Validation Study

Priest Lake Thoroughfare and Breakwater Replacement Study
near Priest River, Idaho

for
Bonner County Public Works

January 20, 2010

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EXECUTIVE SUMMARY

General

This report presents a summary of our findings, conclusions and recommendations regarding the replacement of the Priest Lake Thoroughfare Breakwater near Priest River, Idaho. The existing timber structure, constructed circa 1917, is approximately 1,300 feet in length and located near the mouth of the Thoroughfare, which separates Upper Priest Lake from Priest Lake. The Breakwater has experienced several partial failures within the past 20 years, resulting in breaches of the structure and alterations of water flow near the mouth of the thoroughfare, leading to sediment accumulation and lowering of water depths, which in turn has resulted in restriction of boat traffic on the Thoroughfare, and diminished use of docks in the area. While periodic repairs to the Breakwater have kept the structure operational, without substantial improvements, failure of the Breakwater is imminent.

Compilation and Review of Existing Data

Available data pertinent to our evaluation was obtained from a number of sources including: lake water surface elevations from Avista Corporation and the USGS; historical wind and precipitation data from the NOAA; historical aerial photographs; and Thoroughfare discharge rates and preliminary bathymetric data from the Idaho Department of Environmental Quality. The data was used to develop an understanding of the forces that act on the Breakwater and as input into computer-based numerical models to evaluate the existing Breakwater structure and a proposed replacement structure. Several data gaps were identified during our review and analysis that should be filled during subsequent phases of the project including: detailed topographic and bathymetric data around and within the lower end of the Thoroughfare and on the seaward and landward side of the Breakwater; and soil characteristics along the Thoroughfare and the existing Breakwater by completing a geotechnical engineering evaluation .

Evaluation of the Existing Breakwater

Computer-based numerical modeling was used to evaluate the performance of the existing Breakwater structure. The computer models analyzed the performance of the Breakwater using two criteria: wind-wave energy reduction; and sedimentation in the Thoroughfare. Results of the numerical modeling indicate the following results:

- The existing Breakwater protects the shoreline from direct wave impact, but allows some wave energy to penetrate to the Thoroughfare and north shore.
- The openings in the Breakwater allow sediment to penetrate (escape) to the channel, causing shoaling in the Thoroughfare and erosion of the bottom of the south side of the Breakwater.
- Erosion on the south side of the Breakwater increases wave reflection and exacerbates bottom scour. The bottom scour will result in eventual failure of the Breakwater.
- Gaps in the existing Breakwater dissipate flow energy and reduce flow velocities in the Thoroughfare channel. This reduction in velocities results in deposition of suspended sediment. It is likely that the effect of flow dissipation (and flow energy) has been exacerbated by the scouring of the high ground and undermining of the Breakwater. The flushing effect of

the Thoroughfare flow was probably historically stronger, allowing the channel to continue to self scour before development of the current openings.

- Gaps in the existing Breakwater cause deflection of flow and meandering of the channel. This meandering undermines the Breakwater and contributes to its failure.

On this basis, it is our opinion that the existing Breakwater is not of sufficient integrity to provide long-term protection to the Thoroughfare from wave action and sedimentation. If no action is taken, the Breakwater will continue to deteriorate, and ultimately, fail. More sediment could deposit at the mouth, the Thoroughfare could meander and flow could breach through what remains of the Breakwater.

Replacement Breakwater Concept and Evaluation

Based on the results of this evaluation , the concept of an effective replacement Breakwater structure was developed. Based on our analyses, we propose that a full-depth breakwater be used to replace the existing Breakwater, in order to provide confinement of the Thoroughfare flow, preclude transmission of flow and waves through the breakwater, and re-establish historical hydraulic conditions at the site. On this basis, it is our opinion that a rock-sloped breakwater is the most promising option for a replacement structure.

The following summarizes the results of our evaluation of the proposed breakwater replacement structure:

- The proposed breakwater should minimize direct wave impact on the north shoreline and preclude wave energy penetrating to the Thoroughfare.
- The proposed breakwater should reduce bottom erosion on the south and prevent sediment penetration to the Thoroughfare.
- The proposed Breakwater should reduce wave reflection.
- The proposed Breakwater should provide an increase of flow velocity in the Thoroughfare channel. This increase of velocity could result in deepening of the channel, specifically at the down-drift end of the proposed breakwater.
- The proposed breakwater should minimize shoaling in the Thoroughfare and provide some deepening in the channel.
- A small alteration of water elevation control procedure, such as controlling lake water elevation at a lower level during high flow spring runoff, might result in natural redistribution of sediment and reduction of shoaling at the mouth of the Thoroughfare.

A preliminary cost estimate for the replacement Breakwater structure is in the range of about $864,000 to about $1,080,000 (not including engineering design and permitting costs).

Recommendations

We recommend that Bonner County consider a rock breakwater for replacement of the existing timber Breakwater. Conceptually, we propose a rock breakwater with a lakeside (south) slope equal to 2.5H:1V (horizontal to vertical), and an inner (north) slope equal to 1.5H:1V, with a crest at approximately 5 feet above the nominal high water elevation of the lake (breakwater crest at approximate Elevation 2,439 feet based on NGVD 1929 datum).

Acquisition of additional topographic and bathymetric data, exploration of subsurface conditions at the site and supplemental numerical modeling will be necessary to confirm the location of the proposed breakwater and to establish the breakwater geometry (cross section) and top elevation. An evaluation of conditions in the Caribou Creek drainage and potential transport of sediment from the drainage to the Thoroughfare should be part of these supplemental efforts.

In addition to data acquisition, numerical modeling, and engineering design during subsequent phases of the project, extensive efforts will be required during the environmental permitting and review process. Environmental permitting will require coordination with multiple agencies including The Idaho Department of Environmental Quality, Idaho Department of Lands, Idaho Department of Water Resources, Idaho Department of Fish and Game, and the U.S. Army Corp of Engineers.

We estimate that the fees associated with the tentative scope outlined in the report for additional data acquisition, modeling, engineering design and environmental permitting could be in the range of about $250,000 to $375,000.

INTRODUCTION

GeoEngineers, Inc. and Coast & Harbor Engineering (CHE) are pleased to present the results of our evaluation of the existing Breakwater at the terminus of the Thoroughfare between Upper Priest Lake and Priest Lake near Priest River, Idaho. The approximate locations of the Breakwater and Thoroughfare are shown on the Vicinity Map, Figure 1.

The existing Breakwater is a timber structure extending from a natural sand spit on the west end for a distance of roughly 1,300 feet to the east. We understand that the Breakwater was constructed by the United States Department of Agriculture (USDA), Forest Service (FS) circa 1917 to improve navigation through the entrance of the Thoroughfare by enhancing sediment transport through the channel and into Priest Lake.

Since the 1990s, when a portion of the Breakwater was breached, the flow of water through the Thoroughfare has been altered and sediment accumulation in the mouth of the Thoroughfare increased. The primary source of sediment is believed to be from the Caribou Creek drainage, possibly as a consequence of a fire in the 1960s, road construction and logging in the drainage basin. As a result, water depths have diminished so that use of some private docks on the north side of the Thoroughfare, and passage of boat traffic through the Thoroughfare and into Upper Priest Lake are possible only during the summer season when the lake level is at its highest. For the past approximate 15 years, patchwork maintenance and emergency repairs have temporarily mitigated the breach and natural degradation of the structure. However, without substantial improvements, failure of the Breakwater is imminent.

OBJECTIVES

The primary objectives of this study were to:

1. Evaluate the existing conditions at the site of the Breakwater relative to its intended function;
2. Assess impacts the deteriorated Breakwater has had on nearby properties;
3. Consider how the deteriorated condition of the Breakwater has contributed to sedimentation in the Thoroughfare; and,
4. Develop concept-level breakwater improvement alternatives.

During a meeting of representatives of Bonner County, Idaho Bureau of Lands, the Breakwater Committee and other stakeholders in May 2009, the agreed-upon priorities and purpose of repair or replacement of the Breakwater include:

- Fix/replace the Breakwater to original. Anecdotal information from the group suggests that water depths in the Thoroughfare north of the Breakwater in the range of 2 to 2½ feet were typical before the Breakwater was breached;
- Enhance motorized boat access to Upper Priest Lake;
- Maintain/improve fish habitat;

- Restore pre-breach conditions such that the Thoroughfare channel is "self-cleaning"; and
- Restore wave protection to private properties along Sand Piper Shore.

SCOPE OF SERVICES

The scope of services for this evaluation was presented in our proposal dated March 27, 2009. Written authorization for us to proceed was executed on April 9, 2009. Our specific scope of services included the following tasks:

Task 1, Kickoff Meeting and Site Visit

Meet with representatives of Bonner County and the Breakwater Committee to develop a better understanding of the historic, existing and desired Breakwater and Thoroughfare conditions and visit the project site to become familiar with the site conditions. GeoEngineers also performed an initial geomorphic assessment of the Thoroughfare and Caribou Creek, the major tributary entering the Thoroughfare from the east.

Task 2, Existing Data Compilation and Review

Develop a database for analytically evaluating the existing breakwater and identifying measures to improve/modify the existing Breakwater (if required) to meet performance requirements. The data necessary for our evaluation included: lake water surface elevations as a function of season; historical wind data; bathymetric and topographic data; aerial photographs; Thoroughfare discharge rates; bottom sediment and soil characteristics; previous study reports; project-related design documents; and publications in the public domain.

Upon completion of the acquisition of readily available existing data, review and compilation, we prepared a brief data gap report that identifies unavailable data and level of effort to substitute the missing data with a new data collection program, or by assumptions and prototype data. Results of our prior data gap memo are included herein.

Task 3, Evaluate Performance of Existing Breakwater

Conduct an evaluation of the existing breakwater performance to understand wind-wave energy and sedimentation in the Thoroughfare. This element of our services addresses the following questions:

- What effect does the existing breakwater have on sedimentation in the lower portion of the Thoroughfare?
- What level of wave energy protection does the existing breakwater provide along the Sandpiper Shores pleasure boat moorage areas?

An evaluation of the performance of the existing breakwater to sedimentation was completed based on 2-D flow circulation modeling. Because data on flow velocity in the Thoroughfare and Priest Lake was not available, modeling was conducted at the conceptual level, and the results used for comparative analysis only.

Task 4, Concept of Replacement Breakwater and Reporting

Identify and consider the two most likely alternatives for breakwater alignments and configurations. The selected alternative was built into a numerical modeling grid. Wave and flow circulation modeling was repeated for the same parameters used for the existing breakwater. Results of the modeling were compared to existing conditions.

We provide cost estimates and an initial list of applicable environmental permits for the preferred alternative. We also include recommendations for the next phase of the analysis of the preferred alternative.

Task 5, Microsoft SharePoint Site

Establish a web-based SharePoint site to enable easy access and timely review of information and documents. This element of our services was completed as a first step under our contract with Bonner County. Stakeholders were provided with directions for accessing the site and we posted information as it was developed during the course of our study.

EXISTING DATA COMPILATION AND REVIEW

Information contained in this section is a summary of Task 2. The following information was acquired as an initial effort and was used during Task 3 and Task 4:

- Lake water surface elevations as a function of season. This information was obtained from Avista, Inc. and the United States Geological Survey.
- Historical wind and precipitation data. Because weather data specific to Priest Lake was not available, we used and adapted historical precipitation data from the weather station at the Priest River Experimental Forest, and wind data from the weather station at the Coeur d'Alene Airport.
- Aerial photos. Numerous photos were available and used, in part, to interpret data we acquired during Task 2. Sources include: Randy Ramey (personal correspondence); Bonner County; the USDA, FS; and Idaho Department of Lands.
- Thoroughfare discharge rates. Although historical water flow velocities and volumes through the Thoroughfare were not available, we obtained from the Idaho Department of Environmental Quality hydrologic data for water years 1994 and 1995 for the Upper Priest Lake drainage basin. This data was used to estimate runoff volumes and resulting water velocities for the Thoroughfare geometry.

We list below information that either is not readily available or has not been acquired by others (data gaps). We also provide a general level of effort which will be necessary to obtain the data. Completion of the tasks below will aid in development of final numerical models, which should be an element of Final Design/Environmental Permitting.

- Topographic and bathymetric (hydrographic) data around and within the lower end of the Thoroughfare and on the seaward and landward side of the breakwater. The survey should meet Corp of Engineers Class A criteria (transects at a spacing of approximately 100 feet). On the landward (north) side of the breakwater, the survey should extend to the north bank, approximately ½ mile upstream from the breakwater and encompass at least elevations up to the ordinary high water mark. On the seaward (south) side of the breakwater, the bathymetric survey should extend into the lake until water depths exceed approximately 40 feet. Field work for the bathymetric and topographic surveys likely will require about one week. Processing the data into a format that is suitable for numerical modeling will require an additional approximate week.

- Soil characteristics along the Thoroughfare and around the existing Breakwater. Acquiring this data will require geotechnical borings along the breakwater and sampling bottom sediments at discrete locations along the Thoroughfare. Preliminarily, soil borings should be drilled to depths in the range of about 30 feet to 80 feet below existing bottom elevations (mudline), and spaced about 200 feet on center along the length of the breakwater, for a total of about 8 to 10 borings. The borings will be drilled from a barge when lake level is at normal summer pool elevation. Acquisition of bottom sediment samples in the thoroughfare will be completed from a small boat.

SITE CONDITIONS

General

In order to assess performance of the existing Breakwater and conduct analyses of alternatives, we used existing data to establish conditions at the subject site. Factors which influence performance of the Breakwater and water flow through the Thoroughfare include:

- Wind direction, velocity and recurrence intervals for various maximum wind conditions;
- Water surface elevations in Priest Lake and Upper Priest Lake;
- Annual variations in water flow through the Thoroughfare; and,
- Bathymetry in the Thoroughfare and Priest Lake.

The following sections of this report summarize the data we acquired and how it was used to establish site conditions.

Wind Conditions

Wind data is the basis for wave predictions, numerical modeling, and analysis. Waves are generated as wind directions align along the wave generation fetches. Wave Generation Fetches, Figure 2 shows the directions and relative lengths of the wave generation fetches that produce waves at the project site. The figure shows that the largest wave generation fetches are in a directional sector from 190-220 degrees (0 degrees and 360 degrees correspond to true North). The figure also shows that winds from the directional sector 240 to 100 (through true North) should not produce any significant waves at the Breakwater site.

Wind data from the Coeur d'Alene Airport station were compiled for the 60-year period from 1949 to 2008. The location of the Coeur d'Alene Airport meteorological station relative to the project site is shown in Coeur d'Alene Airport Meteorological Station, Figure 3. Wind data (speed and direction) were measured at 2-minute intervals at an approximate height of 30 feet above ground. The compiled wind data were quality checked, adjusted to the required standards, and statistically processed. The result of the wind data statistical processing is illustrated in a "wind rose" that shows occurrences of wind speeds and directions, as presented in Wind Rose Based on 60 Years of Wind Data at Coeur d'Alene Airport, Figure 4.

The figure shows that the predominant winds at the airport area are from the southern directions, which correspond to the largest lengths of wind fetches for the project site. The statistical analysis also included an extreme analysis that estimated the return period (rate of recurrence) for extreme wind events. Extreme Wind Analysis, Figure 5 shows the results of this analysis.

The figure shows wind speeds for return period of storm events at 2, 5, 10, 25, 50, and 100 years from different directions. For example, the wind speed for a 100-year return period storm event from 190 degrees is 63 knots. The wind speed of a 2-year return period storm event from the same direction, 190 degrees, is equal to 23 knots. The figure shows that, in general, the strongest winds during all considered extreme events originate from the 180-260 degrees directional sector. The maximum wind speeds occur from 170-200 degrees, a narrower directional sector. Considering a coincidence with the longest fetch, this directional sector (170-200 degrees), was used as the design storm directional sector for our initial analysis and also should be used during preliminary and final design. Table 1 below presents the wind speeds for extreme storm events for different directional sectors, and highlights the recommended design sector of 170-200 degrees.

TABLE 1. PRIEST LAKE, IDAHO, SECTOR RETURN PERIOD WIND SPEEDS (KNOTS), (PERIOD OF RECORD: 1948-2008 FROM COEUR D'ALENE AIRPORT)

Return Period (yr)	Wind Sector (°T)1			
	050-100 (kts)	110-160 (kts)	170-200 (kts)	210-270 (kts)
2	22.1	25.5	32.9	23.6
5	29.1	31.0	43.7	32.4
10	33.6	34.2	50.7	37.4
25	39.0	37.7	59.0	43.0
50	42.8	40.0	64.9	46.7
100	46.4	42.2	70.4	50.1

Notes:

1Sector	Range
050-100	045-104
110-160	105-164
170-200	165-204
210-270	205-274

Priest Lake Water Surface Elevations

The water elevations at Priest Lake are variable and seasonally controlled by Avista at the Corps of Engineers Albeni Dam west of Priest River. Elevations of the lake during summer are typically 3 to 5 feet higher than winter elevations.

Data for Priest Lake elevations were compiled at USGS Station 1239300 located at the southern end of the lake. The gauge is at Elevation 2,434.64 feet above National Geodetic Vertical NGVD datum (1929). The approximate location of the USGS station that measures lake levels is shown in Priest Lake Water Elevations, Figure 6.

Lake water elevations have been measured at USGS Station #12393000 since 1928. We compiled and analyzed these measurements as part of our study. The maximum lake water elevation was measured on June 20, 1974 at 6.68 feet above the base gauge level at Elevation 2,434.64 feet. The minimum water elevation in the lake was registered at -0.46 feet below gauge level on January 5 and 6 of 1977 and February 26 and March 2 of 2001.

A representative lake water elevations dataset was developed using the last 10 years of measurements. Priest Lake Water Surface, USGS Station 12393000 (1998-2008), Figure 7 shows lake water surface deviations from base gauge level as a function of time for the period 1998-2008.

Thoroughfare Flow Discharge Data

Thoroughfare flow discharge data were measured at Station "The Thorofare" for the period from January 1, 1994 to December 31, 2005. The approximate location of Station "The Thorofare" is shown on Figure 6. The reported data included mean daily flow discharge in the Thoroughfare in cubic feet per second (cfs). Discharge in Thoroughfare 01/01/1994-12/31/1995, Figure 8 shows the hydrograph of flow in the Thoroughfare for the period of measurements.

Maximum flow discharge in the thoroughfare was measured at 4,640 cfs on May 25 1995. Minimum flow discharge was measured at 76 cfs on September 17, 1994. This dataset represents daily discharges and was selected for further analysis and modeling for this study.

Bathymetry

Bathymetric (lake and Thoroughfare bottom elevations) data for Priest Lake, and specifically for the Thoroughfare, is very limited. For purposes of this study, bathymetric data were compiled from various available sources and gaps in the data were filled with assumptions. The sources of bathymetric data included Idaho Department of Environmental Quality (Priest Lake transect survey 1995) and a NOAA historical chart. Based on these data, the general bathymetry of the Priest Lake area was developed and is shown in Priest Lake Bathymetry in Color Format, Figure 9.

The conceptual information on bottom depths in the project vicinity, around the Breakwater, and in the Thoroughfare was developed by GeoEngineers based on a site visit and non-instrumental observations. These conceptual data were further processed and extended by CHE, based on coordination with local residents. The assumed bathymetry in the project vicinity was constructed, and is shown in color format in Bathymetry in Vicinity of Breakwater, Figure 10[1].

[1] The bathymetry on this figure is based on assumptions only. This bathymetry cannot be used for any purpose outside of the current feasibility study.

Aerial Photographs

Geo-referenced historical aerial photographs for the project site were compiled, rectified, and analyzed. A total of 14 historical geo-referenced aerials were compiled for the period from 1935 to present time (2006). Two aerial photographs showing conditions in the site vicinity are shown in Rectified Aerial Photographs, Years 2006 and 1935, Figure 11.

As shown in the 1935 photograph, there is a significant apparent natural sand spit coincident with the location of the timber Breakwater. Vegetation appears on the south side of the Breakwater. Apparently, this spit formed a peninsula that prevented undermining of the breakwater and provided confinement of the Thoroughfare. This confinement likely enhanced flushing of the Thoroughfare during high spring runoff flows, reducing potential for sedimentation.

The historical aerials, specifically the 2006 photo, also show that land on the south side of the breakwater has eroded with time. Consequently, most of the spit has eroded and the Breakwater has been exposed to direct wave impact during high wind conditions. Waves have continued scouring soil at the toe of the Breakwater, and some scour holes have developed beneath the structure. The scour holes have increased sediment migration from the south to north, into the Thoroughfare. Also, flow from the Thoroughfare has transmitted through the breakwater and scour holes, thus reducing the flushing effect during spring runoff.

Caribou Creek Drainage Qualitative Sediment Summary

General

The following is a brief summary of our efforts to develop on initial understanding of history of changes in the Caribou Creek drainage and how such changes could have influenced sedimentation in the lower reach of the Thoroughfare. Much of this information was provided to us via electronic memo from Mick Shanilec of the Idaho Department of Lands.

Sediment Sources/History

- 1905 severe, stand-replacement fire (10,000 acres)
- 1940s splash dam at the confluence with Bugle Creek (~3.5 miles upstream from the Thoroughfare confluence).
- 1960s fire (info from Carl Ritchie)
- 1960s and 1970s early logging roads with steep grades, wood culverts, and otherwise poorly constructed and prone to runoff and road failure
- Mid 1980s, logging roads were improved with metal culverts, rolling dips, and less steep grades.
- Mid 1980s, logging activity decreased and vegetation buffers utilized near streams.
- 1998 Road 44 failure due to plugged culvert (estimate 2,000 cubic yards of sediment delivered to Caribou Creek)
- 2002 Road 43 failure due to blocked ditch (estimate 10 to 20 cubic yards of sediment delivered to Caribou Creek)

- Sediment source
    - Sediment production from logging activities and roads will likely continue to decrease in the future, but the chance of fire-related and road-related sediment production remains.
    - Substantial volumes of sediment are stored in the bed of the lowest reach of Caribou Creek and the Thoroughfare.
    - Delivery of sand-sized sediment to the lower lake at the mouth of the Thoroughfare is expected to continue into the foreseeable future.
- Sediment deposition
    - Significant sediment bar formation in Caribou Creek is not evident from the photo record beginning in the 1930s, suggesting the Creek has reached a dynamic equilibrium and roughly the same volume of sediment entering the lower reach of Caribou Creek is passing through into the Thoroughfare and ultimately to the lower lake.
    - Anecdotal evidence suggests deposition has occurred at the mouth of the Thoroughfare raising the bed elevation.
    - Sediment deposition occurs at the mouth of the Thoroughfare because in-channel velocity diminishes significantly where the Thoroughfare meets the slack-water lake. Deposition is increased by the dispersal of flow across the delta reducing the channel's sediment-carrying capacity caused by: 1) a large percentage of flow passing through the porous Breakwater and 2) the flow spreading out across the channel as it widens significantly along the length of the breakwater.

EXISTING BREAKWATER PERFORMANCE

General

An evaluation of the existing Breakwater performance was conducted using two criteria: wind-wave energy reduction; and sedimentation in the Thoroughfare. An evaluation of the performance of the wind-wave energy criteria was conducted using 2-Dimensional (2-D) wave refraction/diffraction numerical models SWAN and HWAVE. An evaluation of the sedimentation criteria was conducted using the 2-D flow model SELFE and 2-D sediment transport model MORPHO.

Wave modeling was conducted using 2-D SWAN (Simulating Waves Nearshore), a spectral, third-generation wave model (Holthuijsen et al., 2004). SWAN utilizes coastal bathymetry, incident wave spectra, and local wind conditions to generate and transform waves into the nearshore environment. The model includes generation of wave energy due to wind, refraction, wave-wave interaction, and energy dissipation due to breaking and white capping.

The HWAVE numerical code is a 2-D wave refraction, diffraction and reflection numerical model (Demchenkoet al, 2007). The model simulates nearshore waves and their interaction with coastal structures.

MORPHO (Kivva et al, 2004) is a 2-D (depth-averaged) numerical model that simulates surface water flow, sediment transport and bottom morphology changes in the nearshore zone. The governing equations of the modeling code are derived from the general three-dimensional hydrodynamic equations of continuity and motion for an incompressible fluid with a constant density.

Wave Modeling and Breakwater Performance Evaluation

Wave modeling for the project area was conducted in two steps. As the first step, a large numerical modeling grid was constructed and the 2-D wave refraction/diffraction numerical model SWAN was used to generate waves and propagate them to the project site. Modeling Domain for SWAN Wave Model, Figure 12 shows the area that was used for the SWAN 2-D computer model.

The wave modeling and analysis was conducted for two wave storm scenarios: 2-year and 25-year return period wind storm events. Wind input parameters for the wave modeling were obtained from the results of the extreme wind analysis (Table 1). SWAN Wave Model Results 2-Year and 25-Year Storm Return Periods, Figure 13 shows the results of the modeling on a large modeling grid for the two wave storm scenarios.

Figure 13 shows a field of significant wave height over the modeling domain in color format. Waves are increasing toward the north with the increase in wind fetch. The figure shows that wave heights at the project site during the 2-year return period storm can reach about 3.0 to 3.5 feet, and during the 25-year storm event can reach about 4.5 to 5 feet.

The results of the SWAN numerical analysis (wave heights and frequencies) were used as input parameters for the nested grid wave modeling, which was the second step in our analysis. The nested modeling grid domain was constructed to include the Breakwater and details of the bottom and shoreline configuration at the project site. Nested Modeling Grid, Figure 14 shows the grid configuration for the site and vicinity.

Numerical modeling of the nested grid was conducted with the 2-D wave refraction-diffraction-reflection model HWAVE. Results of the HWAVE numerical analysis for the two wind return period scenarios are shown in HWAVE Wave Model for 2-Year and 25-Year Storm Return Period, Figure 15.

Figure 15 shows wave height distribution over the modeling domain in color format. Based on results of this analysis and because of the shallow water depth along the Breakwater, waves break and wave heights increase up to 4 feet during the 2-year storm and up to 6.5 feet during the 25-year storm. The figure shows that due to the porosity of the Breakwater some waves penetrate (transmit) to the Thoroughfare channel. The transmitted waves are small and might not induce shoreline erosion. However, these waves, in transmission, are capable of transporting sediment into the Thoroughfare through the porous Breakwater and under the Breakwater, through scour holes.

The figure also shows a pattern of wave reflection from the vertical wall breakwater. Wave reflection typically results in steeper waves at the structure, and bottom scour at the toe of the structure. This scour probably contributed to erosion of the natural spit on the south side of the Breakwater and formation of scour holes as described in a previous section.

The following summarizes our evaluation of the existing Breakwater based on the numerical modeling described in the preceding paragraphs:

- The existing Breakwater (if not breached) protects the shoreline from direct wave impact, but allows some wave energy to penetrate to the Thoroughfare.
- The openings in the Breakwater allow sediment to penetrate (escape) to the channel, causing shoaling in the Thoroughfare and erosion of the bottom on the south side of the Breakwater.
- Erosion on the south side of the Breakwater increases wave reflection and exacerbates bottom scour. **The bottom scour, in turn, will result in eventual failure of the Breakwater.**

Flow and Sediment Transport Modeling

The performance of the existing Breakwater was evaluated in regard to sedimentation criteria, and conducted with the SELFE hydrodynamic model, and MORPHO sediment transport and bed change model[2]. A detailed numerical modeling grid was constructed that included the entire Priest Lake area and part of the Thoroughfare. Numerical Modeling Grid for SELFE and MORPHO Models, Figure 16 shows the grid detail we used for the SELFE and MORPHO modeling.

The modeling grid consisted of approximately 13,800 elements. In the vicinity of the project area, the modeling grid was refined to account for variable bathymetry and the porous Breakwater. The modeling was conducted for a compressed 1-year period. Variable, 10-year-averaged daily lake water surface elevations and 1994 daily measured Thoroughfare flow discharges were input to the model. Suspended sediment concentration in the Thoroughfare was input as a constant load. An example of the SELFE modeling results, with a snapshot of current velocities over the modeling domain, is shown in Velocity Model Results Example, Figure 17.

Figure 17 shows a plan-view of depth-averaged velocities over the modeling domain in color format. The color red corresponds to higher velocities, and blue corresponds to low or no velocities. The figure shows that flow with high velocities from the Thoroughfare dissipates along the channel and Breakwater. A significant amount of flow transmits through the porous Breakwater. In other words, the energy of the flow dissipates along the Breakwater. At the end of the Breakwater, flow velocities (and kinetic energy) are reduced dramatically, which results in deposition of suspended sediment and a reduction of flushing capacity of the flow. **It is likely that the effect of the flow dissipation (and flow energy) has been exacerbated by the scouring of the high ground and undermining of the breakwater. The flushing effect of the Thoroughfare flow was probably historically stronger, allowing the channel to continue to self scour.**

Sediment transport modeling was conducted using the output of the flow velocities modeling from SELFE and the same modeling grid for a period of 1-year. The results of the sediment transport modeling are shown in MORPHO Model Results, Sedimentation for 1-Year Period, Figure 18.

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[2] Validation and calibration of the numerical models was conducted during the feasibility study. Modeling results presented herein are to be used for qualitative analysis only.

The figure shows a plan-view of bottom changes (deposition/erosion) for a 1-year period for existing Breakwater conditions in color format. Red corresponds to higher deposition, and blue corresponds to erosion. The figure shows that bottom depths in the Thoroughfare north of the Breakwater, were significantly reduced. It appears that most of the sediment transported by the flow had deposited prior to exiting past the Breakwater. The following summarizes the evaluation of the existing Breakwater based on the results of our flow and sediment transport modeling:

- Gaps in the existing Breakwater dissipate flow energy and reduce flow velocities in the Thoroughfare channel. **This reduction of velocities, in turn, results in deposition of suspended sediment.**
- Gaps in the existing Breakwater cause deflection of flow and meandering of the channel. **This meandering undermines the Breakwater and contributes to its failure.**

REPLACEMENT BREAKWATER CONCEPT AND EVALUATION

Breakwater Concept

Based on evaluation of the existing Breakwater and results of the numerical modeling, the concept of an effective breakwater was developed and results of our analyses are summarized herein. The proposed concept considers a breakwater that is capable of restoring historical hydraulic conditions at the project site. This implies that the Breakwater should provide confinement of Thoroughfare flow, and preclude transmission of flow and waves through the Breakwater. **For this purpose we propose a non-permeable full-depth breakwater to replace the existing Breakwater.**

Several types of non-permeable breakwaters capable of providing the required confinement of Thoroughfare flow are: sheet pile wall; gravity block; and rock sloped. Based on preliminary evaluation of construction costs, maintenance requirements, habitat enhancement consideration and performance for the prevalent site conditions, **we recommend a rock-sloped breakwater as the most promising option based on results of this study.** During preliminary and final design, other types of non-permeable and full-depth breakwaters may be considered, if appropriate.

For this study and evaluation purposes the alignment of the proposed rock breakwater was kept at the same location as the existing Breakwater. **For the next phase of the project, during preliminary and final design, an optimization of the alignment and length of the breakwater should be conducted to achieve maximum economical and environmental benefits.** The alignment of the proposed breakwater is shown in Proposed Breakwater Alignment, Figure 19.

Conceptually, for the purposes of this study, we propose a rock breakwater with lakeside (south) slope equal to 2.5H:1V (Horizontal to Vertical), and an inner (north) slope equal to 1.5H:1V. The crest of the breakwater is proposed at approximately 5 feet above the nominal high water elevation of the lake (breakwater crest at approximate Elevation 2,439 feet NGVD 1929). During the next phase of the project, the design cross-section of the breakwater should be developed and justified with appropriate analysis. Conceptual Cross Section, Rock Breakwater, Figure 20 shows the proposed breakwater geometry.

An evaluation of the proposed breakwater performance was conducted using the same criteria as for the existing breakwater: Wind-wave energy reduction and reduced sedimentation in the Thoroughfare. Similar to the existing Breakwater, the proposed rock breakwater performance evaluation in regard to the wind-wave energy criteria was conducted using the 2-D wave refraction/diffraction numerical models SWAN and HWAVE. And, evaluation of the performance with regard to the sedimentation criteria was conducted with the 2-D flow model SELFE and 2-D sediment transport model MORPHO.

Wave Modeling and Rock Breakwater Performance Evaluation

The proposed breakwater was built into the numerical modeling grid, and wave modeling was conducted with the same methodology and for the same scenarios as for the existing Breakwater. Proposed Breakwater, HWAVE Model, 25-Year Storm Return Period, Figure 21 shows the results for a 25-year return period storm event.

Figure 21 shows no wave penetration to the thoroughfare channel through the proposed breakwater. That implies that no sediment migration to the channel through the breakwater will occur. The figure also shows that the proposed breakwater should protect the shoreline and properties from direct wave impact.

The proposed rock breakwater is a sloped structure. The effect of wave reflection on a sloped structure reduces dramatically with increase of the angle of the slope. Based on previous project experience, it is likely that wave reflection from the slope of the proposed breakwater (2.5H:1V) should be reduced by more than 30 percent in comparison to a vertical wall breakwater. This reflection reduction effect should minimize (or eliminate) bottom scour on the south side of the new breakwater, and provide favorable conditions for establishing vegetation.

The following summarizes our evaluation of the proposed breakwater based on wave modeling results:

- **The proposed breakwater minimizes direct wave impact on the shoreline and precludes wave energy penetrating to the Thoroughfare.**
- **The proposed breakwater reduces bottom erosion on the south and prevents sediment penetration to the Thoroughfare.**
- **The proposed breakwater reduces wave reflection.**

Flow and Sediment Transport Modeling

An evaluation of the performance the proposed breakwater to the sedimentation criteria was conducted using the same methodology as for the existing Breakwater. Two numerical models, SELFE and MORPHO, were used to simulate flow circulation and sediment transport on the numerical modeling grid that included the proposed breakwater.

Modeling was conducted for a compressed 1-year period. Variable, 10-year-averaged daily lake water surface elevations and 1994 daily measured Thoroughfare flow discharges were input to the model. Suspended sediment concentration in the thoroughfare was input as a constant load. An example of the modeling results with SELFE showing a snapshot of current velocities over the modeling domain for existing conditions (a) and with the proposed breakwater (b) are shown in Flow Model during One Instant, (a) Existing Conditions and (b) Proposed Breakwater, Figure 22.

Figure 22(a) shows that for existing conditions, flow with high velocities from the Thoroughfare dissipates along the channel and Breakwater through the porosity in the Breakwater. Figure 22(b) shows that the proposed breakwater confines the flow and provides conservation of high velocities through the Thoroughfare. Further comparison was conducted by subtracting current velocities modeled for existing conditions from those modeled for the proposed breakwater at the same instant of time. Results of this computation are shown in Current Velocity Differences, Proposed Breakwater minus Existing Conditions, Figure 23.

Figure 23 shows a plan view of the differences in current velocities between the proposed breakwater and existing conditions in color format. Red indicates an increase of velocities, and blue indicates a reduction in velocities. The figure shows a significant increase in current velocities along the Thoroughfare channel, especially at the eastward end. An increase in current velocities should provide a flushing effect and reduce sedimentation. **On this basis, it is our opinion that the proposed breakwater should restore the historical flushing effect in the Thoroughfare.**

An evaluation of the proposed breakwater in respect to the sedimentation criteria also was conducted using the 2-D sediment transport model MORPHO. An example of sediment transport modeling results for existing and for proposed breakwater conditions are shown in Results of MORPHO Model, 1-Year Return Period Sedimentation (a) Existing Conditions and (b) Proposed Breakwater, Figure 24.

Figure 24 shows significant differences in bottom depth changes in the Thoroughfare channel between existing conditions and the proposed breakwater conditions. The area of sediment deposition for existing conditions changes to an area of erosion for the proposed breakwater conditions. As expected, scouring occurs at the east end of the proposed breakwater, providing natural maintenance of the depth in the Thoroughfare channel. The effect of the proposed breakwater to restore sufficient water depths for unimpeded navigation in the Thoroughfare can be demonstrated by a rendering of an existing aerial photograph. Rendering, Proposed Breakwater Effect on Existing Thoroughfare, Figure 25 shows the results of the rendering.

Sediment deposition, however, could occur eastward from the existing channel in the deepwater area of the lake. Eventually, this deepwater may become filled with sediment, and further extension of the breakwater or other measures might be required to maintain the channel depth. **One of these measures could include controlling lake water elevation at a lower level during high flow spring runoff in the Thoroughfare. This and other possible measures require additional analysis during preliminary and final design.** It also will be important to communicate this concept to Avista and the Corps of Engineers.

The following summarizes our evaluation of the proposed breakwater based on the results of the flow and sediment transport modeling:

- **The proposed breakwater provides an increase of flow velocity in the Thoroughfare channel. This increase of velocity could result in deepening of the channel, specifically at the downdrift end of the proposed breakwater.**

- **The proposed breakwater should minimize shoaling in the Thoroughfare and provide some deepening in the channel.**
- **A small alteration of water elevation control procedure might result in natural redistribution of sediment and reduction of shoaling at the mouth of the Thoroughfare.**

Replacement Breakwater Estimates

Conceptual cost estimates for construction of the proposed breakwater were prepared, based on data on rock material in the project area from Fred Miller (USGS Open-File Report 82-1061) and information obtained from local contractors Ken Hagman (Copper Bay Construction) and Paul Storro (Storro Brothers Excavating Company). It appears that the required dimensions and quality rock are available from quarries located in relatively close proximity to the project. East River Quarry Rock, Figure 26 shows rock material from the East River Quarry. Based on the photograph, the rock appears to be of sufficient quality for the proposed breakwater.

Construction estimates for the proposed breakwater were completed for both upper and lower limits of probable costs. The following table includes the results of these estimates. Please note that preliminary and final design and permitting costs are not included in the table.

TABLE 2. PROPOSED BREAKWATER CONSTRUCTION CONCEPTUAL COST ESTIMATE

Construction Item	Estimated Cost
Mobilization/Demobilization	$50,000 to $75,000
Excavation	$70,000 to $100,000
Bedding layer in place	$200,000 to $250,000
Armor rock in place	$400,000 to $475,000
Total of Direct Cost	$720,000 to $900,000
Contingency 20 percent	$144,000 to $180,000
Total Estimated Construction Cost	***$864,000 to $1,080,000***

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Discussion and Conclusions

This study was undertaken to assess the viability of repairing the existing timber Breakwater, which was constructed circa 1917, at the thoroughfare entrance to Upper Priest Lake. We evaluated performance of the existing structure in terms of wave refraction, diffraction, reflection, and the consequent transmission of waves through the structure and scour on the south side of the Breakwater. We also considered how the existing Breakwater performs in terms of sedimentation and scour in the Thoroughfare navigation channel. Based on the results of our analyses, we conclude that:

- The existing Breakwater is not of sufficient integrity to provide protection to the Thoroughfare from wave action and sedimentation. If no action is taken, the Breakwater will continue to deteriorate, and, ultimately, fail. More sediment could deposit at the mouth, the Thoroughfare north of the Breakwater will be subject to meandering and flow could breach through what remains of the Breakwater.

- We do not know what, if any, impact the conditions in the Caribou Creek drainage could have on future sedimentation in the Thoroughfare, for existing conditions or in the event that a replacement structure is constructed. Consideration of such impacts were beyond the scope of this study, but should be considered during preliminary and final design of the replacement breakwater.

Based on the foregoing, we considered other types of breakwaters that could stabilize or improve existing conditions at the site. Given the site conditions, results of our analyses, experience and desired changes that a replacement structure should engender, we selected a rock breakwater for consideration. Numerical analyses were undertaken to assess performance of such a structure in the context of wave protection and reducing sedimentation in the Thoroughfare. Results of our analyses suggest that:

- The proposed rock breakwater should reduce meandering and sedimentation in the channel, and should partially deepen the mouth of the Thoroughfare. The proposed breakwater also should improve wave protection for private and public properties. It is possible that some accretion of sediments on the south side of the proposed breakwater could occur over time, providing an opportunity for re-establishment and re-vegetation of portions of the former sand spit. Enhancement of fish habitat was beyond the scope of this study, but can be considered, if warranted, during preliminary and final design.
- Further reduction of shoaling west of and at the mouth of the Thoroughfare might be possible by a small alteration in water elevation control procedure by Avista. Additional analysis is required to develop the specific recommendations to implement this measure. Avista and the Corps of Engineers should be contacted as part of this analysis.
- The proposed rock breakwater should require minimal or no maintenance for a period of 25 to 50 years, or longer.
- An initial, concept-level construction cost estimate for the proposed replacement breakwater is in the range of $864,000 to $1,080,000, not including design and permitting costs.

Recommendations

We recommend that Bonner County consider a rock breakwater for replacement of the existing timber Breakwater at the Priest Lake Thoroughfare. Acquisition of additional data, exploration of subsurface conditions at the site and supplemental numerical modeling will be necessary to confirm the location of the proposed breakwater relative to the existing timber Breakwater. Results of these supplemental tasks also will be used to establish the breakwater geometry (cross section) and top elevation. An evaluation of conditions in the Caribou Creek drainage and potential transport of sediment from the drainage to the Thoroughfare should be part of these supplemental efforts. Results of new data acquisition and analyses will provide the basis for: preliminary design; final plans, specifications and cost estimate; and environmental permitting efforts. We envision the following tentative scope of engineering, design and permitting services:

1. Acquisition of bathymetric and topographic data within and around the project area. The survey area should encompass the Thoroughfare data and Priest Lake to water depths of

at least 40 feet, along the Thoroughfare north and west of the west end of the existing Breakwater on the order of 400 feet, and about ½ mile upstream from the west end of the existing Breakwater.

2. Perform a sediment transport simulation using HEC-RAS hydraulic modeling software version 4.0, or similar to assess possible sediment transport from the Caribou Creek drainage into the Thoroughfare. By applying a hypothetical sediment input to the system and running the model, it should be possible to assess how much sediment could be deposited within the Thoroughfare channel and how much sediment could pass through the channel depositing beyond the end of the breakwater in the deep portion of the lake.
3. Exploration of subsurface conditions along the proposed breakwater alignment, acquisition of sediment soil samples, laboratory testing and geotechnical analyses. We will estimate settlement of the proposed rock breakwater and stability of submarine slopes adjacent to the proposed structure for static and pseudo-static conditions. We also will provide recommendations for mitigating settlement potential and submarine slope instability.
4. Develop a Basis of Design document for the selected preferred alternative. A selection of design parameters such as design life, design storm, habitat requirements, maintenance requirements, design/construction standards and codes, and other applicable criteria will be used in developing a Basis of Design. This task also will include developing and coordinating a detailed plan for bathymetric, topographic, and geotechnical field data collection.
5. Coastal engineering analysis and numerical modeling to refine and optimize the preferred alternative configuration and details of the Thoroughfare and Breakwater. This includes breakwater alignment and length, crest elevation, type of material (sheetpile or rock), dredging requirements, placement of dredged material, and other details.

The detailed coastal engineering analysis will also include the following elements:

   a. Evaluate toe scour to estimate scour depth criteria at locations along the length of the breakwater, taking into consideration varying hydrodynamic and hydrographic conditions.
   b. Evaluate wave transmission relative to breakwater crest height to optimize the crest elevation of the breakwater structure.
   c. Develop wave height criteria for rubblemound structure stone sizing at the breakwater location.
   d. Develop wave loading criteria for vertical sheetpile wall breakwater (if selected as the preferred alternative).

6. Preliminary engineering design to evaluate and optimize possible construction materials, construction methods, and the configuration of the breakwater for the purpose of providing baseline information for developing permit application documents and for estimating construction costs. Engineering analysis will be conducted to develop and refine cross-sectional geometric requirements for the selected breakwater alternative.

The preliminary design of the preferred alternative will be accomplished under this task and will include the following work:

a. Evaluate demolition requirements for the existing breakwater.
b. Develop preliminary design dimensions and layout of the breakwater.
c. Develop gradation for rubblemound structure armor and bedding stone.
d. Develop a quantity and preliminary construction cost estimate for each project element.
e. Develop understanding of construction requirements for development of permit application project description.
f. Develop technical memorandum summarizing preliminary engineering design work.
g. Develop preliminary engineering plans in 11-inch by 17-inch format. The engineering plans will be the basis for the future development of final design drawings, to be completed during the next phase of the project.

7. Develop drawings for environmental regulatory permit applications.
8. Final Engineering Design
    a. Finalize demolition requirements for the existing breakwater.
    b. Develop gradation for rubblemound structures armor, core, and bedding stone layers.
    c. Finalize geometric requirements such as crest width, layer thicknesses, and toe thickness.
    d. Finalize alignment and specify location points for construction.
    e. Specify ground preparation requirements including excavation and geotextile fabric.
    f. Estimate scour to finalize design for structure toe details.
    g. Develop engineering plans and sections.
    h. Develop quantity estimates.
    i. Review requirements for construction of the breakwater, address constructability issues, and make related adjustments to final design.
    j. Develop final design plans in 11-inch by 17-inch and 22-inch by 34-inch formats, and specifications and quantity estimate at 90 and 100 percent levels of completion.
9. Assist with the bidding process by responding to prospective bidder questions and producing technical addenda as necessary. We will also attend a pre-bid meeting and assist with evaluating submittals.
10. Attend five meetings, including meetings with agencies, the County, and public.

11. Environmental Permitting:

Repair of the Priest Lake Thoroughfare Breakwater structure will require an extensive and thorough permit review process. Regulatory authorization will be required from Bonner County, the State of Idaho, and the Federal Government. Despite the fact that written authorization is necessary from several levels of government and many agencies, permitting should be a coordinated effort between the design team and collective regulatory body to maintain project contiguity. While each regulatory authorization process has specific requirements that are unique, many requirements overlap and some are dependent on others. Therefore, for a project of this scope to achieve the appropriate authorizations, it is critical that:

a. A technical team, comprised of representatives from each appropriate regulatory agency and members of the design team, be assembled and maintained throughout the project

b. Meetings and updates occur regularly so individuals don't lose track of progress and decisions that have been made

c. Design parameters remain flexible throughout the permitting process

d. Documents and communication records are clear, up to date, and diligently maintained in a chronological sequence

Specific regulatory authorizations we expect include Bonner County, state of Idaho and Federal agencies.

Bonner County is the local government jurisdiction. We expect the county to require a conditional use permit to be issued for the breakwater structure. Conditional use permits are considered for projects with unique characteristics and are considered individually. To apply for the Conditional Use Permit we expect to submit project-specific plans and details to the Bonner as specified in Title 12, Subchapter 2.2 of the Bonner County Code. We also expect to seek administrative exceptions as applicable to shoreline regulations as specified in Title 12, Subchapter 2.2 of the Bonner County Code. We also expect to seek administrative exceptions as applicable to shoreline regulations because the Idaho Department of Lands will need to issue a Lake Encroachment Permit and the Idaho Department of Water Resources will need to issue a Stream Channel Alteration Permit (see descriptions below).

We expect to coordinate with four Idaho State agencies throughout the permitting process. Of these agencies; three will need to issue regulatory authorization before the project can move forward.

Idaho Department of Environmental Quality (IDEQ) is responsible for implementing Section 401 (water quality certification) of the Clean Water Act on behalf of the Environmental Protection Agency (EPA). Water quality certification will be required before construction of the breakwater can proceed. We expect this process to be closely coordinated with the Section 404 process (see below) because Section 401 conditions are often used, in part, as conditions for Section 404 authorization.

Idaho Department of Lands (IDL) is responsible for issuing a Lake Encroachment Permit under the Idaho Lake Protection Act. The intent of the permit is to weigh the benefit of breakwater structure within the context of private property, navigation, fish and wildlife habitat, aquatic life, recreation, water quality, and aesthetic beauty. Because Priest Lake is a navigable waterway, IDL will need to review the project details and issue a permit before the project can proceed. We expect this process will be iterative with substantial input from multiple agencies and the public at large.

Idaho Department of Water Resources (IDWR) is responsible for issuing a stream channel alteration permit under the Idaho Stream Channel Protection Act. It is somewhat unusual that a Stream Channel Alteration permit and Lake Encroachment Permit are necessary for the same project but because the Thoroughfare has perennial flow, defined bed and banks, and is a documented migration corridor for bull trout, the Stream Channel Alteration permit applies. The intent of the permit is to protect surface water resources, biological communities, and public safety. Like the Lake Encroachment Permit, we expect this process to be iterative with substantial input from multiple agencies and the public at large.

Idaho Department of Fish and Game (IDFG) is not responsible for issuing a specific permit but, as a co-manager of fish and wildlife resources, consultation with them will be mandatory throughout the duration of the project. Some of the permit conditions (local, State, and Federal) are likely to be recommendations made by IDFG.

We expect the ***U.S. Army Corps of Engineers (USACOE)*** to be the lead Federal agency for the project because Priest Lake is considered "waters of the United States." Since dredging and filling will occur below the ordinary high water mark, a Section 404 Clean Water Act permit will be required. We also expect the USACOE will require a Section 10 of the Rivers and Harbors Act permit because Priest Lake is designated navigable by the State of Idaho. It is possible the Section 10 permit won't be required because there is question regarding Priest Lake's federal navigable designation but the USACOE will make the decision on applicability.

Because the USACOE has jurisdiction, the Federal National Environmental Policy Act (NEPA) process will be engaged. The NEPA process will be guided by the USACOE and is intended to give consideration to the environment before moving a project forward. The process many paths and associated timelines ranging from issuance of a Categorical Exclusion (CE) to preparation of an Environmental Impact Statement (EIS). In this case we expect the NEPA could involve the preparation of an Environmental Assessment (EA) and ultimately issuance of a Finding of No Significant Impact (FONSI). However, it must be noted that the process and findings are a Federal responsibility to which GeoEngineers has no control.

Through the NEPA process, the USACOE will be required to coordinate with other regulatory agencies to fulfill their due diligence. As an example, presence of bull trout (*Salvelinus confluentus*) is documented in the project area and the fish are listed, threatened, under the Endangered Species Act (ESA). We expect substantial consultation with the US Fish and Wildlife Service (USFWS) will be necessary to comply with Section 7 and Section 10 of the ESA. Further, given the project area's location within the aboriginal territory of several Indian tribes, it is probable the area was inhabited, at least seasonally, and it is possible that cultural resources exist within the project boundaries. Coordination with the tribes and other interested parties will be initiated to comply with Section 106 of the National Historic Preservation Act (NHPA) so the project is developed in a manner that avoids or minimizes impacts to cultural resources.

Regulatory processes are controlled by each respective agency based on the unique circumstances of the project and their regulatory authority. There is some predictability in the permitting processes; however, it is difficult to predict specific permit conditions, public involvement, plan change requests, additional research needs, and participation by requested entities. For those reasons it is difficult to determine timelines for completion and associated budgets; however, we can offer estimated ranges based on our experience with similar projects.

Our time and budget estimate is based on the following assumptions:

1. The NEPA process will require an EA and result in a FONSI
2. The Federal NEPA process will be the permitting process that takes longest to complete and most detail to satisfy
3. No special fish salvage and/or exclusion design plans will be required
4. No mitigation plans will be required
5. The public will support the project with minimal conditions

We estimate the permitting process could take approximately 18 months. The timeline could be accelerated if we prepare and submit necessary elements of the EA with the permit application documents but doubt the process will take less than a year.

We estimate that the fees associated with the tentative scope of services outlined above could be in the range of $250,000 to $375,000. Please note that the single most uncertain cost is associated with environmental permitting. The preliminary estimated cost range for this element of the project is $75,000 to $150,000. Actual fees also will depend significantly on the cost of the bathymetric and topographic survey, subcontracted offshore subsurface exploration and permitting elements of our services.

LIMITATIONS

Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

Please refer to the appendix titled Report Limitations and Guidelines for Use for additional information pertaining to use of this report.

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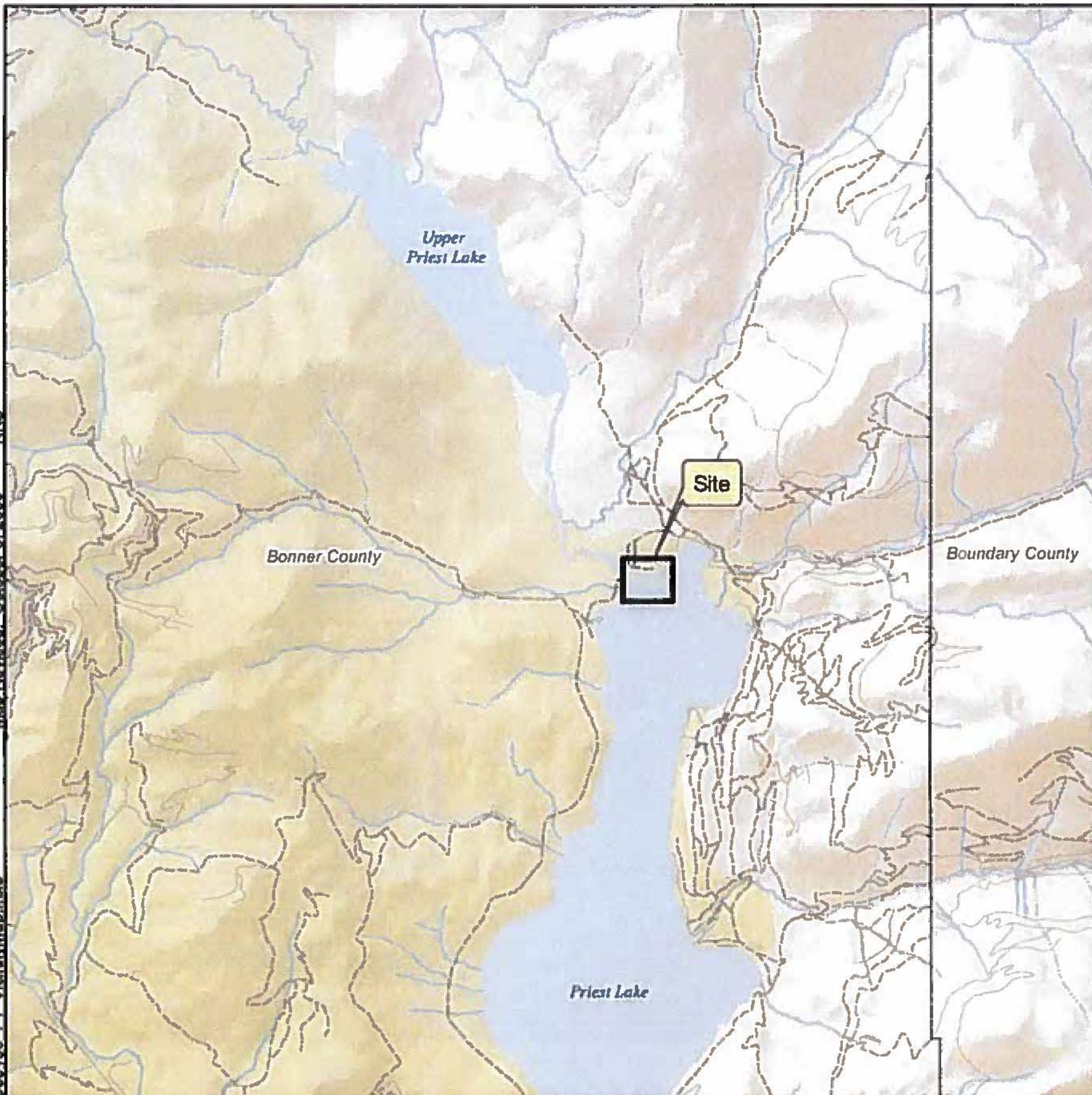

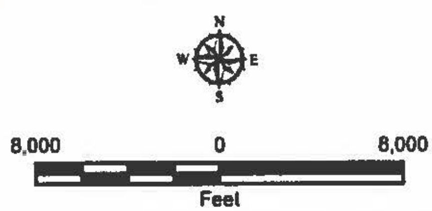

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Data Sources: ESRI Data & Maps, Street Maps 2008

Transverse Mercator, Zone 11 N North, North American Datum 1983
North arrow oriented to grid north

Vicinity Map

Priest Lake Breakwater Study
Priest Lake, Idaho

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Figure 1

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Wave Generation Fetches

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

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Figure 2

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Coeur d'Alene Airport Meteorological Station

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

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Figure 3

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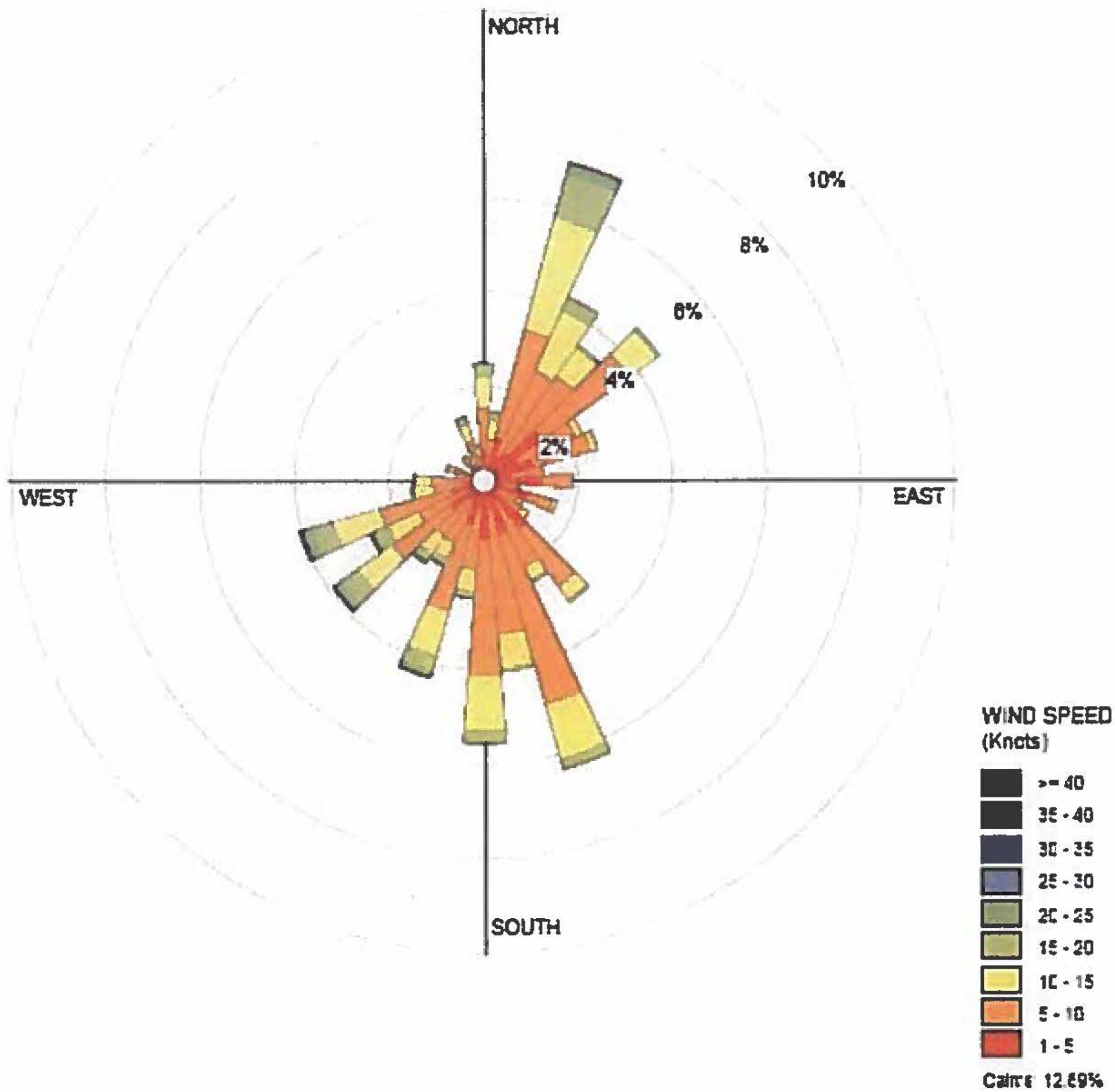

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Wind Rose Based on 60 Years of Wind Data at Coeur d'Alene Airport

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

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Figure 4

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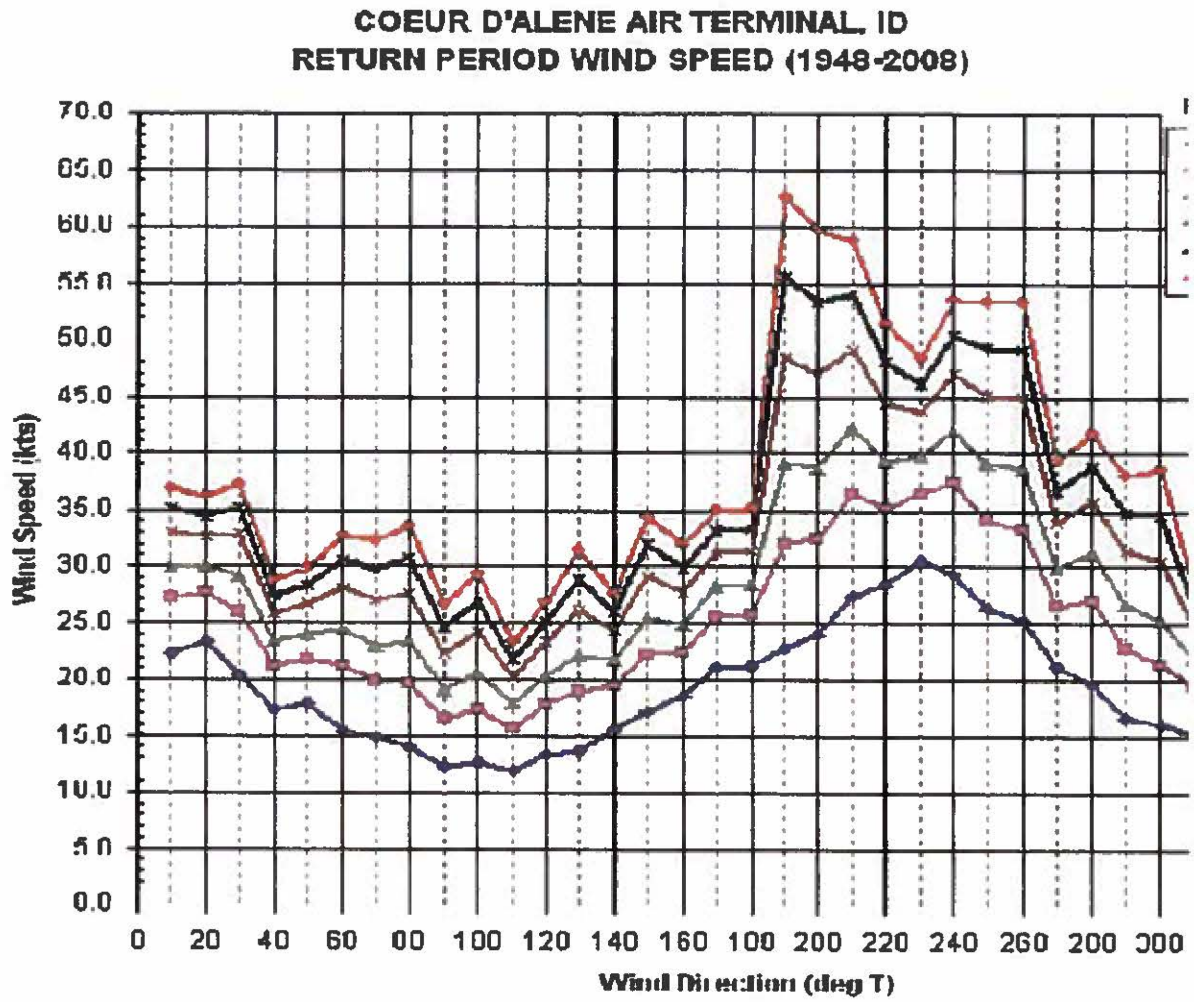

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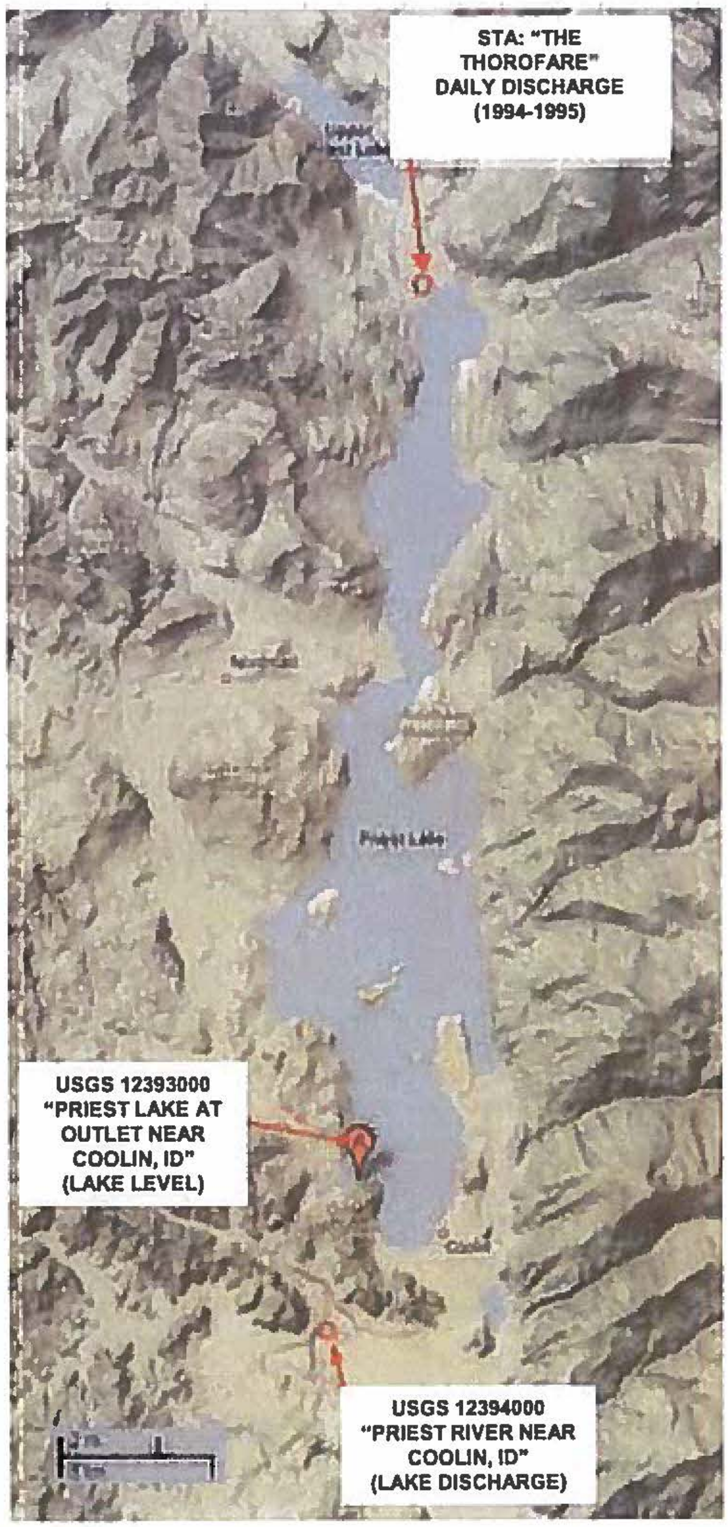

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Priest Lake Water Elevations

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

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Figure 6

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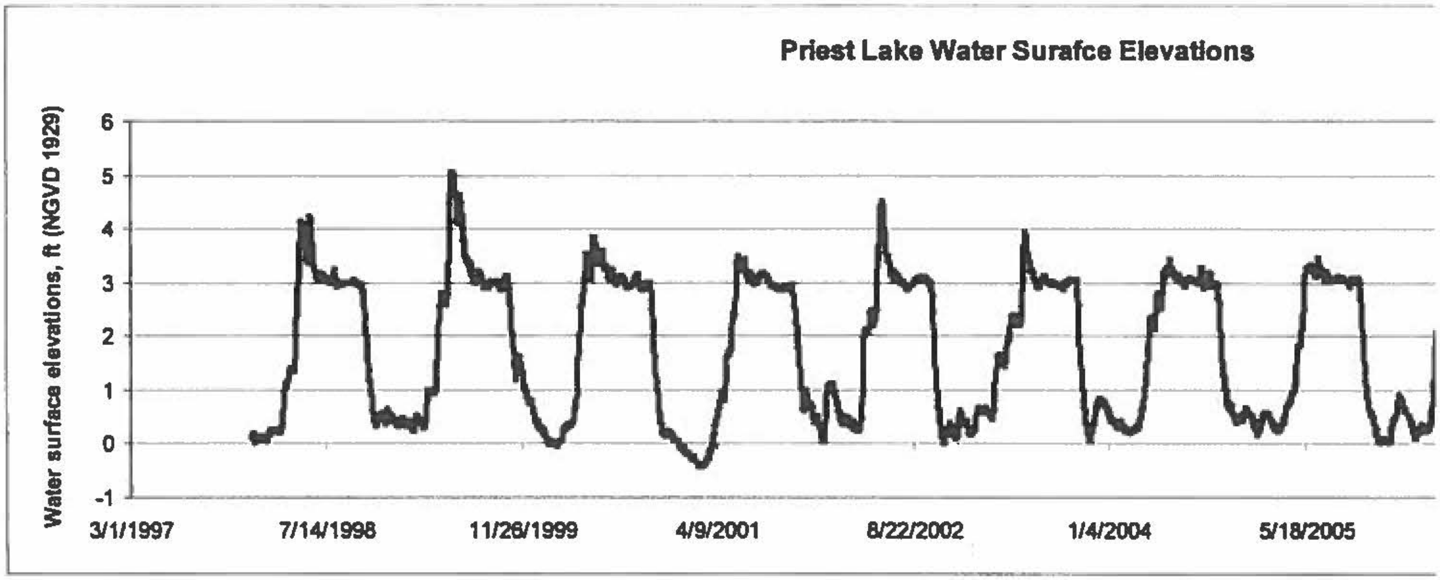

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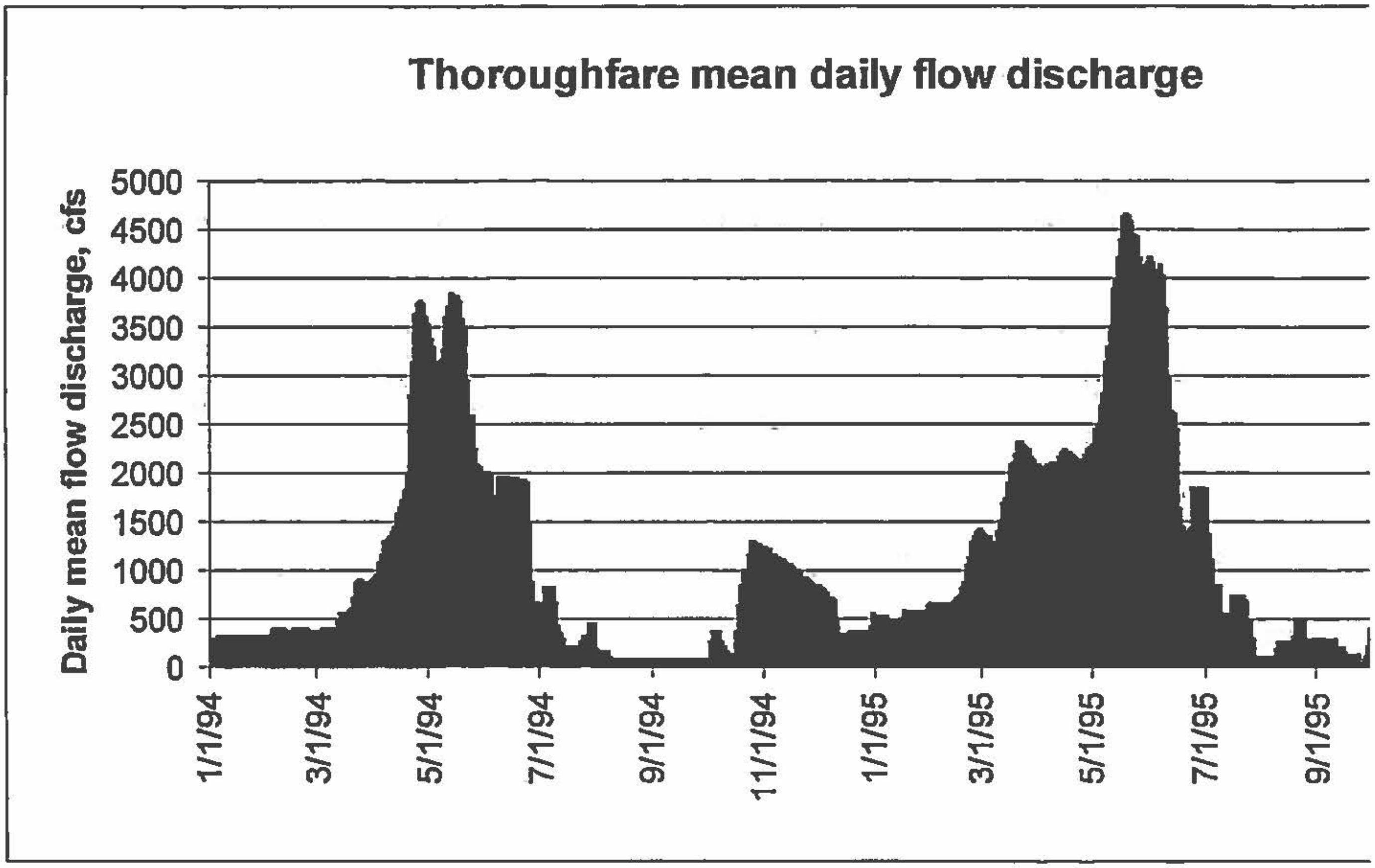

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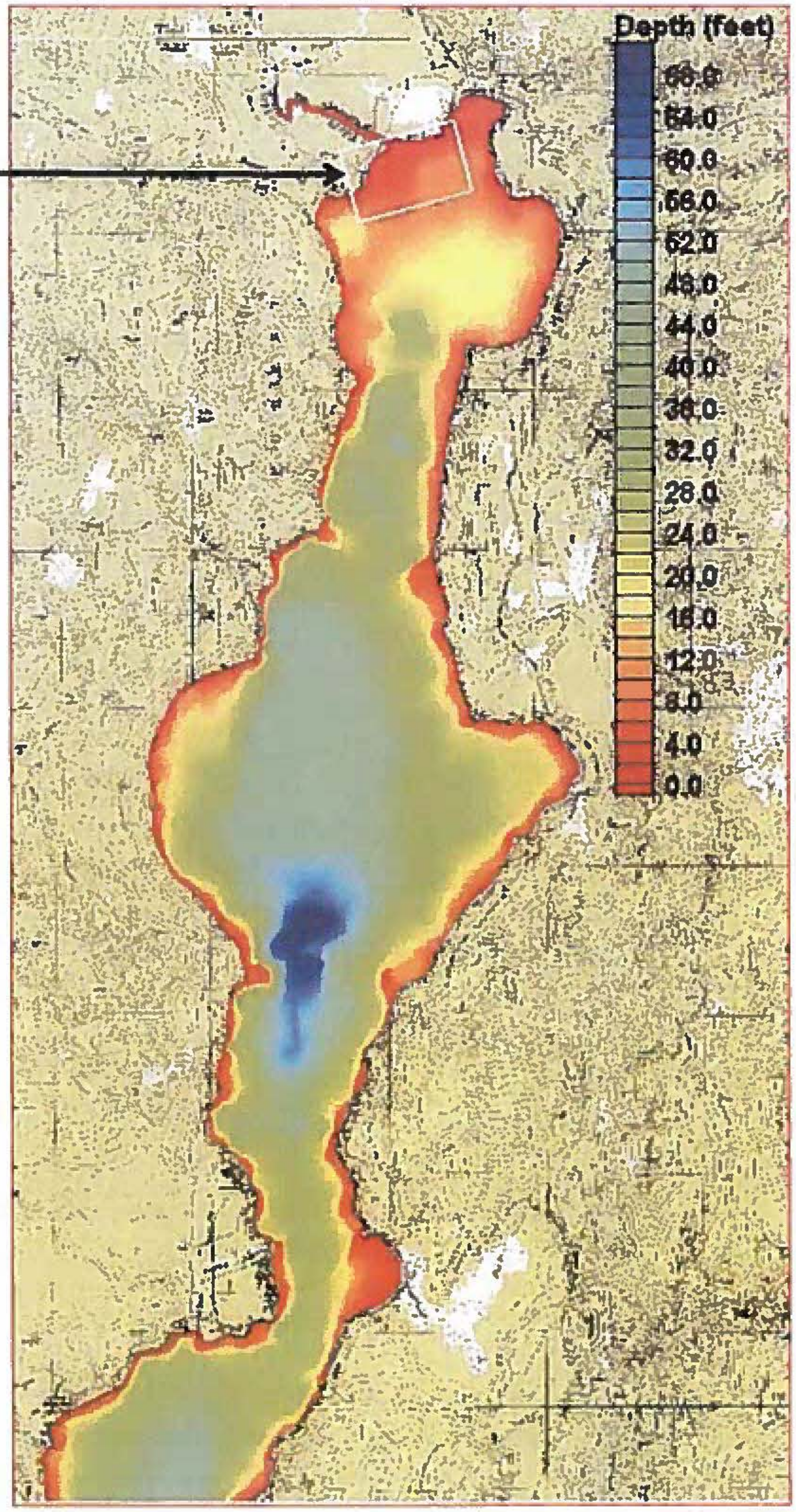
SITE VICINITY



Notes:

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Priest Lake Bathymetry in Color Format

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 9

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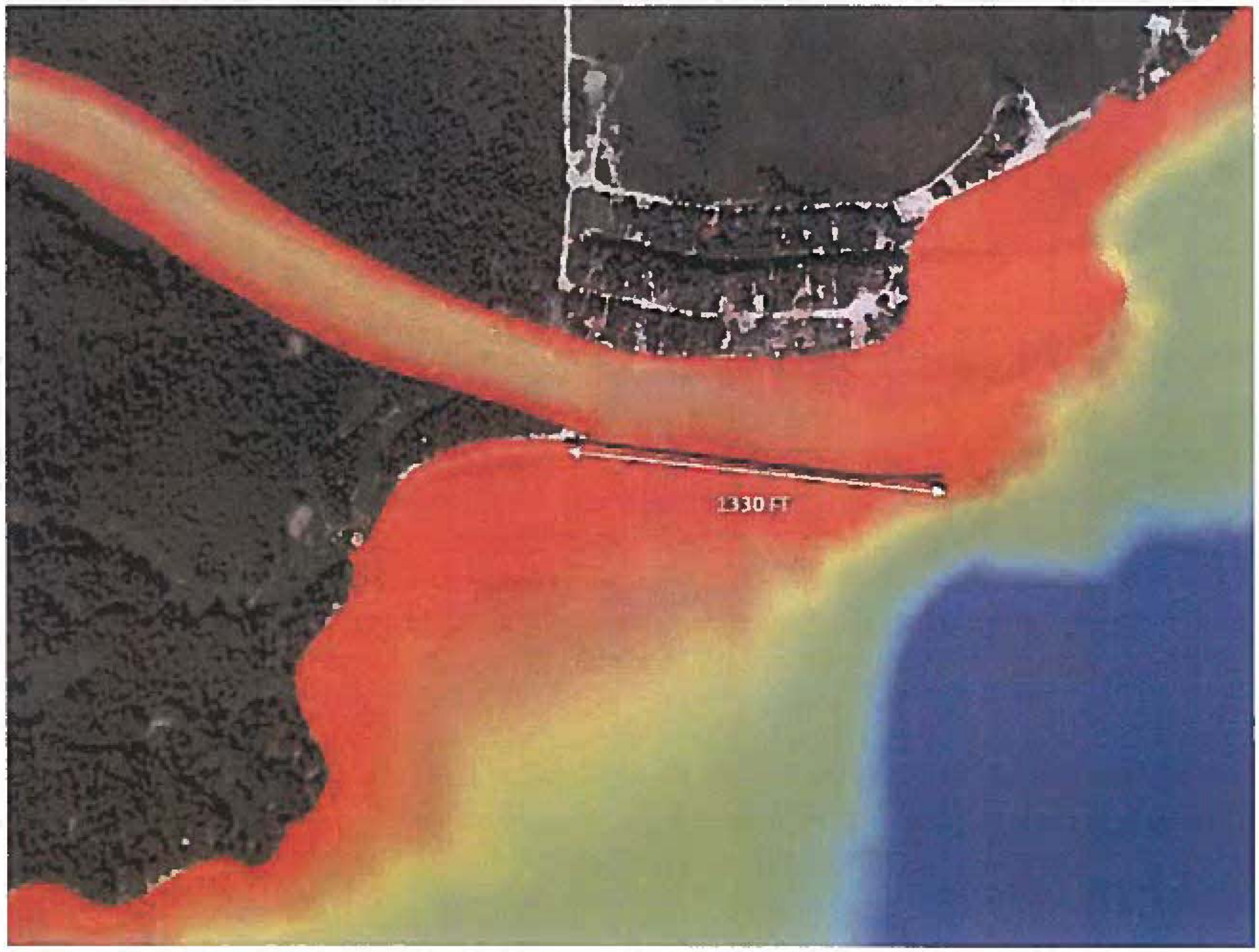

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Bathymetry in Vicin
Validation Study, Priest La Breakwater Replacement n
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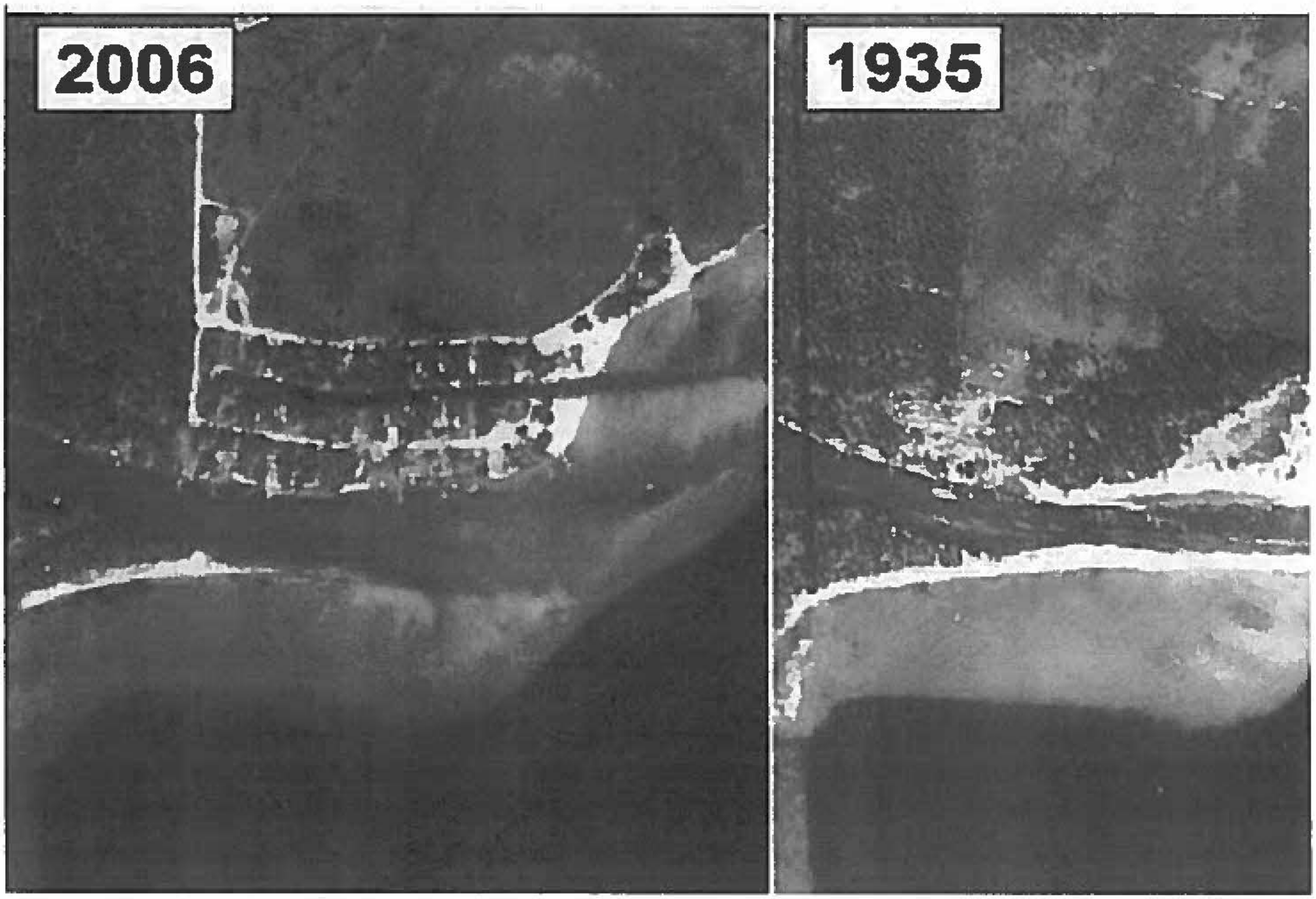

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Rectified Aerial Years 2006 ;
Validation Study, Priest La Breakwater Replacement ne
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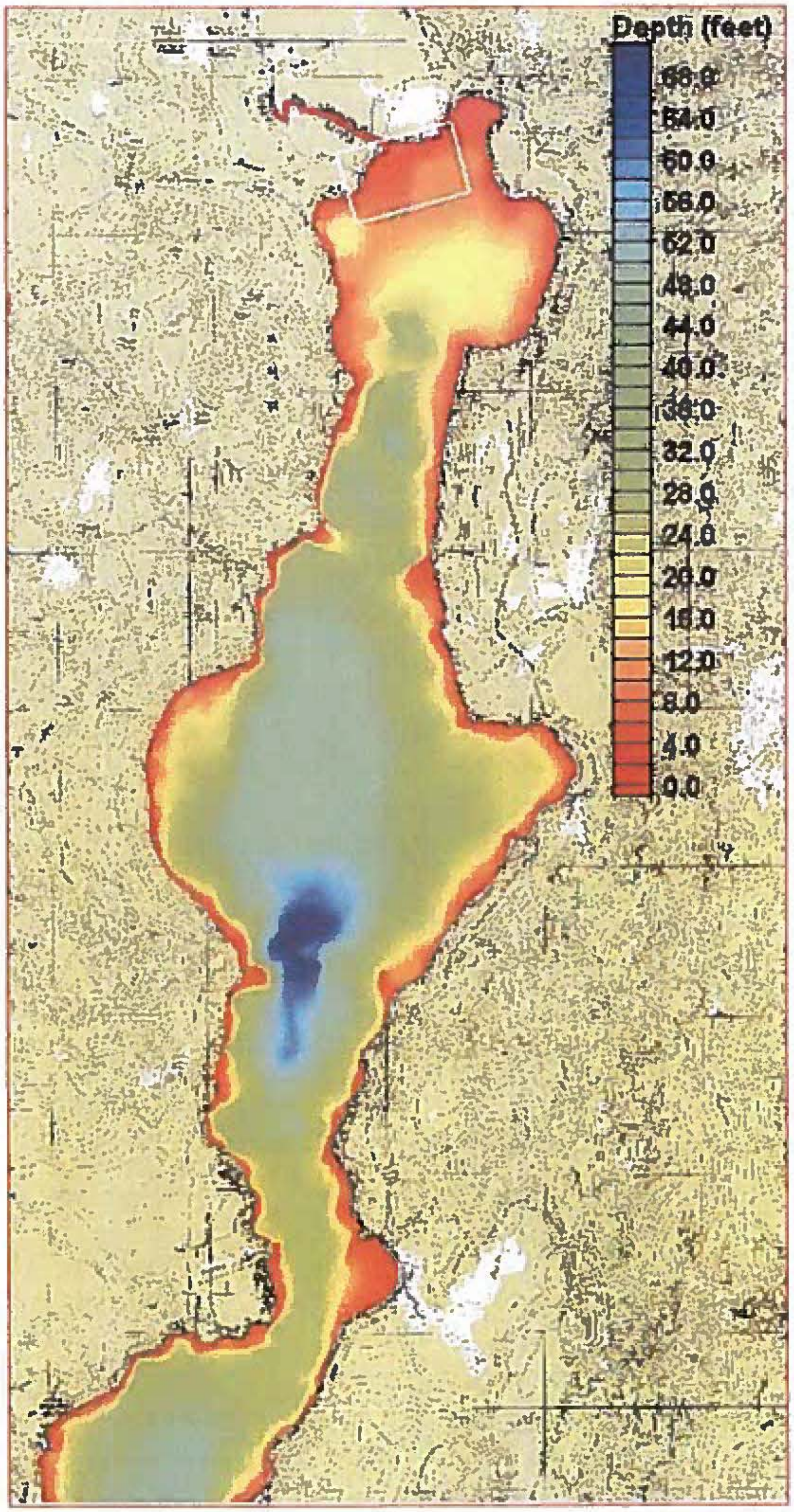

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Modeling Domain for SWAN Wave Model

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS | **Figure 12**

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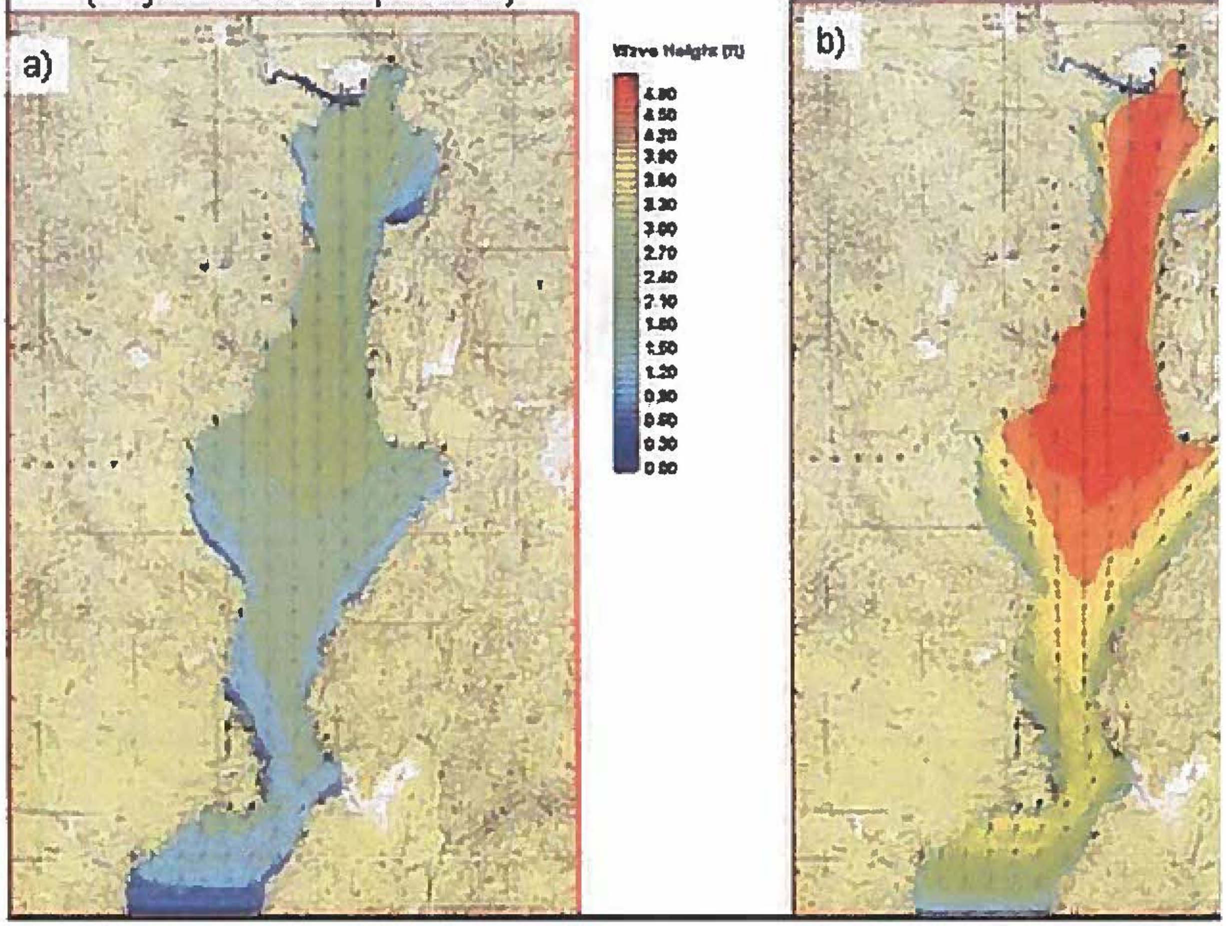
Wave Modeling Results (2-year return period)

Wave Modeling Result (25-year return period



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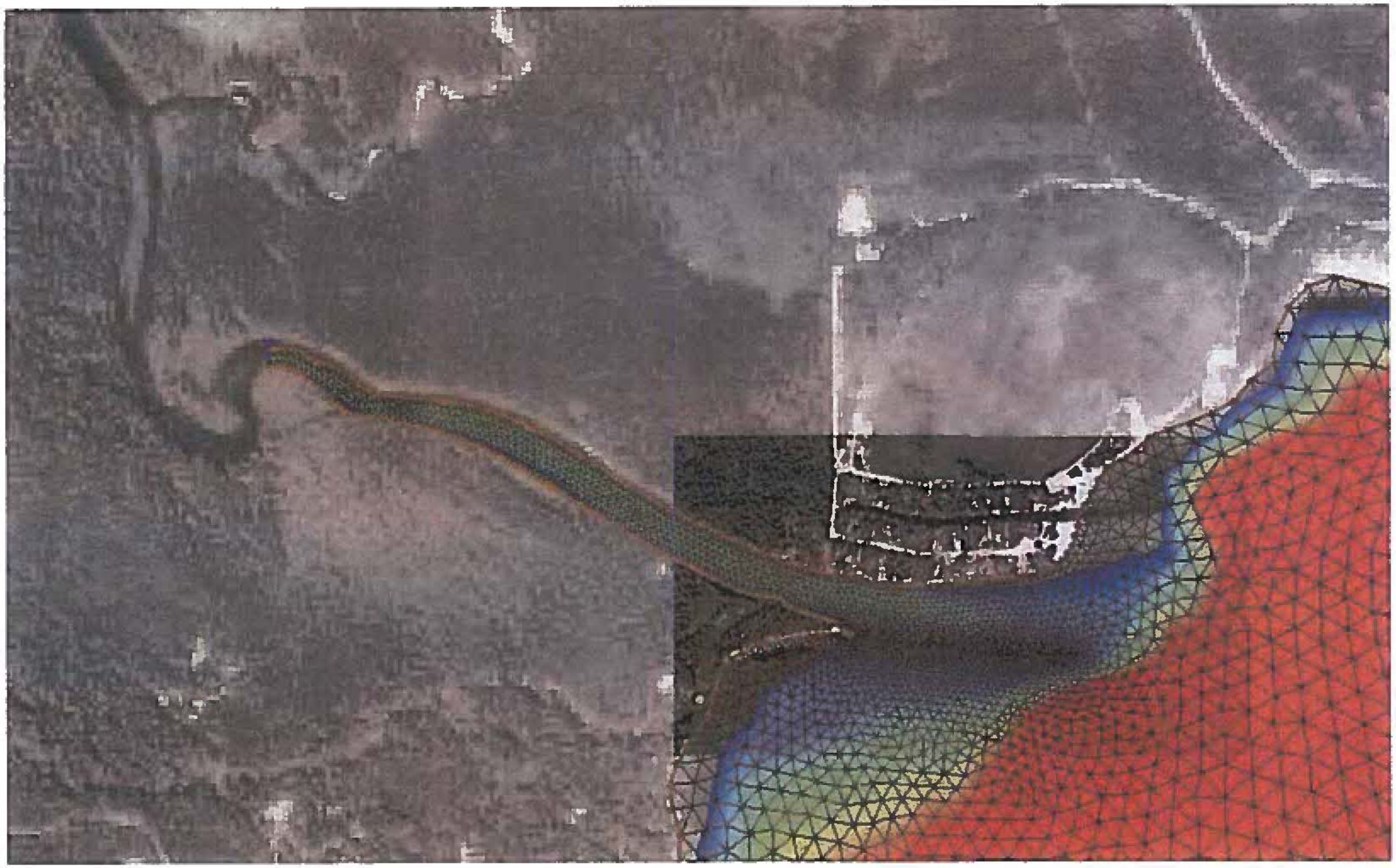
SWAN Wave Model Resu
Storm Retur

Validation Study, Priest La
Breakwater Replacement n

GEOENGINEERS



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Nested Modeling Grid

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 14

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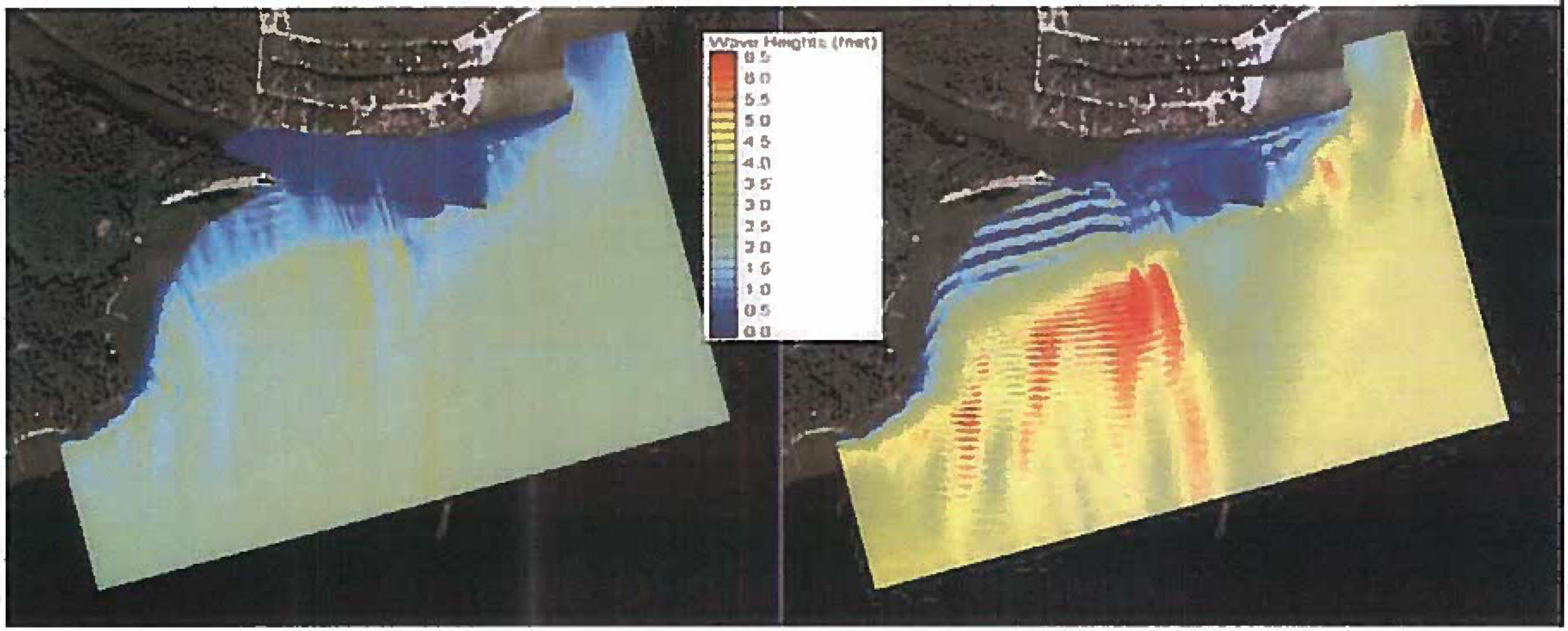
a) 2-year Return Period

b) 25-year Return Period



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HWAVE Wave Model for 2-Year and 25-Year Storm Return Periods

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 15

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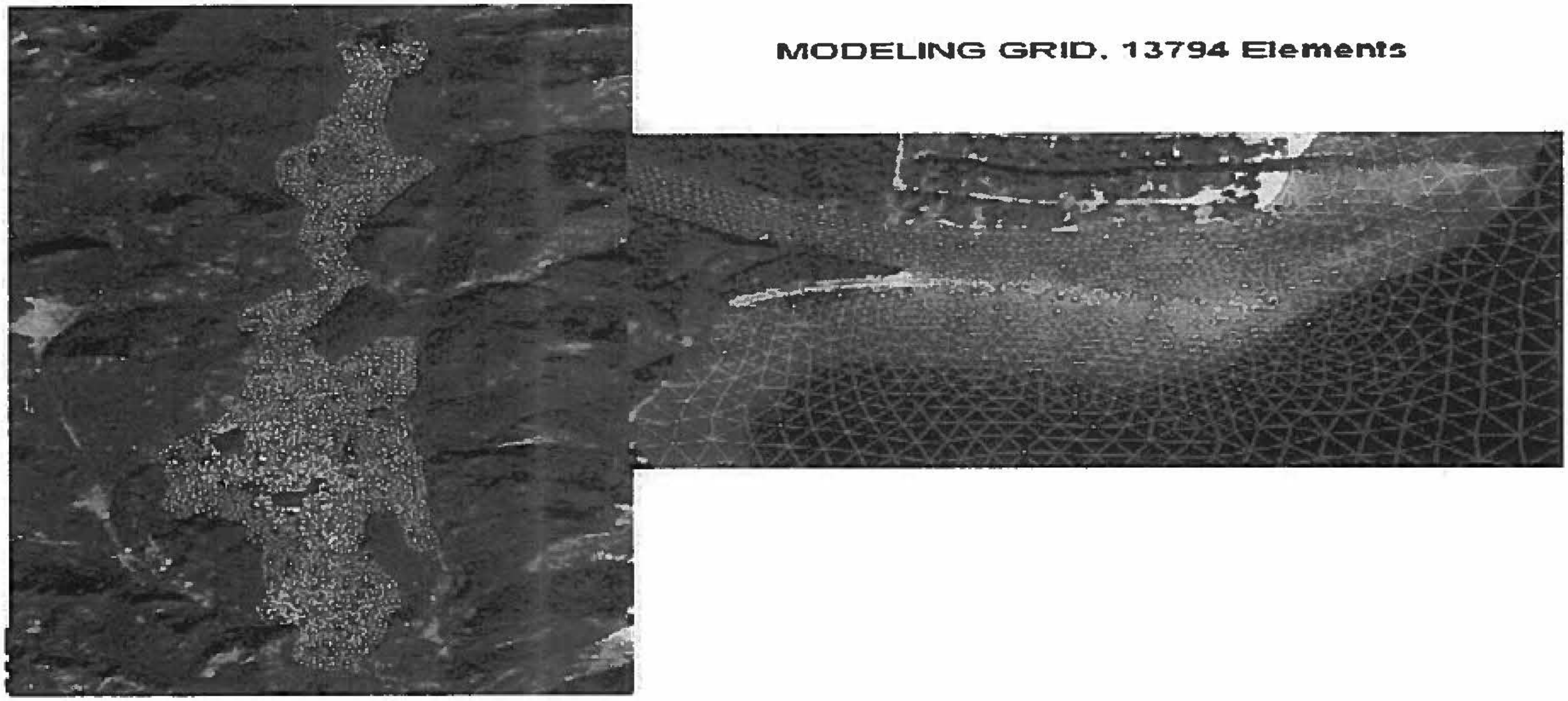
MODELING GRID, 13794 Elements



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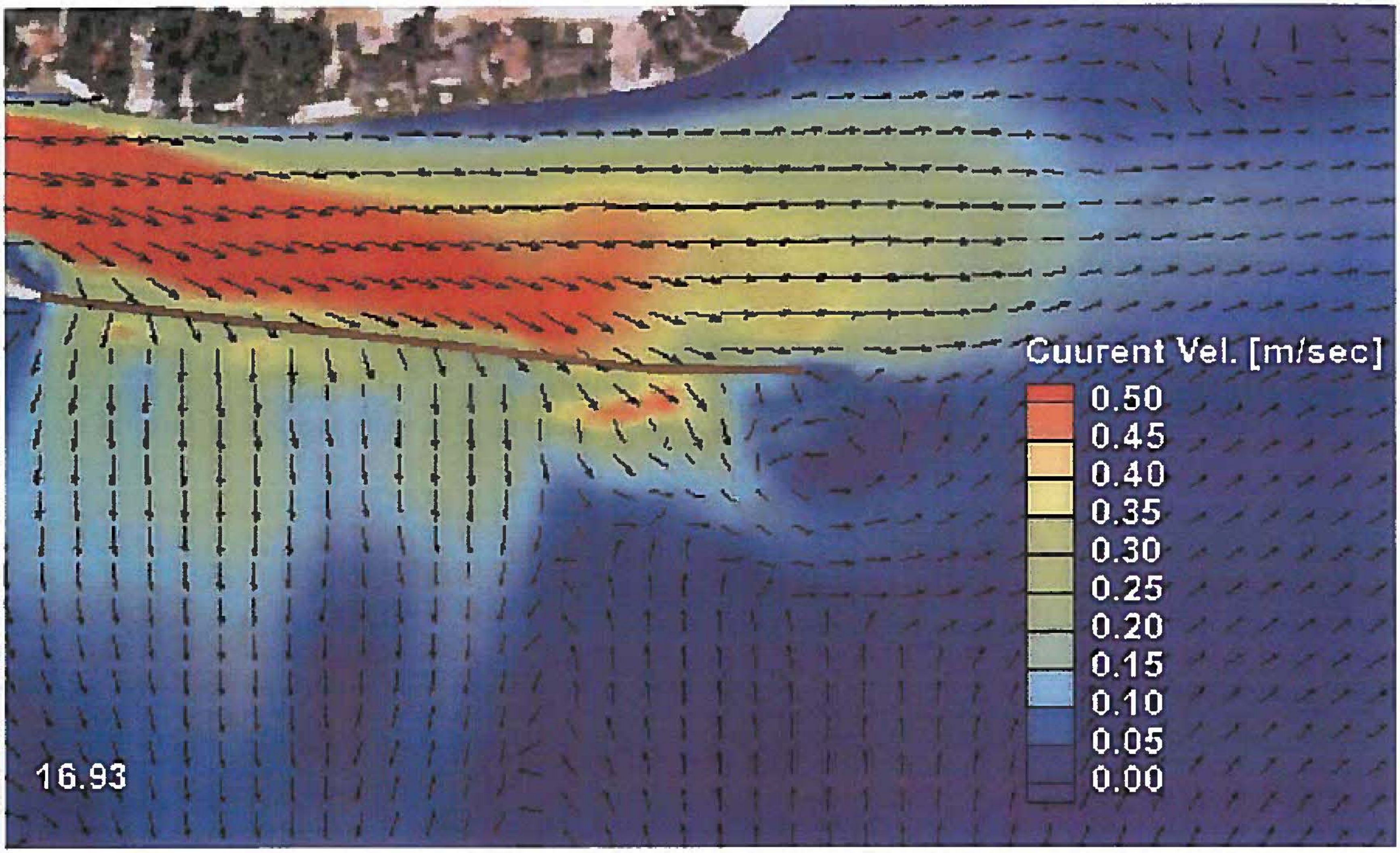
Numerical Modeling Grid for SELFE and MORPHO Models

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 16

Spo:\17\1799001\00\Finals\179900100Figures_landscape.ppt JBH:tlm 10/02/09



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Velocity Model Results Example

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

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Figure 17

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MORPHO Model Results
Sedimentation for 1-Year Period

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS | **Figure 18**

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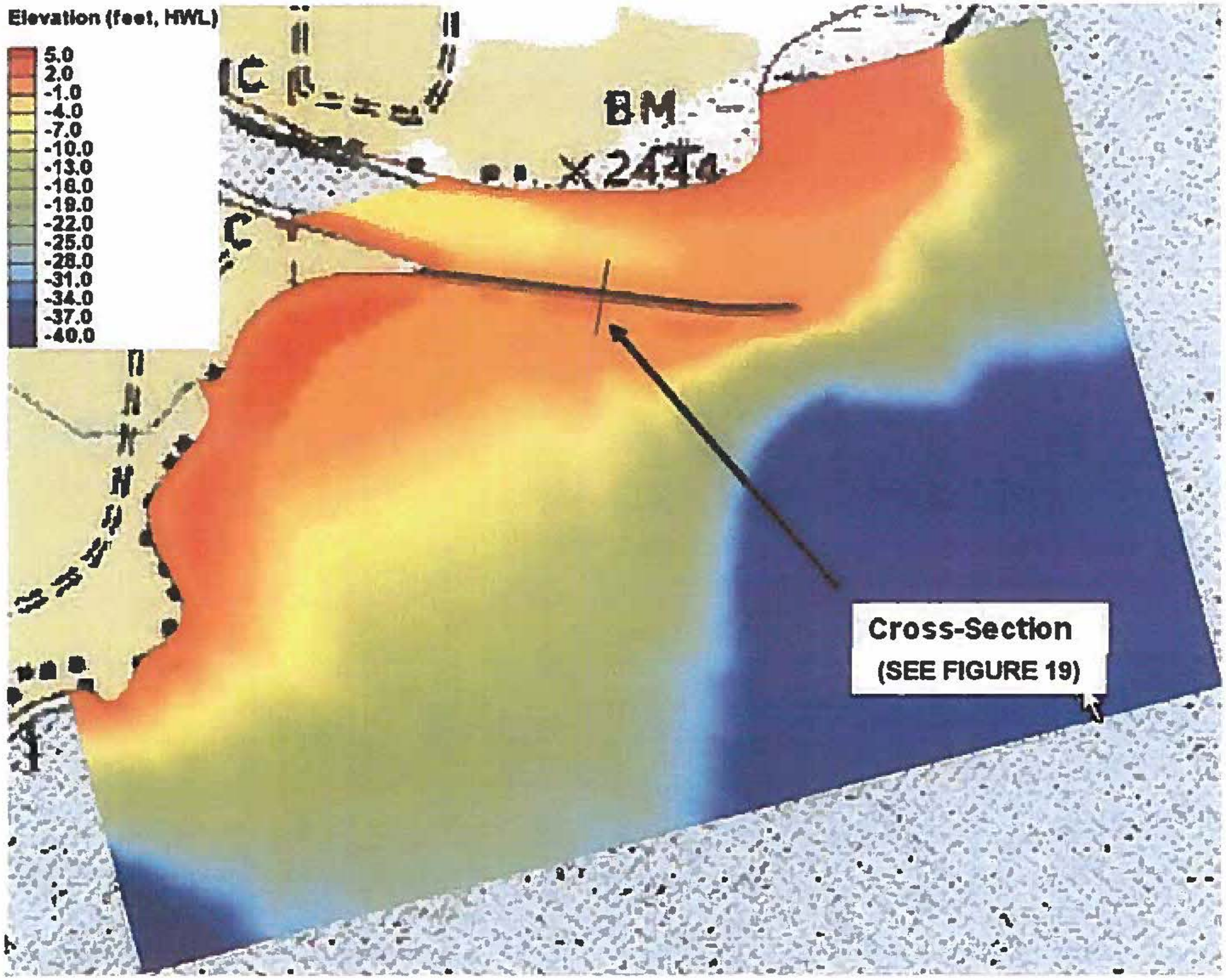

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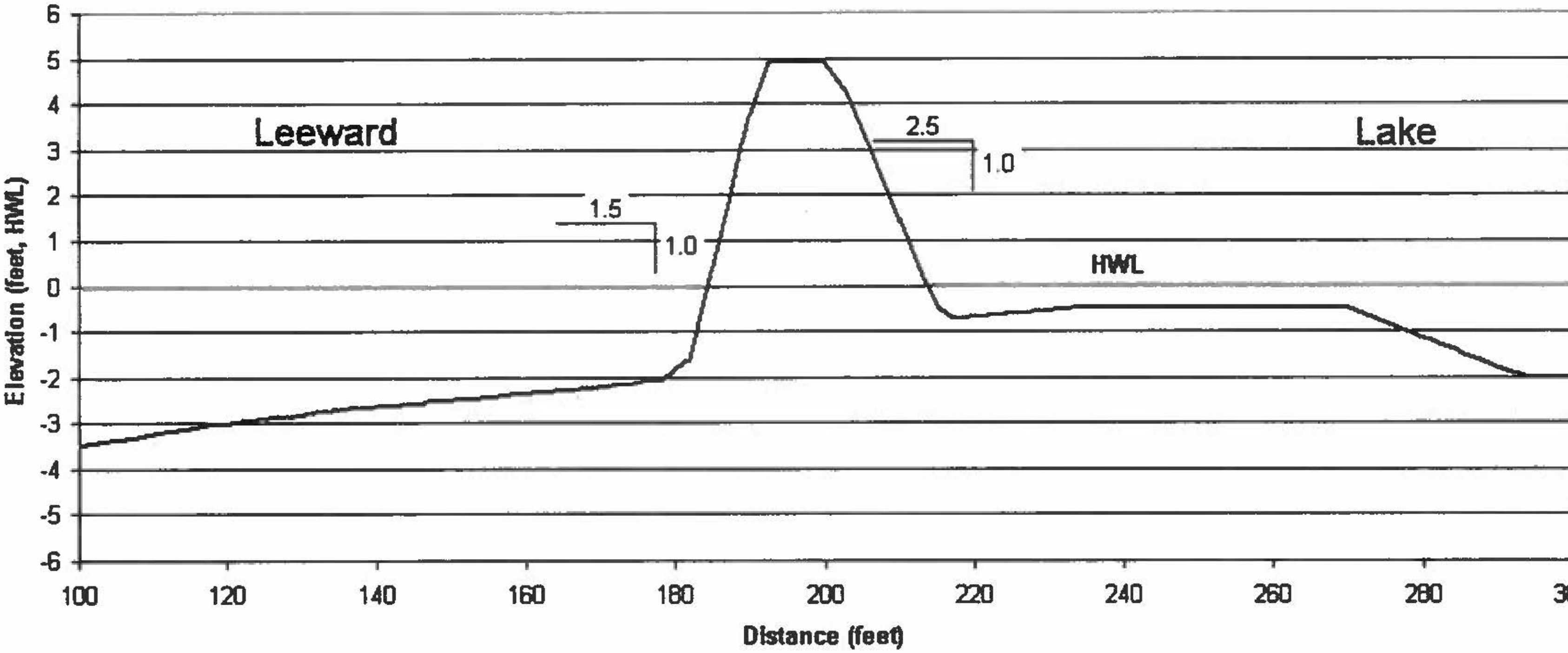
Proposed Breakwater Alignment

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 19



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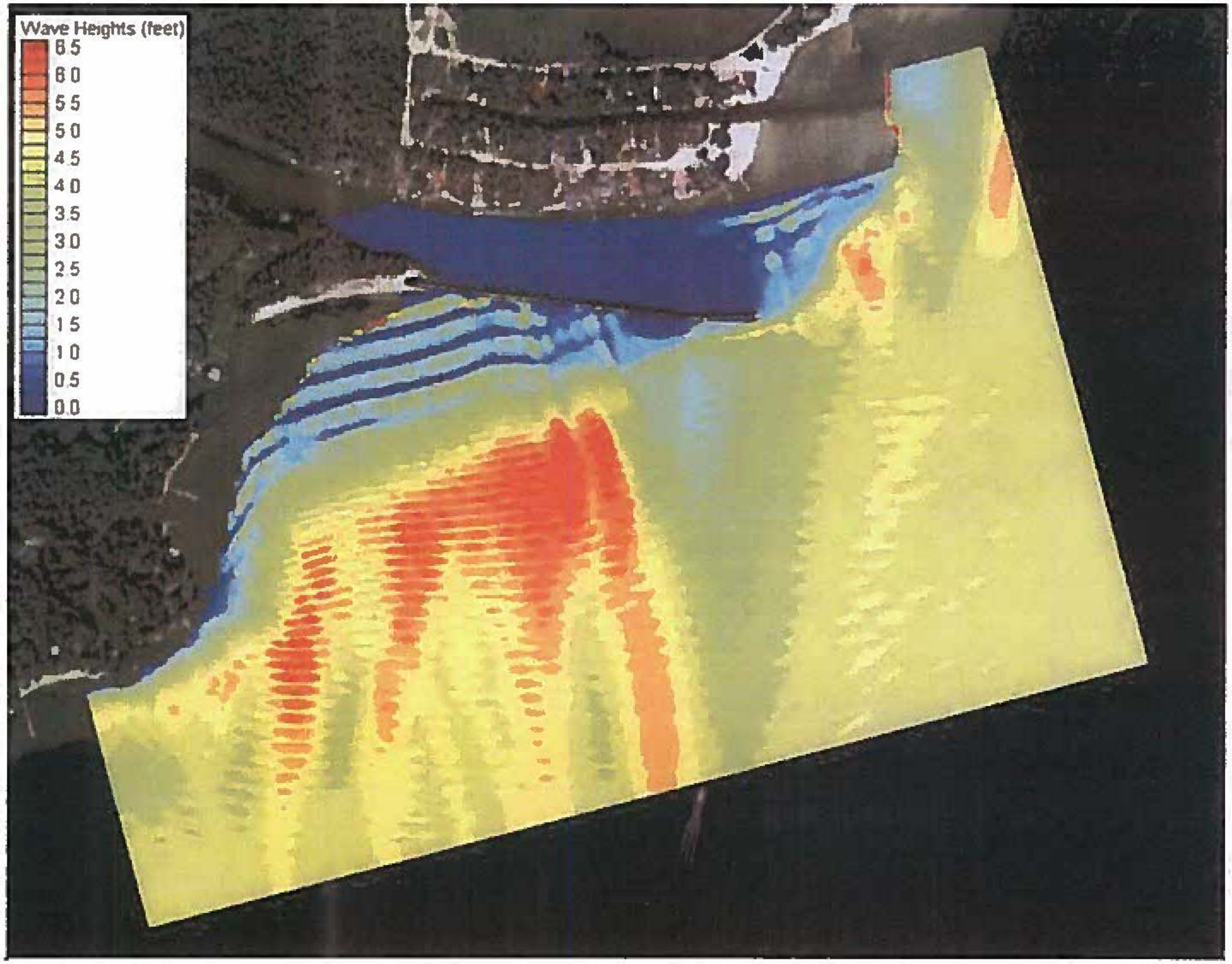
3. Lake and leeward bottom elevations likely are not representative of actual conditions. This figure is a schematic illustration.

Conceptual Cross Section
Rock Breakwater

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 20



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Proposed Breakwater, HWAVE Model 25-Year Storm Return Period	
Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho	
GEOENGINEERS	**Figure 21**

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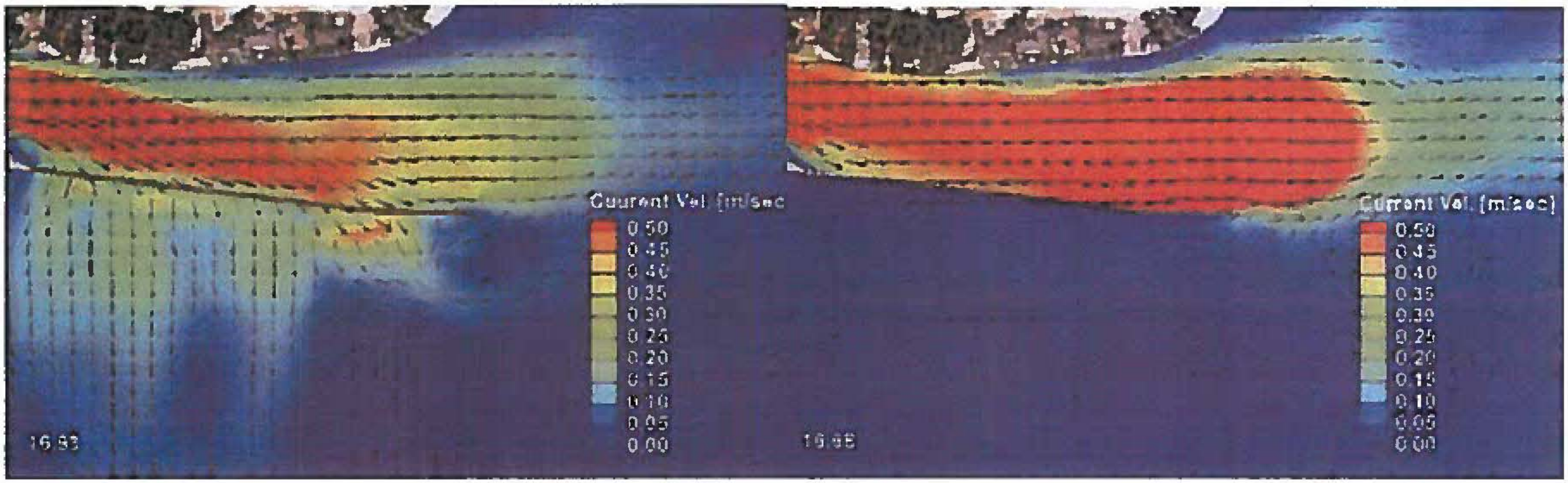

EXISTING **PROPOSED**

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Flow Model during One Instant, (a) Existing Conditions and (b) Proposed Breakwater

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

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Figure 22

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Current Velocity Differences
Proposed Breakwater minus Existing Conditions

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 23

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EXISTING **PROPOSED**

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Results of MORPHO Model, 1-Year Return Period Sedimentation (a) Existing Conditions and (b) Proposed Breakwater
Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho
GEOENGINEERS — **Figure 24**

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Rendering, Proposed Breakwater Effect on Existing Thoroughfare

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 25

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East River Quarry Rock

Validation Study, Priest Lake Thoroughfare and Breakwater Replacement near Priest River, Idaho

GEOENGINEERS

Figure 26

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