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LAKE CHELAN PROJECT PROPOSAL

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LAKE CHELAN

I. PREFACE

In view of the uses of Lake Chelan and their importance, it is imperative that lake water quality be maintained. The purpose of this report is to identify water quality problem areas and recommend study alternatives addressing these problems. It should be noted that funding sources and levels have not been considered in this project proposal. Specific report objectives are as follows:

1. Provide a historical review of previous studies.

2. Outline present water quality concerns.

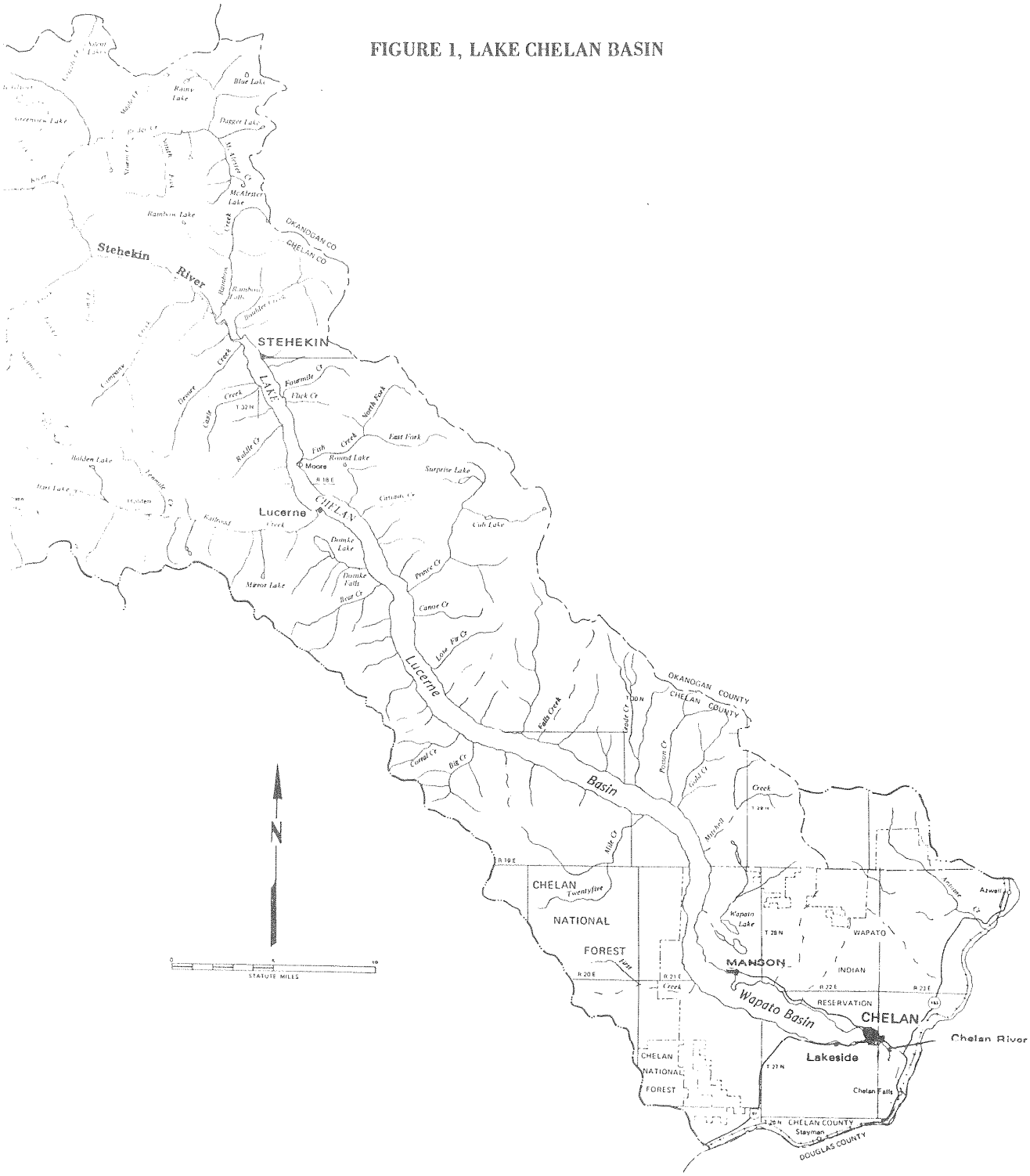
3. Outline a study approach that provides data to address water quality concerns and needs.

II. INTRODUCTION

Lake Chelan is the largest natural lake in Washington and is among the deepest freshwater lakes in the United States. The lake generally has excellent water quality (EPA, 1977; Beck, 1982; Dion, et al., 1976). Lake Chelan consists of two basins; Lucerne and Wapato (Figure 1). Lucerne Basin is the larger, extending approximately 38 miles with an average depth of 350 meters. Wapato Basin is smaller than the Lucerne Basin, but if considered separately, represents a fairly large lake--about 12 miles long, averaging 58 meters deep (Figures 2 and 3). Lucerne Basin receives water from two major sources, the Stehekin River and Railroad Creek, and numerous small streams. No significant tributaries are present in the Wapato Basin. The Chelan River, sole outlet for the entire drainage basin, enters the Columbia River five river miles below the lake.

According to Freeman (1944) and Whetten (1967), the two distinct basins of Lake Chelan are the result of the actions of two major glacial events. First, the Chelan glacier coming down from Stehekin scoured the valley perhaps as far as the Columbia River. Then, it retreated back to the area of the Narrows (see Shrine Beach, Figure 2). Second, the Okanogan lobe of the Cordillian ice sheet came up the Chelan Valley as far as Wapato Point. A lake of meltwater formed between these two glacial lobes. As the Okanogan lobe retreated down the Chelan Valley, it left large volumes of debris in the lower valley originally scoured by the Chelan glacier. The Chelan glacier eventually retreated back up the valley. These events explain the relatively gently sloping terrain and shallow depths of the Wapato Basin, in contrast to the sheer rock walls and profound depths of the Lucerne Basin.

FIGURE 1, LAKE CHELAN BASIN



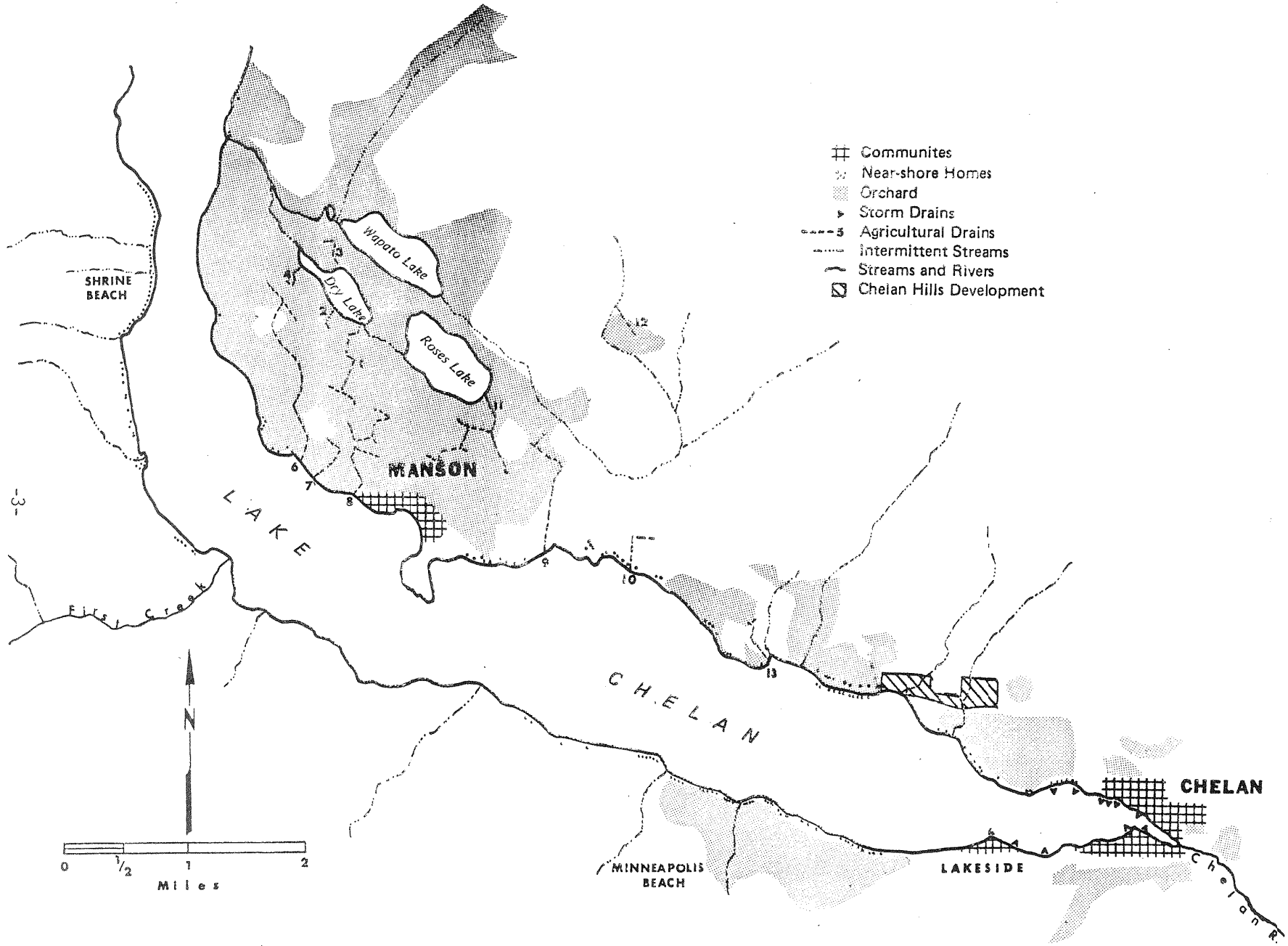


FIGURE 2. LAKE CHELAN: WAPATO BASIN

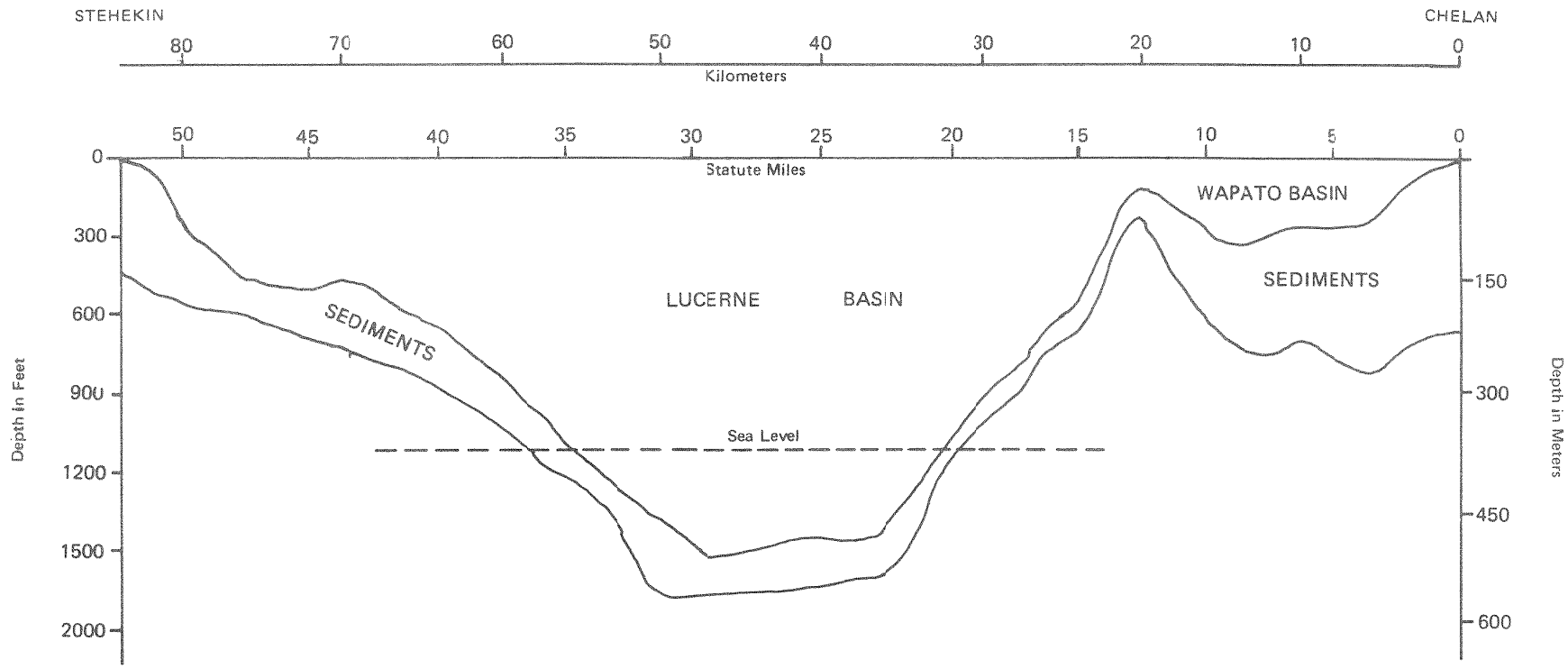


FIGURE 3, EXAGGERATED PROFILE OF LAKE CHELAN DEPTHS AND SEDIMENT LAYERS

*After Whetten, 1967

Land Use

The Lake Chelan drainage basin is largely undeveloped. Detailed basin land use is as follows:

Use	Percent of Total Area
Residential (urban)	<1
Residential (suburban)	<1
Agricultural	2
Forest or unproductive	92
Lake surface	6

From: Dion, *et al.*, 1976.

Development activities have primarily occurred in the two communities of the Wapato Basin (Figure 2). Manson (population 620) is an unincorporated settlement on the north shore. The city of Chelan (population 3,600), the largest community on Lake Chelan, is located at the extreme southern end of the lake. There are also a large number of nearshore homes (approximately 680) located in the Wapato Basin area. Some of these are vacation homes that are used only during summer months. Stehekin, Lucerne, and Holden are small settlements in the Lucerne Basin. Development has been limited in the Lucerne Basin by federal land ownership and difficult access.

Population estimates for the Chelan Basin include about 5,900 permanent residents. During summer months, recreational use of the lake and surrounding areas is high. The tourist influx causes the area to substantially exceed the resident population (CCRPC, 1977).

Most of the agricultural lands are located in the Wapato Basin where both irrigated and dry lands are present. However, inspection of the CCRPC (1977) indicates irrigated lands and specifically orchards, predominate. Forest and unproductive lands are found in both basins; however, predominate in the Lucerne Basin. Land ownership is primarily private in the Wapato Basin, whereas the majority of land in the Lucerne Basin is under federal control.

Water Source

Lake Chelan serves as the major source for domestic/municipal water supplies and irrigation. Most of these uses are confined to the Wapato Basin. The communities of Chelan and Manson rely on the lake for their supply of raw drinking water, as do most nearshore homes. Orchards near Manson and other agricultural uses account for the bulk of water withdrawals from the lake (WDOE, 1984a).

Recreation

Recreational use centers in the Wapato Basin and includes swimming, boating, fishing, and other activities. There are several swimming beaches associated with public parks; Lake Chelan State Park, Lakeside Park, and Longshore Park. In addition to these, there are many private swimming and shoreside recreational areas in the Wapato Basin. Lucerne Basin is very scenic and attracts many private boaters. A ferry runs daily from Chelan to Stehekin during summer months, and weekly during other times of the year, providing transportation for sight-seers and campers. Small shoreside parks are located at various points along the Lucerne Basin, providing camping and toilet facilities.

III. HISTORICAL BACKGROUND

In general, gradually increasing developmental, agricultural, and recreational pressures in the Lake Chelan area have raised interest and concern over lake water quality. Several man-related sources of pollution are present in the drainage basin; e.g., septic tank leachate, mine wastes, sewage overflows, agriculture, irrigation return flows, urban runoff, land development, and recreational activities. Few previous water quality surveys have determined the effects these individual sources might have on ground- and surface-water quality. Because of the great size of the lake, past studies have been limited to intensive surveys of specific problem areas, and general, short-duration surveys in the Wapato Basin.

Overview of Historical Studies

Selected studies are listed in chronological order below:

A. State of Washington Water Pollution Control Commission, Lake Chelan Water Characteristics Survey, 1967 (Cunningham and Pine, 1968).

   Purpose: To identify any water quality trends present in Manson Cove near septic drainfield outfalls from the commmunity of Manson.

B. Environmental Protection Agency, National Eutrophication Survey, Report on Lake Chelan, Chelan County Washington, 1975 (EPA, 1977).

   Purpose: To identify any possible nutrient sources to Lake Chelan as part of a national management practice, directed toward reducing point- and non-point source discharges to lakes and rivers.

C. Chelan-Douglas Health District, Lake Chelan Water Quality Study, 1980-81 (Chelan/Douglas Health District, 1981).

   Purpose: To document the extent of water quality degradation due to various pollution sources; e.g., septic tank leachate, recreational activities, agricultural and urban runoff, using total and fecal coliform bacteria as indicators.

D. Projects Northwest, On-site Sewage Disposal Systems at "Chelan Hills" and Their Relation to Lake Chelan Water Quality, 1981 (Projects Northwest, 1981).

Purpose: To establish the degree of ground/surface water quality degradation in the Lake Chelan Basin, related to the use of septic tanks in the area of the Chelan Hills development on the Wapato Basin north shore.

E. R.W. Beck and Associates, Lake Chelan 208 Study, Water Quality Management Plan, Phase I, Water Quality Investigation (Beck, 1982).

Purpose: To provide general information regarding the status of Lake Chelan water quality and relationships with various point- and non-point sources of pollution, concentrating on the Wapato Basin.

F. Washington Department of Game, Lake Chelan Fishery Investigations, 1982 (Brown, 1984).

Purpose: To obtain baseline fishery information and physical lake surface water data to prepare a comprehensive fishery enhancement plan.

G. Environmental Protection Agency, Land Use Survey and Septic System Analysis, Lake Chelan Washington, July, 1983 (EPA, 1984).

Purpose: To illustrate current land use patterns around the Wapato Basin shoreline and identify possible failing septic systems using aerial photographs.

Sewage Treatment

Of point- and non-point sources of contamination, sewage disposal practices in the Wapato drainage basin have received the greatest interest. Treatment of domestic sewage in the Chelan and Manson areas has undergone several improvement stages. Community and individual septic tanks served the local population until 1948 when the city of Chelan initiated primary treatment. In 1964, the Chelan sewage treatment plant (STP) was upgraded to secondary treatment (Coleman, 1984). Historically, Manson maintained three community septic tanks and drainfields which discharged directly into Lake Chelan at Manson Cove. Complaints about these discharges possibly causing water quality problems in Manson Cove and a water quality study by the State Water Pollution Control Commission (Cunningham and Pine, 1968) led to the construction and completion of a sewage interceptor line from the Chelan STP in 1976.

Today, the Chelan STP serves the Manson/north shore areas and Minneapolis Beach south to the town of Chelan. STP effluent is discharged into the Chelan River near the town of Chelan. The treatment system is currently operating at peak capacity and cannot accept any further sewer connections

without exceeding plant design capacity (0.86 MGD). As a result, a moratorium was placed on hook-ups to the Chelan STP by WDOE in June 1983. This order was based on WDOE reports that the plant was not meeting discharge criteria set forth in the current NPDES operating permit issued in 1983 (WDOE, 1983). This has led to increased pressure from local developers to rely on on-site waste treatment for new construction.

Developmental interests are greatest on the north shore of Wapato Basin where soils surveys show soil types to be widely variable. Soils range from sandy loam to coarse gravel or bedrock (SCS, 1969). Considering this, the acceptance of on-site treatment of domestic wastes in unsewered north-shore areas is in question. As a result, a study was conducted in 1981 to determine the suitability of on-site waste treatment for new construction in the "Chelan Hills" (Figure 2) development (Projects Northwest, 1981). The study concluded that all sites within "Chelan Hills" could utilize septic tanks for wastewater treatment with no detrimental effects to ground- and surface water quality. This report is discussed further in the Previous Studies section, below.

Concurrent with these activities, the city of Chelan has responded to demands for additional waste treatment by planning construction of a larger STP with a capacity of 1.1 MGD (WDOE, 1984b). The new, upgraded system will discharge directly to the Columbia River, and is slated for completion in January 1987. In the interim, WDOE is faced with regulating on-site waste disposal for new construction, while the moratorium on new sewer connections to the existing STP is in effect.

On May 8, 1984, the city of Chelan proposed a plan to increase the capacity of the Chelan STP by 300 units. This would be accomplished by increasing chlorination chamber contact time and reducing solids loading to the sludge digesters by physically removing solids from the system (Coleman, 1984). The plan was approved by WDOE on May 14, 1984, and a new Order issued May 22, 1984, stating that all unallocated plant capacity be documented with WDOE along with notification of any new sewer connections associated with the modifications proposed by the city of Chelan. Additionally, all new permits for use of septic tanks within the sewer district area must be registered with WDOE (WDOE, 1984b).

IV. SELECTED HISTORICAL STUDIES

Of previous Lake Chelan surveys, the "Chelan Hills" (Projects Northwest, 1981) report and 208 study (Beck, 1982), and Chelan/Douglas Health District (Chelan/Douglas Health District, 1981) represent the most detailed analyses of water quality concerns in the Wapato Basin. These studies are reviewed below.

Projects Northwest (1981)

"Chelan Hills" is a proposed development located on the north shore of the Wapato basin within the city limits of Chelan (Figure 2). The Projects Northwest (1981) study was primarily concerned with assessing impacts to Lake Chelan water quality from development-related sources of pollution. Several major topics were considered in the analysis:

- Topography and soils classification.
- Site suitability for use of on-site waste treatment in the "Chelan Hills" development.
- Lake Chelan Basin water budget.
- Groundwater quantity and movement.
- Nutrient sources.

A brief discussion and evaluation of the findings and conclusions for each of the above elements follows.

Topography and Soils Classification

Soils and slope classifications for "Chelan Hills" were determined using data from a Soil Conservation Service (SCS) soil survey (SCS, 1969). Drilling logs from wells within a two- to five-mile radius of the site were used to approximate underlying strata in the development area, as no wells existed on-site (WDOE, 1984c). Samples taken from road cuts 20 to 100 feet deep were examined using sieve and hydrometer tests.

The author concluded that all soils in the project area "contained amounts of fines adequate to aid significantly in filtering septic tank effluent." No underlying impermeable strata were identified from existing information.

The recent evaluation of well logs listed with WDOE indicate that there is a very wide range of soil conditions in the "Chelan Hills" area. Many of the soil types are site-specific; e.g., rock outcroppings and coarse gravel. Because of this, the general conclusions in the "Chelan Hills" report referring to the presence of uniform soil layers over the whole site is questionable. Field verification of listed soil types and shallow test soil cores could provide information detailing soil conditions.

Site Suitability for Use of On-Site Waste Treatment in the "Chelan Hills" Development

Several physical soil parameters were examined to determine the soil's ability to filter septic tank effluent. In addition to soils and well log data, percolation/sieve tests and road cut inspections were used to classify soil type and filtering capacity. Static water levels from surrounding wells were assumed to be closely related to overall groundwater table elevations in the Chelan Hills area. The report states that septic tanks located within the development area would be operating in unsaturated flow conditions, with the effluent moving vertically through topsoil to ground water.

There are several points involved in these assumptions. Vertical movement of drainfield percolate may be precluded by the presence of the impermeable hardpan layers or bedrock outcroppings shown in the soil surveys and drilling logs referenced in Projects Northwest (1981). Ground slopes and topsoil thickness in the project area are widely variable, which can have a great effect on the filtering capacity of the soil.

Depth to groundwater in these areas is uncertain and possibly cannot be extrapolated from static water levels of wells a few miles away. Further, assumptions made in the report describing the fate of septic tank effluent are not substantiated by actual groundwater quality testing.

It is recommended that all static water levels in the wells cited in the surrounding area be field verified. Shallow and deep groundwater testing for physical and chemical parameters in close proximity to operating systems may provide more accurate information about the soil's filtration capacity and groundwater quality. Groundwater table fluctuations should be noted and compared to lake levels.

It is also important to note that even properly installed septic systems still add dissolved nutrients to groundwater no matter the thickness of the soil percolation layer. This is especially true during saturated soil conditions which may occur during snowmelt and spring runoff. All soils exhibit a finite adsorptive capacity for organic nutrients and other contaminants (Bitton and Gerba, 1984).

Lake Chelan Basin Water Budget

A monthly water budget for Lake Chelan was calculated using water records from 1967-1978. Unknown creeks and rivers were assumed to be 12 percent of the total flow of the Chelan River. Precipitation data were obtained from Stehekin, while the nearest evaporation data used was from Wenatchee. Irrigation flow inputs and outputs were estimated using values found in the literature.

A major portion of the Projects Northwest (1981) report depends on the accuracy of the calculated water budget which estimates monthly water fluxes (inputs and outputs). The budget shows large groundwater contributions to the lake during the summer months (May, June, July) with losses to groundwater during October and November. This seems contradictory from what one would expect to occur, considering that the lake level is rising in spring and early summer due to snowmelt. The water table should also rise at this time, causing water to be lost from the lake to unsaturated soil in contact with the high lake level. A preliminary recalculation of the Lake Chelan water budget indicates this is the case. Water is lost to groundwater during months when the lake level is rising (April, May, June), while contributions of groundwater to the lake remain somewhat constant during other months of the year.

The accuracy of water budget calculations could be increased if more intensive monitoring of flows incoming and outgoing in stream and rivers were obtained. Area-weighted data from stations at Stehekin, Lucerne, and Chelan should also be used to calculate precipitation inputs.

Groundwater Quantity and Movement

Surrounding topography and the water budget described above are used in the Chelan Hills report to estimate groundwater movement. This information is combined with static water levels noted in well logs to draw conclusions on the quality and quantity of groundwater reaching the water table. The report states generally that the groundwater flow toward the lake is dependant on local soil conditions.

Groundwater should flow away from the lake during the period when lake level is rising, as discussed above. Test wells with seepage meters and piezometers would be an accurate method of estimating groundwater flow in areas where groundwater movement is suspected, such as natural drainage swales or intermittent stream beds.

Nutrient Sources

This is the most detailed segment of the Chelan Hills report. It concerns the potential effects of nutrients from development-related septic tanks and other sources on Lake Chelan water quality. All other elements discussed above are integrated in this analysis. Projects Northwest sampled lake water for nutrients and some physical parameters in April 1981. All other nutrient data for irrigation return flows, septic tank inputs, and other sources are estimated from previous studies.

The report concludes that a large number of homes (72,600 ± factor of 10) could be built on the north shore of the Wapato Basin before lake water quality would be degraded from existing conditions. This assumption is based on pollutant dilution by the total volume of Lake Chelan. A worst-case scenario is described as all untreated wastes from the development (at full build-out) entering the lake, resulting in only 0.4 percent of total nitrogen loading to Lake Chelan. The greatest amount of phosphorus loading from untreated development organic waste predicted is 1.9 percent of the total yearly input to the whole lake.

The report states the lake is phosphorus-limited, based on the recognized nitrogen-to-phosphorus (N/P) ratio of 7.2:1 by weight. Nitrogen is disregarded in the report as a significant pollutant because phosphorus is assumed to be limiting.

There are many reasons why these conclusions should be questioned. First, the method used to determine the final in-lake concentrations after complete mixing with untreated wastes does not appear to be appropriate. The calculation appears to be based on a single loading and mixing event and not a continuous loading source. If a continuous source is considered, the volume of the lake is not important because the in-lake concentration at equilibrium is only a function of the total inputs and outputs. The volume and mixing characteristics only affect the time it takes to reach equilibrium. Second, the nutrient loading analysis presented in the report does not consider other

development-related sources such as urban runoff, lawn fertilizers, or spills. Third, the lake is not phosphorus-limited at all times. Previous studies (Cunningham and Pine, 1968; EPA 1977) show that N/P ratios can range from 52:1 to 5:1 during any one year at various sites on the lake. If a ratio of 7.2:1 was maintained for the whole lake, the potential for increased algal growth exists if the concentrations of phosphorus and nitrogen increase gradually over a long period. This is a possibility in the presence of non-point source pollution. Lake data taken in 1975 (EPA, 1977) indicated the lake was phosphorus-limited in April and September; and nitrogen-limited in July. This is based on using an N/P ratio of 14:1 or greater to indicate phosphorus limitation (Welch, 1980).

Local Planning Considerations

In summary, the conclusions drawn in the Chelan Hills survey have affected the Lake Chelan area in several ways. First, development interests and Chelan County officials have unofficially based siting criteria for new on-site systems on findings presented in the report. Additionally, while the Chelan STP is presently operating at peak or beyond peak design capacity, new on-site systems are being built within the sewer district.

Beck (1982) and Chelan/Douglas Health District (1981)

In an effort to protect the beneficial uses of Lake Chelan, a water quality study was conducted under authority of Section 208 of the Clean Water Act, PL 92500. This surface water study was carried out by Beck (1982) during February, July, and September, 1982. Its purpose was to develop a water quality management plan for the Chelan area, thereby providing groundwork for a comprehensive water quality analysis and management program.

Limited to the Wapato Basin, the sampling sites were similar to those used by Cunningham and Pine (1968). Two sites in the southern Lucerne Basin were "control" stations to be compared to ten sites in the Wapato Basin. Existing data from previous studies were used in combination with sampling data to describe physical and chemical characteristics of the lake.

The report concludes that the upper lake basin (Lucerne) is completely mixed during the winter months, and partially stratified during the summer. The Wapato Basin did not exhibit any definite temperature trends during the period of study. These findings are not readily supported by other available data. Temperature data from the United States Geological Survey (USGS, 1972) and the Washington State Department of Game (Brown, 1984) showed temperature profiles down to 45 meters, while the total depth of the Lucerne Basin is much greater. Mixing probably occurs in the Lucerne Basin, but to what extent is unknown. Presently, no temperature profile data exist for depths greater than 60 meters anywhere in the lake. In view of this, it is difficult to say where and when turnover/mixing is occurring.

Algal growth was found to be limited in the lake, but nutrient inputs to the Wapato Basin could be sufficient to cause increased algal productivity in the future. Algal growth has been documented previously by Projects Northwest (1981) and a 1983 aerial photography survey (EPA, 1984).

Toxicant levels in Lake Chelan were found to be low. All levels in lake water were below those recommended for protection of public health. Some elevated amounts of copper and zinc were observed in specific agricultural return drains, while levels in lake water were low. Pesticides were also found at low levels in agricultural drains during the study. However, WDOE fish tissue analyses during 1982 and 1983 showed some fish samples containing high levels (4.5 mg/Kg wet weight) of the pesticide DDT (WDOE, 1984d). Sample fish were taken at Lake Chelan dam.

The 208 study also addressed bacteriological contaminants in relation to the study by the Chelan/Douglas Health District in 1980 (Chelan/Douglas Health District, 1981). During the health district survey, samples were taken for fecal coliform and total coliform analyses at 26 sites from March 1980 to January 1981. The objective of the survey was to identify sources of bacterial contamination located in the Wapato Basin. The study provided several conclusions: contamination levels paralleled lake recreational use patterns at urban and undeveloped lake sampling sites; samples taken below agricultural runoff and urban runoff sites were the most significant sources of contamination; and sampling sites in the Wapato Basin generally exceeded domestic raw water drinking water standards, while those north of Lake Chelan State Park did not. The 208 survey included some of the sites where high fecal coliform levels were found in 1980, but showed lower levels of contamination. Most of the sites involved areas close to the city of Chelan. Samples at raw water intakes for the city of Chelan did, however, exceed state public health standards of 1 coliform/100 mL for drinking water (WAC 248-54-175).

Conclusions based on the 208 study are general due to the limited duration (three months) and scope of the project. No general trends in productivity, nutrient loading, or other physical data were detected.

V. REGIONAL NEEDS AND CONCERNS

The Central Regional Office (CRO) of WDOE in cooperation with the Chelan/Douglas Health District, has outlined water quality problem areas and concerns in the Lake Chelan Basin to the Water Quality Investigations Section (WQIS). It appears that some of the needs can be met by additional study, whereas the remainder can be adequately defined and handled by remedial/ regulatory actions. In general, the needs fall into two categories; groundwater and surface water. A discussion of each specified need follows.

Groundwater

Septic Drainfield Leachate

Older homes and new developments rely on septic tanks for on-site waste disposal, sometimes within sewered areas of the north shore.

The Chelan Hills report made the general conclusion that on-site waste treatment is acceptable for new construction. It is clear that predictions made regarding nutrient and bacterial contributions from septic tanks and other sources to groundwater were not conclusive. More concise and accurate soil surveys and information about the characteristics of the groundwater aquifer are needed in the Wapato Basin before potential pollutant loading to the lake and the aquifer; e.g., domestic wells, can be quantified.

Agricultural Return Drains

About 7,000 acres of orchard land are located in the Wapato drainage basin of Lake Chelan. Many of these upland orchards are irrigated and therefore have return flows. These irrigation return flows have pesticides, fertilizers, herbicides, and heavy metals (Chelan/Douglas Health District, 1981; Beck, 1982; EPA, 1983). Intensive surveys of agricultural return drains and domestic wells in the immediate vicinity of orchard areas are recommended to determine loadings to the lake and potential groundwater contamination.

Surface Water

Lake Chelan Water Quality

A general limnological survey of Lake Chelan has never been accomplished. Limited information describing physical, chemical, and biological conditions exists; however it lacks the detail needed to make comparisons. A general limnological study is needed to improve understanding of existing conditions in the lake and allow long-term evaluations to be made. Water and pollutant budgets need to be developed.

Agricultural Runoff and Orchard Return Drains

Surface runoff from upland farming, near-shore orchards, and other farming activities drain directly into the Wapato Basin at several locations (Figure 2). Most drains are maintained by the Lake Chelan Reclamation District. Pesticides, fertilizers, herbicides, and heavy metals have been found in these return drains. Aquatic vegetation exists at discharge points along the lake shore. Submerged and emergent vegetation in the lake is also evident at outfalls of many intermittent flowing streams and drainage swales downslope from orchards and small farms (EPA, 1984). This growth indicates nutrient sources are present. This pattern is particularly noticeable near developed areas. Additionally, tissue samples from fish at Chelan Dam contained elevated levels of pesticides (WDOE, 1984d). Fecal coliform bacteria contamination in these flows is another concern. Information regarding the quality and quantity of the flows into the lake is needed to determine relative and annual loads. Follow-up surveys of bottom sediments near irrigation return flow outfalls are recommended.

Septic Tank Effluent

Many near-shore (Wapato Basin) homes along the lake rely on older septic drainfields, established prior to current on-site waste treatment construction guidelines. The older systems are concentrated among the older, near-shore developments--Shrine Beach, Hollywood Beach, and Granite Falls. Also, some near-shore homes along the north shore may be using septic drainfields that are very close to lake water. Some suspected drainfield failures were noted in aerial photographs (EPA, 1984) at various locations around the Wapato Basin; however, they have not been field-verified. A failure was described as excessive lush growth over septic drainfields, caused by saturation of the soil with nutrient-rich water. Shallow, subsurface groundwater and surface runoff from septic tank leachfields is a suspected source entering the lake near public water supply intakes (Chelan/Douglas Health District, 1981). These sources need to be documented for correction and/or inclusion into the lake nutrient budget.

Recreational Activities

Complaints regarding sewage, oil, grease, and gasoline have been associated with boating activities. The Wapato Basin experiences the most intensive boat use on the lake. Typically, the summer months and weekends in the spring and fall are high-use periods. An estimate of the pollutant contribution associated with boating activities is needed for inclusion into a basin-wide budget. If a problem does exist, a regulatory approach toward setting use guidelines is needed.

Sewage Lift Station Overflows

Some sewage lift stations along the lake shore have failed, causing sewage spills into the lake. This problem has been corrected in some cases by upgrading present facilities. Locations where this is not the case should be evaluated to determine the magnitude of the problem.

Urban Runoff

Urban runoff from the town of Chelan enters Lake Chelan at ten points (Chelan/Douglas Health District, 1981). Most of these are concentrated around the southern tip of the Wapato Basin (see Figure 2). Some stormwater outfalls are located close to domestic water intakes. One in particular is uplake from the Chelan Water Department intake pump. Stations sampled near raw water intakes in 1980 by the Health District showed some fecal coliform contamination problems. The 208 study also studied these sites, but insufficient data were taken to document the source of the problems (Beck, 1982). Intensive surveys during wet and dry periods would be needed to fully characterize stormwater runoff and loads in these areas. The relationship between stormwater discharge points and water intakes also needs to be evaluated.

VI. PROPOSED LAKE CHELAN BASIN SURVEYS

Three types of surveys designed to address general and specific water quality concerns are recommended for Lake Chelan: General Limnological Survey; Hydrogeological Survey; and Intensive Surveys. These are outlined in detail below.

General Limnological Survey (Lucerne and Wapato Basins)

Objective A: Characterize the chemical, physical, biological, and trophic conditions present in Lake Chelan.

Purpose: To record the present status of Lake Chelan and the individual basins in physical, chemical, biological, and trophic terms, integrating this information with results of intensive surveys. To also provide a basis for comparison with past and future lake studies.

Methods:

Task 1 - Establish a water budget from existing data and determine the significance of first-order perennial streams in the lake basin.

Task 2 - Sample major influent rivers/streams/drains over a period of one year for the following:

Physical	Chemical	Biological
Conductivity	pH	Fecal Coliform
Temperature	Dissolved Oxygen	
Flow	$CaCO_3$	
	Alkalinity	
	NH_3-N	
	NO_2+NO_3	
	T-PO_4-P	
	O-PO_4-P	
	Major cations and anions	

Task 3 - Sample approximately four vertical profile lake stations in the Lucerne Basin over a period of one year for the following parameters:

Physical	Chemical	Biological
Temperature	pH	Chlorophyll *a*
Secchi depth	Dissolved Oxygen	Fecal Coliform
Conductivity	$CaCO_3$	
	Alkalinity	
	NH_3-N	
	NO_2+NO_3	
	T-PO_4-P	
	O-PO_4-P	
	Major anions and cations	

NOTE: Because of the great depth, only select parameters will be analyzed at all depths and stations.

Task 4 - Sample approximately six vertical profile lake stations in the Wapato Basin over a period of one year for the following parameters:

Physical	Chemical	Biological
Temperature	pH	Chlorophyll *a*
Secchi depth	Dissolved Oxygen	Fecal Coliform
Conductivity	$CaCO_3$	
	Alkalinity	
	NH_3-N	
	NO_2+NO_3	
	T-PO_4-P	
	O-PO_4-P	
	Major anions and cations	

NOTE: Because of the great depth, only select parameters will be analyzed at all depths and stations.

Task 5 - Refine the water budget and develop a nutrient budget for both Wapato and Lucerne Basins.

Subtask 1 - Develop a morphometric map of the Lucerne and Wapato Basins from continuous bathymetric profiles.

Hydrogeological Survey (Wapato Basin)

Objective A: Characterize the groundwater aquifer near developed areas of the Wapato Basin and determine the potential contamination from domestic and agricultural sources.

Purpose: Estimate groundwater movement, direction, and quality and determine if any relationships exist between land use and groundwater quality.

Methods:

Task 1 - Compile existing well logs for the Lake Chelan area and field verify surface and water table elevations.

Task 2 - Classify surface soils through field verification of available data and determine if a relationship exists with underlying strata noted in well logs.

Task 3 - Develop a geophysical map of the Wapato Basin.

Task 4 - Develop or compile land-use information for the Wapato Basin area.

Task 5 - Based on information obtained in Tasks 1 - 4, identify the numbers; types; e.g., shallow or deep; and locations of existing and new groundwater monitoring wells needed to characterize groundwater quality in residential; e.g., septic tanks; agriculture; and unproductive drainages based.

Task 6 - Monitor groundwater quality, elevations, and movement at the sites selected in Task 5. Parametric coverage to include:

Physical	Chemical	Biological	Toxics
Temperature Conductivity	pH $CaCO_3$ NH_3-N NO_2 + NO_3-N T-PO_4-P O-PO_4-P Major anions Major cations	Total and fecal coliforms	Selected parameters at selected sites

Task 7 - Determine if relationships exist between land use and groundwater quality.

Task 8 - Establish a relationship between groundwater table fluctuations and water level of the lake.

Intensive Surveys (Lucerne and Wapato Basins)

Objective A: Describe and quantify areas where macrophytes and periphyton are established.

Purpose: To identify overland, point source, and groundwater nutrient inputs to the Wapato Basin.

Method:

Task 1 - Conduct shoreline surveys to identify locations, types, and relative macrophyte and periphyte abundance.

Objective B: Quantify bacterial and chemical loads from urban stormwater runoff.

Purpose: To identify and quantify urban stormwater loads in consideration of potential or measured localized water quality impacts.

Method:

Task 1 - Intensive sampling of stormwater flows for chemical and biological parameters including two dry- and two wet-period surveys.

Objective C: Quantify and qualify agricultural return flows.

Purpose: To determine the extent or potential ground- and surface-water contamination from agricultural return water.

Methods:

Task 1 - Sample agricultural return water for chemical, nutrient, selected priority pollutants, and biological constituents during two wet- and two dry-period surveys.

Task 2 - Collect and analyze sediment samples adjacent to selected agricultural drain outfalls for priority pollutants.

Task 3 - Note locations of uncontained perennial and intermittent return flows.

Task 4 - Sample the shallow subsurface groundwater near selected locations described in Task 3.

Objective D: Evaluate the pesticide levels in Lake Chelan fish.

Purpose: Identify geographic extent of contaminated fish.

Method:

Task 1 - Collect fish from four areas of Lake Chelan for pesticide analyses.

Objective E: Evaluate the importance of the sewage lift stations to Lake Chelan water quality.

Purpose: Determine if additional remedial action is needed.

Methods:

Task 1 - Review status of all lift stations in the basin, and the failure frequency and duration.

Task 2 - Determine if corrective measures are warranted.

Objective F: Evaluate water quality impacts due to boating activities.

Purpose: Provide a relative measure of the contribution boaters make to localized water quality problems in Wapato Basin.

Methods:

Task 1 - Quantify the type and extent of boat usage in the Wapato Basin.

Task 2 - Evaluate potential pollutant loads attributable to boating practices.

Task 3 - Recommend mitigating steps if warranted.

Objective G: Determine whether specific bacteria sources are responsible for potable water supply degradation in the Wapato Basin.

Purpose: To recommend corrective measures.

Methods:

Task 1 - Identify bacteria sources in relation to the proximity of water intakes.

Task 2 - Determine if localized circulation patterns can explain the high bacteria concentrations observed in the water supplies.

Timing Considerations

The time required to complete the study as proposed ranges from 2 to 2 1/2 years. This period assumes that a single field team of two will perform the general limnological and intensive surveys. The hydrogeological work would be performed by another team within the specified time period.

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