts to plant and animal life on the Reservation.
Fairness/Equity of Impacts	Impacts to the ecology of the Reservation, from air pollutants, are not known at this time. Therefore it is not known if any part of the ecosystem is impacted more than another.

Localized Effects of Atmospheric Changes (stressor and element) Primary stressor types evaluated include global warming and depletion of the ozone layer. There are no

known or measurable impacts to the Reservation at this time. Potential future impacts could include reduced productivity of agricultural lands, reductions in forest and wetland habitats, increased catastrophic fires, and extinction of some plant and animal species.

Localized Effects of Atmospheric Changes	
Criteria	**Evaluation**
Changes Since Settlement	Green house gases are increasing on a global scale. Global and regional climate has warmed over the past two decades.
Magnitude of Impacts	There are no documented environmental effects on the Reservation to date.
Severity of Impacts	There are no documented environmental effects on the Reservation to date.
Reversibility of Impacts	Global warming and ozone depletion are still thought to be reversible by most scientists.
Degree of Uncertainty	There have been no studies assessing impacts on the Reservation caused by atmospheric changes. There is some question about the accuracy of models predicting changes in the environment that will be brought about by global warming.
Current Trends	Levels of green house gases continue to increase. Adverse impacts due to global warming have probably not yet occurred on the Reservation.
Impact to Future Generations	All of the impacts of atmospheric changes will be on future generations. Predictions estimate increases of 2.5° to 5.0° C in average global temperature by the end of the next century. Possible loss of agricultural productivity, reductions in forest lands and wetlands, loss or reduction of many plant species and increased frequency of wildfires.
Fairness/Equity of Impacts	Effects of global warming will be felt by all humans on earth. Impacts to ecosystems will be equally distributed in local areas but each species or element of the environment will respond differently.

Localized Effects of Hanford Nuclear Reservation (stressor) Areas downwind from Hanford, including the Reservation, other areas of north Idaho, and eastern Washington were exposed to radiation. Iodine-131 is no longer contributing to the ecosystems of the Reservation, due to its very short 8-day half-life. No studies on the effects of radiation on plants and wildlife have been conducted this far from the source, and reconstructing dose estimates is difficult due to the amount of time that has passed. Impacts to the ecosystems of the Reservation have not been determined.

Localized Effects of Hanford Nuclear Reservation	
Criteria	**Evaluation**
Changes Since Settlement	Radiation was released in large quantities to the air, water and soil from the Hanford Reservation, from 1944 to 1972.
Magnitude of Impacts	Areas downwind and downstream of Hanford were exposed to radiation. Radioactive contamination of the Columbia River impacted downstream communities to the Pacific coast.

	Radioactive particulates settled onto vegetation in Spokane and the Coeur d'Alene Reservation during releases from Hanford.
Severity of Impacts	Aquatic and terrestrial wildlife living on the Reservation would have been affected by radiation to varying degrees depending on tolerance.
Reversibility of Impacts	Because Iodine-131 has a half life of only 8 days it is no longer contributing to ecosystems on the Reservation.
Degree of Uncertainty	No studies on the effects of radiation on wildlife or plants have been conducted on the Reservation. Reconstructing dose estimates is difficult due to the amount of time that has passed.
Current Trends	Recent studies are aimed at learning the impacts of Hanford emissions on ecosystems.
Impact to Future Generations	Airborne radiation that reached the Reservation has dissipated and will have little effect on future generations, unless genetics were altered due to radiation. Potential for bio-accumulated effects to manifest themselves in the long term is not known at this time.
Fairness/Equity of Impacts	Ecosystems in eastern Washington, Oregon, and northern Idaho were affected more than other areas.

Ground Water Contamination (stressor) Aquifers under pasture, farm lands, and urban areas are most commonly impacted. None of the twenty-three wells tested on the Reservation in 1995 exceeded maximum acceptable levels of contaminants established by the EPA for drinking water standards. Contaminated ground water can impact riparian plants and animals, fish, and wildlife where subsurface and surface waters meet, but no such impacts have been identified on the Reservation.

Ground Water Contamination	
Criteria	**Evaluation**
Changes Since Settlement	All of the sources of ground water contamination on the Reservation such as agricultural chemicals, livestock, petroleum products, aggregate mining activities, and landfills did not exist prior to European settlement.
Magnitude of Impacts	Samples from the Reservation reveal that most known contamination is localized, and in close proximity to the source of contamination. Other than naturally high levels of some minerals, there is no known widespread contamination of the ground water supply.
Severity of Impacts	Potentially, ground water pollution could adversely impact fish habitat, riparian plants and animals, terrestrial wildlife, lakes and wetlands.
Reversibility of Impacts	Ground water contamination can be cleaned up to the extent that contaminated soil can be removed and the area treated with bacteria.
Degree of Uncertainty	How extensively sub-surface flow is impacting surface water quality on the Reservation is unknown. No studies have been conducted that indicate whether ground water elevation changes are impacting the environment.
Current Trends	Use of underground storage tanks by farmers and other users has declined in recent years due to stricter regulations.

	Efforts to identify and clean up leaking underground tanks have increased in recent years.
Impact to Future Generations	Expanding population on the Reservation is likely to bring greater impacts to ground water supplies. Contamination from leaking underground storage tanks will decrease due to declining use. Lowering of the water table in some areas could affect surface water recharge, especially during low flow periods.
Fairness/Equity of Impacts	By its nature, ground water contamination impacts aquatic species more than others.

Hydrologic Changes (stressor) Hydrologic changes appear to have occurred in all watersheds on the Reservation, as evidenced by increased peak flows, reduced base flows, reduced stream bank stability, and increased sediment delivery. Agriculture, grazing, roads, well use, stream channelization, and human development have all contributed to changes in hydrology. Areas with high proportions of agriculture are more severely affected. Peak stream flows have increased from 55 to 93 percent in some streams on the Reservation which could lead to degraded fish habitat. Decreased low flow and sedimentation are also affecting fish habitat in some streams.

Hydrologic Changes

Criteria	Evaluation
Changes Since Settlement	Agricultural development, grazing, extensive timber harvesting, roads, ground water use, channelization of rivers and streams, and increased human development have all occurred since European settlement. Peak flows have increased in some watersheds. Base flows are reduced in several watersheds. Increased sediment delivery and peak flows have contributed to reduced stream bank stability in many watersheds.
Magnitude of Impacts	Hydrologic changes appear to have occurred in all watersheds on the Reservation. Areas with higher proportions of agriculture are more severely affected.
Severity of Impacts	Peak stream flow increases on the Reservation range from 55% to 93%, which could lead to higher sediment loads, decreased stream bank stability, and degraded fish habitat. Decreased low flow in some streams is affecting fish habitat on the Reservation.
Reversibility of Impacts	Changes in peak flow, low flow, and yield, associated with reductions in forest canopy cover, can be reversed to the extent that forest cover and Palustrine wetlands are recovered. Restoration of streams into their natural channels could contribute to restoring more natural conditions. Reductions in the associated impacts to stream channel condition, fisheries habitat, and other factors affected by stream hydrology will take longer to be reversed than changes in hydrology itself.

Degree of Uncertainty	The pre-settlement hydrologic regimes for streams on the Reservation are unknown. The site specific degree of change in channels due to peak flow increases is unknown. It is also not known to what extent forest canopy can be removed without impacting water yield to the point it is detrimental to dependent resources, such as cutthroat trout.
Current Trends	Additional reductions in forest cover, due to timber harvest, are likely. This could lead to increased changes in stream hydrology. Changes due to road construction will continue to increase as more roads are built.
Impact to Future Generations	Peak flow increases will persist to the degree that reductions in canopy cover exceed the historic range of variability, and stream channelization continues. Increased development on the Reservation is likely to magnify hydrologic problems.
Fairness/Equity of Impacts	By its very nature, changes in hydrologic response tend to impact aquatic species more than others. However, impacts associated with the changes, such as unstable channels and flooding, can also impact adjoining terrestrial ecosystems. This includes associated wildlife habitat and populations.

Non-point Source Surface Water Pollution (stressor) Non-point pollution, especially sediment and nutrient production, has affected the entire Reservation. Forestry, agriculture, recreation, roads, and energy systems have all contributed to increases in temperature, nutrients, sediment, and chemicals in the surface waters of the Reservation. These impacts have severely degraded fisheries habitat. Elevated nutrient concentrations occur primarily where agricultural practices are more prevalent. Nutrient loading in Lake Coeur d'Alene, however, has decreased since 1975.

Non-point Source Surface Water Pollution

Criteria	Evaluation
Changes Since Settlement	Major sources of non-point pollution, such as forestry, agriculture, recreation, roads, and energy systems, have all been introduced to the Reservation since European settlement.
Magnitude of Impacts	Non-point pollution, especially sediment and nutrient production, has affected all streams, rivers and lakes on the Reservation. Elevated nutrient concentrations occur primarily where agricultural practices are more prevalent.
Severity of Impacts	Increases in temperature, nutrients, chemicals and sediment have severely degraded fisheries habitat.
Reversibility of Impacts	Increased stream temperatures and sediment loads are reversible to the extent that stream side shading is re-established and sediment sources eliminated. Chemical and nutrient loading can be reduced by controlling upland sources.
Degree of Uncertainty	Relative impact to Reservation streams and resources from non-point source surface water pollutants is well known, and degree of uncertainty is low. Actual amounts of pollutants attributable to a particular source are not as well understood.

Current Trends	Nutrient loading to Lake Coeur d'Alene has declined since 1975. However, loading remains high at the south end of the lake. Erosion is highest in the late winter or early spring when thawing ground, melting snow and rainfall readily transport soil. Major sources of sediment are expected to continue to increase, as are the impacts to fish and wildlife habitat, and wetlands. Application of modern management practices are having varying degrees of success in preventing non-point source pollution throughout the Reservation.
Impact to Future Generations	At least some sources and impacts of non-point source surface water pollution will persist or increase as development increases on the Reservation.
Fairness/Equity of Impacts	Current information indicates that non-point source surface water pollution has degraded fisheries, and other aquatic species, more than other environmental elements.

Point Source Surface Water Pollution (stressor) Identified point sources of pollution that affect the surface waters of the Reservation include the Potlatch Corporation mill and the municipal wastewater treatment plant in St. Maries, the Plummer municipal wastewater plant, and (prior to closure) the Rayonier mill in Plummer, the wastewater treatment plants of Tensed, DeSmet, and Worley, and a fertilizer plant in the Hangman Creek drainage. Each point source contributes small amounts of mostly nutrients into the surface waters. When combined with non-point source nutrient loading, the cumulative effects degrade fish habitat, increase aquatic plant life, and subsequently decrease dissolved oxygen in streams. It is not known what proportion of the fisheries habitat degradation is attributable to point source pollution.

Point Source Surface Water Pollution

Criteria	Evaluation
Changes Since Settlement	Several waste water treatment facilities, two sawmills and a fertilizer plant contribute point sources of pollution to surface water.
Magnitude of Impacts	The Potlatch mill and the St. Maries waste water treatment plant discharge into the St. Maries River. Plummer Creek receives waste water from a municipal treatment plant and, prior to closure, the Rayonier mill. Tensed, DeSmet, and Worley Waste Water Treatment Plants, and a fertilizer plant discharge point sources of pollution into Hangman Creek.
Severity of Impacts	Nutrient loading from point sources degrade fish habitat, alter aquatic plant life and decrease dissolved oxygen in streams. Each point source contributes little disturbance but together with non-point pollution the cumulative impacts can be quite large. Discharge of toxic chemicals or biological contaminants could have severe impacts on wildlife exposed to surface water.
Reversibility of Impacts	The impacts of point sources of pollution are reversible to the extent sources are identified and contaminants removed from the system.

Degree of Uncertainty	It is unknown to what extent point sources of pollution are responsible for degrading fisheries habitat, wetlands, and wildlife habitat on the Reservation.
Current Trends	Increased population could put stress on the existing waste water treatment facilities as more residences are established in certain areas.
Impact to Future Generations	Population growth will increase the load received by waste water treatment plants, and increase industrial and other sources of pollutants. This will pose an even greater risk to future generations.
Fairness/Equity of Impacts	To date, the impacts of point source surface water pollution have been greater to aquatic species than any other element of the environment. Terrestrial species may have been affected to the extent that water quality and habitat associated with lakes and streams have been affected.

Wetlands (element) Approximately 21,417 acres of Palustrine wetlands on the Reservation have been lost to land conversion, draining, and development. This represents a loss of an estimated 83% of the Palustrine wetlands originally on the Reservation. Many of the remaining wetlands have been degraded by roads, development, agriculture, forestry, and grazing. Loss of wetland acreage and wetland function is partly responsible for flooding, flashy hydrology, increased nutrient and sediment loads, and degraded fisheries habitat in many Reservation streams. Impacts may also include elimination of wetland species that once existed in areas now converted to other uses.

Wetlands

Criteria	Evaluation
Changes Since Settlement	Since European settlement, most of the Palustrine wetlands located on the Reservation have been eliminated, or their function severely altered. Wetlands have been impacted by chemicals and physical alteration caused by numerous human related activities that did not exist prior to settlement.
Magnitude of Impacts	Hydrology and water quality have been impacted on the entire Reservation to some extent due to wetland loss, especially in the Hangman Creek Watershed. Wild rice is grown on 120 acres of wetlands.
Severity of Impacts	Potentially as much as 83% (21,417 acres) of the Palustrine wetlands on the Reservation have been lost since settlement (Cd'A Tribal GIS, 1998). Lost wetland acreage is partly responsible for the high nutrient and sediment load, degraded fisheries and the flashy hydrology in Hangman Creek, and other streams on the Reservation. The loss of wetlands is a severe impact in and of itself, as all habitat and other functions are lost as well.
Reversibility of Impacts	Loss can be permanent or reversible. Existing dikes, levees, sediment and nutrient loading from upland sources, exotic species, water yields in tributary streams, and impacts from roads, would all have to be restored to pre-settlement wetland conditions.
Degree of Uncertainty	Historic and present acres of wetlands are estimates. Historic species composition, function, hydrology and the exact area is unknown. There is also considerable uncertainty as to the impacts associated with

	planting and harvesting wild rice in the southern wetlands on the Reservation.
Current Trends	Physical loss of wetlands has slowed, although conversion is still occurring. Increased population growth and associated development will increase impacts in the future. Sedimentation, chemical inputs and nutrient loading continue to be a problem for wetlands on the Reservation.
Impact to Future Generations	Loss of wetlands will continue to impact their function as nutrient and sediment traps, wildlife habitat and flood control in the future.
Fairness/Equity of Impacts	Loss and alteration of wetlands on the Reservation have a greater impact on the diversity of fish, wildlife and plant communities dependent upon these areas.

Native Plant and Animal Populations and Species Diversity (element) Plant, animal, and fish populations on all parts of the Reservation have been impacted by logging, agriculture, development, hunting, recreation, and other human activities. Approximately 21,417 acres of wetlands, and 114,411 acres of forest, grassland, and shrub land have been converted to farmland, pasture, or other human development. These conversions and activities have decreased habitat connectivity, altered species abundance and diversity, decreased plants associated with late successional forest types, and likely eliminated some plants and animals from the Reservation (especially those associated with prairies, wetlands, or old growth forests). Impacts also include a reduction in the numbers of westslope cutthroat trout and bull trout to levels that could lead to extinction on the Reservation. Full impacts are unknown as historical data concerning plant and animal populations at the time of Reservation establishment do not exist.

Native Plant and Animal Populations and Species Diversity

Criteria	Evaluation
Changes Since Settlement	The cumulative effects of land use have led to declines in most native plant, fish, and wildlife populations.
Magnitude of Impacts	Approximately 21,417 acres of Palustrine wetlands have been converted to other land uses. An estimated 114,411 acres of combined forest, grassland, and shrub types have also been converted, including all the native bunchgrass prairie community which is believed to have existed on the Reservation. Forest types once dominated by large, mature or old growth ponderosa pine and white pine have been lost. Total white pine populations have been greatly reduced due to timber harvest and blister rust.
Severity of Impacts	The loss of wetland, forest, shrub and grassland habitat has an impact on plant species populations, diversity, and connectivity of habitat. Grizzly bears, Canadian lynx, gray wolf, wolverines and woodland caribou populations may have been extirpated from the Reservation. Native populations of steelhead and salmon, in Hangman Creek, are extinct. Cutthroat trout and bull trout populations are severely depressed throughout the Reservation.

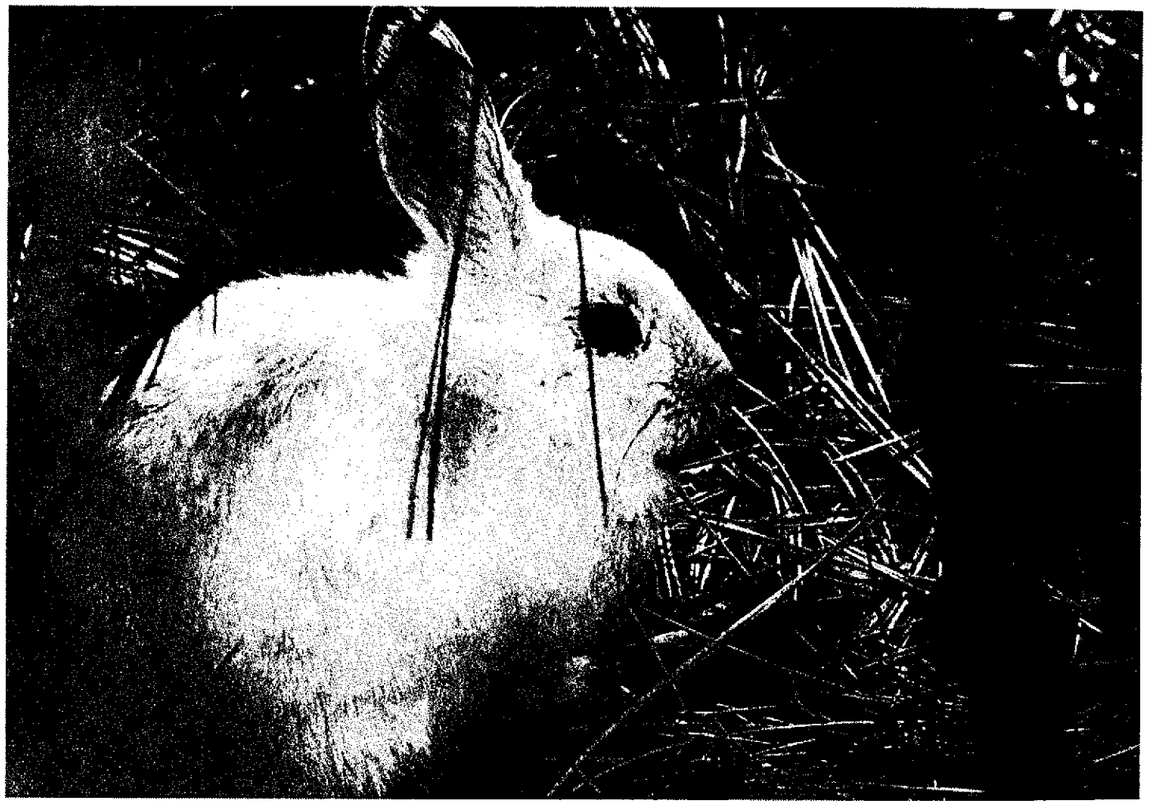
Reversibility of Impacts	Native plants species, and communities, can be recovered to the extent that key stressors are eliminated. This includes restoring native grasslands, wetlands and old growth forest conditions. White pine's role, on sites where this species used to be a dominant factor, cannot be restored due to blister rust. Wildlife populations can be recovered to the extent native plant communities and habitat is restored. Some species may never return to the Reservation.
Degree of Uncertainty	It is not known what the actual populations of the various native species were, or how many species were actually present. There have been no studies of the actual site specific impacts to wildlife habitat on the Reservation. There is no information on actual populations, or the number of species present. Assumptions that grizzly bear, wolf, Canadian lynx and woodland caribou were native to the Reservation were based on habitat typing. No historic information was able to be located for this report.
Current Trends	Forest plants associated with old growth forests are rapidly declining. Cumulative effects on streams are reducing fish populations. Many native plant species are being replaced by more aggressive exotic plants.
Impact to Future Generations	Westslope cutthroat trout and bull trout are in danger of being eliminated from Reservation streams. Dwindling wildlife and fish populations could lead to further restriction on hunting and fishing seasons.
Fairness/Equity of Impacts	Plants and animals dependent on wetlands, aquatic habitats, native grassland, and old growth forests have been the most seriously impacted.

Tribal Culturally Important Species Populations and Diversity (element) Human development, introduction of non-native plant and animal species, and land management practices have reduced the abundance of many of the known culturally important plant and animal species. About 135,828 acres of native vegetation was converted to other uses, eliminating both the vegetation and the animal species dependent on that vegetation, and possibly extirpating some plant or animal species from the Reservation entirely. Salmon and steelhead populations have been eliminated from the Hangman Creek watershed. Populations of cutthroat and bull trout are dwindling due to habitat alteration and competition and predation from non-native fish species. Some culturally important plants have been eliminated or reduced in abundance by invasive, non-native plant species. The full extent of impacts to culturally important plant species cannot be assessed because the importance of many plants is known only to selected individuals or families.



Birds such as this Chestnut-sided Chickadee are typical of the diverse native wildlife found on the Coeur d'Alene Reservation.

Tribal Culturally Important Species Populations and Diversity	
Criteria	**Evaluation**
Changes Since Settlement	Human development has reduced the abundance of many known Tribal culturally important species.
Magnitude of Impacts	About 135,828 acres of forest, grassland, scrub shrub and wetland have been converted to other uses. Another 193,465 acres of forested lands have been impacted by uses which alter forest structure and function. Non-native species have invaded and out-competed native fish, wildlife and vegetation throughout the Reservation, and are found in all habitats, including lakes, rivers and streams, wetlands, riparian areas, agricultural lands and both dry and moist forest lands.
Severity of Impacts	Salmon and steelhead populations have been eliminated in the Hangman Creek watershed. Those species dependent on old growth, wetland, and native grassland habitat have been greatly reduced or eliminated, including sharp tail grouse, blue grouse, water potato and camas. It is possible that unnamed culturally important species have been lost entirely from the Reservation.
Reversibility of Impacts	Total eradication of all non-native species which impact culturally important species is not possible. Most species can be restored to the extent that sources of impact are eliminated and habitat restored.
Degree of Uncertainty	Complete inventories of culturally important species are not available. The cultural significance of many plants is known only to selected individuals.
Current Trends	Human development and associated impacts are continuing to have an effect on culturally important plants and animals. Although many stressors remain, improved management practices and other mitigation efforts are being implemented to improve fisheries habitat on the Reservation. Attempts are also being made to better inventory large game and other culturally important wildlife species on the Reservation.
Impact to Future Generations	Reduction or loss of important species will add to potential loss of knowledge of uses by Tribal members. Detrimental impacts are expected to continue to exist, although some improvements may occur as well.
Fairness/Equity of Impacts	The bulk of native species were probably lost in the western lowlands of the Reservation. Species dependent on aquatic, native grassland, wetland, and old growth habitat have been more affected.



Like most of the native species, the snowshoe hare has cultural significance to the Coeur d'Alene People.

Native Wildlife and Fisheries Habitat (element) Nearly all of the native wildlife and fisheries habitat on the Reservation has been altered by human development, land conversion, management activities and presence of non-native species. Approximately 135,828 acres, including all of the native bunchgrass prairie and 21,417 acres of Palustrine wetlands, were converted to agriculture or other human development. Forest types dominated by large, old growth ponderosa pine or white pine have been virtually eliminated by logging, fire, or disease (i.e. white pine blister rust). Fisheries habitat has been severely impacted by sediments, nutrients, stream channelization, and loss of stream side vegetation related to changes in vegetation cover and land management. Non-native plant, animal, and fish species are directly competing with their native counterparts. White pine blister rust has permanently altered forest structure and function on those sites where white pine was a dominant species, thus impacting wildlife associated with white pine forests. Exact evaluation of impacts cannot be assessed because pre-settlement wildlife and fisheries habitat conditions have not been quantified.

Native Wildlife and Fisheries Habitat	
Criteria	**Evaluation**
Changes Since Settlement	There have been dramatic changes in the landscape and watersheds of the Coeur d'Alene River Basin and ancestral lands of the Coeur d'Alene Tribe since European settlement. Forest lands, grasslands, and wetlands have been converted to other land uses or altered by human development. Erosion of the landscape has been widespread and excessive. Sediment has been delivered to stream channels. Livestock grazing occurs in most of the watersheds and along streams. Watersheds and channels have been de-stabilized. Water has been withdrawn for agricultural and domestic uses. Old growth forests have been virtually eliminated.
Magnitude of Impacts	Approximately 21,417 acres of Palustrine wetlands have been converted to other land uses. An estimated 114,411 acres of combined forest, grassland, and shrub types have also been converted, including all the native bunchgrass prairie community which is believed to have existed on the Reservation. Forest types once dominated by large, mature or old growth, ponderosa pine and white pine have been lost.
Severity of Impacts	Forest connectivity has been reduced along with actual acres of forest habitat. Loss of wetland habitat reduces its availability to waterfowl, fur bearers and other wildlife. Its loss also affects hydrologic response to storms, increasing potential degradation of fisheries habitat. Fisheries habitat has been severely impacted in all Reservation streams. Bull trout are listed as threatened and Cutthroat trout were proposed for listing under the Endangered Species Act, although the U.S. Fish and Wildlife Service has stated that listing is not warranted at this time.. Exotic species are impacting native plant communities. Blister rust has permanently altered forest structure and function on those sites where white pine was a dominant species.
Reversibility of Impacts	Native wildlife and fish habitat can be restored to the extent management practices are altered, and restoration takes place where needed.
Degree of Uncertainty	The pre-settlement wildlife and fisheries habitat conditions have not been quantified. This makes assessment of impacts less accurate.

Current Trends	Use of clear cutting, and other even-aged methods has increased in recent years. Demand for forest products will most likely remain high, placing added pressure on forested habitats. Age classes will probably continue to decline across the landscape. A trend towards oligotrophy (low nutrients, unproductive) has been established in the north end of Coeur d'Alene Lake and a trend towards a eutrophic condition may be occurring in the southern end of the lake. Sediment, phosphorus and bacterial contamination has improved in recent years in upper Hangman Creek, but no improvements were apparent in lower Hangman Creek.
Impact to Future Generations	Impacts of human development on wildlife and fisheries habitat will continue over the next 100 years. Continued reductions in habitat and increased human disturbance could lead to loss of certain species on the Reservation.
Fairness/Equity of Impacts	Wetland, aquatic, old growth and native grassland habitats and the species dependent upon these habitats have been most severely impacted on the Reservation.

Non-native Plant and Animal Species (stressor) All ecosystems on the Reservation have been impacted by non-native species. Seventeen exotic fish species have been stocked in Lake Coeur d'Alene and its tributaries. Noxious weeds such as spotted knapweed, and yellow hawkweed have invaded agricultural and forest lands. Impacts associated with exotic species probably cannot be reversed, at least in the next 100 years. This is especially true with respect to the impact blister rust has had on white pine forests. Wetlands have been affected across the Reservation and Eurasian milfoil currently presents a potentially significant risk to aquatic systems if it becomes introduced to Lake Coeur d'Alene.

Non-native Plant and Animal Species

Criteria	Evaluation
Changes Since Settlement	An estimated 189 non-native plant and animal species have been introduced to Kootenai and Benewah counties. These species more than likely occur on the Reservation. Several non-native animal species have been introduced to the Reservation, including domestic and farm animals, ring-necked pheasants, gray partridge, and wild turkey. Seventeen exotic fish have been stocked in Lake Coeur d'Alene and its tributaries.
Magnitude of Impacts	All ecosystems on the Reservation have been influenced in some way by non-native species. 135,828 acres of non-native crop species have been planted on the Reservation. 120 acres of wetlands are used for non-native wild rice production.

Severity of Impacts	34 of the exotic plant species are classed as noxious weeds. Noxious weeds can cause habitat degradation, and decrease biological diversity. Non-native fish species have contributed to decreased bull trout and cutthroat trout populations on the Reservation. White pine blister rust has permanently altered forest structure and function on those sites where this species was a dominant feature.
Reversibility of Impacts	Many non-natives are impossible to eradicate.
Degree of Uncertainty	Specific magnitude and severity of impacts from most exotic species on the native ecosystem are not known. Population and distribution of all exotics on the Reservation are not currently known.
Current Trends	Eurasian milfoil has recently invaded some lakes in Kootenai County, although it is not yet present in Coeur d'Alene Lake.
Impact to Future Generations	The impacts of non-native species will persist. Eurasian milfoil could potentially infest Coeur d'Alene Lake.
Fairness/Equity of Impacts	White pine has been one of the most severely impacted species due to introduction of an exotic species. Disturbed lands are usually more affected by non-native plant species than undisturbed sites. Wildlife and fish will be affected by loss of native plants and competition from other non-native animals.

Soil Productivity Human development has caused large scale changes to soil characteristics throughout the Reservation. This includes impacts caused by agricultural practices, forestry practices, road construction, and other site disturbing activities associated with human development. Reductions in soil productivity are most pronounced on agricultural and forest lands, due to the frequency of physical disturbance. Reductions in productivity are most often off set by increased use of fertilizers, which pose additional risks to the environment.

Soil Productivity

Criteria	Evaluation
Changes Since Settlement	Human activities have caused large scale changes to soil characteristics throughout the Reservation.
Magnitude of Impacts	About 135,828 acres have been affected by agricultural practices. Most of the 193,465 acres of forest have been subject to logging, burning and other practices that affect the soil productivity. 284 miles of paved and 2,571 miles of native surface and gravel roads have been constructed, thus impacting soil characteristics.
Severity of Impacts	70,000 of the 135,828 acres of farm land are classified as having highly erodible soils. These lands can lose 3 - 35 tons per acre per year, depending on conservation measures, under agriculturally induced erosion processes. Structure, organic matter and the abundance of soil-dwelling organisms has been altered on impacted sites.

Reversibility of Impacts	Eroded soil cannot be replaced. Organic matter can be restored to soil by adding vegetative matter, leaving woody debris after logging or growing long-term perennial crops. Soil structure, levels of organic matter and soil-dwelling organisms in soil will not approach pre-1900 conditions unless allowed to build up over several decades or longer. It will require decades to restore soil-dwelling organisms and soil structure.
Degree of Uncertainty	Site specific information on forest land soil productivity is lacking. Pre-settlement soil measurements do not exist.
Current Trends	Development and road building have increased over the last 10 years. Soil erosion is most severe during the fall, winter and spring. Rain on snow events cause high erosion rates. Changes in farming practices, and other mitigation efforts are reducing soil losses to erosion. Compaction remains a concern on forested lands being managed for timber production.
Impact to Future Generations	Reduced soil productivity on agricultural lands will require increased fertilizer and pesticide use, increasing risks associated with these chemicals. Changes in forest soils could lead to reduced timber yields and impair native plant and animal habitat. Development will continue to remove vegetation, increase compaction, and displace soil on the Reservation.

Quality of Life Report
Executive Summary

Introduction

The goal of the Quality of Life Sub-Group was to assess and describe the impacts of twenty-five "environmental concerns" on the community's "quality of life." One of the first objectives that needed to be accomplished in order to begin the assessment was to delineate the defining criteria for "quality of life." In lieu of a "definition" per se, the sub-group developed a set of parameters and common language for "quality of life" that could be applied uniformly in the assessment, yet a set of criteria that was cognizant of the community's diversity and would not preclude the views of any given segment of the community. These criteria became known as the ***"Categories for Quality of Life."*** As these five categories are typically interdependent, no one category was understood as primary to or more important than the others, which is evident in the "circle diagrams" developed for each topic. The "categories" are

- "Economic and Subsistence,"
- "Spiritual/Moral,"
- "Aesthetics,"
- "Community Well-being,"
- "Personal Well-being."

The criteria are shown in the master circle diagram which begins the "Circle Summaries" section. In addition, a "matrix" was established that could record an individual's opinion on the "**economic/subsistence**," "**spiritual/moral**," and "**aesthetic**" quality of life concerns along a continuum from "**community well-being**" at one end to "**personal well-being**" at the other end. Other criteria evaluated included impacts on Tribal culture, degree of uncertainty, trends, seasonal differences in severity of impacts, impacts on future generations and fairness/equity of impacts.

Given the general lack of documented research on the community's quality of life, the sub-group elected to pursue its own primary research. Aware of the need to gauge both the "subjective" meanings often associated with the phrase "quality of life," as well as "objective" interplay of "natural and environmental resources and economics," the sub-group sought methodologies that were both qualitative and quantitative in nature. The assessment approaches relied primarily on the use of a "focus group" (qualitative in nature) and an economic analysis (quantitative in nature). In addition, interviewing a limited sample of community members and conducting public opinion surveys supplemented the information obtained in the focus group sessions.

This summary of the Quality of Life section consists of the following:

- Main conclusions from Dr. Power's report—"The Importance of Natural and Environmental Resources in the Economy of the Coeur d'Alene Reservation."
- Circle diagram of the final categories for the Quality of Life Sub-Group.
- Circle Summaries for each of the 25 EAP environmental concerns, based on the QOL Focus Group Sessions.
- Summary of Interviews Supplemental to Focus Group Information.
- Results of the Quality of Life Public Opinion Surveys completed at the 1998 Family Awareness Day and the 1998 Career Day in Plummer.

"The Importance of Natural and Environmental Resources in the Economy of the Coeur d'Alene Reservation," by Dr. Thomas Power

1. Introduction and Conclusions

In order to put Tribal efforts to protect, enhance, and manage environmental quality on the Coeur d'Alene Reservation in an accurate economic context, the Quality of Life Sub-Group of the Environmental Action Plan Project commissioned this study of the importance of natural and environmental resources in the Reservation economy. Based upon an analysis of the available data, a review of historical documents, and interviews with leaders on and off the Reservation, this study reaches the following conclusions:

1. Since time immemorial the Coeur d'Alene have relied upon the natural landscapes that were their homeland for material and spiritual sustenance. This reliance on the natural landscape extended far beyond specialized dependence upon a few resources that had commercial value to distant outsiders. It included the full range of nature's bounty including what are now usually described in terms of environmental goods and services.
2. In the contemporary economy, Benewah County, in which the southern part of the Reservation lies, is very highly dependent on the wood products industry. The Reservation itself, however, is less dependent on wood products both because the largest mills and mill town are largely located off of the Reservation and because recreation-related developments, including the Tribal Casino, have grown in importance on the Reservation. Kootenai County, in which the northern part of the Reservation is located, is much less dependent upon wood products.
3. Agriculture, although important to the Reservation economy, makes up a relatively modest part of the overall economy.
4. The Reservation and the surrounding economy are currently experiencing significant growth that is not tied to the traditional natural resource industries. That growth is tied to new and returning residents' pursuit of higher quality living environments. This is not a new phenomenon in the region. The Coeur d'Alene, Spokane, and Western Montana areas have been experiencing this type of amenity-supported economic vitality for a decade or more.
5. Tribal government enterprises and programs have also been an important source of this current economic vitality. These new enterprises and programs have not been focused upon the traditional natural resource sectors. Instead they have focused on recreation, including the Tribal Bingo Casino, and efforts to protect and enhance the Reservation's natural landscapes and environmental values. These new sources of employment and revenue for the Tribe have helped reduce pressure on the Reservation's natural resources and natural environment. The Tribal Casino now provides about a quarter of estimated total employment on the Reservation.

6. The reliance of the Coeur d'Alene Tribe and its members on wood products and agriculture is not primarily through the employment opportunities those natural resource industries provide. Relatively few Native Americans on the Reservation are directly employed in wood products and agriculture. Those natural resource industries, however, provide important support to both Tribal government and individual Tribal members as a result of income flows from the sale of timber and the leasing of agricultural lands. For instance, between 1995 and 1997 an average of $1.3 million flowed into the Tribal general fund from agricultural lease and stumpage payments. Those natural resource income flows to the Tribal government also support extensive Tribal employment opportunities on the Reservation. In 1997 approximately $2.5 million flowed to individual allotment owners.

7. As important as wood products and agriculture are to the Reservation, Tribal, and surrounding economies, they are not likely to be sources of additional jobs and income in the future. At best, they are likely to be a constant source of economic support. More likely, given national and international economic conditions, they will be modestly declining sources of jobs and income in the future.

8. Looking forward, wood products and agriculture can be expected to continue to play a significant role in the Reservation economy, but new jobs and incomes to support the growing population are almost certain to be associated with the Reservation's ability to attract and hold new residents and businesses. This will depend on the Reservation continuing to be perceived as providing residents with unusually high quality living environments. In that sense, a protected natural landscape and environmental quality will be central parts of the Reservation's economic base.

9. The current economic vitality and growth present the Tribe with difficult challenges. While it is environmental quality that is attracting people and businesses, that very economic vitality can threaten environmental quality. The economic future of the Reservation will be closely tied to how well the Tribe manages this challenge.

Final Categories for Quality of Life Sub-Group
December 7, 1998

Economic/Subsistence (Qualitative)
Ability to earn a living
Ability to receive and share the "gifts" of the landscape with those in need
Fairness, equity, costs/benefits
Productivity of land

Aesthetics
Recreation: hunting, hiking, etc.
Appreciation of nature and natural beauty
Open space
Ability to hear the song of the Hawk and to observe the flight of the Eagle and to sing and dance "beauty" back into the landscape

Community Well-being
Future generations
Inclusiveness, cross-cultural
Native American & non-Native American
Balance among competing needs
Good community processes
Human population movement
Land use
Ability to address and relate to the landscape as "family," a community made up of Human, Ancestral, Animal and Spiritual Peoples

Spiritual/Moral
Freedom
Culture, traditions, religion
Ability to receive and share benefits of *sumesh** song

Personal Well-being
Health
Income
Individual rights and responsibilities
Peace of mind

- *Sumesh* can be defined as "the spiritual guidance and life-giving vitality emanating from a personal relationship with a particular Animal Spirit (e.g. Bear, Wolf, or Eagle)."

MATRIX

	Spiritual	
Economic	***Aesthetic***	
Community------Individual	Community------Individual	

Agricultural Chemicals
Quality of Life Sub-Group

Spiritual/Moral
Some people may oppose any use of chemicals while others find them necessary to produce food and maintain life.

Economic/Subsistence (Qualitative)
Ag Chemicals are very important to successful harvests, but may have detrimental effects on traditional Tribal foods such as camas, water potato, and fish.

Tribal Culture
Ag chemicals could have a negative impact on traditional foods.

Personal Well-being
Each person must decide if they want ag chemicals to increase production and bring economic benefits or if they fear the ag chemicals and are disturbed by their use.

Aesthetics
Ag chemicals may harm birds, fish, animals, and plants. There is a beauty in healthy wheat fields and unblemished foods.

Community Well-being
Conversion of land from traditional foods to farming hurts community well-being. Community well-being is helped by the economic benefits of ag chemicals.

Degree of Uncertainty
High degree of uncertainty regarding immediate and long-range impacts on the environment.

Fair and Equitable
Ag chemicals will cause more damage if you are interested in traditional foods, live near farmland, or are susceptible (such as asthma).

Trends, Seasonal Differences, and Future
Farmers are using fewer chemicals. More use of Integrated Pest Management may cause even fewer chemicals in the future.

Energy Production and Consumption
Quality of Life Sub-Group

Spiritual/Moral
Energy production separates us from the land, from the animals and plants, and from the weather.

Economic/Subsistence (Qualitative)
Energy is vital for a healthy economy, but hydro power has hurt aspects of the recreational economy, such as salmon runs and changes in Lake Coeur d'Alene.

Tribal Culture
Dams have changed parts of the traditional culture of the Tribe.

Personal Well-being
Energy brings light and heat but can also drive away salmon and change the lake.

Aesthetics
Dams are not attractive and neither are roads cut into logging areas.

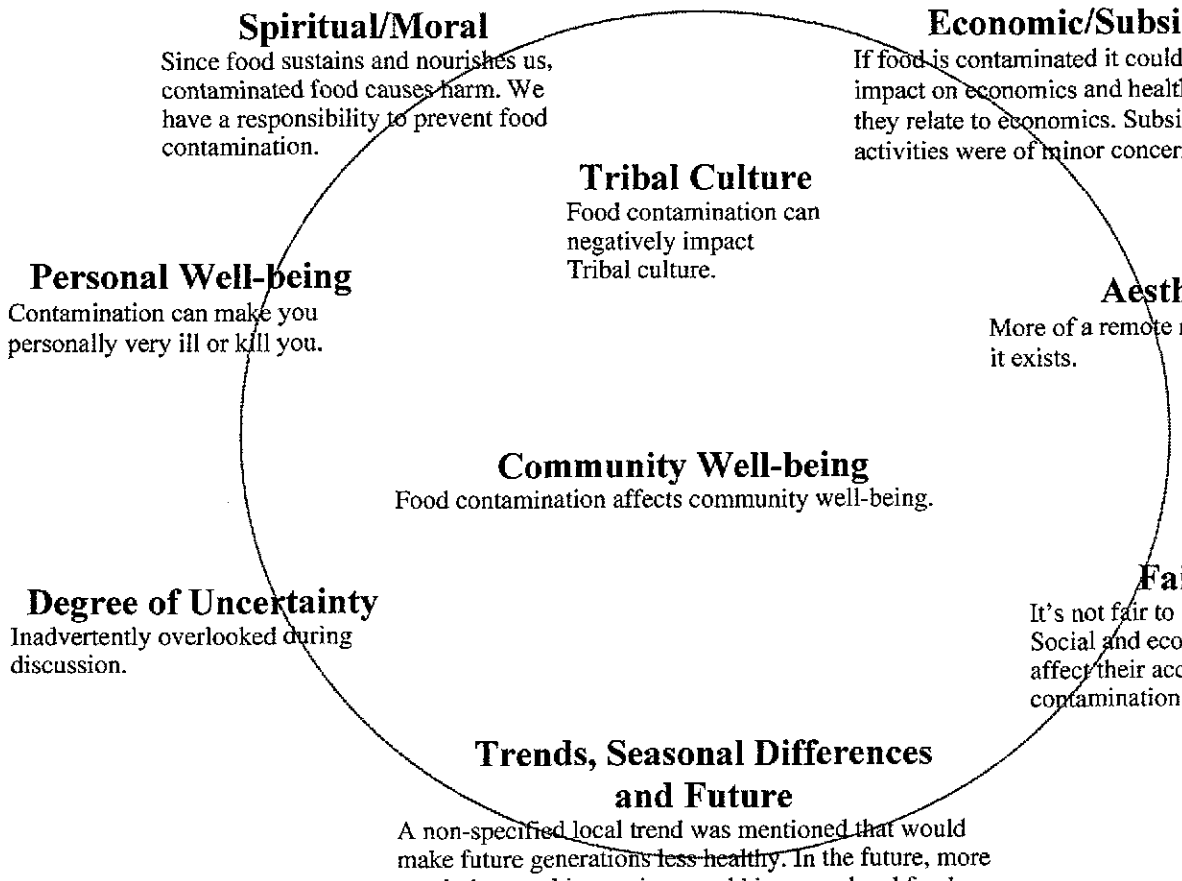
Community Well-being
Energy is both positive and negative, bringing cheap power to people and hurting habitats due to hydropower.

Degree of Uncertainty
We don't know all the impacts of energy production/consumption and deregulation brings an uncertain future.

Fair and Equitable
The effects are not distributed equally. Utilities charge different rates. Fishermen do not have salmon or native fish as catch anymore.

Trends, Seasonal Differences, and Future
Deregulation will have a major impact on the Coeur d'Alene Reservation, and we are not sure what that impact will be. Low energy costs bring vacationers to our area.

Food Contamination
Quality of Life Sub-Group



Spiritual/Moral
Since food sustains and nourishes us, contaminated food causes harm. We have a responsibility to prevent food contamination.

Economic/Subsistence
If food is contaminated it could have a big impact on economics and health problems as they relate to economics. Subsistence activities were of minor concern.

Tribal Culture
Food contamination can negatively impact Tribal culture.

Personal Well-being
Contamination can make you personally very ill or kill you.

Aesthetics
More of a remote relationship, but it exists.

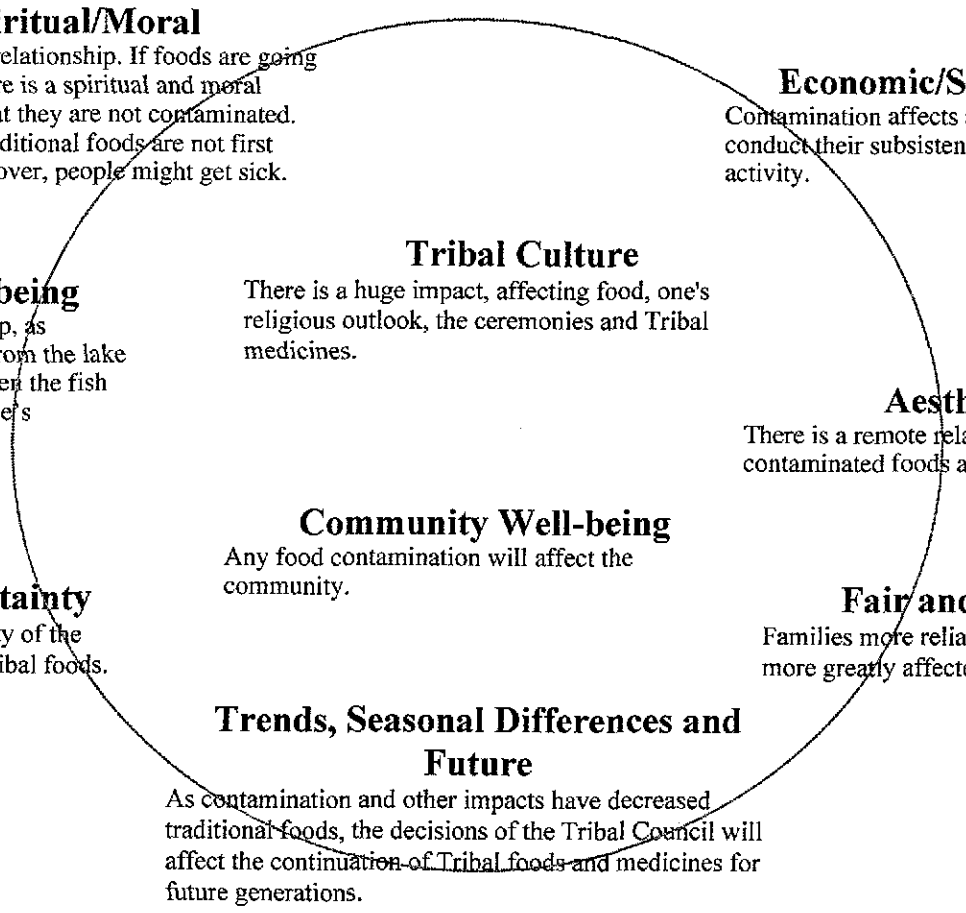
Community Well-being
Food contamination affects community well-being.

Degree of Uncertainty
Inadvertently overlooked during discussion.

Fair and Equitable
It's not fair to those exposed to contamination. Social and economic conditions of persons may affect their access to information on food contamination.

Trends, Seasonal Differences and Future
A non-specified local trend was mentioned that would make future generations less healthy. In the future, more regulations and inspections could improve local food safety.

Tribal Cultural Food and Medicines Contamination
Quality of Life Sub-Group



Spiritual/Moral
There is a close relationship. If foods are going to be shared, there is a spiritual and moral responsibility that they are not contaminated. In addition, if traditional foods are not first properly prayed over, people might get sick.

Economic/Subsistence
Contamination affects areas where people conduct their subsistence and economic activity.

Tribal Culture
There is a huge impact, affecting food, one's religious outlook, the ceremonies and Tribal medicines.

Personal Well-being
There is a strong relationship, as exemplified when the fish from the lake began to taste different. When the fish are contaminated, part of one's personal culture dies.

Aesthetics
There is a remote relationship, as contaminated foods are not pleasing.

Community Well-being
Any food contamination will affect the community.

Degree of Uncertainty
There is no degree of uncertainty of the impacts of contamination on Tribal foods.

Fair and Equitable
Families more reliant on Tribal foods are more greatly affected and impacted.

Trends, Seasonal Differences and Future
As contamination and other impacts have decreased traditional foods, the decisions of the Tribal Council will affect the continuation of Tribal foods and medicines for future generations.

Forest Health
Quality of Life Sub-Group

Spiritual/Moral
The health of the forest speaks to the health of the traditional Coeur d'Alene people spiritually.

Economic/Subsistence (Qualitative)
Healthy forests have been key to the local economy for 100 years. Healthy forests are key to some people as part of their community and places to gather important plants and animals.

Tribal Culture
It is essential and it needs to be considered very closely.

Personal Well-being
People like to enjoy healthy forests. When there is less diversity, it causes concern.

Aesthetics
There is a strong relationship as people don't like to look at mono-culture or clear-cut forests.

Community Well-being
For traditional communities, the health of the forest is vital because the forest is part of the community.

Degree of Uncertainty
Low degree of uncertainty. Pretty clear that forest health has much to do with all parts of our quality of life.

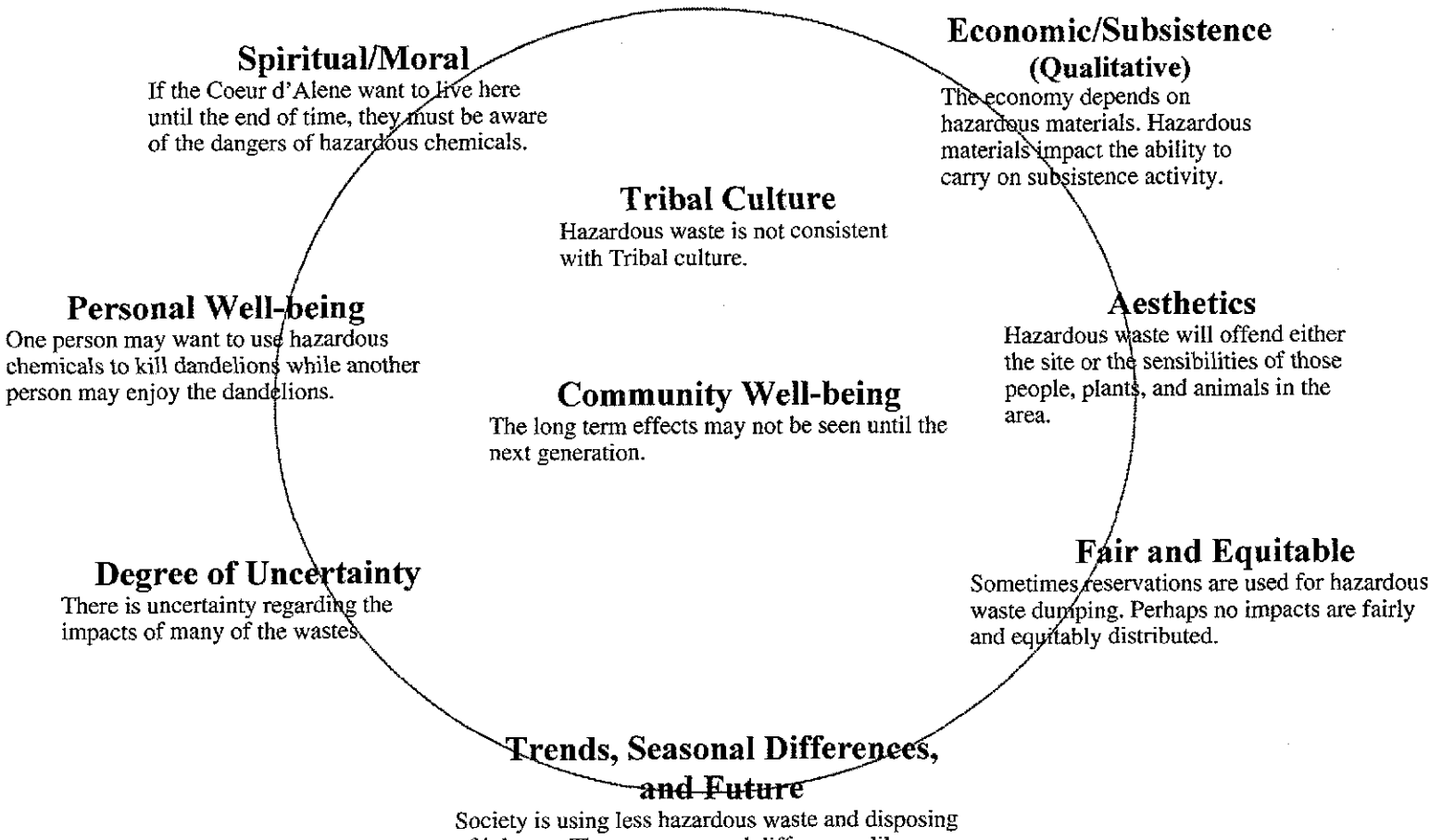
Fair and Equitable
Many impacts are distributed fairly and equitably across the community, but land owners and traditional Coeur d'Alene may feel greater impacts.

Trends, Seasonal Differences, and Future
Forests have to be sustainable in many different ways--how trees grow; species diversity; water quality; and quality of life.

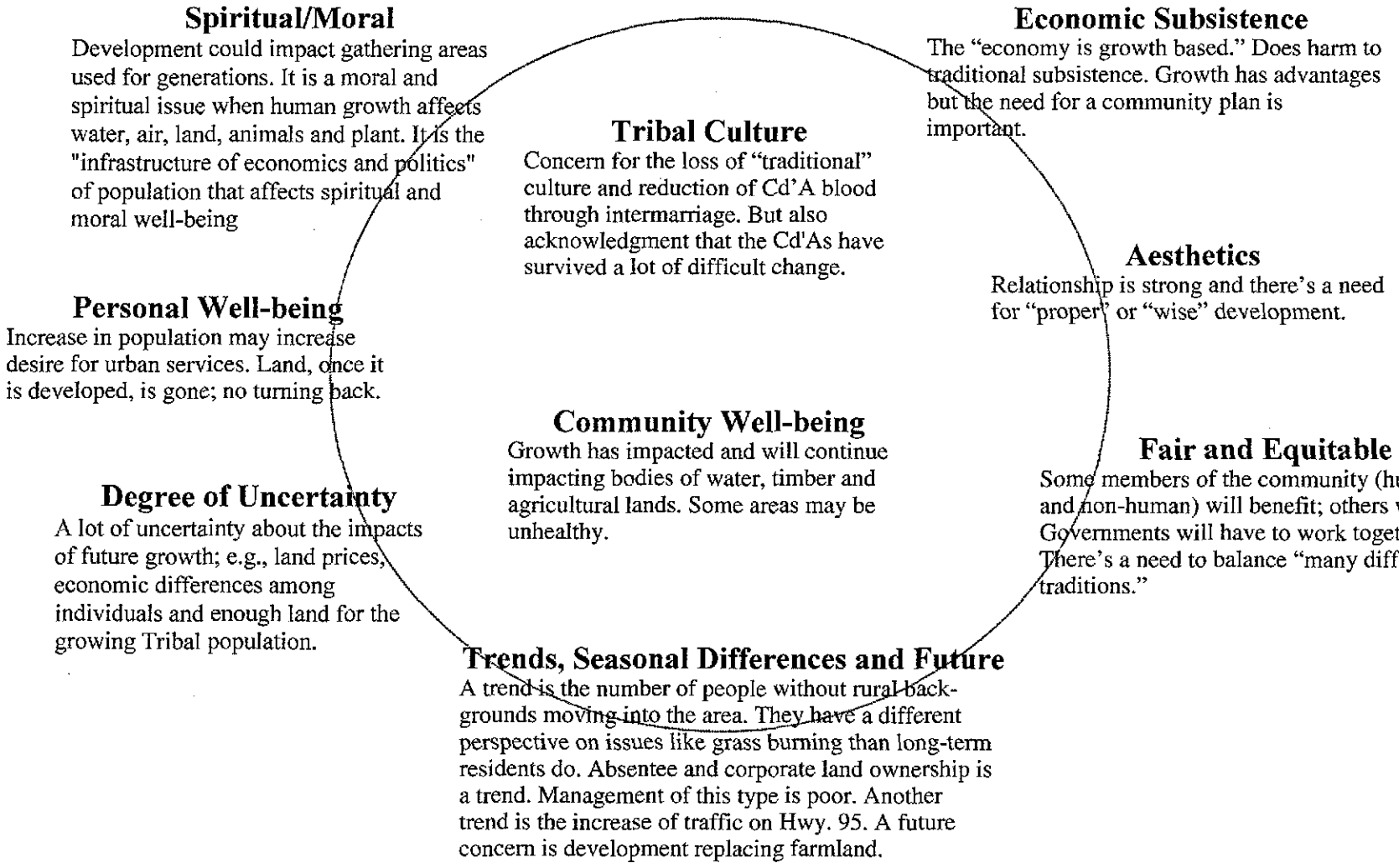


Ponderosa pines like this one (with Lake Coeur d'Alene shown in the background) comprise much of the forest cover found on the Coeur d'Alene Tribe's native homeland.

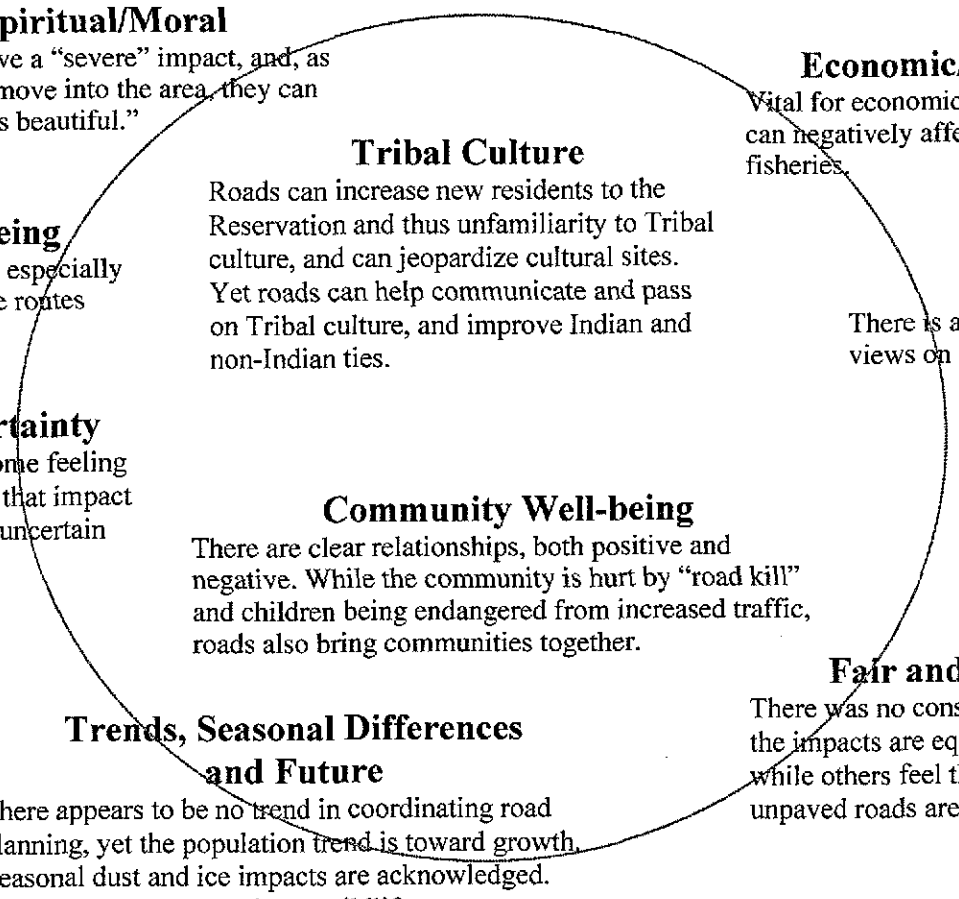
Hazardous Waste
Quality of Life Sub-Group



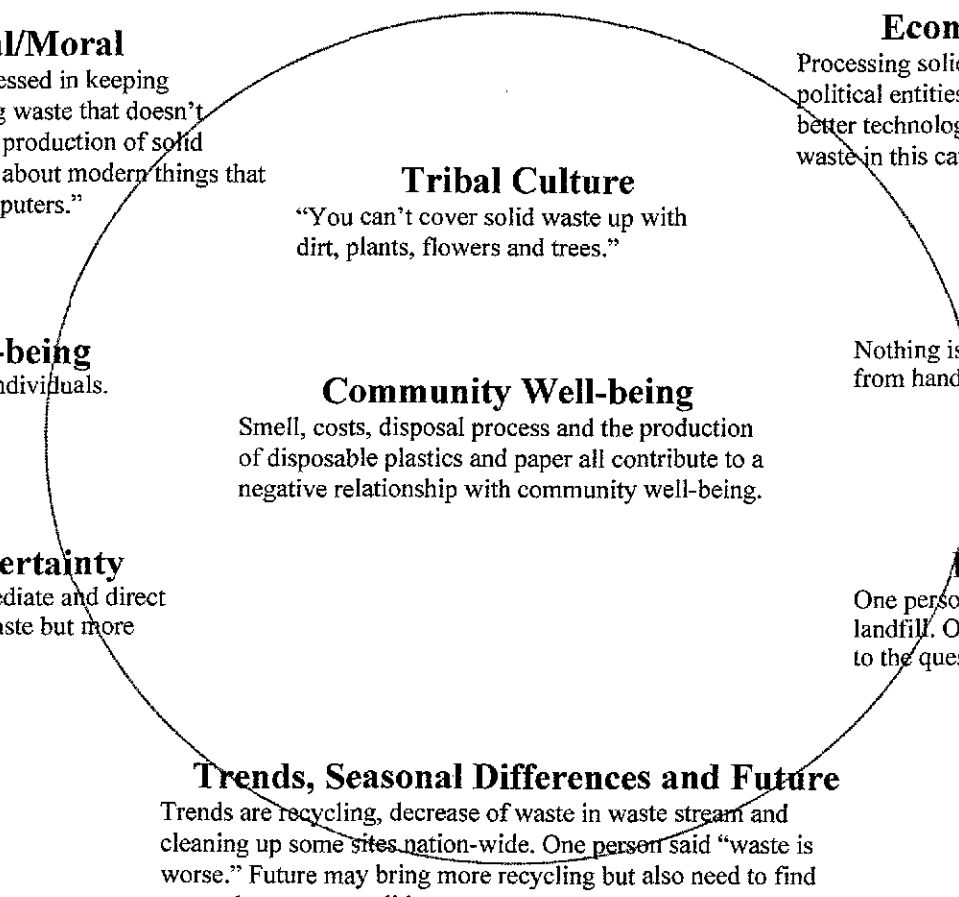
Human Population Growth and Development Patterns
Quality of Life Sub-Group



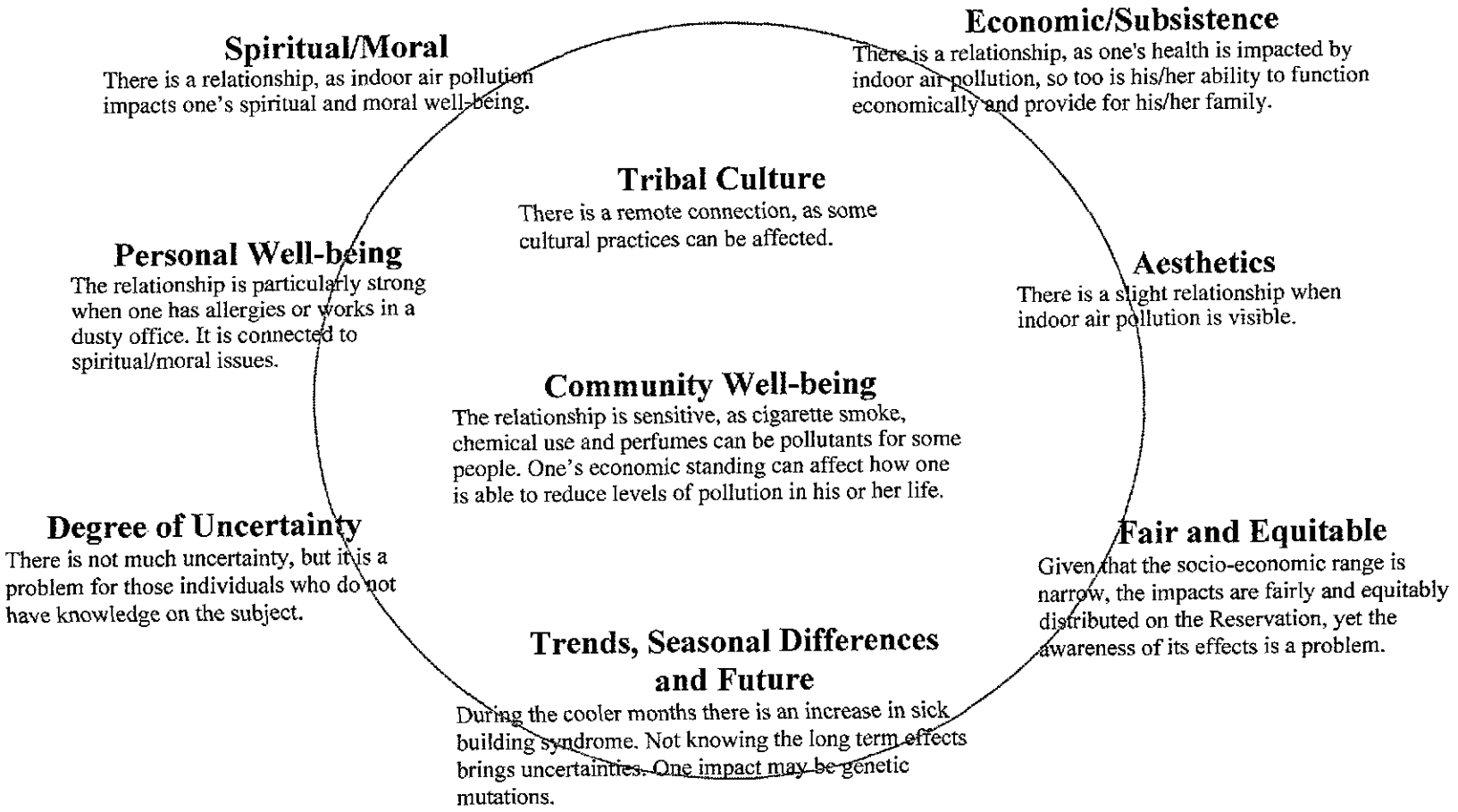
Roads
Quality of Life Sub-Group



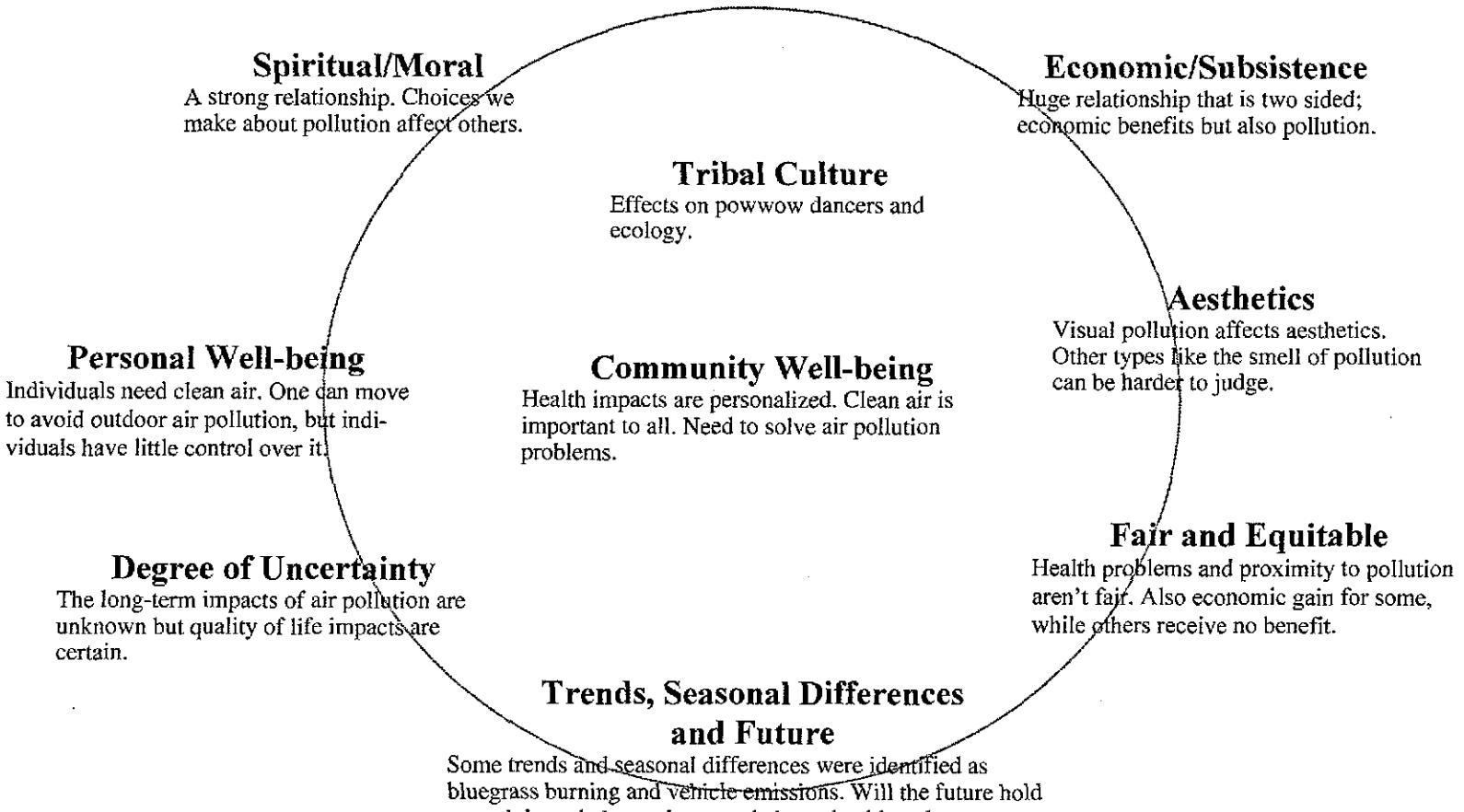
Solid Waste Generation and Disposal
Quality of Life Sub-Group



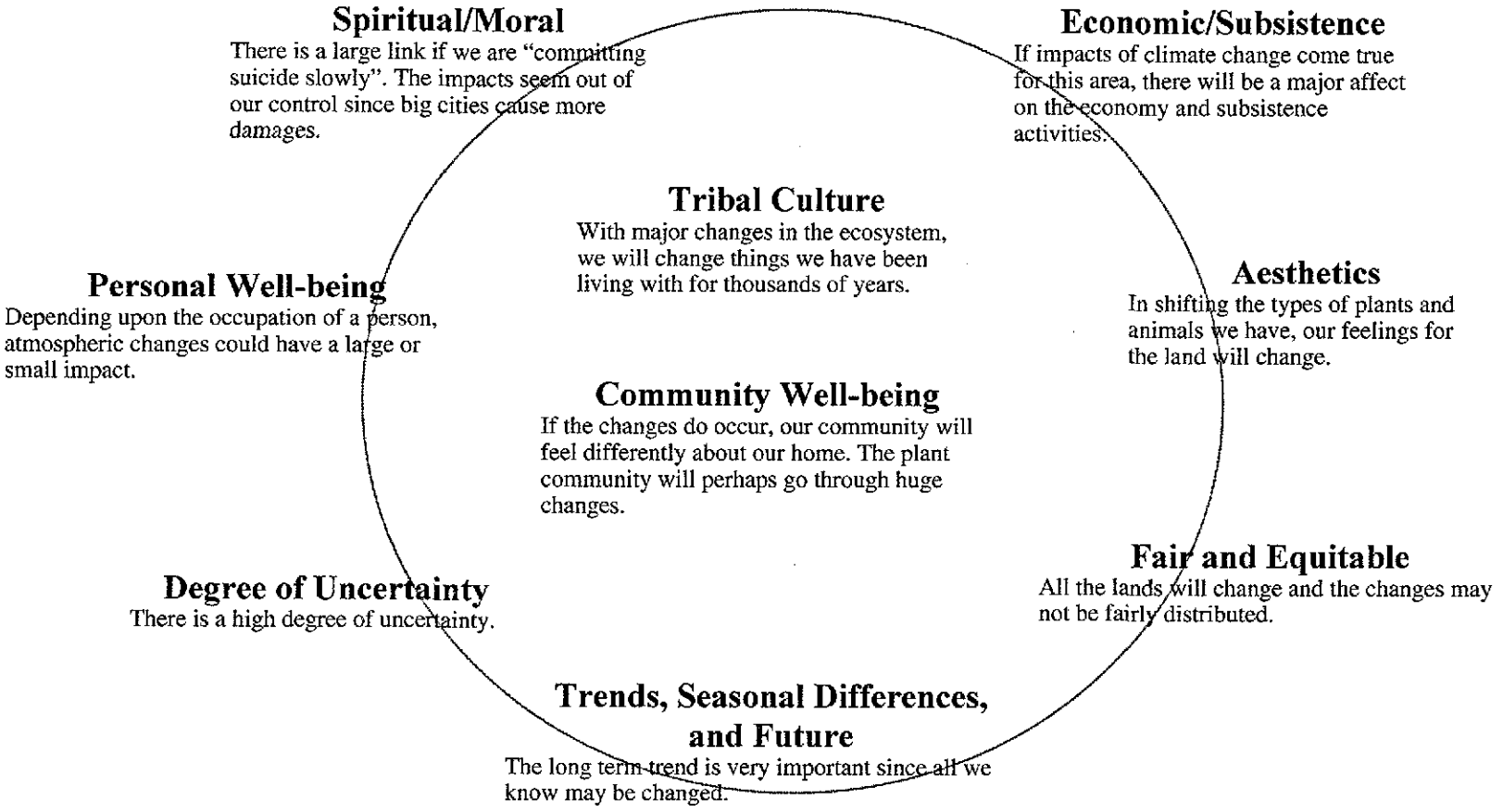
Indoor Air Pollution
Quality of Life Sub-Group



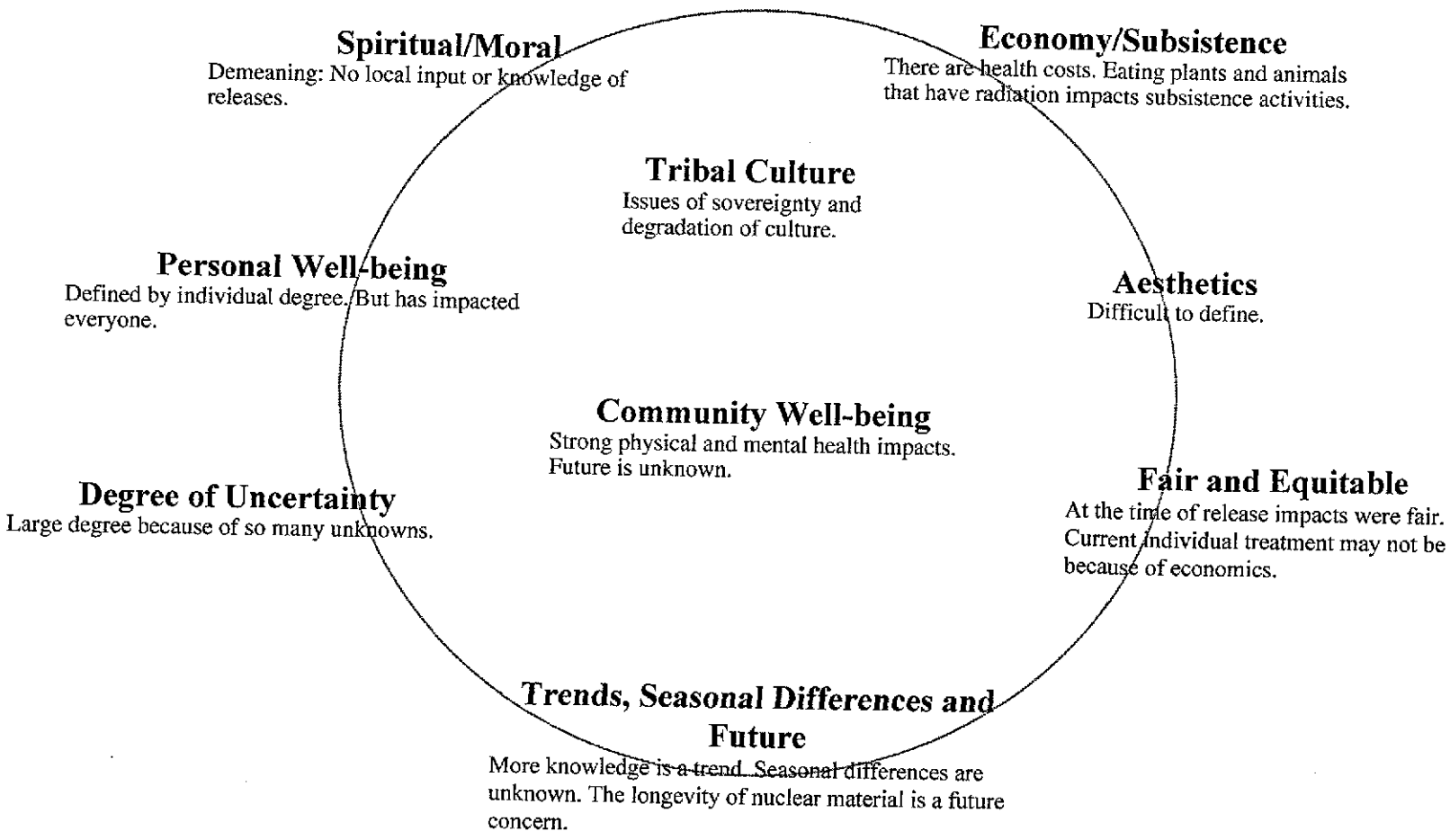
Outdoor Air Pollution
Quality of Life Sub-Group



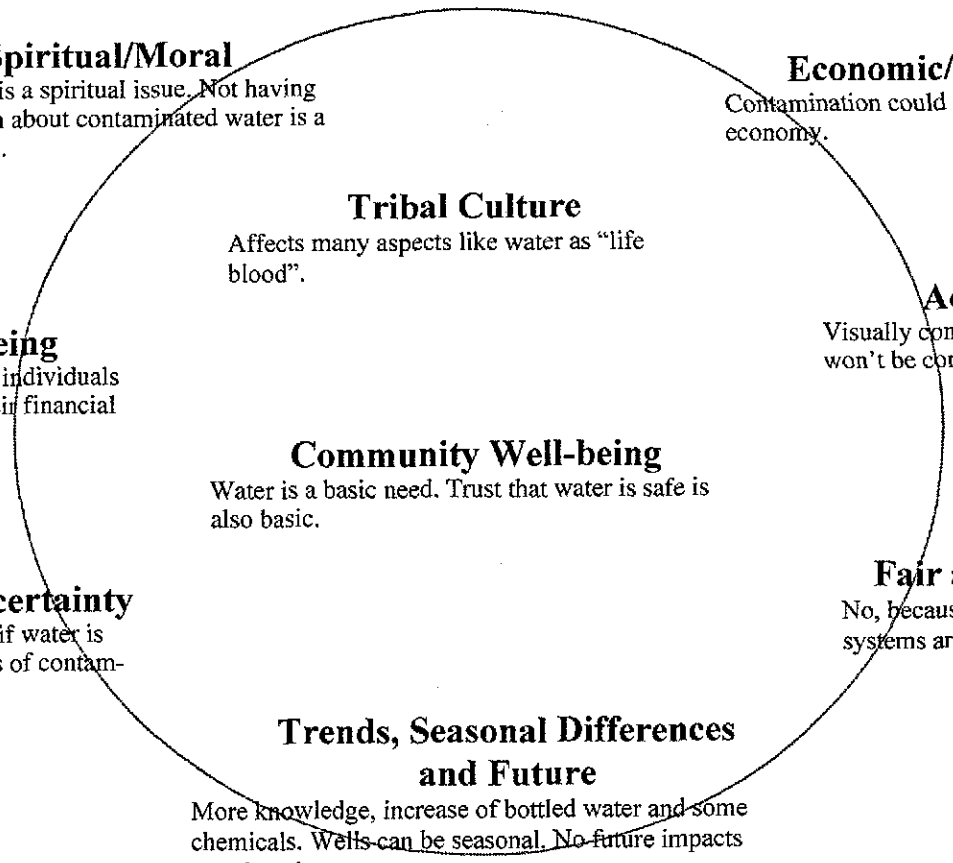
Localized Effects of Atmospheric Changes
Quality of Life Sub-Group



Localized Effects of Hanford Nuclear Reservation
Quality of Life Sub-Group



Drinking Water Quality and Contamination
Quality of Life Sub-Group



Spiritual/Moral
Safe water is a spiritual issue. Not having information about contaminated water is a moral issue.

Economic/Subsistence
Contamination could negatively affect economy.

Tribal Culture
Affects many aspects like water as "life blood".

Aesthetics
Visually contaminated water won't be consumed.

Personal Well-being
All individuals need water, but individuals make choices depending on their financial resources.

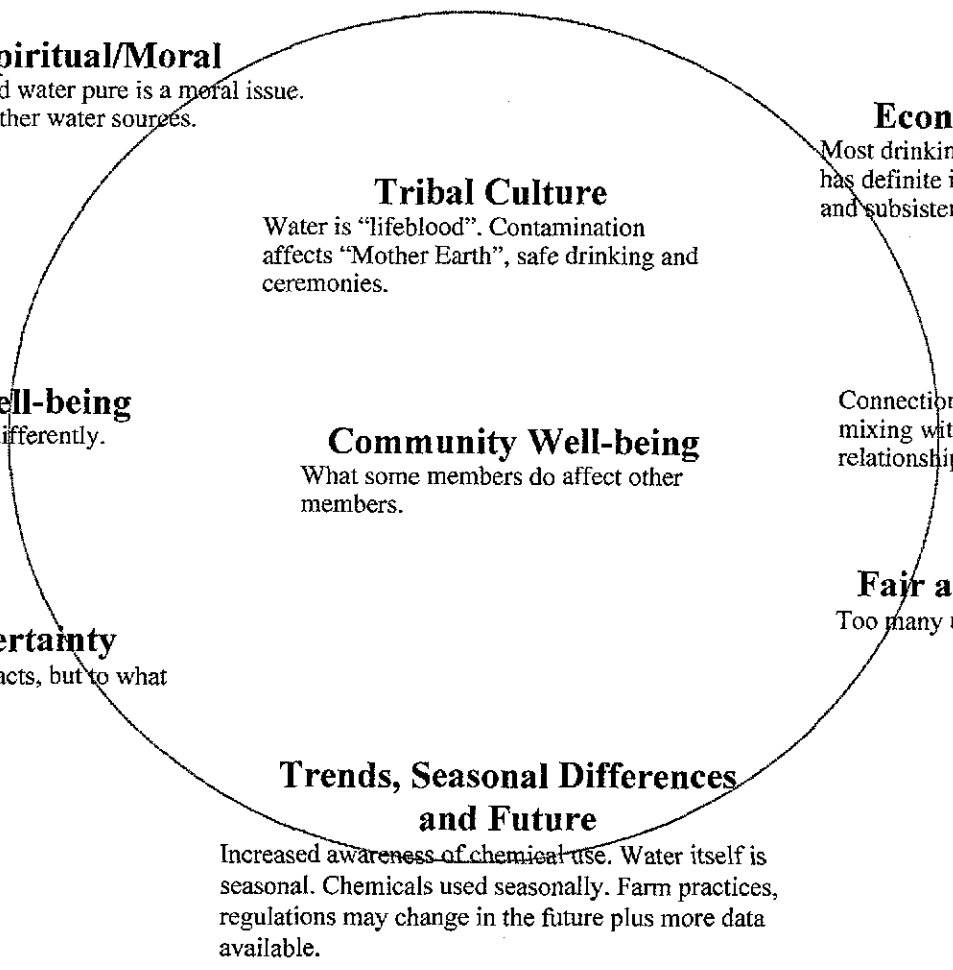
Community Well-being
Water is a basic need. Trust that water is safe is also basic.

Fair and Equitable
No, because sources and delivery systems are different.

Degree of Uncertainty
Data is uncertain, but if water is contaminated, impacts of contamination are certain.

Trends, Seasonal Differences and Future
More knowledge, increase of bottled water and some chemicals. Wells can be seasonal. No future impacts mentioned.

Ground Water Contamination
Quality of Life Sub-Group



Spiritual/Moral
Keeping ground water pure is a moral issue. Connected to other water sources.

Economic/Subsistence
Most drinking water is ground water so has definite importance to the economy and subsistence.

Tribal Culture
Water is "lifeblood". Contamination affects "Mother Earth", safe drinking and ceremonies.

Aesthetics
Connection here to ground water mixing with surface water. Hard relationship to determine.

Personal Well-being
Affects individuals differently.

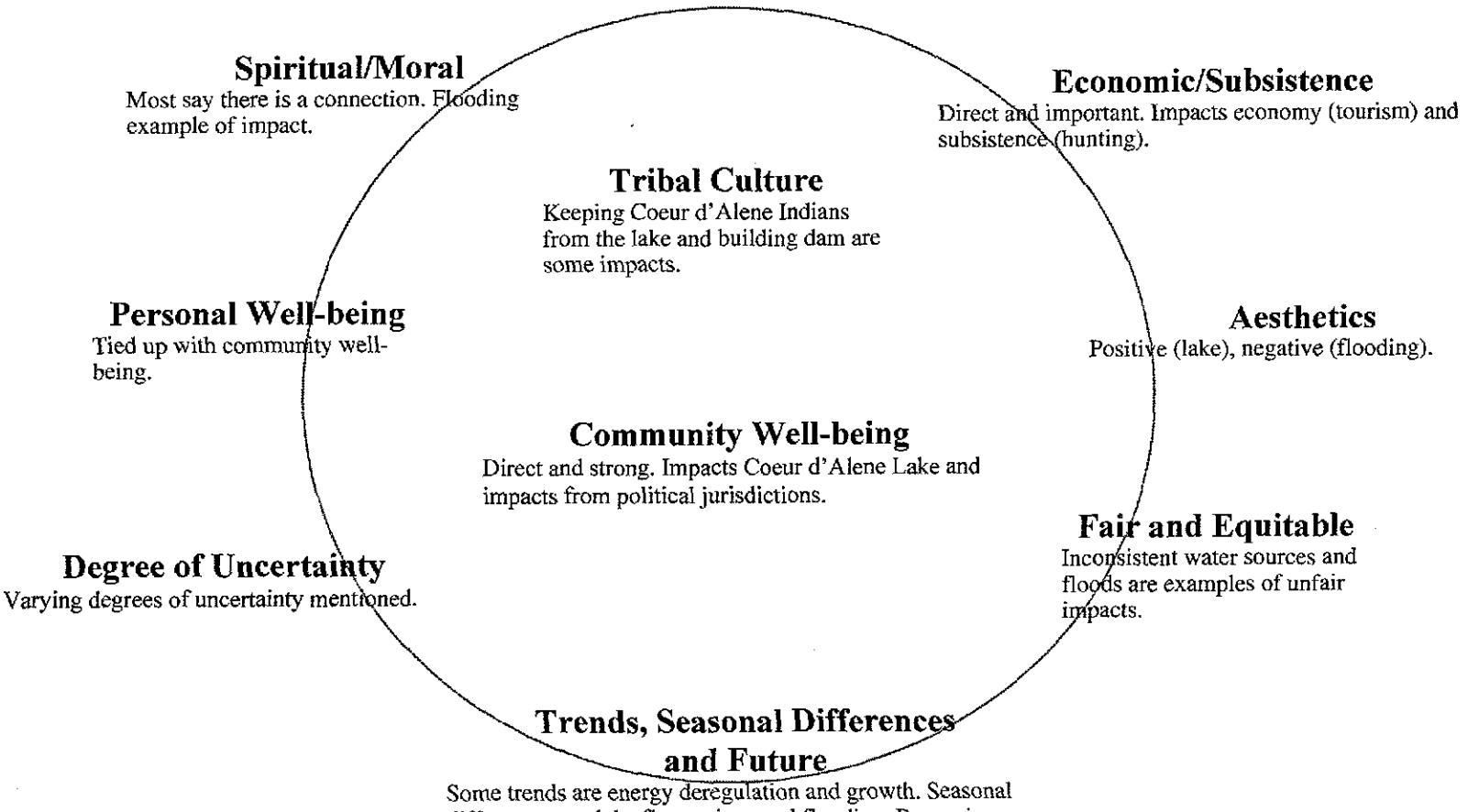
Community Well-being
What some members do affect other members.

Fair and Equitable
Too many unknowns to know.

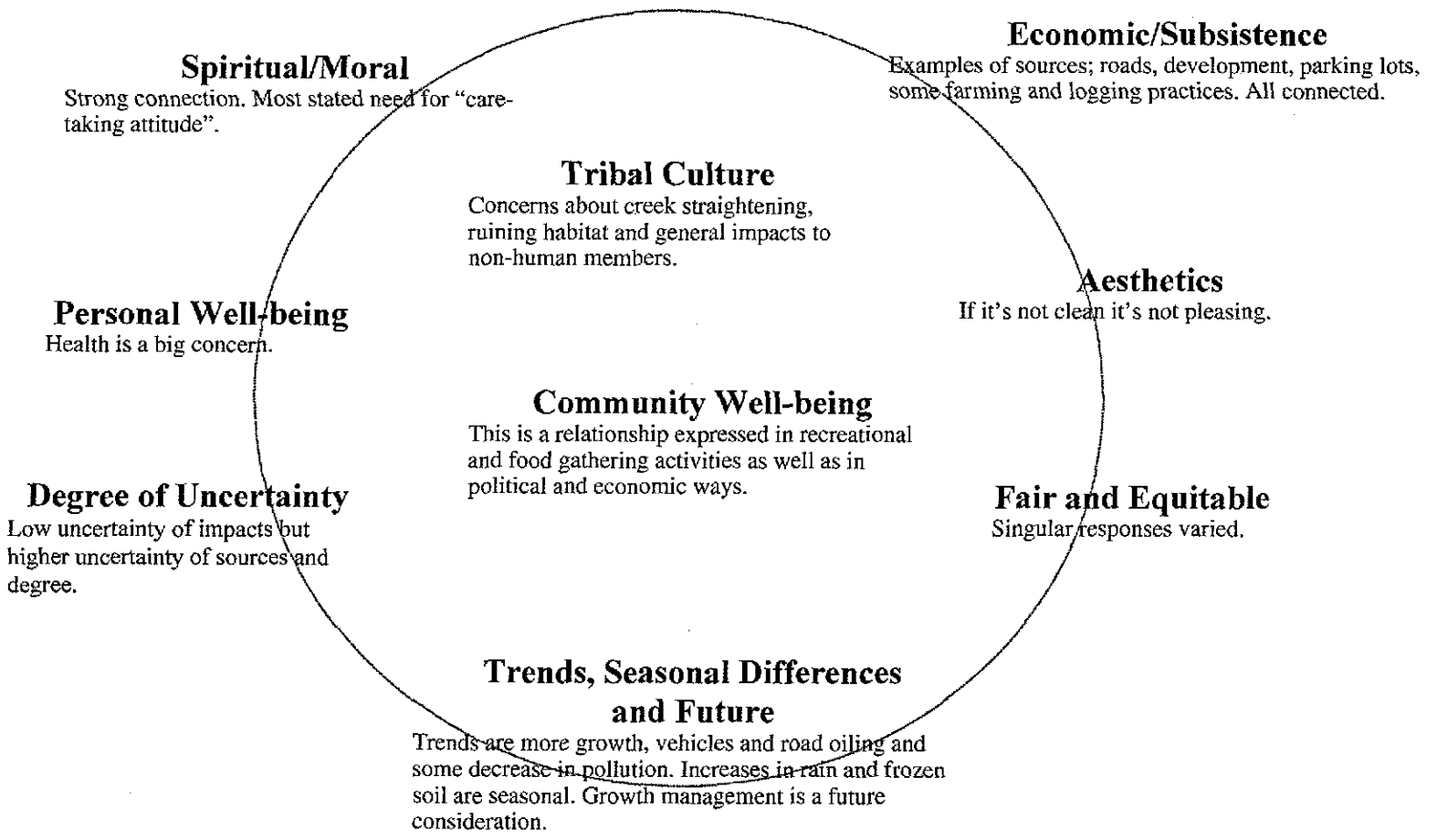
Degree of Uncertainty
No uncertainty that it has impacts, but to what extent?

Trends, Seasonal Differences and Future
Increased awareness of chemical use. Water itself is seasonal. Chemicals used seasonally. Farm practices, regulations may change in the future plus more data available.

Hydrologic Changes
Quality of Life Sub-Group



Non-Point Source
Surface Water Pollution
Quality of Life Sub-Group



Point Source
Surface Water Pollution
Quality of Life Sub-Group

Spiritual/Moral
Economic gain can be at the cost of spirituality and morality in some cases.

Economic/Subsistence
Relationship expressed in creating jobs but also pollution. Connected also by levels, regulation, decision and treatments of pollution.

Tribal Culture
Provides some jobs for Tribe but also impacts "Old" culture.

Personal Well-being
No concerns to a variety of concerns; depends on individual situations.

Community Well-being
Concerns for health and clean-up costs, increase in pollution, non-humans have no voice.

Aesthetics
Water that is polluted isn't visually pleasing. Unpleasant in non-visual ways as well.

Degree of Uncertainty
It's uncertain whether this pollution can be adequately identified and regulated. One person believed it could.

Fair and Equitable
Most agreed impacts were not fair and equitable.

Trends, Seasonal Differences and Future
Growth is both a trend and a future concern. Pollution standards are stricter. Politics will impact the future. Seasonal differences not mentioned.

Wetlands
Quality of Life Sub-Group

Spiritual/Moral
As wetlands have inherent value and are associated with private religious beliefs, there is a strong relationship. When economic benefits supercede those values and beliefs, spiritual and moral injury results. But given the personal beliefs, there are differing views on the topic.

Economic/Subsistence
There is a strong yet complex and controversial relationship, given benefits of wetlands amenities and removal.

Tribal Culture
Wetlands represent an island of what traditional culture was like, surrounded by economic growth. They are under threat of destruction.

Personal Well-being
Given individual differences, the relationship can be one of physical and mental health.

Community Well-being
Among the benefits are clean water, wildlife habitat and indicator of the health of the entire community. When diversity is lost so too is the community's well-being.

Aesthetics
There is a varied yet big relationship. With a loss of diversity there is a loss of connection to the earth and beauty.

Degree of Uncertainty
There is a very low level of uncertainty, community values differ, resulting in controversy over what should be done with wetlands.

Fair and Equitable
Those individuals who rely upon wetland species, when those species are impacted so too are those individuals.

Trends, Seasonal Differences and Future
The trend in loss of wetlands is beginning to reverse with increased knowledge of its benefits. But educating people about the value of wetlands and distinction of communal and private property rights is needed.



The Pygmy Owl—a native species that shares the land with the Coeur d'Alene Tribe and adds to its rich diversity.

Native Plant and Animal Populations and Species Diversity
Quality of Life Sub-Group

Spiritual/Moral
There is a strong relationship, involving stewardship and a moral obligation to protect native plant and animal populations; you should relate to them spiritually and morally in the same manner you would relate to any family member.

Economic/Subsistence
Subsistence activities have a closer relationship with native plant and animal populations than economics.

Tribal Culture
Given Tribal relationships with native plants and animals, which value all species, the impacts are greater than for non-Tribal members, who may only value species that give a return to them.

Aesthetics
There is a strong relationship, though varied with individuals.

Personal Well-being
Varies with individual, depending on how outdoor oriented he or she is.

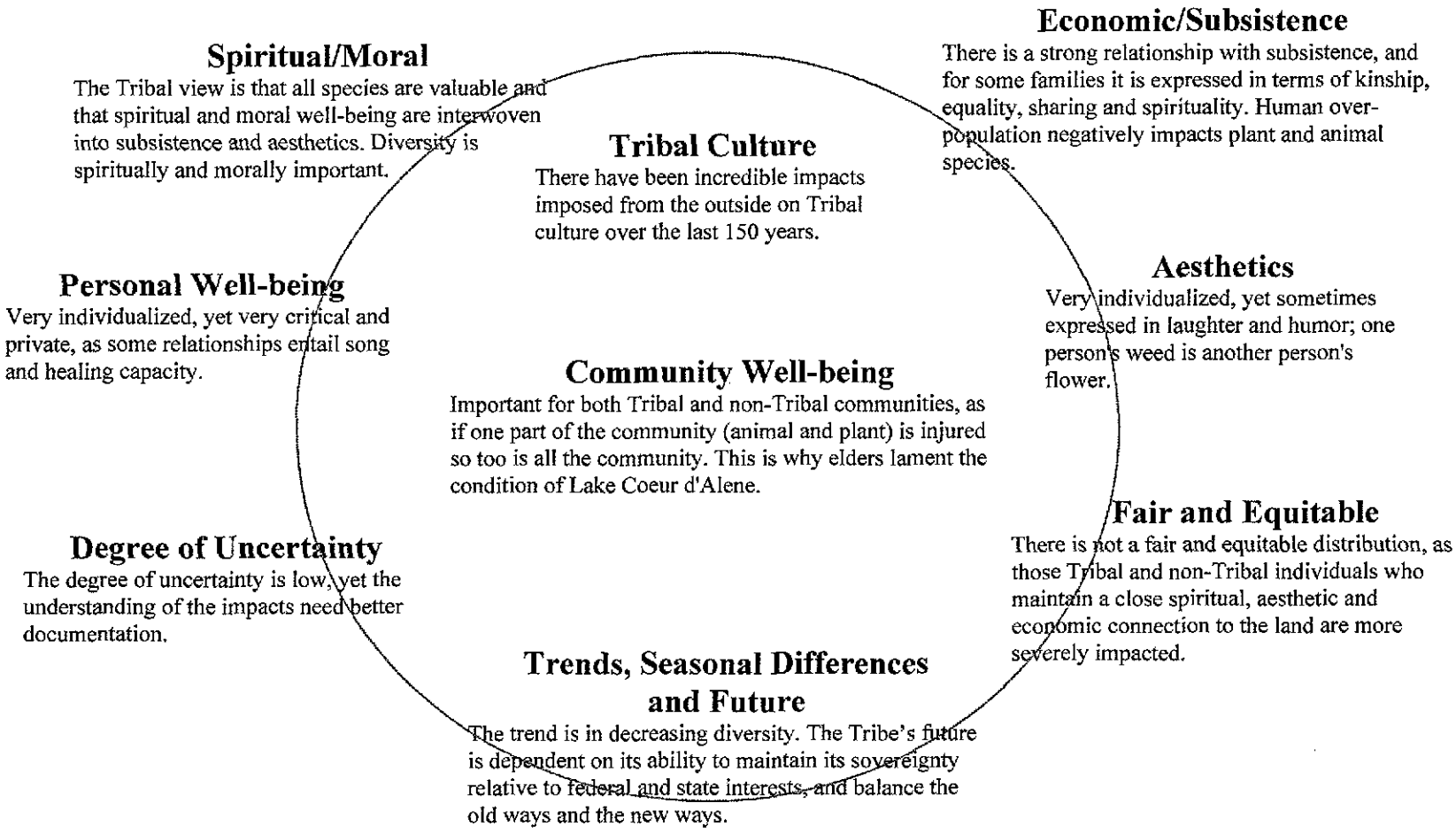
Community Well-being
There is an important and strong relationship, encompassing hunting, aesthetics, and economy. A good economy makes a community function.

Degree of Uncertainty
Both Tribal and non-Tribal members share the conviction in a low degree of uncertainty. But there is a lack of understanding of the implications of the impacts.

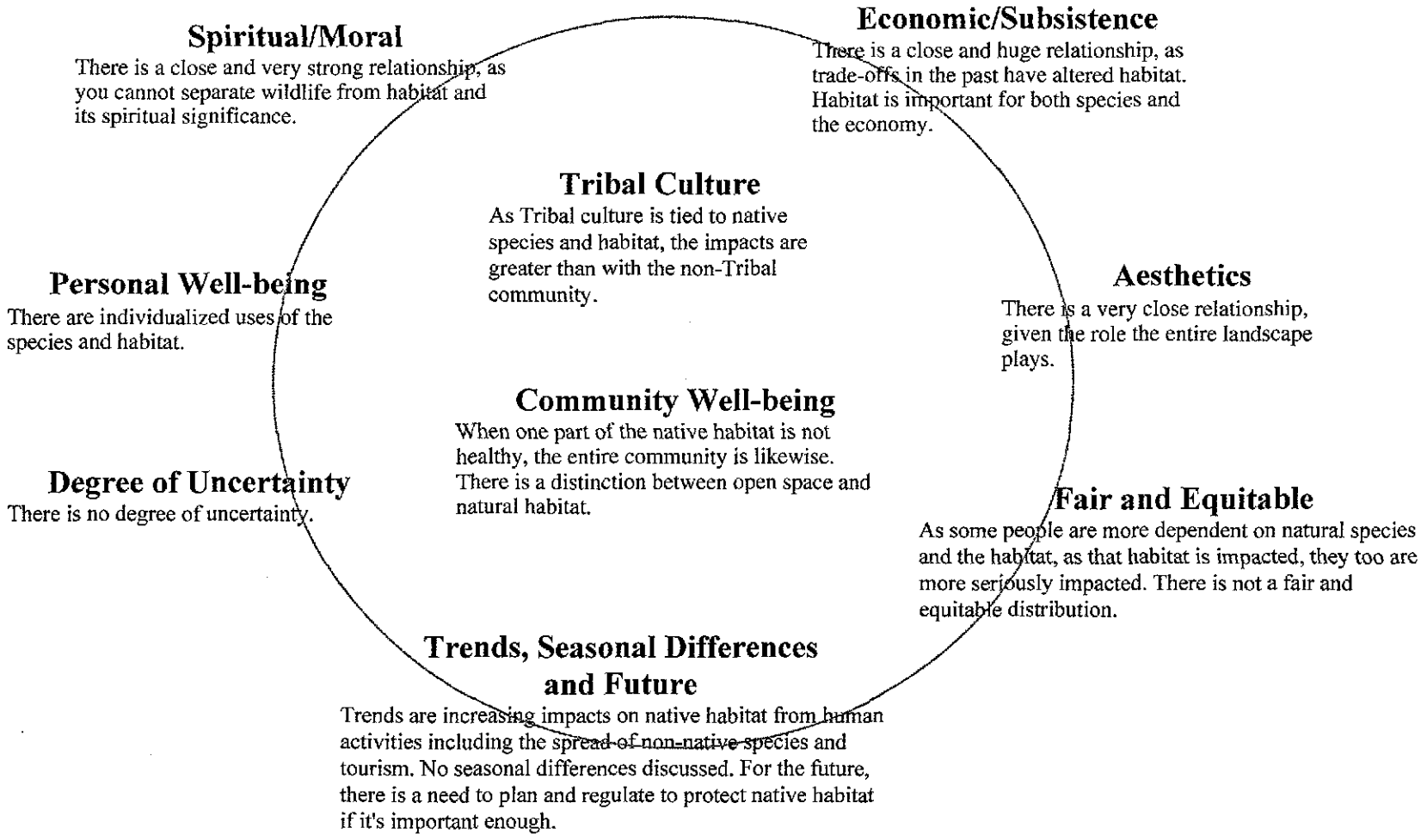
Fair and Equitable
Tribal culture is much more severely impacted, and thus there is not a fair and equitable distribution of the impacts.

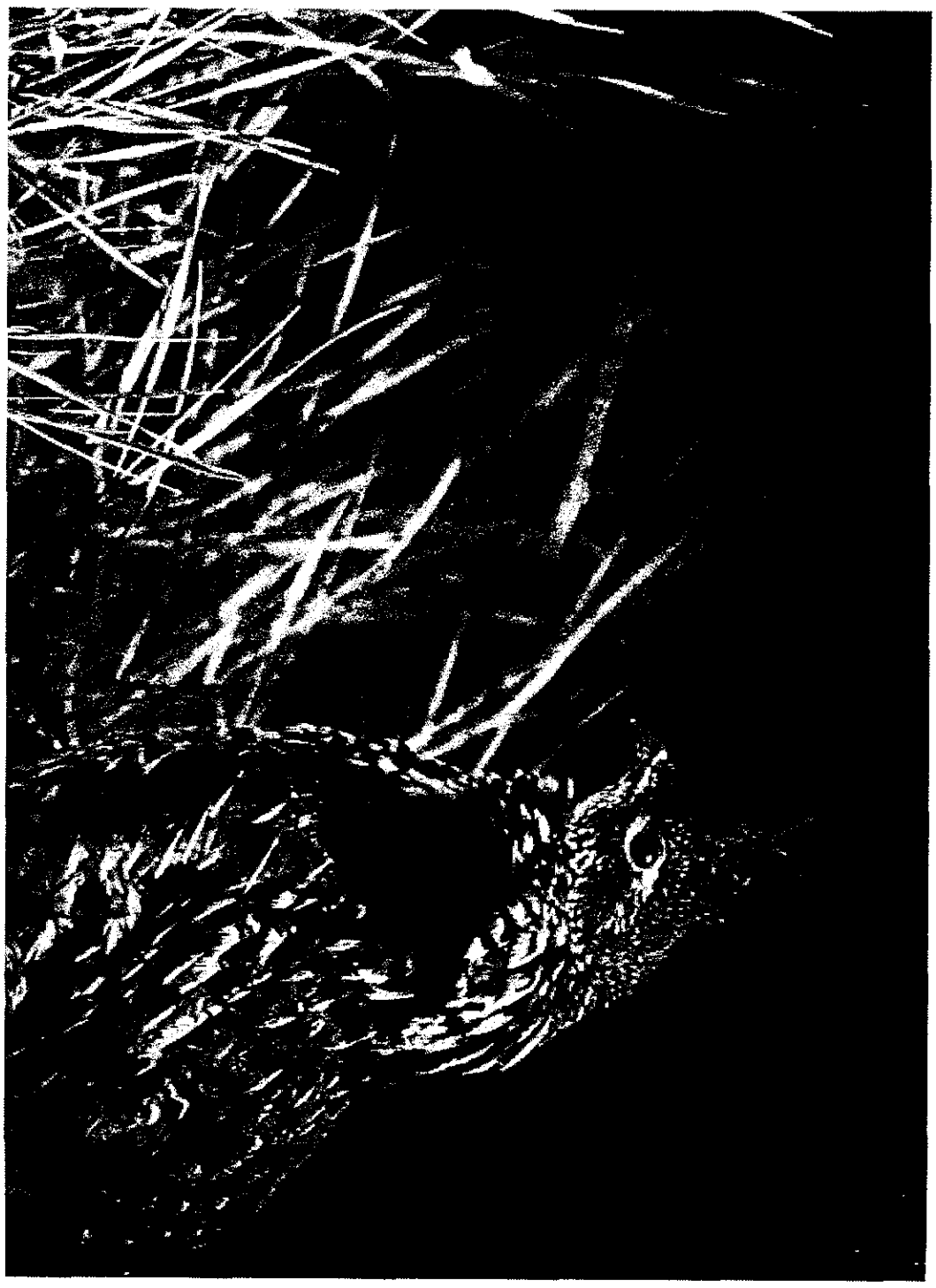
Trends, Seasonal Differences and Future
The trend may be an increase in non-native species, and as native species decrease, the Tribal knowledge of how to use them also decreases. Seasonal changes are not a huge factor. One member felt we are going to be better off in the future than we are today.

Tribal Culturally Important Species Population and Diversity
Quality of Life Sub-Group



Native Wildlife and Fisheries Habitat
Quality of Life Sub-Group





The Ruffed Grouse is one of many species that are culturally important to the Coeur d' Alene Tribe.

Non-Native Plant and Animal Species
Quality of Life Sub-Group

Spiritual/Moral
Most agree a relationship exists but the definitions vary on an individual basis.

Economic/Subsistence
Strong and direct relationship both for intentionally introduced species like wheat, and unintentionally introduced species, like white pine blister rust.

Tribal Culture
Large impacts for obvious reasons, but impacts could depend on culture's adaptation.

Personal Well-being
Most of what we eat is non-native so this relationship is very large.

Aesthetics
Beauty is in the eye of the beholder.

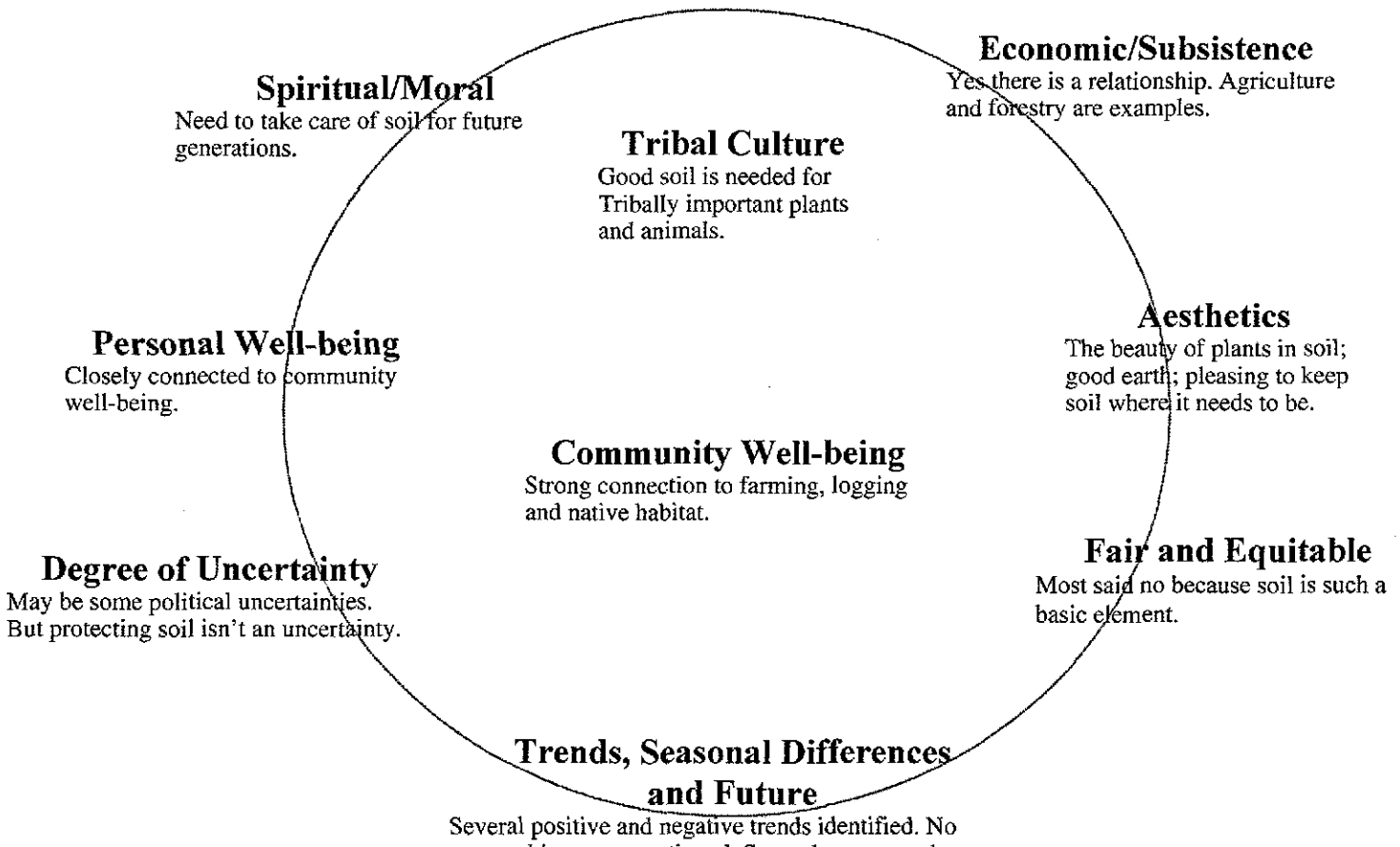
Community Well-being
"Clear and direct" relationship with both negatives and positives.

Degree of Uncertainty
No degree of uncertainty; tied up with many other categories.

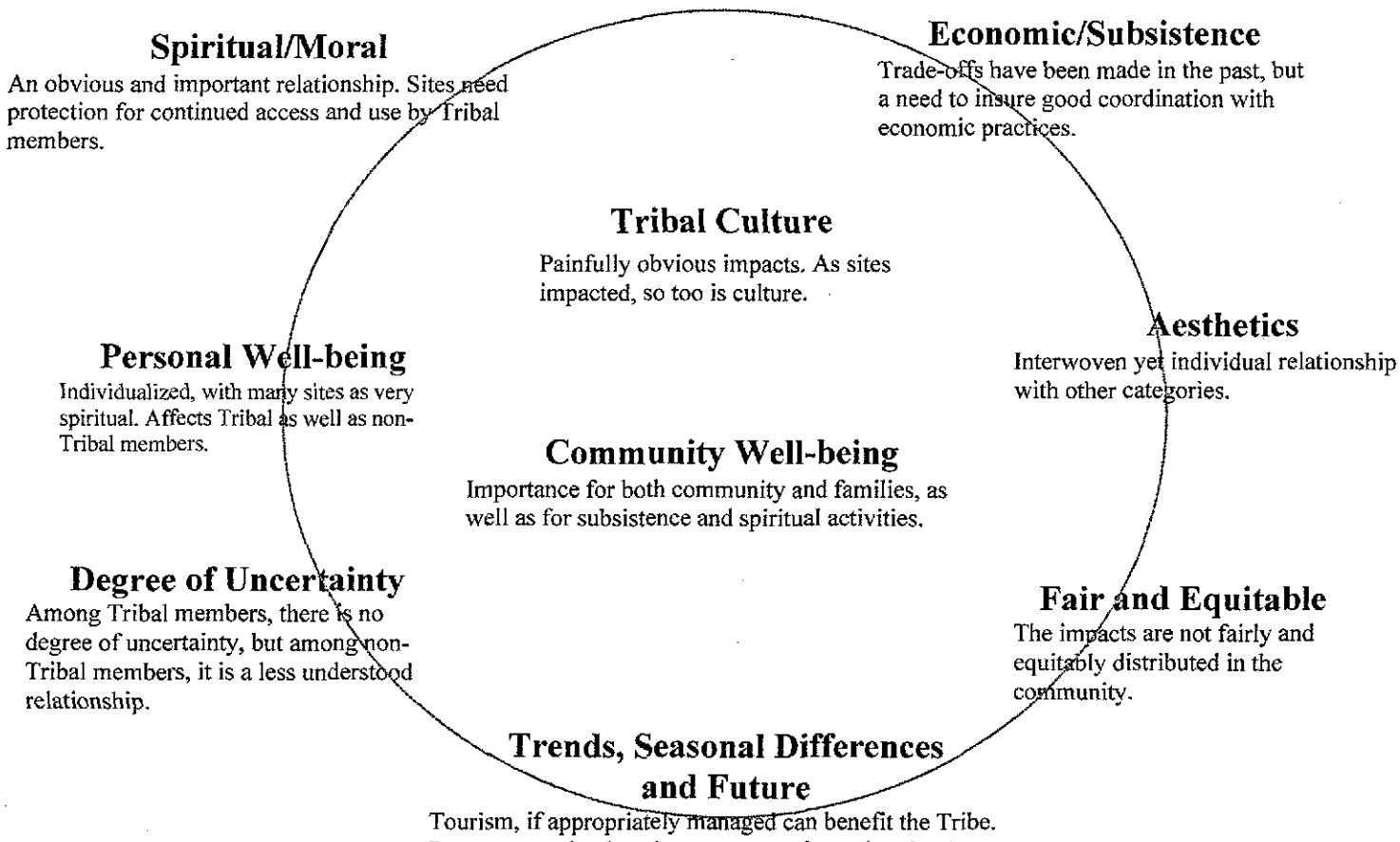
Fair and Equitable
A mixed response. Some believe the sheer amount of non-natives make them distributed equally. Others said it depended on circumstances and opinions about non-native species.

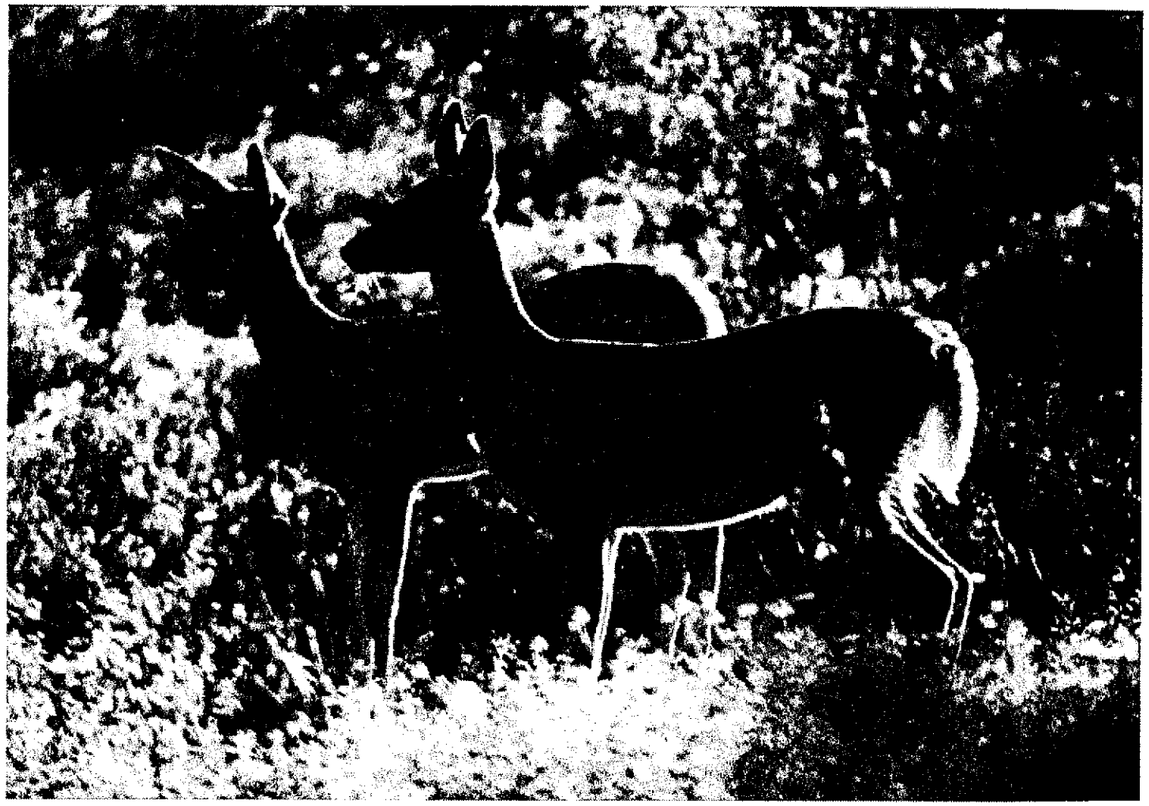
Trends, Seasonal Differences and Future
A trend of increasing numbers of non-native species. Control of non-natives are seasonal. In the future, decisions will have to be made regarding which non-natives can stay and which should go.

Soil Productivity
Quality of Life Sub-Group



Tribal Cultural Sites
Quality of Life Sub-Group





The deer people are an important part of the Coeur d'Alene Tribal family. These fawns remind us of the need to consider environmental impacts on future generations.

Summary of Interviews Supplemental to Focus Group Information

Prepared by Rodney Frey
12 March 1999

Purpose and Method

The following information is a selective summary of twelve interviews conducted between September 30, 1998 and November 12, 1998 among residents of the Coeur d'Alene Reservation community, including the city of St. Maries. The intention in conducting these interviews was to broaden the demographic representation of the Quality of Life assessment, expanding the scope of the information obtained from the Focus Group sessions. In selecting these interviewees, the members of the Focus Group developed a demographic profile of their own membership. Based upon non-representative and under-representative community segments, "holes" were determined. Using a "snowball" sampling method, i.e., who in the community is informed on this subject, members of the Focus Group were asked to identify additional community members who might represent these "holes" and be willing to be interviewed. Approximately fifty individuals were so identified. In conducting these additional interviews, it was not the intent to develop a statistically reliable and valid systematic random sample.

A simplified, shortened version of the questionnaire used in the Focus Group sessions was developed. It retained the five key categorical questions, i.e., What is the relationship between the economy or subsistence activity and the environment? What is the relationship between the spiritual and moral well-being and the environment? What is the relationship between recreational use or aesthetics or artistic appreciation and the environment? What is the relationship between the community's well-being and the environment? What is the relationship between the individual's well-being and the environment? The interviewees were then asked to rank according to their severity of importance the five categories and any particular issues he or she may have brought up during the interview.

Eleven interviews were conducted by undergraduate and graduate students from the Department of Anthropology at the University of Idaho, under the direction and coordination of Rodney Frey. A twelfth interview was conducted by a member of the Focus Group. At the time, all of the college students were enrolled in a Research Methodology course taught by Frey, and also participated in a morning "workshop" introducing the interview questionnaire, as well as the Coeur d'Alene Tribe's Environmental Action Plan project. It was planned that high school students from Lakeside High school would be paired and accompany the college students. The mentoring relationship would be mutually beneficial, as high school students would be provided a "role model" and learn something of conducting ethnographic interviewing, while the college students would learn something about the "local culture" and have a guide to the interviewee's residence. Because of logistical and scheduling considerations, in only a few instances did any "paired interviews" transpire.

Given the considerations just mentioned and that interviewers were engaged in full-time academic studies and had little extra time, only twelve interviews were completed in the time frame available. Nevertheless, the additional information obtained further qualifies and adds perspective to the overall Quality of Life Assessment.

Demographic Profile

Of the twelve interviews, four were Tribal Members, all males, with ages of 90, 53, 48 and 31. Their occupations were those of educator, environmental quality manager, natural resource administrator, and Tribal government administrator. All were high school graduates, with one having completed a bachelor's degree and two currently attending college. All have resided their entire lives on the Reservation.

Of the eight Euro-American interviewees, one was female while the other seven were males, ages 72, 69, 67, 59, 55, 51, 48 and 43. Their occupations included that of retired farmer, natural resource manager, self employed, logger, mortgage company manager, highway district manager, economic development administrator, and priest. All were high school graduates, with one interviewee having two associate's degrees, two interviewees with some college course work, and three interviewees having completed bachelor's degree. Three of these interviewees have resided in the community for 7, 10 and 24 years, while all of the other Euro-American interviewees have resided their entire lives in the community, e.g., 72, 67 and 51 years.

Selected Summary

The following summary includes selected comments by interviewees, in their own words, that reflect, 1. the full range and diversity of views and perspectives held by all the interviewees, and 2. particularly insightful comments not articulated nor represented by Focus Group members. I have taken the editorial license in arranging interviewee comments to reflect the overriding question solicited from the questionnaire. Confidentiality of the interviewees and anonymity of their comments is maintained throughout this summary. For comment comparison, I have arbitrarily assigned a number designation for each interviewee.

1. What is the relationship between the economy or subsistence activity and the environment?

#1 "Actually, they are all good. The logs have come up to a pretty good price, so I can make a living cutting timber. The quality of life is great, you couldn't ask for a freer place to live, as far as just the freedom to breathe; to have your area to be in, and the environment is, you couldn't ask for a better environment, it's beautiful here. That's one of the incentives to keep it that way."

#2 "That relationship is, to me, the environment is everything around you. The air, the people, the land, it just encompasses everything; so it is within yourself, and that also affects the environment around you, such as the other people and their quality of life."

#3 "Early in my life, I was brought up to look at that as a resource, in terms of take and use only what you need; and that has not happened in today's society; today's society has taken and has destroyed a lot. It has utilized a lot of the resources and hasn't put anything back; we can see that in what is happening in the Coeur d'Alene Basin, we can see that in terms of what is happening in the Hanford reach, we can see that in what's happening in the Columbia River Basin, and I can see that across the country, that today's society continues to take from the environment, but only recently have they finally realized how much they destroyed. . . . Instead of working with the environment, instead of working with mother nature with what we had, we now put a dollar figure on these things, and we essentially tapped into areas that should never have even been touched; and for me, I can't put a dollar figure on what was lost, because it was part of my culture, part of my tradition, part of my way of life was lost, and there is no amount of money that can bring it back. . . . From my perspective, I am trying to move away from that idea that economics is the driving force behind everything. I am one of those few people here, on this Reservation, that still practices and believes in the traditional ways. . . . Sharing with each other, insures that we are able to survive."

#4 "Of course trees have been our mainstay, and depended on for our living, the thing that I do, is I select a log and trees respond to good treatment and if they are managed properly it's a wonderful thing to work in the woods and have a nice stand of trees; some of our logging practices, I think, some of the companies have been careless; the overall degradation, I guess, of streams and clear-cuts and things like that, they have an affect on the air and the animal life in particular and also on human life, recreation life and otherwise."

#6 "I think it's very important. I mean it's something that, especially in this area, we are not like a big metropolitan area, where we have big corporations and big companies, a lot of people rely on the natural resources around here for economy; loggers, foresters, farmers, everybody does, we are utilizing our surroundings to be able to live."

#7 "It is real important, there is probably, when I was a kid there was not as much timber on some of the mountain tops, and now a lot of the time they strip it. And now in farming they use a lot more fertilizers and produce a lot better crops than they did then. But, I am not too sure that it is good for the soil. . . . Well, if people earn a good living they can have a better Quality of Life and also be better for their kids, grand kids, whatever."

#8 "Very important, it depends on the area and what the ability to produce or the economy is in that area, what their natural resources are; like here we are in timber dependent community so the environment and what we are allowed and not allowed to do and should be doing, plays a very important part in the economy of the community."

#10 "Quality of Life is extremely important. But, if you are unemployed and have no way of earning a living, the Quality of Life then, drops a notch or two on your

importance issue. So, there is a balance thing here that we all need to address. We can't let our emotions jump in here and just absolutely be against them because they're a bunch of liberals from Berkeley, California, that want to come up here and tell us how to run our woods, or our Lake, or our lands. That's silly, I mean we are beyond that. We need to set that attitude aside as we need to set aside the attitude that, boy we just need to lock up everything because there, those mining companies, those logging companies, those construction companies, that road building, those retailers are just ruining our community. I like to have toilet paper at home, that comes from trees; we need to do a certain amount of logging, to make our lives as we've grown to understand them exist."

#11 "Yes, . . . there would be, because sometimes you have to do things to be economical, you have to do things you probably wouldn't do if you could get an income without over working the ground or over exposing the ground to things. Sometimes with the prices that they are, you just have to produce, and sometimes over production is not a healthy thing. Although, I do believe that in the last probably the last 5 or 6 years, it really has sort of changed of producing grain and that in this country with recrop and minimum tillage and that type of farming; that helps, but, you have to produce in order to get, make an economical operational and sometimes some things get abused doing it. Unfortunately, a lot of the times it's the land."

#12 "Well, subsistence activity has really changed over the years, 50 years ago, or more, people were much more dependent upon hunting, deer and elk, than they are today. Hunting is still important, for a number of people, but, they're not as dependent upon that for their livelihood as they once were. . . . I'm involved often times in community dinners and feasts that are put on, and it seems very easy to go to the Tribe and to have people designated as hunters to bring in a very adequate supply of deer or elk. . . . The economy has shifted from subsistence living to store bought and usually less expensive things; which are much less healthy and people have a lot of physical disabilities today, because they don't eat the same foods that they once did. But I think if people want to bring in more lean deer meat instead of fat hamburgers, if they are hunters, I think most of them don't have to much difficulty bringing in deer and elk, but we don't have that many real hunters anymore. I think that the people's physical well-being is diminished a great deal because they've changed their eating habits."

2. What is the relationship between the spiritual and moral well-being and the environment?

#1 "We can make things dirty, we can mess up streams, but as a whole, the world is, it's like getting a scratch, the thing scabs over and heals; and the earth is very good at healing itself, and if there is anything spiritual to be had from that, I'd say that's it, the nature's ability to survive, until something happens within nature to make it not that way. Let's say nature itself, makes a different turn, which is totally out of our control."

#2 "It still goes back to the respect for the environment. Not taking more than what you actually need to use, and when you do take some respect of having it and using it, such as eagles for eagle feathers, you use all parts of it, same things with animals for hunting purposes, to use everything and not waste, to share it, to give it to other people."

#3 "(The Creator) put the water here, he put the rocks here, he put the animals here, he put the people here, and said take care of what I have given you; and if you take care of what I have given you, you can be here forever. . . . That spirituality is there; we look at the animals that are there as brothers and sisters, when I take an animal, deer or elk, for my use or subsistence, I thank my brother for giving his life so I can live. When I go and gather berries, pick roots, or get medicinal plants, I give back something to Mother Earth so that she allows me to continue use. The birds, are the people that we look to, they're brothers and sisters in this world, it's not an animal, it's not a fish, it is a brother, sister, mother, father, or child. We are all only here as a part of that overall environment, and we share. Spirituality is tied to every aspect of life; and you don't go out and just destroy something for the sake of destruction."

#5 "Yes, I think the fact that the old timers, they are very spiritual. They learned everything by the language, but, time came when they tried to ignore the language and it has had quite an effect on the tribes. So we are trying to get it back now."

#6 "Every time I see the lake I would feel good, and maybe pray to that lake, or see a mountain way off somewhere I would pray to it. If we didn't take care of our air quality and we had smoke in here all the time and had haze in here all the time, I couldn't see that mountain, so there would be no spiritual connection there. If I can't see it I would have no connection to it."

#7 "I am not sure, I don't know; for some people, I am not a religious person, some people that would have more effect on than me. If they are all right spiritually, it would affect their Quality of Life."

#8 "Wherever you live you will want the ability to have free speech and free spiritual abilities as well. I would assume that would be something that the Tribe would look at closer than I would."

#9 "Yes there is, to me, there is a relationship of spiritual to every aspect of life. The Lord has given us this planet to utilize, we have to be stewards, this is my personal belief, this planet is here to utilize, we are a growing population and He totally expected that when He created the world; He is going to come back one of these days, in his time and things are going to be changed, the earth is going to be changed. That is what the Christian Bible says, and that is my belief. We have always been charged to take from the earth what we need, in part using this soil that is our best ability . . . To me, I have learned morality through the Bible, and in that morality I have learned; there are people who go out and rape the land, and I don't think they have very many

morals. Because, they are not considering what's happening to the earth or what's happening to our future generations, as they rape the land. That ties into it, there is a lot of relationship between the spiritual, which is morality to me, and the moral-being of the environment."

#12 "I think in general we are talking about an Indian community that was very close to nature because they lived in nature; they hunted and fished and dug roots and picked berries. I think that created an inner peace and it gave them a way of life. They were together, they were more natural peoples living in union with the environment. Whereas now, they've pretty much adopted an economic model; they get their paychecks and they take care of themselves in an economic way, they have become more materialistic and not as dependent upon the environment. They are not as respectful to the environment and the Creator; in a lot of ways there was a spiritual union between people and the environment, almost as though the things of nature had a personality or a spirit of themselves. Hunters would ask the spirit of the deer to be available to help them find deer so they could bring home meat to feed their family and there was kind of a contractual agreement that they would not be abusive of nature and that they would be grateful in a spiritual way, grateful to the Great Spirit, to the spirits of nature that provided these things. There would be a gratitude and a spirit of oneness, a spirit of things that you do and things you don't do. It was important aspect of sharing, that when there was hunting done, in the early days of the Coeur d'Alenes, they would have these big hunts, and the meat would be shared between families. . . . It was always very important, people would go out and pick huckleberries and they would stop and give thanks in a spiritual way. An old man told me about fishing, they would go fishing and everybody would work on these fish runs and bring them in, and at the end of the day to the master or chief of the camp, who was in charge of that particular activity, they would redistribute the fish to all those families depending on their need, rather than depending on how much work they did to get them. So, there was much more spirit of sharing; and I think that went on into the days of early farming, they would help each other harvest their fields and share their equipment, and there was much more spirit of sharing and spirit of equality, and a kind of honor amongst people, that they respected and cared for each other more. Now, I think, with the economic model that is so prevalent, people work for their own cash and you don't think of sharing your cash like you might think of sharing fish or the game you brought home. I think it's the lifestyle that has moved away from living in this natural environment, which I think was a very spiritual; whereas now, things are much more materialistic in the Indian community, and I am speaking of the Indian style here. So, because people have moved out of the woods and onto the highways and into the shops and stores and mills and Casinos they don't have that same sharing and interdependence and the feeling of self-worth and cared for and everybody is cared for the same. Now there is more scrambling for jobs, to have better employment, higher salaries, there is more dissatisfaction over who is making what salary for what work they perform, lack of equality. So, spiritually things have changed a great deal . . ."

3. What is the relationship between recreational use or aesthetics or artistic appreciation and the environment?

#8 "There again is one of the reasons, the main reason why people live here. It's the ability that they have to recreate, I myself am not an outdoor person, but I love the scenery, and I love to watch the Canadian Geese and the ducks, and the trees changing, it is just a beautiful area. There again that is important to me, for my Quality of Life."

#9 "The more populated that the environment becomes the less aesthetically pleasing everything is. To me, buildings, roads, factories, all that, ruins the environment we're going to be using for these activities; hunting and hiking and the open space. Is there any relationship, absolutely, and the Quality of Life, yes, the Quality of Life is being able to be quiet, to enjoy the natural environment too."

#11 "For recreational use in the environment, I think that is something that should be policed to a great deal more than it is, because a lot of, there is an awful lot of recreational abuse to our environment as far as the availability of 4-wheel drive rigs and snowmobiles, and it doesn't take too long that things can be ruined in a hurry, I think."

#12 (referring to the) "effort to do drumming and singing and dancing and bead work, that enhances your self-image and makes you kind of proud. A women I work with has said, this makes us proud to be Indian, because people see us now as spiritual people rather than before, when everybody saw us as drunks. So anything that enhances your image to yourself and to the community as an Indian, people see any beauty, that is going to enhance your life and your well-being. That's on the artistic level. The sound of the drum does something to Indians, and I believe in a concept of genetic memory, when that drum goes, there is something from 10,000 years of ancestors using that drum, it does something to your spirit."

4. What is the relationship between the community's well-being and the environment?

#4 "I think that people get together and have community activities and associate with one another is essential. When you break down the lines of communication in the community between people, you break down a society, and you break down the trust of one another. You really need to have relationships, meetings, picnics, parties, whatever."

#7 "The farms are getting bigger, that's less people, so the city here has shrunk quite a bit in say the last 25 or 30 years; there's not as many people here, there's not as many businesses, because there are not as many farmers to support it. You have a lot better price in the big cities, so the shopping goes there, and it doesn't support your immediate community. If they diminished the lands then that is going to affect your whole community. . . . The employment here has been terrible; a lot of unemployment, so that cuts the whole community's Quality of Life down."

#9 "Yes, if the community is well balanced, if people aren't taking advantage of others, such as welfare; I have seen over and over again, people are taking advantage of the welfare system so the other people are working harder not being able to get out to enjoy a more quality serene life. There is a big relationship right there, it wedges between those that don't want to do and take advantage, and those that absolutely have to do and pay more taxes to take care of those people who are taking advantage of everything else; and it's not fair. Yes, there is a correlation/relationship between the community's well-being and the environment and the Quality of Life."

5. What is the relationship between the individual's well-being and the environment?

#6 "If you drive anywhere on the Reservation, you see clear cut, you look at it and it's like, you feel bad and think how can anyone do that to Mother Earth; it's like scarring her. That is beginning to make me mad now, cause I think what's going to be left for my grand kids. I used to look at quantity, now as I get older, I look more towards the quality."

#7 "If a person isn't happy with their surroundings and, which includes family, environment, and the community, they are not going to feel as good about themselves and they probably won't be such a good support for their families."

#11 "Well, it is up to the individual to control his own destiny as far as surviving with the environment. . . . If you aren't able to protect what you have, you are not going to be very productive as far as making an economical use of anything, and, you are going to have to protect what you have and not abuse it."

6. Rank according to their severity of importance to you the five categories and any particular issues you have brought up for discussion.

#1 "Legislation that may effect private land. The thing about it is, I look at the environment has no voice of its own. So, if you are a bureaucrat, for instance, politician or whatever, and you decide that is a good issue, environmental issues always seem to be hot, and if you can get votes that way, the environment can't say *wait a minute, NO! I'm fine*. Legislation laws can be passed based on *junk science* and people's emotions, because a lot of people live very much off the environment, the environment doesn't have its own voice, or maybe spirituality to it; it can't choose a religion it can't choose a god, it just is. That's why it's important for us to be the custodians of it. To me, that is more of a threat than my land eroding away into the sea, or something."

#2 "Spiritualism." "It goes back to the basic belief in respect for yourself, if you have that respect for yourself, that respect will come out and assist you in all that surrounds you. So, if I really care about myself, I really care about my well-being, I will then care about what kind of environment surrounds me."

#3 "Family and tradition."

#4 "I think our social culture has deteriorated since the late 60's, and of course, that develops a lot of crimes and problems because of drugs."

#5 "That is hard to say, what I hear from the old timers, we used to go out and drink water anywhere, it was all good water; but now you can't do that."

#6 "I guess, probably it would be the air. The air quality is pretty important, I think people have always been concerned with the water quality, and things that we can see, but nobody has really *really* looked at air, you can't see, you can't bottle it, you don't know how dirty it is. . . . spiritual that would be the most important."

#7 "The most important is personal well-being."

#8 "I guess, I think you have to go with your personal well-being first; and then the communities where you reside, I mean you have to be happy first where you're at, and the community has to do well or else, you won't be able to stay there; and I think that the rest falls into place. The recreational and the hunting, that's in that community you choose and if you are a happy person, I think your spiritual moral would fall into that category, in a sense because you have peace of mind, and if the community is doing well the economics play a part in that community."

#9 "This is hard, all of these are tied together. To me God is No. 1, so that would be the spiritual; and then my family is No. 2, that would be personal well-being; and then community well-being; economics; and aesthetics would be No. 5. . . . Taking care of our resources. So Quality of Life, is good for my grand kids and their grand kids. Setting areas aside such as parks like we have been doing, not selling them off, so my kids will have a space that will be set aside now for my grand kids, because it is getting more crowded all of the time. I guess having the freedom also to be able to pursue those Quality of Life issues."

#10 "It's (i.e., have a job) the highest thing on the priority list, it's the item that makes you choose, can you live with an environmental rule? There are tradeoffs, and if, but if you are starving, environmental rule could be that you couldn't hunt out-of-season, I don't give a rip....if you are starving, I will suffer the consequences, go to prison if necessary, if I don't eat something today I will die. Same thing with breathing or whatever. So you take care of the most important thing first."

#11 "Personal well-being and then the economic subsistence because if your personal well-being is good, then you are going to have the ability to earn a living; and then the spiritual, community well-being, aesthetics."

#12 "The most important would be the loss of land, the allotment process and the loss of the water that's part of the Reservation, to me are the most important. Secondly, which I don't want to talk about and which none of the local people want to talk about is the, seeing the effects of four generations of alcoholism. Those two would be the most important to me. The logging and clear-cutting, the diminished game, television has had an impact, as part of the whole picture, but they aren't number one

or two. The aboriginal spirituality, call it spirituality instead of religion, that's part and parcel of the way of life, it's a view of this world and a way it should be, that is just gone for a lot of reasons, I think. The overwhelming impact of white society has just taken a toll; and part of that toll, as a way of escape a lot of times is the drinking, was the bootleggers. That is not explored and not talked about, but it's part of what has really destroyed our good Quality of Life."

Quality of Life Public Opinion Survey

Family Awareness Day - Plummer, Idaho

Summer 1998

Are you a Coeur d'Alene Tribal member?
No 14 Yes 16

Are you an enrolled member of any tribe? If so which tribe?
No. 7 Yes 23 Coeur d'Alene 16 Yakama 1 CS & KT 1
Kalispel 1 Colville 2 Spokane 1 Mandan-N. Dakota 1

- No, but my dad is an enrolled Alaska Native

Do you live on the Coeur d'Alene Indian Reservation?
No 5 Yes 24 No Answer 1

Circle the age group that you belong to:

15 and under	16-25	26-35	36-45	46-55	56 +
8	5	2	7	6	2

Describe what you think is a good quality of life:

- Drug and alcohol free, family and friends.
- Surrounding area - beauty! Family - maintaining balance - physical - mental - spiritual - social.
- Lots of money.
- Animals.
- Clean air, water, etc.
- Friendly people, beautiful landscapes, and forested hills and clean water.
- Being able to live and use our land and being able to hunt, fish, and camp.
- The environment.
- Family, clean air, water - mountains, beautiful forests, abundant fish and wildlife.
- Drug free, family, good jobs, education, and tradition.
- Drug free and alcohol free.
- The environment.
- Being healthy and clean environment.

- Good water for yourselves.
- Being drug and alcohol free, living our culture, have respect for and from everyone especially the young.
- Being able to live the Indian way and exist in harmony with today's world.
- I don't understand.
- You always have the choice of how you want to live it.
- Living in a good environment.
- Well on the reservation graduating high school.
- Quality jobs for all that provide ample income to support a family, recreation opportunities close by and a well-stocked library.
- To live life healthy.
- Don't understand.
- Doing what you enjoy.
- Living for beliefs and for your elders.
- Good clean air, water, etc.
- To be able to earn a living and live and have a relationship with people and the environment.
- Everything lives with unity.

Is there any relationship between the environment and a good quality of life? If so, what is important in the environment for a good quality of life?

- Yes, experience the environment, woods, streams, enjoy them.
- No clear-cuts, huge buildings, or pollutants; helps maintain balance, ties to past!
- I don't know.
- Yes, everything that lives.
- Pure water and land.
- Yes.
- Yes, protecting the environment is very important to being able to have good quality of life.
- Yes, clean water, air, well managed forests, streams and lakes.
- Everything in the environment is important to a good quality of life.
- Yes. Testing of clean water, mapping different types.
- Trying to keep everything clean!

- Yes, a healthy environment makes a healthy life.
- The Creator allows us to utilize and learn from his earth. Therefore Mother Earth is important.
- The way it works.
- Everything, to have a good quality of life you have to respect everything around you. Without the environment what do you have to live for?
- Food, and all that good stuff.
- Definitely a balance of both economic growth and nature.
- No comment.
- Yes; clean air and water. Wildlife that can be viewed, hunted, fished, etc.
- Both clean healthy and cares about each other.
- Yes, nature.
- Your health (quality of air and water.)
- Respect your environment. It gives you what you need to live.
- Yes, keep America clean.
- Yes - clean air and water for fishing and swimming.
- Yes, everything must live.

What do you value about the environment?

- Its beauty.
- All that is natural.
- I don't know.
- Everything.
- All, as above.
- Open country.
- Being able to go out and enjoy the outdoors.
- The trees.
- Public access to recreational lands.
- Fresh water, trees, and wildlife.
- Everything it does.
- The plants.
- Seeing people trying to save the environment.
- Your streams.

- I like the weather in this area.
- A good example of the circle.
- Everything.
- Mother Earth provides everything you need or will ever need, it gave you life and becomes angry when you abuse it. It has a spirit we have to respect because without it there would be nothing. I value everything - I cannot pick one thing.
- The trees.
- Kindness.
- Places to go.
- Air, water, wildlife, etc.
- It's where we live.
- Animals.
- It's clean and peaceful.
- The trees for shade and water to cool off.
- Everything.
- Everything.
- Life.

Are you concerned about the environment? Why or why not?

- Yes, losing it.
- The overgrowth of hawkweed! Limit the cutting to sustainable.
- Don't know.
- Yes, because it's important.
- Yes, pollution.
- Yes.
- It seems people want to use, but don't want to take care of it or keep the quality.
- Yes.
- Yes, the current policies (in Coeur d'Alene for the Lake) do not promote restoration of water quality.
- Yes; people don't put enough importance into keeping it safe.
- Yes, it does for all.
- Yes, because people are ruining it.

- Yes - seeing all the trash along the highway.
- Yes, because of fish and wildlife.
- Yes, I'm concerned on a worldwide scale, because the future of life on earth depends on the environment.
- Yes, as a child I learned from my family to enjoy it, and then in later years witnessed the destruction due to man's thoughtlessness.
- Yes, don't know.
- Of course, too many people don't respect and realize what they are doing to it.
- Yes, we have to breathe the air and drink the water.
- No, have no reason.
- Yes.
- Well, sometimes, because I live here.
- Yes.
- Yes, because it's where we live and how it looks for when outsiders come around.
- Yes, I don't want it ruined
- Yes, Plummer has bad water.
- Yes, it is getting polluted really fast.
- Yes, too much logging and water pollution.
- Yes, we should all be concerned.
- Yes, animals are dying because of selfishness.

Have you heard about the Environmental Action Plan (EAP) being done by the Coeur d'Alene Tribe with the participation of the community? If so what do you know about it?

No 18 Yes 10 No Answer 2

- Not much.
- Hope it helps!
- I follow the progress and support the way we're progressing.
- I have heard the phrase, but not what it means/does.
- Not much.
- No - Not enough information, like signs, brochures, or public advertisement.
- Nothing.

What environmental problems, if any, do you think are present on the Reservation? What do you think causes these problems?

- Pollution, people.
- Zoning - hawkweed! Chemicals from farming.
- Don't know.
- Litter, people.
- Water and garbage.
- Lake Chatcolet is getting worse; clear-cutting uglies up our beautiful hills.
- Pollution.
- Don't know.
- Dirty water - too many people.
- Pollution.
- People not using the trash cans.
- Air pollution, water pollution; a cause is lack of information.
- Agricultural, the destruction of streams and wildlife habitat for more land. Logging, clear-cutting, again the streams, wildlife, and watershed is infected.
- Air - cars.
- I'd say almost everything - people- ignorant people - Indians and non-Indians cause the problems.
- The air, cars, and smoking.
- None.
- Litter, fish habitat, lack of concern, poor logging practices.
- It's dirty, need taking care of better.
- Don't understand.
- Water qualities and litter and careless people.
- Littering; people's carelessness.
- Not too aware?
- Culture.

What do you think is the best way to address the environmental problems on the Reservation?

- Try to solve the problems.
- Identify, locate solutions, actions, community or Tribe take a lead role.

- Don't know.
- I don't know.
- EAP participation.
- We need the old public garbage pit at DeSmet - it was hidden, well-controlled, and easy to get rid of all the larger stuff that now gets piled all over.
- To get people to help with stuff.
- Community involvement.
- To get ideas from others.
- Keep up the good work you are doing!
- I believe we need to educate the public, and involve them in a comprehensive solution, looking at every interest!
- Get it under control.
- Get everyone involved! Elders - parents - teens - children - toddlers - babies; it's a circle of life.
- They need improving.
- Drinking, drugs, and more.
- Hard to say.
- Setting aside funds; hiring professionals; working together.
- By doing it yourself.
- Through advertisements.
- Youth groups, volunteers, and sponsors.
- Community gatherings; events like this family awareness day.
- Logically and strategically.

Career Day in Plummer

November 1998

Are you a Coeur d'Alene Tribal member?

No 18 Yes 13

Are you an enrolled member of any tribe? If so which tribe?

No 13 Yes 18 Coeur d'Alene Tribe 13 Colville 3 Flathead 1 Salish 1

Do you live on the Coeur d'Alene Indian Reservation?

No 2 Yes 29 .

Circle the age group that you belong to:

15 and under	16-25	26-35	36-45	46-55	56 +
16	13	1	1		

Describe what you think is a good quality of life:

- Freedom to pursue life, liberty, happiness - freedom of religion. Ability to support, nurture, raise a family. Positive natural surroundings and recreational opportunities.
- Job, family, friends, etc.
- Playing football.
- Basketball.
- A nice house, making money.
- Being free.
- Beautiful nature; happiness, etc.
- Nature.
- Happiness (nature).
- Having fun.
- Having a fun job and fun children.
- Having a good time.
- Being a magician.
- Being cool, having fun.
- A good job, kids, money.
- A good job, money, kids.
- Family time.

- Animals.
- Everything.
- It's great.
- Just living.
- Air, just living as you and everyone else is.
- Being able to go into the wild.
- The resources.
- Have fun.
- Good environment, enough natural resources.

Is there any relationship between the environment and a good quality of life? If so, what is important in the environment for a good quality of life?

- Freedom from pollution - preservation of wildlife, forests, grassland, good fisheries.
- Yes - water, forest.
- Yes - water.
- Yes, to keep the air clean.
- Out in the wildlife, seeing a lot of animals.
- The trees do a lot for the world.
- No.
- It's important to keep our environment clean and healthy.
- The environment should be clean.
- Yes, trees and all that.
- If you didn't have any trees or anything then we wouldn't have oxygen and our life wouldn't be fun.
- The whole environment makes a good quality of life.
- Getting an education.
- Having a job that I enjoy.
- Yes, good environment is healthy.
- No.
- Camping with family.
- Yes.
- Yes, the animals.

- Yes, because if you don't have good environment you would be bored all the time.
- Air, because you wouldn't be able to live without it and it shouldn't be polluted.
- Yes, we need the forest to live.
- Don't know.
- Yes, water.
- I don't know.
- Everything.

What do you value about the environment?

- Beauty, realistic access to land use.
- Forests, wetlands.
- Trees.
- The fresh air and nice looking sites.
- Everything.
- Right now, the people are working to make it better.
- I like animals, and trees, and mountains.
- All the animals.
- That it is clean.
- All the wildlife and scenery.
- Wildlife, trees.
- Everything clean.
- The trees and animals.
- Everything.
- Getting to know people.
- The people.
- The trees.
- The trees and animals.
- The beautiful songs of nature.
- Birds.
- Trees and grass.
- My family.

- How good it looks.
- I like it all to be not polluted like the air and everything beautiful.
- The animals.
- It keeps the air clean.
- It's okay.
- Take care for the animals.
- Clean water and air.

Are you concerned about the environment? Why or why not?

- Grass burning. Water pollution from agricultural erosion and chemical run-off.
- Yes, erosion, over-cutting, wetlands, etc.
- Not really, because I don't know what is going on.
- Yes, I farm.
- Yes, if we don't take care of our environment we'll have more endangered species and our own lifespan will be shorter.
- Not out here, but in New Jersey.
- Yes, animals are disappearing, we need to save them.
- Yes, because I want the environment to be the best it can.
- We would die without the environment.
- Yes, we need to take better care of it.
- Yes, 'cause it's dirty and needs to be clean.
- Yes, because animals are being shot and trees are being cut down.
- Kind of.
- No.
- No, I think it's good already.
- Yes, because people aren't taking good care of it.
- Yes, too much garbage in the ozone.
- Yes, all living things should be taken care of.
- Yes, lots of pollution.
- Yes, cutting down the trees.
- No, because it still looks good.
- Yes, because I like to take care of the environment.

- Kinda, because the forests are becoming very thin.
- Yes, because there are trees that are getting cut down for dumb things.
- Yes, because it's getting worse.
- No, because I like to take walks in the woods.
- Not really.

Have you heard about the Environmental Action Plan (EAP) being done by the Coeur d'Alene Tribe with the participation of the community? If so what do you know about it?

No_25_ Yes_3_

- Sort of, not much.
- Yes, all of it.
- Yes, what you told us at the meeting in Worley.

What environmental problems, if any, do you think are present on the Reservation? What do you think causes these problems?

- Grass burning. Water pollution from agricultural erosion and chemical run-off.
- Water quality, farming.
- Pollution and the Plummer Mill.
- Pollution.
- Dumps, people put everything in them and if they don't feel like putting it in the dumpster they set it on the ground and I think this affects the soil and water.
- I don't think there is anything wrong with the Reservation.
- Lack of trees and animals.
- Littering, people are causing this.
- Litter by careless people.
- Too many trees being cut down by the mill.
- Litter, people.
- Too many drunks.
- I don't know.
- Pollution.
- None.
- Pollution, litter from careless people.
- Yes.

- The money.
- The mill and poachers that shoot deer and wildlife when not supposed to.
- I think that there are a lot of problems on the Reservation, and I just can't name one.
- Pollution.
- Need more elk and deer.
- Water problems; I don't know.

What do you think is the best way to address the environmental problems on the Reservation?

- With a planned process involving a combination of scientific expertise and community/human input.
- Problem solving.
- Find a way to not pollute.
- I'm not sure.
- Get people together to clean up our areas.
- Seminars.
- Have youth programs that go out and clean up the Reservation.
- Clean it up, kill people.
- Look around.
- Clean up Plummer.
- Keep it clean.
- Keep it clean.
- Meetings.
- Make more laws and have enforcement and fees.
- Work on them.
- Don't know.
- I don't know.
- Get volunteers to help fix it up.
- I just think that there are just so many ways to fix them.
- Just keep trying.
- Have a clean-up crew.
- Longer hunting season.
- I don't know.



Pheasants such as this rooster are one of many non-native species now found on the Coeur d'Alene Reservation.

Acronyms List

AIDS -	Acquired Immune Deficiency Syndrome
ANA -	Administration for Native Americans
ASCS -	agricultural stabilization and conservation service
BOD -	Biological Oxygen Demand
BMPs -	Best Management Practices
DBH -	diameter at breast height
DDT -	a banned agricultural chemical
DEQ -	Department of Environmental Quality
EAP -	Environmental Action Plan
EPA -	Environmental Protection Agency
ESA -	Endangered Species Act
FSA -	Farm Services Agency
GIS -	Geographic Information System
GUP -	General Use Pesticides
HEDR -	Hanford Environmental Dose Reconstruction
HCWMP-	Hangman Creek Watershed Management Plan
HHIN -	Hanford Health Information Network
HTDS -	Hanford Thyroid Disease Study
HUS -	Hemolytic Uremic Syndrome
IDWR -	Idaho Department of Water Resources
ICBEMP -	Interior Columbia Basin Ecosystem Management Project
IWRRI -	Idaho Water Resources Research Institute
KEC -	Kootenai Electric Cooperative
LUST -	Leaking Underground Storage Tanks
MBF -	1000 board feet (lumber measurement)
MCPA -	an agricultural chemical
NAAQS -	National Ambient Air Quality Standards
NOAA -	National Oceanographic and Atmospheric Administration.
NPDES -	National Pollution Discharge Elimination System
NRCS -	Natural Resources Conservation Service
NRD -	Natural Resources Department
NWI -	National Wetlands Inventory
PAHs -	polynuclear aromatic hydrocarbons
PM -	Particulate Matter
RC&D -	Resource Conservation and Development
RUP -	Restricted Use Pesticides
S&WCD -	Soil and Water Conservation District
SCS -	Soil Conservation Service
T&E -	threatened and endangered
TERO -	Tribal Employment Rights Office
TSS -	Total Suspended Settlement
USDA -	United States Department of Agriculture

USDI - United States Department of Interior
USFS - United States Forest Service
USFWS - United States Fish and Wildlife Service
USGS - United States Geological Survey
UST(s) - Underground Storage Tank(s)
VOC - Volatile Organic Compounds
WCED - Western Center for Environmental Decision-Making
WWP - Washington Water Power (now Avista Corp.)
WWTP - Waste Water Treatment Plant

List of Tribal Culturally Important Species

(Coeur d'Alene Tribe archival information, 1995 and Tribal Language Center, 1999)

PLANTS (the context is plants used for foods, not construction or other uses)

Family	*Latin name*	Common name	Coeur d'Alene name
Usneaceae	*Alectoria jubata* L.	Black tree moss (lichen)	sech'echt, smalqn
Pinaceae	*Pinus ponderosa* Dougl.	Ponderosa pine, yellow pine	Not Available
	Pinus contorta Dougl.	Lodgepole pine, black pine	qoqo'lit
	Pinus albicaulis Engelm.	White bark pine, silver pine	tadalqw
Salicaceae	*Populus tremuloides* Michx.	Aspen, quaking aspen	du⊬du⊬p or dare⊬du⊬du⊬p
	Populus trichocarpa T. & G.	Black cottonwood	mulsh
Portulacaceae	*Claytonia lanceolata* Pursh	Springbeauty, Indian potato	Not Available
	Lewisia rediviva Pursh	Bitterroot	sp'it'em
Berberidaceae	*Berberis repens* Lindl.	Oregon grape	sqweyu'
	Berberis aquifolium Pursh	Oregon grape	
Grossulariaceae	*Ribes* spp.	Gooseberry	hnt'it"me'lps
	Ribes spp.	Wild currant	sts'erus
Rosaceae	*Amelanchier alnifolia* Nutt.	Serviceberry	s⊬aq
	Crataegus douglasii Lindl.	Black hawthorn, black hawberry	sqhu'nech
	Crataegus columbiana Howell	Red hawthorn, red hawberry	Not Available
	Frageria spp.	Strawberry	stsaqwm
	Prunus virginiana L.	Chokecherry	⊬aqhw⊬uqhw (plural); laqhwluqhw
	Prunus emarginata (Dougl.) Walp. var. *emarginata*	Bittercherry	pachlen
	Rosa spp.	Wild rose, roseberry, rose hips	Skhwaayapa'qn (wild rose)
	Rubus parviflorus Nutt.	Thimbleberry	polpolqn
	Rubus leucodermis Dougl.	Black raspberry	mtsukw, ti⊬te⊬'lmkhw (blackberry vine)
	Rubus idaeus L.	Red raspberry	hnhalaatse'
Eleagnaceae	*Shepherdia canadensis* (L.) Nutt.	Soapberry, foam berry, Indian ice cream	sqhusm
Umbelliferae	*Heracleum lanatum* Michx.	Cow parsnip	qhoqh⊬p
	Lomatium cous (Wats.) Coult. & Rose	Cous	ka'us, piwye
	Lomatium spp.	Wild celery	Not Available
	Sium suave Walt.	Water-parsnip	Not Available
Cornaceae	*Cornus stolonifera* Michx.	Pacific dogwood	stichskhwelp
Ericaceae	*Arctostaphylos uva-ursi* (L.) Spreng.	Bearberry, kinnikinnick	(berry) ilch, (plant) alcha⊬palqw
	Vaccinium membranaceum Dougl.	Huckleberry	st'shastq; st'sha (plural)

	Vaccinium spp.	Small blueberry	st'eq'ɬn
Gentianaceae	*Frasera montana* Mulford	White frasera, stink root	mqsms
Caprifoliaceae	*Sambucus* spp.	Elderberry	ts'ekukw, ts'ek'ukw, (elderberry bush) 'ts'akukwalqw
Compositae	*Balsamorhiza sagittata* (Pursh) Nutt.	Balsamroot	Not Available
Alismataceae	*Sagittaria latifolia* Willd.	Water potato, wapato	sqigwts
Lilliaceae	*Allium geyeri* Wats.	Wild onion	sisch
	Allium cernuum Roth	Wild onion	qwliw'lsh
	Camassia quamash (Pursh) Greene	Camas	etqhwe', apɬ'etkhwe' (baked), p'ekhwpukhwn (camas bulbs), saha'wlutqhwe' (raw)
	Fritillaria pudica (Pursh) Spreng. (*Lillium columbianum*)	Yellow bell	Not Available

BIRDS - List of Tribal, Culturally Important Species Continued

Order and Family	*Latin name*	Common name	Coeur d'Alene name
Gaviiformes: Gaviidae	*Gavia immer* (Brunnich)	Common loon	ch'eqhq'n
Ciconiiformes: Ardeidae	*Botaurus lentiginosus* (Rackett)	American bittern	Not Available
Anseriformes: Anatidae	*Olor columbianus* (Ord)	Whistling swan	qhewitqhawit (generic name for a white swan)
	Branta canadensis (Linnaeus)	Canada goose	s(ihnt
	Anas platyrhynochos platyrhynochos Linnaeus	Mallard	qhwatqhwat (generic name for duck)
	Anas acuta Linnaeus	Pintail	Same as above
	Anas carolinensis Gmelin	Green-winged teal	Same as above
	Anas discors discors Linnaeus	Blue-winged teal	Same as above
	Anas cyanoptera septentrionalium Snyder and Lumsden	Cinnamon teal	Same as above
	Mareca americana (Gmelin)	American widgeon	Same as above
	Spatula clypeata (Linnaeus)	Shoveler	Same as above
	Aix sponsa (Linnaeus)	Wood duck	Same as above
	Aythya americana (Eyton)	Redhead	Same as above
	Aythya collaris (Donovan)	Ring-necked duck	Same as above
	Aythya valisineria (Wilson)	Canvasback	Same as above
	Aythya affinis (Eyton)	Lesser scaup	Same as above
	Bucephala clanguala americana (Bonaparte)	Common goldeneye	Same as above
	Bucephala albeola	Bufflehead	Same as above

	(Linnaeus)		
	Oxyura jamaicensis rubida (Wilson)	Ruddy duck	Same as above
Galliformes: Tetraonidae	*Dendragapus obscurus pallidus* Swarth	Blue grouse	sq'wedups (generic name for grouse)
	Bonasa umbellus phaia Aldrich and Friedman	Ruffed grouse	Same as above
	Pedioecetes phasianellus columbianus (Ord)	Sharp-tailed grouse, prairie chicken	Same as above
Charadriiformes: Scolopacidae	*Capella gallinago delicata* (Ord)	Common snipe	p'esta
Columbiformes: Columbidae	*Zenaidura macroura marginella* (Woodhouse)	Mourning dove	Not Available
Passeriformes: Corvidae	*Pica pica hudsonia* (Sabine)	Black-billed magpie	Not Available
	Corvus brachyrhynchos hesperis Ridgeway	Common crow	aɬqhaqhaqh

MAMMALS - List of Tribal Culturally Important Species Continued

Order and Family	*Latin name*	Common name	Coeur d'Alene name
Lagamorpha: Leporidae	*Sylvilagus nuttallii nuttallii*	Nuttall's cottontail	sqwitsmsh (generic name for rabbit)
	Lepus americanus pineus	Snowshoe hare	Same as above
	Lepus townsendii townsendii	White-tailed jack rabbit	Same as above
Rodentia: Sciuridae	*Spermophilus columbianus columbianus*	Columbian ground squirrel	Not Available
	Spermophilus lateralis tescorum	Golden-mantled ground squirrel	Not Available
	Marmota flaviventris avara	Yellow-bellied marmot	sch'i'm (generic name for marmot)
	Marmota caligata nivaria	Hoary marmot	Same as above
Rodentia: Castoridae	*Castor canadensis leucodontus* Kuhl	Beaver	hnmulshench
Rodentia: Cricetidae	*Ondatra zibethicus osoyoosensis*	Muskrat	chelekhw
Carnivora: Canidae	*Canis latrans lestes*	Coyote	smiyiw
	Canis lupus	Wolf	hnt"lane'
	Vulpes vulpes macroura	Red fox	sqhwe(wqhwe(w
Carnivora: Ursidae	*Ursus americanus cinnamomum*	Black bear	hnɬamqe'
	Ursus arctos idahoensis	Grizzly bear, brown bear	smaqhi'ch'n
Carnivora: Mustelidae	*Lutra canadensis nexa*	River otter	ltku
Artiodactyla: Cervidae	*Cervus elaphus nelsoni*	Elk, wapiti	spiɬts'e'
	Odocoileus hemionus hemionus	Mule deer	St'unɬts'e'
	Odocoileus virginianus	White-tailed	wishu's

	ochrourus	deer	
	Alces alces shirasi	Moose	quasi'qs
	Rangifer tarandus montanus	Caribou	ul syukhmusmu'lmkw he ts'i'
Artiodactyla: Antilocapridae	*Antilocapra americana americana*	Pronghorn, antelope	st(in
	Oreamnos americanus missoulae	Mountain goat	Not Available
	Ovis canadensis canadensis	Bighorn sheep, mountain sheep	Not Available
Artiodactyla: Bovidae	*Bison bison bison* (Linnaeus)	Bison, buffalo	q'wdq'wed

FISH - List of Culturally Important Species Continued

Family	***Latin name***	**Common name**	**Coeur d'Alene name**
Acipenseridae	*Acipenser transmontanus* Richardson	White sturgeon	hnqha'qha'mn
Salmonidae	*Prospium williamsoni* (Girard)	Mountain whitefish	mimnuft
	Oncorhyncus clarki lewisii Richardson	Westslope cutthroat trout	p't'aswel (generic name for trout)
	Salmo gairdneri Richardson	Steelhead salmon (Spokane river)	smfich (generic name for salmon)
	Salvelinus malma (Walbaum)	Bull trout	snp'arq'qn
	Oncorhynchus tshawytscha (Walbaum)	Chinook salmon (Hangman Creek)	smfich
Cyprinidae	*Ptychocheilus oregonensis* (Richardson)	Northern squawfish	Not Available
Catostomidae	*Catostomus catostomus* (Forster)	Longnose sucker	elshe'lecht (generic name for sucker)
	Catostomus macrocheilus (Girard)	Largescale sucker	Same as above
	Catostomus columbianus (Eigenmann and Eigenmann)	Bridgelip sucker	Same as above

There are certainly plants which were eaten at one time and are not listed here, but this list is a compilation of all available information on the Coeur d'Alene food plants. The selection of these species has been made rather conservatively, and there are likely to be species which were utilized that are not listed here, but it was deemed best to underestimate rather than overestimate the number of species available. The mammals listed are taken from Teit (1930-96).

It is likely that there are several additional species of plants and animals that are important to the Coeur d'Alene Tribe for purposes other than food that are not listed here.

Glossary

Acute: Having a short and relatively severe course.

Anadromous: Those fish that complete part of their life cycle in salt water as well as fresh water.

Aquifer: Any body of porous saturated material, such as rock, sand, gravel, etc., capable of transmitting ground water and yielding economically significant quantities of water to wells and springs.

Basalt: A fine grained igneous extrusive volcanic rock, commonly dark in color and composed mainly of minerals rich in magnesium and iron.

Best management practices: Accepted methods for controlling non-point source pollution; may include one or more conservation practices.

Biota: All plant and animal species occurring in a specific area.

Chronic: Persisting over a long period of time.

Coliform bacteria: A group of bacteria found in the colons of animals and humans, but also in natural soil and water where organic content is high. The presence of coliform bacteria in water is an indicator of possible pollution by fecal material.

DDT: This chlorinated organic insecticide was discovered by Swiss chemist Paul Muller in 1939.

Dermatitis: Inflammation of the skin.

Discharge: Outflow of water; related terms are runoff, streamflow, and yield.

Disease vectors: Invertebrates or non-human vertebrates which transmit infective organisms from one host to another.

Disturbance: An effect of a planned human management activity, or unplanned native or exotic agent or event, that changes the state of a landscape element, landscape pattern, or regional composition.

Diversity: The distribution and abundance of different plant and animal communities and species within an area.

Ecology: Scientific study of relationships between organisms and their environment.

Ecosystem: A community of organisms and their physical environment interacting as an ecological unit.

Elements: Ecological Component affected by the stressor.

Endocrine: Pertaining to internal secretions, hormonal.

Eutrophication: The natural process by which lakes and ponds become enriched with nutrients, resulting in increased growth of algae and reduced water clarity. If the process is accelerated by human activities it is termed cultural eutrophication.

Exotic Species: Non native; an organism or species that has been introduced into an area.

Filariasis: A disease caused by the parasitic nematode worm *Wucheria bancrofti* or *Brugia malayi*. The parasite blocks the lymphatic system and causes lymphatic oedema, resulting in the swelling and thickening of skin tissues and the tissues immediately below the skin. The disease most commonly occurs in tropical regions and is spread by bloodsucking insects (which carry the larval worms).

Floodplain: Land adjacent to lakes or rivers that is covered as water levels rise and overflow the normal water channels.

Gastrointestinal: Pertaining to or communicating with the stomach and intestine.

Greenhouse effect: The heating effect exerted by the atmosphere upon the earth by virtue of the fact that the atmosphere (mainly its water vapor) absorbs and remits infrared radiation. The shorter wavelengths of solar radiation are transmitted rather freely through the atmosphere to be absorbed at the earth's surface. The earth then remits this as long-wave (infrared) terrestrial radiation, a portion of which is absorbed by the atmosphere and again emitted - some back downward to the earth's surface (ICBEMP, 1997a).

Greenhouse gas: Atmospheric gases that are nearly transparent to solar radiation but almost opaque to longwave terrestrial radiation. These include water vapor, carbon dioxide, tropospheric ozone, nitrous oxide, methane, chlorofluorocarbons, halocarbons, and precursors of any of these gases.

Ground water: Any water of the state which occurs beneath the surface of the earth in a saturated geological formation of rock or soil.

Hemolytic uremic syndrome: Hemolytic uremic syndrome (HUS) is a rare condition affecting mostly children under the age of 10. HUS is characterized by destruction of red blood cells, damage to the lining of blood vessel walls, and, in severe cases, kidney failure. Most cases of HUS occur after an infection in the digestive system caused by the *E. coli* bacterium found on contaminated food like meat, dairy products, and juice. The first stages of HUS frequently present with gastrointestinal symptoms such as abdominal pain, vomiting, and bloody diarrhea.

Lacustrine wetland: All wetlands associated with lakes and ponds which exceed 2 meters in depth. For discussion in this document, deep water habitat will not be considered. Therefore, all lacustrine wetlands on the Reservation (those associated with lakes) are of the littoral type subsystem.

Littoral wetland: Wetlands that extend from the shore of a lacustrine system to a depth of 2 meters (about 6.5 feet) below low water, or to the maximum extent of nonpersistent emergent plants (Mitsch and Gosselink, 1993). These types of wetlands are found on the Reservation in association with the shallower areas of Coeur d'Alene, Black, Benewah, Chatcolet, Hidden and Round Lakes.

Macrophytes: Rooted and floating aquatic plants, commonly referred to as water weeds.

Native Species: Indigenous; living naturally within a given area.

Neoplasms: New abnormal growth of tissue.

Neurological: Of or pertaining to neurology.

Neurology: The branch of science which treats of the nervous system.

Nitrogen: An essential nutrient for aquatic organisms; comprises about 80 percent of the earth's atmosphere.

Non-native Species: Plants, wildlife and fish species that are not naturally found in a certain areas.

Non-point source pollution: Pollution discharged from a wide land area, not from a specific point.

Nutrient loading: The addition of nutrients, usually nitrogen or phosphorus, to a water body.

Nutrients: Elements or compounds essential to life, including but not limited to carbon, nitrogen, phosphorus, and trace elements.

Palustrine wetland: Wetlands of this type include riparian habitat in addition to upland wetlands. Palustrine systems found in north Idaho include all non-tidal wetlands dominated by trees, shrubs, persistent emergents and emergent mosses and lichens. Palustrine wetlands are scattered throughout the Coeur d'Alene Reservation in the flood plains of all of the rivers and streams, in forests, and in and around agricultural fields.

Phosphorus: An essential nutrient for aquatic organisms, usually derived from weathered rock.

Point source pollution: Pollutants discharge from an identifiable point such as pipes, ditches, channels, sewers, tunnels and containers of various types.

Pollution: Any alteration in the character or quality of the environment which renders it unfit or less suited for beneficial uses.

Salmonid: Fish belonging to the family Salmonidae; including salmon, trout, chars, whitefish and grayling. Characterized by the presence of an adipose fin and a fleshy appendage at the base of the abdominal pelvic fins. The family contains approximately 70 species of fishes that originally were distributed throughout the Northern Hemisphere.

Sediment: Fragmented organic and inorganic material, removed by erosion and transported by water, wind, ice and gravity.

Seral stage: A stage of succession.
Early seral-communities that occur early in the successional path and generally have less complex structural development than later successional communities.
Mid-seral-communities that occur in the middle of the successional path.
Late-seral-communities that occur in the later stage of the successional path with mature, generally larger individuals.

Sources: Specific event or entity causing the stressor.

Stressor: Any biological, physical or chemical entity or event that can induce adverse effects on an element or ecosystem.

Succession: The more or less predictable change in species composition in an ecosystem over time, often in a predictable order, following a natural or human disturbance. An example is the development of a series of plant communities (called seral stages) following a major disturbance.

Thyroid: A butterfly-shaped endocrine gland in the neck that is found on both sides of the windpipe. It secretes the hormone thyroxine which controls the rate of metabolism.

Toxicity: The quality of being poisonous, especially the degree of virulence of a toxic microbe or poison.

Watershed: The region draining into a river, river system or body of water.

Wetland: Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.