FINAL REPORT
LAKE HATTIE OUTLET WORKS
LEVEL II STUDY

November 1, 2003

Prepared For:
Wyoming Water Development Commission
6920 Yellowtail Road
Cheyenne, Wyoming 82002

Prepared By:
WWC Engineering
611 Skyline Road
Laramie, Wyoming 82070

Subconsultants:
Simons & Associates, Inc.
P.O. Box 3000, PMB 307
Edwards, CO 81632

University of Wyoming
P.O. Box 3295
Laramie, WY 82071

Rio Verde Engineering
P.O. Box 642
Pinedale, WY 82941
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 INTRODUCTION</strong></td>
<td>1</td>
</tr>
<tr>
<td>1.1 – Study Scope</td>
<td>2</td>
</tr>
<tr>
<td>1.2 – History (As previously summarized in Lake Hattie Rehabilitation Project, Level II Final Report dated March 14, 1986)</td>
<td>2</td>
</tr>
<tr>
<td>1.3 – Project Meetings</td>
<td>5</td>
</tr>
<tr>
<td><strong>2.0 WIND, WAVE, AND SEDIMENT MECHANICS EVALUATION</strong></td>
<td>8</td>
</tr>
<tr>
<td>2.1 – Review of Available Information</td>
<td>8</td>
</tr>
<tr>
<td>2.2 – Site Visit</td>
<td>12</td>
</tr>
<tr>
<td>2.3 – Sediment Sampling</td>
<td>13</td>
</tr>
<tr>
<td>2.4 - Hydraulic and Sediment Transport Analysis</td>
<td>15</td>
</tr>
<tr>
<td>2.5 - Summary and Recommendations</td>
<td>17</td>
</tr>
<tr>
<td><strong>3.0 LAKE OUTLET STRUCTURE EVALUATION</strong></td>
<td>20</td>
</tr>
<tr>
<td>3.1 – Recommended Design Alternatives</td>
<td>25</td>
</tr>
<tr>
<td><strong>4.0 OPERATION PLAN</strong></td>
<td>27</td>
</tr>
<tr>
<td><strong>5.0 PRELIMINARY PLANS &amp; COST ESTIMATES</strong></td>
<td>28</td>
</tr>
<tr>
<td>5.1 – Preliminary Design</td>
<td>28</td>
</tr>
<tr>
<td>5.2 – Cost Estimate</td>
<td>34</td>
</tr>
<tr>
<td><strong>6.0 ECONOMIC ANALYSIS</strong></td>
<td>36</td>
</tr>
<tr>
<td>6.1 – Funding Components</td>
<td>36</td>
</tr>
<tr>
<td>6.2 - PCLHID Financing Options</td>
<td>37</td>
</tr>
<tr>
<td>6.3 – Additional Funding Sources</td>
<td>37</td>
</tr>
<tr>
<td><strong>7.0 CONCLUSIONS AND RECOMMENDATIONS</strong></td>
<td>39</td>
</tr>
</tbody>
</table>

# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 – Location Map</td>
<td>1</td>
</tr>
<tr>
<td>1.2 – Existing Outlet Works Cross Section</td>
<td>4</td>
</tr>
<tr>
<td>1.3 – Cost per Share Analysis</td>
<td>6</td>
</tr>
<tr>
<td>2.1 – Summary of Wind Velocity (based on 5 second maximum data)</td>
<td>9</td>
</tr>
<tr>
<td>2.2 – Recent History of Lake Hattie Water Levels</td>
<td>10</td>
</tr>
<tr>
<td>2.3 – Typical Cross-Section Showing Bank Erosion along Southern Shoreline near Existing Outlet Structure</td>
<td>11</td>
</tr>
<tr>
<td>2.4 – Vertical banks along southern lake shore</td>
<td>12</td>
</tr>
<tr>
<td>2.5 – Sediment Sample Locations</td>
<td>13</td>
</tr>
<tr>
<td>2.6 – Grain Size Distribution Analysis Results</td>
<td>14</td>
</tr>
<tr>
<td>2.7 – Typical Gradation Curve</td>
<td>15</td>
</tr>
<tr>
<td>2.8 – Wave Height vs. Wind Velocity</td>
<td>16</td>
</tr>
<tr>
<td>5.1 – Diversion Wall Diagram</td>
<td>29</td>
</tr>
<tr>
<td>5.2 – Intake “Silo” Diagram</td>
<td>30</td>
</tr>
<tr>
<td>5.3 – Recommended Design Alternative Cost Summary</td>
<td>34</td>
</tr>
</tbody>
</table>
LIST OF APPENDICES

Appendix

A – Design Alternatives
B – Cost Estimates
1.0 INTRODUCTION

Lake Hattie Reservoir is located approximately 15 miles west of Laramie in southwest Albany County. The reservoir is fed by canals from both the Big and Little Laramie Rivers and was constructed to provide storage capacity for irrigation water drawn from these rivers. The stored water is released through large control gates and outlet pipes into the Hattie Canal No. 1. This canal provides irrigation water to the ranchlands along the North Canal and the lower section of the Pioneer Canal.

![Figure 1.1: Location Map](image)

The outlet pipes and control gates are located in the southeastern corner of the lake in an area which has historically seen significant sediment deposition. This continued sediment deposition has led to ongoing operation problems with the control gates and the outlet pipes as well as sediment problems in the first stretch of the Hattie Canal No. 1.
1.1 – Study Scope

This report is the culmination of a Level II study commissioned in the spring of 2003 by the Wyoming Water Development Commission (WWDC). The stated purpose of this study is to “evaluate the feasibility of revising the operations and rehabilitating the outlet works of Lake Hattie Reservoir.” As part of this study the design team of WWC and its sub-consultants worked in cooperation with members of the State Engineer’s Office (SEO), the WWDC, and the Pioneer Canal-Lake Hattie Irrigation District (PCLHID) to solicit their valuable input as well as to inform them of the study findings. The source and the mechanics of the sediment deposition were evaluated for varying wind and wave conditions in the area surrounding the outlet structure. The history and operation of the existing outlet structure were reviewed for possible improvements. Dozens of outlet structure modifications were evaluated in terms of effectiveness and cost. Of these modifications a few choice alternatives were explored in more depth and recommendations made regarding their construction, operation, and maintenance. Preliminary plans and cost estimates were prepared for each of the recommended alternatives to aide in the selection process. Throughout the evaluation of alternatives the design team has worked closely with all parties involved to provide and explain preliminary cost estimates and to gather feedback on the projects financial limitations. A combination of design alternatives is recommended for further study and final design. This report concludes with a conceptual design and operational plan of the recommended combination of design alternatives.

1.2 – History (As previously summarized in Lake Hattie Rehabilitation Project, Level II Final Report dated March 14, 1986)

In the early 1900’s there was extensive interest in the potential for developing the water and land resources in the vicinity of Laramie. Plans were made to divert waters into the Laramie River basin from Douglas Creek and its tributaries (all tributaries of the North Platte River) and to develop storage and distribution canals on the Laramie Plains. Most of the plans never came to fruition. However, those for the construction of Lake Hattie Reservoir were realized.

On May 11, 1908, the Laramie Water Company filed for a water right to store 60,000 acre-feet in Lake Hattie Reservoir. It became obvious shortly afterwards that a different dam site (the present dam) would provide more storage capacity with a lower embankment. Thus, an
application for a permit to enlarge Lake Hattie Reservoir with a relocated dam was filed on September 18, 1908. The enlargement was to bring the total active storage capacity of the reservoir to 68,500 acre-feet.

The Laramie Water Company applied for water rights to divert water from both the Big and Little Laramie Rivers to supply Lake Hattie Reservoir. The records of the Laramie Rivers Company (J.G. White & Co., 1912) indicate that over 60,000 acre-feet of water was diverted to Lake Hattie in 1912. Apparently the supply canals and the dam were completed prior to the spring runoff of 1912.

Over the years, the ownership of Lake Hattie Reservoir changed several times. Because the revenues from the sale of water were not great, little maintenance work was carried out. In 1972, due to disintegration of the upstream slope protection of the dam, the State Engineer limited storage in Lake Hattie to no higher than elevation 7,263 feet, or approximately 27,400 acre-feet of active storage. This order by the State Engineer stood until Lake Hattie again changed ownership and the Laramie Rivers Company became active. In 1980, the Laramie Rivers Company obtained financing from the Wyoming Department of Economic Planning and Development (DEPAD) and the Wyoming Farm Loan Board to repair the dam. That same year the Wheatland Irrigation District filed an abandonment petition with the Board of Control seeking to abandon the portion of storage capacity in Lake Hattie which had not been used because of the State Engineer’s limitation order. Repair of the dam was accomplished in 1983 with cooperation from the City of Laramie. With the dam repaired, the State Engineer’s order was rescinded and Lake Hattie received water during the high water year of 1983. The diversion of water to Lake Hattie helped reduce the flooding in the City of Laramie during the flood period of 1983. Some water was also diverted from both the Big and Little Laramie Rivers for storage in the reservoir during 1984 and 1985.

The petition for abandonment filed by the Wheatland Irrigation District was considered by the Board of Control and the Wyoming Supreme Court. In October 1985, the Supreme Court issued its decision stating that the permitted storage in Lake Hattie should be reduced to that capable of being stored below elevation 7,263 feet, or about 27,400 acre-feet of active storage. The lost storage volume in Lake Hattie was again filed on in 1986 but the likelihood of water levels exceeding elevation 7,263 feet was greatly reduced.
In 1985 WWDC contracted with Western Water Consultants, Inc. (WWC), in association with PRC Engineering Corporation and Western Research Corporation to conduct a Level II Study of The Lake Hattie Rehabilitation Project. This Level II Study included an evaluation of the outlet structures at that time which consisted of four 48” cast iron conduits controlled by four slide gates at the downstream toe of the dam. These slide gates were largely submerged during the inspection but a good deal of rust was noted. The Pioneer Canal-Lake Hattie Irrigation District was formed in 1987 and took over ownership and maintenance on Lake Hattie. Also in 1987, WWC completed the Preliminary Designs and Report for the Lake Hattie Rehabilitation Project, Level II – Phase II. These designs were realized in 1990 when built up sediment was removed and a new control gate structure was constructed on the upstream side of the dam. These new slide gates were oriented on a slant so that their opening stems ran up the face of the dam.

No significant improvements have been made to the outlet pipes or control gates since 1990. In the past 13 years sediment has steadily been deposited in the area surrounding these control gates as well as in the downstream canal. Currently the outlet gates are buried by the sediment such that they can not be opened. In attempts to open a few of the gates, members of the irrigation district have broken at least one of the operating stems.

It is important to note that the amount of water diverted to Lake Hattie fluctuates dramatically from year to year depending on snow and rainfall in the region. The Wheatland Reservoirs have senior water rights to Lake Hattie’s water right and for that reason there are many years in which Lake Hattie receives little to no inflow. Furthermore, the reservoir loses approximately three vertical feet of stored water a year to evaporation. In prolonged dry periods no water is diverted to the lake and there may not be any water available for release. In the past
few years in particular the water level in Lake Hattie has been very low, even lower than the outlet structure. This point is important in two ways. The first is that any improvements must be designed to withstand long periods of drought and still function properly in the scattered flood years. Secondly, water level fluctuations are important because they mean that Lake Hattie is not a reliable source of irrigation water for the PCLHID. This lack of reliability limits the commitment of the irrigation district to fund improvements.

1.3 – Project Meetings

Throughout the course of this study and report the design team has attended the monthly meetings of the PCLHID Board of Directors to share progress updates and to gather information regarding the district member’s first-hand knowledge of the recent and historical operation of Lake Hattie. A brief summary of the meeting minutes follows:

The first meeting on July 9th provided an opportunity to introduce the design team and for all parties to express their expectations of this study. The design team sought the observations and perceptions of the PCLHID Board members on the sedimentation problems at Lake Hattie. The Board members explained some solutions they have tried and offered a few new alternatives to explore further.

A second meeting on August 12th gave the design team an opportunity to share their preliminary findings on the sources and transportation mechanics of the sediment being deposited on the outlets. The design team also explained several alternatives that had been explored and discussed the advantages and disadvantages of each along with the estimated costs. In order to narrow the design team’s efforts, the Board selected a maximum annual per share increase that they felt the members of the PCLHID would be willing to pay. The Board suggested that an annual increase of $1.00 per share was the most that PCLHID members may be willing to accept. This limited the total PCLHID financial commitment to $143,000. (This upper financial commitment assumes the PCLHID is able to secure a 30 year note at 6% from the WWDC loan program.)
<table>
<thead>
<tr>
<th>Total Cost to PCLHID (50% Capital + 100% O&amp;M)</th>
<th>One-Time Cost per Share (10,400 Type A &amp; N shares)</th>
<th>Annual Cost per Share (30 year loan @ 6%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$50,000</td>
<td>$4.81</td>
<td>$0.35</td>
</tr>
<tr>
<td>$75,000</td>
<td>$7.21</td>
<td>$0.52</td>
</tr>
<tr>
<td>$100,000</td>
<td>$9.62</td>
<td>$0.70</td>
</tr>
<tr>
<td>$125,000</td>
<td>$12.02</td>
<td>$0.87</td>
</tr>
<tr>
<td>$143,000</td>
<td>$13.75</td>
<td>$1.00</td>
</tr>
<tr>
<td>$150,000</td>
<td>$14.42</td>
<td>$1.05</td>
</tr>
<tr>
<td>$200,000</td>
<td>$19.23</td>
<td>$1.40</td>
</tr>
<tr>
<td>$250,000</td>
<td>$24.04</td>
<td>$1.75</td>
</tr>
</tbody>
</table>

**Figure 1.3: Cost per Share Analysis**

This financial limit must cover all of PCLHID’s expenses which include their 50% portion of the capital improvements and 100% of the operation and maintenance costs for the next 30 years. The upper financial commitment of the PCLHID eliminated all but a few of the previously explored design alternatives and gave the design team a much clearer idea of what to look for in an appropriate solution. The Board did agree that a larger project could be possible, but only if additional funding was found which would still limit the PCLHID annual increase to $1.00 per share. The design team promised to explore a few additional alternatives which might meet the spending limit and to seek out possible additional sources of funding.

A third meeting was held on September 9th to distribute working draft copies of this final report and discuss the design team findings to date. The recommended design alternatives were discussed at length along with their benefits and costs. The PCLHID asked that less expensive alternatives be sought out. In order to reduce project costs the PCLHID agreed to a lesser design release rate of as little as 100 cfs. The design team promised to review all previously explored alternatives again using the smaller design flow as well as seek out less expensive alternative designs. The procedures for additional study work and construction design were also reviewed.

A fourth meeting was held on September 16th to again share findings with the PCLHID. WWC distributed handouts on how project costs were derived for a few of the alternatives favored by the Board. Again the Board asked WWC to explore ways of further reducing costs.
The Board offered a couple of additional design alternatives to examine for feasibility and cost estimates. The Board decided to plan a district wide meeting in order to distribute information on various alternatives and to gather feedback.
2.0 WIND, WAVE, AND SEDIMENT MECHANICS EVALUATION

The existing slide gates have become inoperable because of the build up of sediment on and around the outlet structure. If this sediment deposition could be greatly reduced or diverted away from the outlet structure, the existing control gates could function properly after being repaired. For this reason it is important to evaluate where the sediment is coming from and how it is being transported to the outlet structure.

Sedimentation issues at the outlet of Lake Hattie are largely a function of wind and associated wave activity mobilizing and transporting sediment in a generally easterly direction toward the outlet (due to the orientation of the lake and predominant wind patterns). In order to develop an appropriate plan to minimize sedimentation of the outlet it is necessary to understand the forces at work and the mobility of sediment by conducting a wind and sediment mechanics analysis. Several sub-tasks were conducted as part of the wind and sediment mechanics evaluation.

1. Obtain and review available information (wind data, bathymetry, operation rules/practice, sediment data, outlet plans/geometry, canal geometry, aerial photography, etc.)
2. Conduct a site visit to observe conditions and to collect sediment samples as well as to identify primary sources of sediment.
3. Utilize wind data, available bathymetric data/mapping, and wind/shear stress algorithms to compute hydraulic shear stress acting on the bed of the lake under a range of wind and water level conditions (considering seasonal wind and operational patterns).
4. With the shear stress analysis, conduct sediment transport analysis to develop information on currents and movement of sediment, debris, and ice for a range of conditions in the lake and head of canal.

2.1 – Review of Available Information

Available information was obtained and reviewed to gain an understanding of the site-specific aspects that result in the observed sedimentation of the outlet works. Information sources included wind data, outlet plans/geometry, operation rules, canal geometry, aerial photography, maps, soils data, and bathymetric information. The key information from these sources used in the analysis is explained below.
Wind Data

Wind data were obtained from the airport west of Laramie (Laramie General Brees Field). These data included hourly information for a recent several year period that contained values for 5-second maximum sustained wind velocity. This information was used to approximate peak wind velocity information for Lake Hattie. Wind velocity-duration curves were developed for each month of the year. Figure 2.1 presents a summary of the wind velocity data by showing the median 5-second maximum wind velocity and the maximum of these values for each month as well as for the entire recorded history of the airport.

<table>
<thead>
<tr>
<th>Month</th>
<th>Median Velocity (mph)</th>
<th>Maximum Velocity (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>32</td>
<td>66</td>
</tr>
<tr>
<td>October</td>
<td>28</td>
<td>66</td>
</tr>
<tr>
<td>November</td>
<td>27</td>
<td>54</td>
</tr>
<tr>
<td>December</td>
<td>32</td>
<td>60</td>
</tr>
<tr>
<td>January</td>
<td>30</td>
<td>61</td>
</tr>
<tr>
<td>February</td>
<td>32</td>
<td>59</td>
</tr>
<tr>
<td>March</td>
<td>32</td>
<td>58</td>
</tr>
<tr>
<td>April</td>
<td>36</td>
<td>55</td>
</tr>
<tr>
<td>May</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>June</td>
<td>35</td>
<td>52</td>
</tr>
<tr>
<td>July</td>
<td>32</td>
<td>48</td>
</tr>
<tr>
<td>August</td>
<td>32</td>
<td>48</td>
</tr>
<tr>
<td>September</td>
<td>31</td>
<td>48</td>
</tr>
</tbody>
</table>

Figure 2.1: Summary of Wind Velocity (based on 5 second maximum data)

As shown by the table, the median maximum 5-second wind velocity averages about 32 miles per hour, with maximum values ranging up to 66 miles per hour. It is possible that wind speeds at Lake Hattie may be higher than the values at the Laramie airport, however, no local wind data were found to compare. The USBR publication, Design of Small Dams (1973), recommends using a value for design purposes of 100 miles per hour for areas that are not topographically sheltered from the wind.
**Lake Hattie Operation**

The operation of Lake Hattie depends on the availability of water as dictated by water rights. Data were gathered on the volume of water stored in Lake Hattie from April 1988 to October 2002. Fluctuations in the total storage volume during this period of about 14 years were graphed and are shown below. It is important to note that even though the records show water being present in Lake Hattie, the water may not be available for release if it is below the outlet control elevation of 7251.9. Water below this elevation is dead storage volume. During the past 14 years Lake Hattie has only had active storage (reservoir water surface above the outlet control elevation) a little less than 50% of the time. Furthermore, there was 10 feet of active storage about 34% of the time and 20 feet only about 1% of the time. This information again stresses the unreliable nature of water availability from Lake Hattie.

**Aerial Photographs**

Several pertinent aerial photographs are available from the University of Wyoming including:
• 1947 stereo pairs (1:27,700)
• 1966 (1:20,000)
• 1981 infrared
• 1997 Digital Ortho Photo (1:34,500)

Such photographs are often used to measure large scale changes in the location and shape of the lake shoreline to quantify the amount and rate of bank erosion over time. However, due to scale differences and varying water levels, shoreline movements are difficult to measure in the available photographs.

**Topography/Geometry**

A localized topographic survey was conducted by WWC in the vicinity of the Lake Hattie outlet structure. Cross-sections of the existing southern bank were created and compared information from previous surveys. The comparison showed that the southern bank has receded through erosion. The bank erosion was corroborated with observations of vertical banks and tension cracks at the top of some existing banks along the southern shoreline.

As-built drawings of the existing outlet structure were used to gather information such as the elevations of the control gates, outlet pipe invert, outlet energy dissipation structure, and beginning invert of the canal. It is important to note that the beginning invert of the canal is the controlling elevation for gravity drainage from Lake Hattie. The control gates, outlet pipes, and energy dissipation structure are all lower than the canal’s controlling elevation (7251.9).
Previously Collected Soils Data

Some recent soils data were available from soil borings collected in the late 1980’s during the previous analyses and improvements made in the vicinity of the outlet. These data generally only describe the sediment characterization by size gradation and classification at a range of depths below the soil surface. As a result these data were not directly useful in analyzing sediment transport for purposes of this study.

2.2 – Site Visit

Site visits were conducted on July 9th and 10th, 2003 to become familiar with the specific characteristics of Lake Hattie, the outlet structure, and the first portion of the receiving canal.

![Figure 2.4: Vertical banks along southern lake shore (as seen from above the outlet structure)](image)

Photographs were taken of key features of the outlet structure, energy dissipation structure, and the canal as well as bank and shoreline conditions for consideration in the analysis. These photographs show indications of bank erosion along the lake’s southern shoreline. The vertical banks shown in the photo above are typically created by erosion caused by wind and
wave activity. Also observed (but not photographed) were tension cracks at some locations at the top of vertical banks indicative of future bank failure.

2.3 – Sediment Sampling

New sediment samples were collected from key locations around the outlet structure and in the first stretch of the canal. The locations of these sediment samples are shown below. The grain size distribution of sediment samples is indicative of the method of transportation of that sediment. For this reason, the sediment samples were analyzed by mechanical separation using sieves to determine their grain size distribution. The grain size analysis results are shown below along with a typical gradation curve. Most of the samples from the southern shoreline and around the outlet structure consist of relatively fine particles (silt or finer with some sand). This is to be expected because the smaller particle sizes are more easily transported by wind and wave action. However, there are a few samples taken near the control gates and the beginning of the canal that contained coarser particles (up to gravel sized material). These larger sediment particles are generally not moved by wind or surface currents. They are generally tumbled along the bottom of a stream or lake bed. This may be an important factor when designing remediation measures.

Figure 2.5: Sediment Sample Locations
<table>
<thead>
<tr>
<th>Sample #1</th>
<th>Sample #2</th>
<th>Sample #3</th>
<th>Sample #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dia. (mm)</td>
<td>% Finer</td>
<td>Dia. (mm)</td>
<td>% Finer</td>
</tr>
<tr>
<td>19.000</td>
<td>89</td>
<td>19.000</td>
<td>100</td>
</tr>
<tr>
<td>9.500</td>
<td>77</td>
<td>9.500</td>
<td>100</td>
</tr>
<tr>
<td>4.750</td>
<td>65</td>
<td>4.750</td>
<td>100</td>
</tr>
<tr>
<td>2.000</td>
<td>50</td>
<td>2.000</td>
<td>96</td>
</tr>
<tr>
<td>0.600</td>
<td>---</td>
<td>0.600</td>
<td>---</td>
</tr>
<tr>
<td>0.425</td>
<td>27</td>
<td>0.425</td>
<td>83</td>
</tr>
<tr>
<td>0.300</td>
<td>23</td>
<td>0.300</td>
<td>78</td>
</tr>
<tr>
<td>0.150</td>
<td>19</td>
<td>0.150</td>
<td>61</td>
</tr>
<tr>
<td>0.075</td>
<td>13</td>
<td>0.075</td>
<td>45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample #5</th>
<th>Sample #6</th>
<th>Sample #7</th>
<th>Sample #8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dia. (mm)</td>
<td>% Finer</td>
<td>Dia. (mm)</td>
<td>% Finer</td>
</tr>
<tr>
<td>19.000</td>
<td>100</td>
<td>19.000</td>
<td>100</td>
</tr>
<tr>
<td>9.500</td>
<td>100</td>
<td>9.500</td>
<td>100</td>
</tr>
<tr>
<td>4.750</td>
<td>100</td>
<td>4.750</td>
<td>100</td>
</tr>
<tr>
<td>2.000</td>
<td>96</td>
<td>2.000</td>
<td>100</td>
</tr>
<tr>
<td>0.600</td>
<td>---</td>
<td>0.600</td>
<td>---</td>
</tr>
<tr>
<td>0.425</td>
<td>89</td>
<td>0.425</td>
<td>99</td>
</tr>
<tr>
<td>0.300</td>
<td>84</td>
<td>0.300</td>
<td>98</td>
</tr>
<tr>
<td>0.150</td>
<td>77</td>
<td>0.150</td>
<td>94</td>
</tr>
<tr>
<td>0.075</td>
<td>62</td>
<td>0.075</td>
<td>83</td>
</tr>
</tbody>
</table>

*Figure 2.6: Grain Size Distribution Analysis Results*
Figure 2.7: Typical Gradation Curve

2.4 - Hydraulic and Sediment Transport Analysis

In order to analyze sediment transport, it is necessary to first analyze the hydraulic shear stresses that are exerted on the lake bed and shoreline as well as through the upper reaches of the outlet canal. The hydraulic analysis methods used included particle stress calculations for both wind-driven currents and wave activity, and open channel hydraulics for the upper reaches of the canal.

Wind data obtained in the information review task were utilized to generate the range of velocities and wind directions that affect Lake Hattie while considering the seasonal patterns of reservoir storage (water surface elevation fluctuations). This data, combined with the recommendation for design wind conditions from the Design of Small Dams publication (previously referenced), shear stresses for wind velocities ranging from 50 to 100 miles per hour were computed. For this calculation the wind/shear stress equation from the RMA-2 portion of TABS-2 system of two-dimensional models from the Corps of Engineers was utilized. However, the model itself was not utilized due to budget constraints and the probable lack of calibration data caused by current low lake levels. Instead available funding was used to apply a significant
level of practical experience using appropriate levels of technology rather than an over-emphasis on complex numerical modeling that would absorb a disproportionate share of the budget.

These shear stresses were then compared with the critical shear stress required to move sediment particles of various sizes. Critical shear stresses were calculated using the Shield’s equation. A comparison of shear stresses generated by the wind with critical shear stresses showed that the winds experienced at Lake Hattie can transport silt and finer material, along with finer fractions of sand. However, the shear stresses generated by the wind are not sufficient to transport significant quantities of larger sized sand and gravel particles. These larger particles must be transported through other means such as wave impact action.

Wave impact action is an important means of sediment transportation particularly in the southeastern portion of the lake. The erosive energy of wave impact action is largely controlled by wave height. Two different methods were used to predict wave heights for a range of wind velocities and fetches. (Fetch is basically the length of the body of water over which the wind blows – for Lake Hattie the fetch ranges from about 3.4 miles to 4.4 miles depending on water level.) Based on the first analysis, wave heights of between 4 and 5 feet would be expected at a wind speed of 100 miles per hour (as shown below). The U.S. Army Coastal Research uses a

![Wave Height vs. Wind Velocity](image)

*Figure 2.8: Wave Height vs. Wind Velocity*
second method of wave height prediction which results in waves of 4 to over 6 feet depending on depth of water. Such waves have sufficient force to mobilize sediment in the gravel and larger sized particles in very shallow areas or where the wave impacts the face of the dam or steep bank along the lake. This appears to be the mechanics of the transportation of larger particles along the face of the dam and southern shoreline near the outlet structure. These larger particles have been deposited around outlet works and been flushed through the outlet pipes into the beginning of the canal. Since wave impact action rather than wind-generated shear stresses are transporting these larger particles, a complete solution will include some means of protecting the shoreline from waves.

A hydraulic analysis of the upper reaches of the canal indicates that velocities are relatively low due to the adverse slope leading out of the outlet pipes to the beginning of the canal. The slope of the upper end of the Hattie Canal No. 1 is very slight for a considerable distance downstream of the energy dissipater resulting in continued low velocities. These sustained low velocities lead to the deposition of the coarser-sized sediment eroded or mobilized by wind shear and wave impact in the energy dissipater and the upper reach of the canal. However, heavy equipment can be used to periodically remove this sediment deposition when water is not being released from Lake Hattie.

2.5 - Summary and Recommendations

The evaluation of sediment mechanics indicates that the source of sediment being deposited on and around the outlet structure is very extensive. Finer-sized particles are originating from shoreline erosion, primarily along the southern banks of Lake Hattie. The wind-generated shear stresses are sufficient to transport significant quantities of this finer-sized material (fine sand and finer) along the bed and banks of the lake. Several feet of this type of sediment has been deposited around and on the existing control gates. The existence of coarser-sized sediment (up to gravel) found around the outlet structure and in the Hattie Canal No. 1 indicates that wave impacts are mobilizing some larger sized material on the face of the dam or other areas in close proximity to the outlet gates. These coarser sizes of sediment are flushed into the outlet pipes and are deposited in the slower flows of the energy dissipater and the beginning of the canal.
Due to the significant length of shoreline that is currently experiencing erosion and the fact that wind-generated shear can transport the finer-sized bank material the entire length of the lake, it is not feasible to protect the entire shoreline where such erosion can and will continue to occur. Thus, controlling the entire source of sediment is not a reasonable alternative. Therefore, the proposed alternative must try to minimize the amount of sediment being deposited, particularly focusing on the area immediately surrounding the outlet structure.

One possible means of minimizing sediment deposition is to build a diversion wall or embankment parallel to the face of the dam which extends some distance northward along the dam. An inlet sill would be constructed at the north end of this wall to allow water to flow into the area between the wall and the face of the dam. This inlet sill could be constructed out of locally available riprap or other stable material and should be set so that the top of the inlet sill is at the same elevation as the controlling outlet elevation (7251.9). This diversion wall or embankment system would cause water to be withdrawn from an area of less sediment deposition and would protect the area immediately surrounding the outlet structure from direct wave impact action. The height of this wall should be several feet above the existing bed and could extend as high as Lake Hattie’s high water elevation of 7278. However, this may be higher than can reasonably be constructed without incurring excessive materials and construction costs, therefore the top of wall should be set at a minimum elevation of 7257. The area between the dam and the wall should be excavated several feet below the level of the control gates to form an area for settling and trapping of sediment. This will minimize the amount of sediment settling on top of the gates themselves and could allow for a water jet system to flush sediment from the gates back into the basin. The sediment basin can be sized using available sediment settling and velocity criteria for a reasonable range of discharges through the system. The bed and banks of this system should be stabilized to prevent local mobilization of sediment. Even though this system is expected to significantly reduce direct transport of sediment to the outlet structure, some suspended sediment will continue to arrive and be deposited at the outlet structure. In addition to suspended solids, wind-born debris such as weeds and some fine sediment will continue to be deposited around the outlet structure. Therefore, a diversion wall design alternative is not complete without a means of routinely removing sediment from around the outlet structure.
Acceptable designs for periodic sediment removal must be cost effective and relatively easy to perform. In periods of high water levels, this could be accomplished by operating a dredge or sand pump. As the water level drops to lower levels the inlet sill will become exposed and water may be trapped in the basin behind the diversion wall. However, it is anticipated that this water will slowly seep into the lake bed or could be removed by pumping. Once this basin area has sufficiently dried, sediment removal could be accomplished by backhoe or other appropriate heavy equipment (assuming adequate access is provided to the outlet structure). It is anticipated that a small amount of cleaning, possibly each year, would prevent significant build up of sediment at the control gates (especially with the bed of the sediment basin being lower than the gates).
3.0 LAKE OUTLET STRUCTURE EVALUATION

As discussed in the above section, an acceptable design alternative must include: 1.) a means of protecting the outlet structure from direct wave impact action, 2.) stabilization of the bed and banks immediately surrounding the outlet structure, and 3.) a means of easily cleaning the control gates on a periodic basis. With these criteria in mind the design team began brainstorming as many different outlet configurations and sediment stabilization methods as possible ignoring cost. A list of the design alternatives explored is shown below:

- **Stabilize local soils:** Install soil stabilization measures such as rip rap along southern shore where majority of sediment is originating.
- **Breakwater / Jetty:** Construct strategically placed berms in the lake to alter the lake currents and reduce the sediment deposition at the outlets.
- **Periodic Dredging:** Hire a contractor on a scheduled basis to dredge large quantities of sediment away from the outlets and either haul it away or pump it to a pre-determined location where the sediment will not be washed or blown back into the lake.
- **Periodic Excavation:** Hire a contractor on a scheduled basis to use heavy equipment such as loaders to excavate the sediment around the outlets.
- **Alluvial Intake:** Install a large perforated pipe collection field in front of outlet to draw water from reservoir sub-surface. This method uses deposited sediment to filter water as it is released through the dam.
- **Deep Water Intake:** Extend the intake pipes out into the reservoir a sufficient distance to get beyond the current area of sediment deposition.
- **Extend Intake Pipes to the North:** Extend intake pipes north along the face of the dam a sufficient distance to get beyond the current area of sediment deposition and construct a new outlet structure.
- **Extend Canal and Bore New Outlet Pipes:** Extend the Hattie Canal No. 1 along the toe of the dam and bore new outlet pipes through the dam at a location of less sediment deposition and construct a new outlet structure.
- **Siphoning:** Similar to pumping the discharge. A small vacuum pump or water pump would still be necessary to initiate siphon action each year.
- **Pumped Discharge:** Purchase and install large pump station which had capacity to transport water around or over the dam.
- **Multiple Elevation Inlet Gates:** Construct either an intake tower or sloping intake structure with multiple inlet gates. The gates could then be operated in a manner which draws water from elevations where sediment load may not be so heavy.
- **Pinch Valves:** Replace the existing slide gates with inflating bladder pinch valves. These valves could be operated by air compressors either placed on top of the dam or in the back of a truck.
• **Small Floating Sand Pump:** Periodically use pump with agitating action to wash sediment from around the outlet structure and pump it to a designated disposal site.

Detailed descriptions and diagrams of each of these as well as the design alternatives discussed below are included in the Appendix A along with their total project costs. Once this list of possible solutions was compiled, each of these design alternatives was explored in more depth for suitability, constructability, operation, serviceability, and both short and long term costs. These alternatives and their costs were presented to the PCLHID Board at the August 12th Workshop meeting.

The Board discussed how their portion of the total project costs would be distributed throughout the PCLHID members. The PCLHID has five (5) types of shares which correspond to different priority rights to the irrigation water in the Pioneer Canal and the outflow of Lake Hattie. The share types are A, B, C, N, and Deeded. Type A and Deeded shares are the highest priority. Type B shares allow for withdrawal of additional water during wet years. Type C shares are the lowest priority and only allow for withdrawal after all Type A and Type B rights have been satisfied. Type N shares only pertain to lands serviced by the North Canal. The Board decided that the PCLHID’s portion of the total project costs would be distributed on a per share basis to all Type A and Type N shareholders. There are approximately 7,000 Type A shares and 3,400 Type N shares meaning PCLHID’s portion of the total project cost would be distributed among 10,400 shares. The Board elected to limit the PCLHID’s financial commitment to an annual increase approximately $1/share to Type A and N share holders. This restricted PCLHID’s portion of the total project costs to approximately $143,000 as discussed earlier. This spending limit eliminated the majority of the alternatives previously explored.

Additional design alternatives were sought which focused more on cost savings. In order to reduce construction and operation costs these additional alternatives focused on reusing the existing control gates and outlet pipes. For this to be possible the deposition of sediment around the outlet structure must be greatly reduced. The most economical method of slowing sediment deposition would be to construct a wall or berm parallel to the dam as discussed in the recommendations of the wind, wave, and sediment evaluation. This wall or berm would function as a settling basin, or sand trap trench, for water approaching the outlet structure.
Sand trap trenches constructed of both earthen berms and a sheet piling walls were explored and are described below:

- **Earthen Berm Sand Trap Trench:** Construct an embankment of local fill material and stabilize the banks with concrete or Geo-Tubes.
- **Sheet Piling Sand Trap Trench:** Drive sheet piles into the lake bed to a sufficient depth to prevent toppling by wind, wave, ice, or hydrostatic pressures.

Both of these alternatives create a sedimentation basin, or sand trap trench, with a concrete bottom and either concrete side slopes or sheet pile walls. The north wall of this sedimentation basin has a weir inlet which is set at the same elevation as the controlling downstream elevation (7251.9). The solid walls and concrete floor of the sedimentation basin would provide a hard surface to clean to and would allow for easy measuring of sediment buildup. Both of these alternatives would greatly reduce the amount of sediment arriving at the outlet structure by withdrawing water from the weir to the north and forcing the water to flow through the sand trap trench. However, they would both require periodic sediment excavation by one of the previously explored methods in order to continue functioning properly.

It is important to note that the WWDC only participates in cost sharing of projects which improve the storage, transmission, and supply of water. This does not include the continued operation and maintenance costs of such projects. The periodic excavation of sediment is considered continued maintenance cost and would therefore be the sole financial responsibility of the PCLHID.

At the September 9th meeting with the PCLHID Board the design team recommended that the sheet piling sand trap trench be constructed to slow the transportation of sediment to the outlet and that a small floating sand pump be purchased by the PCLHID. This combination of alternatives has many advantages that neither has by itself. The sand trap trench will lessen the amount of sediment that will need to be removed every year, maybe to the extent that the sand pump will not be needed every year. The concrete bottom and vertical steel sides of the trench provide hard surfaces which will greatly ease the cleaning process and will provide a consistent means of gauging the amount of sediment buildup. Some sand pumps have the added advantage of being able to use just the water jet pump to feed a fire hose. This arrangement would allow the sand trap trench and the control gates to be washed down even in years of low water by placing the pump intake into the dead storage volume. The sand pump is portable and should be stored offsite in a shelter when not in use to prevent any damage by weather, ice, or vandalism.
This sand pump arrangement should prove to be a convenient and inexpensive means of removing what sediment does arrive at the control gates.

This recommendation was discussed at length with the PCLHID Board. However, the Board commented that they had previously used a small sand pump to remove sediment. Furthermore, the Board felt that the recommended sand trap trench could be simplified to reduce cost by paring the design down to a single sheet piling wall extending northward from the southern shoreline. The Board felt this sheet piling wall would slow sediment deposition on the gates and greatly reduce the frequency of cleaning the control gates. In addition, the Board felt that it is critical that the gates be modified in some manner that will allow them to be opened more easily even when a limited amount of sediment is deposited against the gates. The Board recommended that either vertically-oriented gate valves be installed or that “garage” structures be constructed over the existing gates which would support the majority of the weight of the sediment. The Board felt that if the gates could be opened any deposited sediment would be flushed through the outlet pipes and would be deposited in the downstream canal where the PCLHID could more easily remove the sediment as necessary.

The design team explored the ideas of reducing the sand trap trench to a single wall, modifying the control gates by installing slide gate “garages”, and replacing the slide gates with vertical knife gates. During the research of vertical knife gates it was discovered that eccentric plug valves are used in slurry applications and may be applicable at Lake Hattie. All of these alternatives are described below.

- **Modified Sheet Piling Diversion Wall**: Reduce the sand trap trench idea to a single full-height wall to divert the point of withdrawal to the north.
- **Slide Gate “Garages”**: Fabricate metal enclosures that would bear the weight of deposited sediment and leave a void space for the existing slide gates to open into.
- **Vertical Knife Gates**: Remove the existing slide gates and modify the outlet structure to allow for the installation and operation of vertically-oriented knife gates.
- **Eccentric Plug Valves**: These valves are used in slurry applications and wastewater pipelines where sediment could cause operation problems. By mounting the valves in a reverse flow arrangement the valve can be opened and closed regardless of sediment buildup.

These alternatives were reviewed with the Board on September 16th. The Board was reminded that of these alternatives the modified sheet piling diversion wall was the only alternative which would reduce the amount of sediment arriving at the outlet structure. The
Board asked that the design team explore if the diversion wall could be shortened and still be effective. They also decided to call a district wide information meeting to gather feedback on the alternatives and to share cost information. In the meantime the design team continued searching for less expensive design alternatives.

Historical water level frequencies were used to arrive at an acceptable shortened height for the diversion wall. The reduction in wall height meant that a cast-in-place concrete diversion wall was also economically feasible.

- **Shortened Modified Sheet Piling Diversion Wall**: Install a single partial-height wall of sheet piling to stop the direct deposition of the majority of the sediment at the outlet structure.
- **Cast-In-Place Concrete Diversion Wall**: Construct the single partial-height wall of cast-in-place concrete instead of sheet piling.

In addition to these alternatives a member of the PCLHID proposed constructing an intake “silo” directly on top of the existing outlet structure. This design would allow for the installation of vertical gates on the outside of the “silo” and would create a very localized diversion wall. This intake “silo” would extend all the way up to elevation 7278 so that the vertical gates could be operated even during full reservoir conditions. The space between the intake “silo” and the dam would be filled to create an access way. This design alternative was explored as well as a scaled down modified intake “silo”.

- **Intake “Silo”**: Construct a concrete drop structure with vertical gates at multiple elevations to allow for withdrawal of water from the upper water levels in the reservation.
- **Modified Intake “Silo”**: Same as the Intake “Silo” only the concrete structure is only extended to elevation 7264 (1 foot above the 1908 water right elevation). In years when the water exceeds this elevation the water would flow into the top of the “silo” and would be controlled by the existing slide gates. Also, the area behind the “silo” is not filled in. Access will be by boat and ladder.

Both of these alternatives include the installation of vertical gates which meets the Board’s request. They both also allow for the withdrawal of water at multiple elevations which can be used to reduce the amount of sediment being released through the outlet pipes and into the downstream canal. However, neither design slows the arrival of sediment at the outlet structure. Eventually sediment will build up around the lower vertical gates making them harder to operate. Once these gates are opened the sediment will be forced into the outlet pipes and hopefully on
into the downstream canal. However, sediment may continue to build up inside of the structure and the outlet pipes if the sediment is not periodically removed.

3.1 – Recommended Design Alternatives

Through the course of this study two main objectives of an acceptable design alternative have been identified. The first objective is to reduce the sediment deposition around the outlet structure and in the downstream canal. The second objective is to modify the control gates to operate even in conditions of some sediment buildup. At first glance these two objectives may appear independent but in reality a design alternative won’t be a long term success unless both objectives are met.

Slowing the deposition of sediment at the outlet structure will greatly reduce the frequency of cleaning of the control gates, the outlet pipes, and the downstream canal. Less frequent cleaning results in lower operation costs over the long term. It also reduces the responsibility of the PCLHID to manage annual cleanings. However, it is important to realize that there is no sediment-proof solution. Therefore, periodic removal of sediment will still be necessary. The design goal is simply to reduce the amount of sediment to be removed.

Modifying the control gates so that they continue to function even in moderate sediment conditions is based on the understanding that it is impossible to prevent all sediment from reaching the outlet structure. At some point the control gates may have to operate through some sediment buildup depending on the effectiveness of sediment exclusion and periodic cleaning. Regular removal of deposited sediment will limit but not eliminate the number of times this will be necessary.

Because of the limited financial ability of the PCLHID the recommended design includes several alternatives which work in combination to meet both of these objectives. In order to slow the arrival of sediment at the outlet structure the Cast-In-Place Concrete Diversion Wall should be constructed. Alone this alternative may reduce the deposition of sediment to the extent that the existing slide gates could continue to be used if cleaned every few years. In order to perform this cleaning a Small Floating Sand Pump should be purchased by the PCLHID. This sand pump can be used in both low water and high water conditions to remove sediment from around the outlet structure. If the slide gates continue to experience operational difficulties a
Modified Intake “Silo” should be constructed. This structure uses vertical gates for the primary outlet control and uses the existing slide gates only in high water years.

While it is recommended that both the diversion wall and the modified intake “silo” be built, either of these alternatives may be constructed independently. This decision must be made on the basis of prioritizing the objectives by the PCLHID. If the PCLHID wishes to reduce the amount of sediment at the outlet structure and in the downstream canal the diversion wall should be constructed first. However, this will require that the existing slide gates be regularly cleaned to ensure they continue operating properly recognizing that the quantity of sediment reaching the gates would be significantly reduced by the diversion wall. If the majority of the PCLHID feel that modifying the control gates is paramount then the modified intake “silo” should be constructed. If operated properly, this “silo” will reduce the amount of sediment entering the outlet pipes and the downstream canal. However, sediment may frequently need to be removed from the lower vertical gates to ensure their proper operation. With both of these alternatives a small floating sand pump should be purchased and used to remove sediment as necessary.
4.0 OPERATION PLAN

The operation of the proposed design is fairly simple. The existing control gates and outlet pipes would initially be cleaned and repaired. If the diversion wall is constructed it will only require periodic inspection to check its structure integrity and continued proper operation. It may be necessary at some future time to excavate sediment deposited on the lake side of the wall to ensure the diversion wall continues to function as intended. If no additional modifications are made to the outlet structure, the control gates will need to be cleaned before being operated. The diversion wall will only slow the deposition of sediment around the outlet structure and some cleaning will still be required.

If only the modified intake “silo” is constructed sediment can be expected to continue being deposited at its current rate of 500 cubic yards per year. The sediment immediately surrounding the “silo” will have to be removed before the vertical gates are opened. During periods of moderate water levels the top of the “silo” can be used as a working platform for this sediment removal. A large metal grate will provide access into the “silo” if sediment begins to accumulate on top of the existing slide gates. For water levels up to the 1908 water right the existing slide gates will be opened fully and the release rate will be controlled by the new vertical gates. In order to minimize sediment deposition in the downstream canal water should be withdrawn from the highest possible vertical gate. During years when storage levels exceed the 1908 water right water will flow into the grated top of the “silo” and the release rate will be controlled by the existing slide gates.

A sand pump should be purchased with either of the above alternatives. The sand pump should be sized so that it can be loaded and unloaded from a standard pickup or a trailer by two people. These same two people would then operate the sand pump to remove up to 500 cubic yards of sand in 2-3 days. The labor costs of these personnel are included in the cost estimate but the individuals are not identified. The PCLHID will be responsible for operation, maintenance, and storage costs of the sand pump.
5.0 PRELIMINARY PLANS & COST ESTIMATES

Preliminary designs and initial cost estimates for the recommended alternatives are attached. These preliminary designs and cost estimates warrant further investigation before monies are budgeted and the project is taken to construction. However the estimates below are the best possible based on the level of detail in the preliminary design and will serve as an important tool in evaluating project financing.

5.1 – Preliminary Design

**Diversion Wall**

The preliminary designs of the concrete diversion wall and the intake “silo” as well as the specifications of one possible floating sand pump are shown on the following pages. The concrete diversion wall shall be constructed parallel to the face of the dam. This wall shall run north from the existing control gates along the face of the dam approximately 200 feet. This wall will force water to be withdrawn from 200 feet north of the outlet structure where there is less sedimentation occurring. This will result in cleaner water being discharged through the dam. If deposited sediment is regularly removed from around the outlet structure, the sedimentation problem in the downstream canal should be greatly reduced.

The historic water levels of Lake Hattie were analyzed to find a wall height which was a balance between effectiveness in all water levels and construction costs. This statistical analysis indicates that a wall height of at least 6 feet above the dead storage elevation will prevent the *majority* of the sediment from being directly deposited around the outlet structure. (Some sediment removal will still be necessary.) The exact cross-section of the cantilevered wall can not be designed until more is known about the stability of the soils on the lake bottom. However, for the purpose of estimating costs a typical cross-section for retaining soil on one side was used. This is a conservative estimate because the lateral loading of the diversion wall should be less than soil on one side since the hydrostatic pressure will be the same on both sides of the wall.
Intake "Silo"

The intake “silo” is a concrete drop structure that will cover two adjacent existing slide gates. The “silo” will extend 1 foot above the 1908 water right elevation of 7263 so that the vertical control gates can be easily manipulated the majority of the time. A small boat will be used to get to the silo and a cast-in ladder will provide access to the top of the structure. A total of six 36” diameter vertical headgates will be installed on the sides of the drop structure. The operating handles of these vertical gates will be extended to the top of the structure and shall have locking mechanisms to prevent unwanted operation. During low water years the lake discharge will be regulated by operating one or more of the vertical gates. The intention is to withdraw water from high in the reservoir where there is less sediment. As the water level of the reservoir drops the gates will have to be manipulated to maintain a steady release rate. The top of the “silo” will consist of a large grate inlet so that in high water years (when the vertical gate operating handles are submerged) the water will drop into the structure through the grate and be
controlled by the existing slide gates. For this reason the existing slide gates inside the structure must remain operable. The bottom of the “silo” will consist of the existing concrete outlet structure plus any structural modifications that are necessary. A diagram of this structure is shown below.

![Intake “Silo” Diagram](image)

During high water years this entire structure may become submerged. This could create a potential hazard for boaters and others using the lake for recreation. For this reason some form of warning bouys and signs will be needed to prevent accidents.

It will be necessary to periodically remove sediment from inside of this structure in order to ensure the existing slide gates remain operable and that the outlet pipes do not become clogged. This cleaning can be accomplished by removing the grated top of the structure and using a sand pump.

**Sand Pump**

The sand pump unit shall have a capacity of pumping 500 cubic yards of sediment in 2-3 days. The sand pump unit shall be mounted on pontoons and be operable from a separate nearby boat. The unit must be able to be loaded, unloaded, and operated by no more than two
individuals. An ideal unit will have two separate pumps both of which are easily serviceable and use commonly available parts. The first pump is to be used to withdrawal water from the lake and discharge it through a high-pressure nozzle which is used by an operator to agitate the sediment into solution. This pump shall also be equipped with a means of attaching a larger discharge hose to be used for pressure washing the diversion wall and control gates in very low water years. The second pump is the sediment slurry intake pump. It will suck up the sediment in solution and discharge the slurry either into trucks for removal or directly to a designated on-shore disposal site. (This disposal site must not drain back toward the outlet structure or back into the lake). A small two person boat is also recommended during cleaning to allow for complete access around the intake “silo” and diversion wall during high water years. The cost of this boat is included in the cost estimate for operating the sand pump every year for the next 30 years. Product specifications on one applicable sand pump are attached on the following pages.
The PS135E dredge was developed in response to thousands of requests we have received from waterfront property owners. Decades of runoff and vegetation decay has robbed the storage capacity of lakes and ponds throughout the United States. The PS135E dredge is a compact, highly portable, gasoline engine powered sediment removal pumping system, designed to provide the homeowner with the ability to excavate and transfer unwanted subsurface sediment. It is particularly effective in removing sand, silt, and that fluffy black stinky mud that has ruined your ability to enjoy your waterfront. It is not possible for a dredge in this price range to excavate thousands of cubic yards of material in a short period of time. The excavation capability of this unit is in the neighborhood of 10-25 cubic yards per hour depending upon: the nature of your sediment, distance pumped, and your energy & skill levels. To give you a point of reference, a pile of sand the size of a Ford F250 pickup truck would be about 20 cubic yards. That generally represents the size of a hole that you can make in an hour. If you are cleaning a modest area for example; around a dock or boat slip, you can expect to get the job done relatively quickly. On the other hand, if you have a large surface area to cover, say 1 to 2 acres, you are going to be whittling away at it for awhile. Using our pickup truck example again, if you dredge for 4 hours every other weekend for 6 months, you would be able to park a fleet of 50 trucks in the hole that you created. The intent here is to provide you with the means to diminish your sediment problem with a quality, yet affordable piece of equipment. You are also going to have to deal with the fact that you will be pumping a lot of water along with the sediment. The mud is not going to come out of your discharge hose looking like toothpaste. Even expensive industrial dredges can’t do that. On the other hand, this unit will provide you with the means to improve the quality of your waterfront, and the quantity of removed sediment will be limited only by the amount of time & energy that you put in to it.

Our PS135E dredges are shipped to you completely assembled, and ready to go to work. You simply add gas to the fuel tanks, fill the pump cases with water for the first time, attach the quick connect hoses, and you are ready to pump. No tools are necessary.

Specifications:

**Dredge pump:**
8 horsepower, Honda air cooled 4 cycle engine, 3600 RPM  
Self Priming  
Maximum Flow: 350 gpm  
Suction: 3 inch  
Discharge: 3 inch  
Impeller: high chrome iron, semi-open, clog resistant  
Wearplate: stainless steel  
Volute casing: cast iron  
Mechanical seal: silicon carbide  
Solids Handling: 1.5 inch solids  
Pump weight: 130 lbs
Agitator Pump:

5.5 horsepower, Honda air cooled 4 cycle engine, 3600 RPM
Self Priming
Suction: 1.5 inch
Discharge: 1 inch
Impeller: cast iron
Volute: cast iron
Mechanical Seal: silicon carbide
Pump weight: 57 lbs

Maximum practical dredging depth: 6 feet standard, 12 feet w/optional extension rod
Floatation platform: Tubular steel base and upper structure, urethane powder coated finish
Modular floatation pontoons: High density polyethylene, foam filled, UV & chemical resistant
With stainless steel fasteners

Suction hose: 3 inch by 15 feet for 6 feet dredge depth, 3 inch by 20 feet for 12 feet dredge depth
Floating discharge hose: 3 inch by 25 feet sections, w/quick disconnect couplings
Onshore discharge hose: 3 inch by 50 feet sections, w/quick disconnect couplings

Swamp capacity: 796 lbs.
Total weight: 395 lbs.
Dimensions: 7'1" L x 4'9" W x 3'9" H
Draft: 10 inches

Piranha Pumps Are Made By:

Equipment Specialties Company

To Contact Us:

Phone: (505) 822-0449
Fax: (505) 858-0171

Click Here For Information Request Form
5.2 – Cost Estimate

The breakdowns of the cost estimates for each of the recommended design alternatives are included in Appendix B. A summary of these total project costs is shown below. These cost estimates include as many of the foreseeable costs associated with construction, purchasing, and operation over the expected useful life. The cost estimate assumes a useful life of 30 years. This does not mean that the system will be inoperable in 30 years it merely means that at that time substantial system repairs and upgrades may be necessary. The cost estimate also makes the following assumptions:

- A disposal location for the sediment spoils can be identified nearby. There will be no dumping fee for this disposal and it will not require any special design or maintenance. This may require coordinating with the BLM or local property owners.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Objective</th>
<th>1</th>
<th>2</th>
<th>Total Project Cost</th>
<th>PCLHID Portion*</th>
<th>Annual Cost per Share**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Floating Sand Pump</td>
<td>X</td>
<td></td>
<td></td>
<td>$115,000</td>
<td>$115,000</td>
<td>$0.80</td>
</tr>
<tr>
<td>Cast-In-Place Concrete Diversion Wall ***</td>
<td>X</td>
<td></td>
<td></td>
<td>$96,000</td>
<td>$48,000</td>
<td>$0.34</td>
</tr>
<tr>
<td>Modified Intake &quot;Silo&quot; ***</td>
<td>X</td>
<td></td>
<td></td>
<td>$163,000</td>
<td>$81,500</td>
<td>$0.57</td>
</tr>
</tbody>
</table>

NOTE: Objective 1 = Reduce Sediment Deposition at Existing Outlet Structure Location
Objective 2 = Modify Control Gates to Function Even in Moderate Sediment

* PCLHID Portion reflects the Total Project Cost less the amount anticipated to be paid by grant money from the WWDC. WWDC does not contribute funding for continued operational costs such as periodic sediment removal.

** Annual Cost per Share is based on a 30 year loan at 6% interest paid by a total of 10,400 shares. (7,000 A shares and 3,400 N shares)

*** Both the Diversion Wall and the Modified Intake “Silo” must include some means of periodically removing sediment in order to ensure their proper continued operation.
• Local soils have not been tested for their suitability to support the concrete diversion wall. Instead a conservative estimate of a standard cantilevered retaining wall was used.
• No significant structural improvements are necessary to the existing concrete outlet structure prior to the installation of the modified intake “silo.”
• The construction will be carried out when the water level is below elevation 7,246 feet. This will greatly reduce or even eliminate the need for dewatering during construction.
• The existing control gates and outlet pipes will continue to be serviceable for the entire 30 year design life without repairs or cleaning beyond the initial construction.
• The cost estimate does not include any costs associated with cleaning the downstream canal beyond the initial construction. The sedimentation problem in the downstream canal may be greatly reduced by regular cleanings of the sediment from the outlet structure.
• The cost estimate of operating the sand pump includes the cost of removing 500 cubic yards of sediment a year. It may be discovered that the construction of a diversion wall greatly slows the buildup of sediment thereby reducing the frequency of required cleanings. However, some means of removing sediment, such as a sand pump will still be necessary.
• If no nearby disposal site where the sediment will not be washed or blown back into the lake can be identified, it will be necessary to pump the waste sediment into trucks and haul the sediment away. The cost of these trucks is not included in the cost estimate.
• Fuel costs continue to steadily rise. For this study a conservative constant fuel cost was assumed at $4.00/gallon. However, if fuel shortages develop and the cost of fuel significantly increases the operational costs borne by the PCLHID will increase accordingly.

These assumptions greatly affect the overall cost of the project. During the preparation of the final designs and the operation plan each of these assumptions needs to be revisited to ensure they are still valid. The operational costs could be significantly reduced if the PCLHID members were willing to donate things such as fuel for the pump, a two person boat, or their own time to operate the pumps. They could even set up a regular rotation of district members so that the same individuals don’t keep doing all of the work.
6.0 ECONOMIC ANALYSIS

The PCLHID Board currently plans to distribute their portion of the overall project costs to all of their Type A and Type N shareholders on a per share basis. This includes approximately 7,000 Type A shares and 3,400 Type N shares. The PCLHID Board also selected a maximum level of commitment of an increase of $1.00 per share annually. This limits the PCLHID total project costs to $143,000 over a 30 year design life assuming standard WWDC support funding. In the August 12th meeting with the PCLHID Board Bruce Brinkman of the WWDC suggested that standard WWDC support funding of capital improvements was a good assumption.

The design team examined dozens of alternatives and has recommended the design which best addresses the long-term sedimentation problem while still remaining within the spending limits of the PCLHID. As stated in the previous section the cost estimate for the project is based on many assumptions which will have to be verified as part of the final design. A preliminary financing program is shown below to aid in the decision making process of the WWDC and PCLHID as they decide what action to take next.

6.1 – Funding Components

The total project cost provides an important way to compare alternative designs. However, it does not provide a clear picture of who will pay for what. For this project it is important to breakout each party’s financial responsibilities. Through grants the WWDC normally contributes 50% of the design and construction costs of projects which improve the storage and transmission of surface waters. It is important to note that WWDC does not contribute any funds to the continued operation and maintenance costs of any project. This contribution by WWDC will greatly aid in the construction of the concrete diversion wall and the intake “silo” as well as the initial cleaning and repairs to the existing outlet pipes and control gates. However, the costs of purchasing the floating sand pump as well as the costs of regular operation, storage, and maintenance costs of the sand pump will be borne solely by the PCLHID unless additional funding sources can be identified.

Beyond the 50% grant participation, the WWDC typically offers fixed interest rate loans to assist entities such as PCLHID finance their portion of a project. At the time of this report WWDC was offering 30 year loans at 6% interest rate. It is not mandatory that the PCLHID take
advantage of this loan program if they are able to find other sources of financing. However, for the purposes of this study the standard 50% participation and a 30 year loan at 6% were assumed.

6.2 - PCLHID Financing Options

The PCLHID has several possible financing options to cover their portion of the construction and all of the operation and maintenance costs for the next 30 years. The WWDC will offer a 30 year loan at a 6% fixed interest rate to help the PCLHID pay for their portion of the construction costs. However, the WWDC does not loan money for continued operation and maintenance costs. It is the sole responsibility of the PCLHID to cover these ongoing expenses.

It may be possible for the PCLHID to secure a loan from another funding agency at more favorable rates than those offered by the WWDC. Furthermore, if the project included eligible components, additional grant money may be available from other agencies to further lessen the 50% of the construction cost to be paid by PCLHID.

6.3 – Additional Funding Sources

As part of this study the design team did some preliminary searching for additional sources of funding. Several federal and state agencies were contacted to see if they had any support programs that would apply to the recommended improvements. In discussing the project with these agencies one of the potential benefits of the recommended design include a sheltered fish habitat inside of the concrete diversion wall. This area could also be used to launch boats in an area that is protected from winds out of the west.

Of the agencies contacted many did not have any funding programs which would apply to any of the recommended design alternatives. Two of the agencies contacted have monies that could possibly be applied for if the proposed improvements were slightly expanded to include additional features.

- **Wyoming Department of State Parks & Cultural Resources:** This grant program distributes $100,000 every two years to “governmental agencies for public boating facility improvements. The purpose of the program is to increase boating opportunities for the public throughout the state.” Again this is a matching funds program and is only applicable to “construction, restoration, repair, and other improvements to publicly owned boating facilities. Proposals for ramps, docks, campgrounds, parking lots, shelters, picnic tables, restrooms, fish cleaning stations, pumps, water systems and other such facilities located where they are of high utility to boaters are eligible.”
Already there is an existing boat ramp near the reservoir outlet that should not be affected by the proposed construction. This existing boat ramp is concrete with an attached floating dock all of which are in good condition. The only possible improvement to this dock is to lengthen the ramp itself to extend into the lake even in low water years.

- **U.S. Department of Agriculture Rural Development Office:** Through the Community Facility Program there may be loan money available to help non-profit organizations who are undertaking projects which provide benefits to their community. It could be argued that the recreation value of Lake Hattie is a benefit to its community.

None of the agencies contacted above will participate in the ongoing costs of operating and maintaining the sand pump. This cost will forever be the sole responsibility of the PCLHID.
7.0 CONCLUSIONS AND RECOMMENDATIONS

The Lake Hattie control gates and outlet pipes were last improved in 1990. Since that time sediment has continued to be deposited on and around the control gates as well as in the downstream canal. As part of this study the sources of this sediment were analyzed along with its method of transport. It was concluded that the sources were too widespread to economically be stabilized. Rather it is recommended that any rehabilitation efforts be focused on improving the area immediately surrounding the outlet.

Through the course of this study two design objectives were identified: 1) reduce the sediment deposition on and in the immediate vicinity of the outlet structure, and 2) modify the control gates to allow for their continued operation even in the presence of moderate sediment buildup. A combination of design alternatives is recommended in order to meet both of these objectives.

A diversion wall should be constructed parallel to the face of the dam in order to prevent direct sediment deposition on the outlet structure and to force water to be withdrawn from an area to the north where there is less sediment. This diversion wall should greatly reduce the amount of sediment arriving at the outlet structure, but alone it will not completely solve the problem. Therefore a sand pump should also be purchased and used to regularly remove sediment that does build up around the control gates and transport it to a designated disposal site. In order to make the control gates operable even in moderate sedimentation conditions, an intake “silo” structure with vertical gates should be constructed directly over the existing slide gates.

It is recommended that all three of these design alternatives be constructed as soon as possible. However, this may not be economically feasible. If this is the case, the PCLHID must prioritize the design objectives recognizing the tradeoffs with each alternative. The PCLHID may decide to not fund any of the recommended alternatives and either select their own solution or to make no improvements at all. However, at a bare minimum the existing control gates and outlet pipes should be cleaned and repaired prior to the diversion of any active storage volume to Lake Hattie. Finally, regardless of the design alternative the PCLHID selects, a program of regularly removing sediment from around the outlet structure must be identified and initiated in order for the dam to continue functioning properly.
APPENDIX A

Design Alternatives
<table>
<thead>
<tr>
<th>Alternative</th>
<th>Objective 1</th>
<th>Objective 2</th>
<th>Total Project Cost</th>
<th>PCLHID Portion*</th>
<th>Annual Cost per Share**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilize Local Soils</td>
<td>X</td>
<td></td>
<td>$720,000</td>
<td>$360,000</td>
<td>$2.51</td>
</tr>
<tr>
<td>Breakwater / Jetty</td>
<td>X</td>
<td></td>
<td>$0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periodic Dredging</td>
<td>X</td>
<td></td>
<td>$254,000</td>
<td>$254,000</td>
<td>$1.77</td>
</tr>
<tr>
<td>Periodic Excavation</td>
<td>X</td>
<td></td>
<td>$121,000</td>
<td>$121,000</td>
<td>$0.85</td>
</tr>
<tr>
<td>Alluvial Intake</td>
<td>X</td>
<td></td>
<td>$1,285,000</td>
<td>$642,500</td>
<td>$4.49</td>
</tr>
<tr>
<td>Deep Water Intake</td>
<td>X</td>
<td></td>
<td>$912,000</td>
<td>$456,000</td>
<td>$3.19</td>
</tr>
<tr>
<td>Extend Intake Pipes to the North</td>
<td>X</td>
<td></td>
<td>$755,000</td>
<td>$377,500</td>
<td>$2.64</td>
</tr>
<tr>
<td>Extend Canal and Bore New Outlet Pipes</td>
<td>X</td>
<td></td>
<td>$1,622,000</td>
<td>$811,000</td>
<td>$5.67</td>
</tr>
<tr>
<td>Siphoning</td>
<td>X</td>
<td></td>
<td>$0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumped Discharge</td>
<td>X</td>
<td></td>
<td>$5,401,000</td>
<td>$5,401,000</td>
<td>$37.73</td>
</tr>
<tr>
<td>Multiple Elevation Inlet Gates</td>
<td>X</td>
<td></td>
<td>$394,000</td>
<td>$197,000</td>
<td>$1.38</td>
</tr>
<tr>
<td>Pinch Valves</td>
<td>X</td>
<td></td>
<td>$204,000</td>
<td>$102,000</td>
<td>$0.71</td>
</tr>
<tr>
<td>Small Floating Sand Pump</td>
<td>X</td>
<td></td>
<td>$115,000</td>
<td>$115,000</td>
<td>$0.80</td>
</tr>
<tr>
<td>Earthen Berm Sand Trap Trench</td>
<td>X</td>
<td></td>
<td>$344,000</td>
<td>$172,000</td>
<td>$1.20</td>
</tr>
<tr>
<td>Sheet Piling Sand Trap Trench</td>
<td>X</td>
<td></td>
<td>$372,000</td>
<td>$186,000</td>
<td>$1.30</td>
</tr>
<tr>
<td>Modified Sheet Piling Diversion Wall</td>
<td>X</td>
<td></td>
<td>$321,000</td>
<td>$160,500</td>
<td>$1.12</td>
</tr>
<tr>
<td>Shortened Modified Sheet Piling Diversion Wall</td>
<td>X</td>
<td></td>
<td>$109,000</td>
<td>$54,500</td>
<td>$0.38</td>
</tr>
<tr>
<td>Cast-In-Place Concrete Diversion Wall</td>
<td>X</td>
<td></td>
<td>$96,000</td>
<td>$48,000</td>
<td>$0.34</td>
</tr>
<tr>
<td>Slide Gate &quot;Garages&quot;</td>
<td>X</td>
<td></td>
<td>$162,000</td>
<td>$81,000</td>
<td>$0.57</td>
</tr>
<tr>
<td>Vertical Knife Gates</td>
<td>X</td>
<td></td>
<td>$217,000</td>
<td>$108,500</td>
<td>$0.76</td>
</tr>
<tr>
<td>Eccentric Plug Valves</td>
<td>X</td>
<td></td>
<td>$139,000</td>
<td>$69,500</td>
<td>$0.49</td>
</tr>
<tr>
<td>Intake &quot;Silo&quot;</td>
<td>X</td>
<td></td>
<td>$268,000</td>
<td>$134,000</td>
<td>$0.94</td>
</tr>
<tr>
<td>Modified Intake &quot;Silo&quot;</td>
<td>X</td>
<td></td>
<td>$163,000</td>
<td>$81,500</td>
<td>$0.57</td>
</tr>
</tbody>
</table>

NOTE: Objective 1 = Reduce Sediment Deposition at Existing Outlet Structure Location
Objective 2 = Modify Control Gates to Function Even in Moderate Sediment

* PCLHID Portion reflects the Total Project Cost less the amount anticipated to be paid by grant money from the WWDC. WWDC does not contribute funding for continued operational costs such as periodic sediment removal.

** Annual Cost per Share is based on a 30 year loan at 6% interest paid by a total of 10,400 shares. (7,000 A shares and 3,400 N shares)

*Figure A.1: Cost Summary of Design Alternatives*
Alternative: Stabilize local soils

Description:
The southern shoreline has high vertical banks which appear to be severely eroded by wind and wave action. The majority of the sediment being deposited near the outlet appears to be originating from this shoreline. Erosion from this shoreline may be greatly reduced by selective placement of riprap protection thereby slowing the flow of additional sediment towards the existing outlet structure.

Construction Overview:
The vertical banks along the southern shoreline will be re-graded and riprap will be placed to stabilize the slopes. The area of riprap placement will be approximately 7,000 feet of shoreline by 50 feet in width. Covering this area with 12 inches of riprap will require 13,000 cubic yards of riprap.

Advantages:
1. This alternative tries to lessen the amount of new sediment available to plug the outlet pipes.
2. After proper cleaning and repairs the existing control gates and outlet pipes could continue to be used.
3. Allows for the existing maximum release rate of 370 cfs.

Disadvantages:
1. The riprap alone will not entirely prevent future sedimentation problems. It only prevents new sediment from entering the lake from the southern shoreline. New sediment will continue to enter from other sources and existing sediment will continue to be redistributed on the bottom of the lake including near the outlet.
2. This alternative will require initial cleaning and repairs to the existing control gates and outlet pipes.
3. Riprap protection will change the use of the southern shoreline and reduce access.
4. Riprap may need continued maintenance.
5. Vertical banks will need to be re-graded prior to riprap placement.
6. Existing boat ramp may need to be relocated.

Total Project Cost = $ 720,000
Alternative: Construct a Breakwater/Jetty

Description:
Construct a breakwater or jetty to change the sediment flow patterns near the existing outlet.

Construction Overview:
Either re-distribute existing sediment or import riprap material to construct a jetty that would beneficially alter wind and wave action. This may cause the sediment to be deposited in another location which does not affect the operation of the existing gate controls.

Advantages:
1. After proper cleaning and repairs the existing control gates and outlet pipes could continue to be used.
2. Low tech solution with no moving parts.
3. Allows for the existing maximum release rate of 370 cfs.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing control gates and outlet pipes.
2. Construction of jetty in deeper water may be difficult.
3. Location and design of new jetty would be based on modeling and may prove ineffective.
4. There is an existing naturally occurring jetty which doesn’t appear to be working.

Total Project Cost  ?
**Alternative: Continued periodic hydraulic dredging**

**Description:**
This option does not try to reduce the amount of sediment arriving at the outlet. Instead it assumes sediment will continue arriving at the current rate and simply allows for periodic hydraulic dredging of the sediment before it gets to the point of filling the outlet pipes and requires more expensive remediation. It is assumed that 5,000 cubic yards will need to be dredged every ten years. A hydraulic dredge would suck up the sediment and pump it to an acceptable spoils location on shore. This spoils disposal site must not drain back into the lake or toward the outlet structure. It is important to note that dredging operations require a considerable amount of water to pump the sediment. This water may be lost for irrigation use if not recaptured in some manner.

**Construction Overview:**
A dredging operation will need to be undertaken every 10 years. The PCLHID may either purchase their own dredging equipment or hire a contractor each time.

**Advantages:**
1. After proper cleaning and repairs the existing control gates and outlet pipes could continue to be used.
2. Allows for the existing maximum release rate of 370 cfs.
3. If regular excavation schedule is followed the sedimentation in the downstream canal will be greatly reduced.
4. Sediment could be excavated in years of high water levels.

**Disadvantages:**
1. This alternative does not reduce the amount of sediment arriving at the outlet.
2. This alternative will require initial cleaning and repairs to the existing control gates and outlet pipes.
3. This alternative requires continued funding diligence. The PCLHID must establish and maintain an account to pay for regular cleaning schedule. WWDC funding may not be available on a continued basis.
4. Very extensive Environment Impact Studies and permitting process may be required to undertake large scale dredging operation.
5. While dredge is in operation the suspended solids level in the lake may be greatly elevated and may change the use of the lake and affect the fish and wildlife.
6. Sediment to be dredged must be submerged. Therefore the lake water level must be high.

**Total Project Cost** = $254,000  
(Initial cleaning and repairs + cost of dredging in Year 10 and Year 20)
Alternative: Continued periodic excavation of sediment

Description:
This option does not try to reduce the amount of sediment arriving at the outlet. Instead it assumes sediment will continue arriving at the current rate and simply allows for periodic excavation of the sediment with heavy equipment. This excavation must be performed before the sediment gets to the point of filling the outlet pipes and requires more expensive remediation. The outlet works were last cleaned and sediment excavated in 1989 as part of the dam rehabilitation project. It has been 14 years since that cleaning and the sediment has built up well above the outlet works. If sediment continues being deposited at the same rate a ten year excavation cycle would be appropriate. The time period between excavations could be varied depending on field conditions but once every ten years will be used for planning.

Construction Overview:
In 1989 5,400 cubic yards of sediment were excavated as part of the outlet works improvements. This alternative assumes that a similar quantity of 5,000 cubic yards of sediment will have to be excavated every 10 years. The initial excavation will also need to include cleaning and repairs to the existing control gates and outlet pipes.

Advantages:
1. Low initial cost.
2. After proper cleaning and repairs the existing control gates and outlet pipes could continue to be used.
3. Allows for the existing maximum release rate of 370 cfs.
4. If regular excavation schedule is followed the sedimentation in the downstream canal will be greatly reduced.

Disadvantages:
1. This alternative does not reduce the amount of sediment arriving at the outlet.
2. This alternative will require initial cleaning and repairs to the existing control gates and outlet pipes.
3. Periodic excavation will need to be done when the water level is very low or it becomes more expensive.
4. Arrangements must be made with BLM and local property owners to identify a location for wasting the excavated spoils.
5. This alternative requires continued funding diligence. The PCLHID must establish and maintain an account to pay for regular cleaning schedule. WWDC funding will not be available for this alternative.

Total Project Cost = $121,000 (Initial cleaning and repairs + cost of excavation in Year 10 and Year 20)
Alternative: Alluvial Intake

Description:
This alternative includes a large buried network of perforated intake piping. The drainage layers above the intake piping would be designed to prevent clogging by the sediment. Water would flow from the intake pipes to a new control structure on the existing outlet pipes.

Construction Overview:
With the lake water level very low, an area would be graded and the network of perforated pipes would be placed and covered with designed drainage layers. Water from the pipes would have to be collected and piped to a new control structure at the existing outlet pipes.

Advantages:
1. After proper cleaning and repairs the existing outlet pipes could continue to be used.
2. If the drainage layers are properly designed sedimentation is no longer an issue.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing outlet pipes.
2. A new control structure will be needed.
3. If not properly designed the drainage layers could become clogged by the sediment and there is no way to backwash the system.
4. The only way to inspect or repair the system is to wait for a low water level period and excavate the pipes.
5. Will require large amounts of drainage material and perforated pipes.
6. May not be able to get desired discharge rate since the upstream effective head is reduced as the water passes through the filter layers.

Total Project Cost = $1,285,000
Alternative: Deep Water Intake Pipes (100 cfs)

Description:
This option extends the outlet pipes into the lake in order to get out beyond the area of sedimentation. In order to achieve the design flow of 100 cfs only two of the existing 48” outlet pipes would need to be extended.

Construction Overview:
Based on aerial photos and field measurements the pipes would have to be extended 1,500 feet to the northwest. Two of the existing control gates would have to be removed and the existing outlet pipes would have to be cleaned. Two new inline control gates would have to be designed and installed. The cost estimates below are based on all of this construction being completed when the water level is very low as it was in 1997.

Advantages:
1. After proper cleaning and repairs the existing outlet pipes could continue to be used.
2. Water withdrawn from area of less sedimentation may reduce sediment problems in downstream canal.
3. Once installed there is no longer a concern with sedimentation in southeast corner of Lake Hattie.
4. This design has a proven history at both Sodergreen Lake and Fremont Lake.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing outlet pipes.
2. New inline control gates will be needed.
3. If sediment does get into pipe and needs cleaning the longer pipes will be much more expensive to clean.
4. In low water years the pipes will be exposed and may be damaged by boats or vehicles.
5. Ice may cause problems either crushing or bursting pipes.
6. Expensive construction and many technical questions about supporting the pipes in deeper portions of the lake.

Total Project Cost = $912,000
Alternative: Relocate Intake by extending pipes north along the face of the dam

Description:
This alternative includes the extension of 2 of the existing outlet pipes north along the face of the dam approximately 1500 feet. This arrangement will withdraw cleaner water from a location of less sediment deposition. A new intake structure will need to be built further north along the dam. A new drop structure connection to the existing outlet pipes will also be required.

Construction Overview:
Two of the existing slide gates will need to be removed and a new drop structure built to connect the new pipe extensions to the existing outlet pipes.

Advantages:
1. After proper cleaning and repairs the existing outlet pipes could continue to be used.
2. Relocates the intake to an area of much less sedimentation.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing outlet pipes.
2. A new intake structure and a drop structure connection to the existing outlet pipes will be needed.
3. Pipe extensions are susceptible to damage by waves, ice, boats, and vehicles.
4. Pipes may be exposed to environmental elements for long periods of time if low water years persist.

Total Project Cost = $755,000
Alternative: Relocate Intake by extending canal on east side of dam and boring new outlet pipes

Description:
This option completely abandons the existing outlet pipes and the intake location. Hattie Canal No. 1 will be extended along the east side of the dam and new outlet pipes will be bored through the base of the dam. A new outlet control structure and an energy dissipater will also be constructed.

Construction Overview:
The canal will be extended approximately 2,500 feet northward. Two new 48” outlet pipes will be bored through the base of the dam. A concrete control structure will be constructed.

Advantages:
1. Moves intake to location of low sedimentation.
2. New outlet pipes through the dam will have longer life than existing outlet pipes.
3. Do NOT need to clean and repair existing outlet pipes.
4. If four 48” diameter outlet pipes are installed they will allow for the existing maximum release rate of 370 cfs.
5. May be the most permanent solution.
6. No continued operation expenses.

Disadvantages:
1. New outlet pipes will require seepage collars.

Total Project Cost $ 1,622,000
Alternative: Siphon Piping

Description:
This option takes advantage of atmospheric pressure to create a siphon which requires no mechanical input once established. The siphon pipes would lift water from the lake and pass it through the existing outlet pipes to the canal downstream. This system will only work when the water in the lake is higher than the canal.

Construction Overview:
Intake pipes would be extended out into the lake and could be placed on top of the area of sedimentation and then discharge into the existing outlet pipes. A series of valves and a temporary pump would be needed to flood the siphon and prime it prior to each use.

Advantages:
1. In this application this alternative has no distinct advantages over deep water intake pipes.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing outlet pipes.
2. This system only works when the water level in the lake is higher than the canal which is the same as just extending the outlet pipes.
3. There are limits to a siphon height based on elevation which prevent siphoning over the top of the dam. The outflow would have to go through the existing outlet pipes, thus this alternative has all of the same disadvantages as any other alternative which reuses the existing outlet pipes.

Total Project Cost = ?
Alternative: Pumped Discharge

Description:
This option requires the installation and operation of large pumps to lift water from deeper portions of the lake to a new control structure built over the existing outlet pipes. These pumps and their diesel motors could be built onto trailers which would allow for them to be relocated as sediment built up in one area. Based on preliminary design of the pumping system 4 pumps and motors will be necessary to carry only 100 cfs. Furthermore these pumps do not have the capacity to lift the water up and over the dam so they will have to discharge into the existing outlet pipes.

Construction Overview:
The pumps and motors come as pre-manufactured units. The existing control valves would have to be modified or removed and a new control structure would be needed to collect pump discharges and pass the water through the existing outlet pipes.

Advantages:
1. After proper cleaning and repairs the existing outlet pipes could continue to be used.
2. May operate any number of pumps to meet changing water demands.
3. Movable pumps could be relocated as sediment builds up in one area.
4. This is the only option which allows for use of the dead storage volume in Lake Hattie.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing outlet pipes.
2. New control structure must be constructed over existing outlet pipes
3. System is susceptible to loss due to vandalism or theft.
4. Continued operation costs are susceptible to fluctuations in the cost of diesel.
5. System involves many components which may need costly mechanical repairs.
6. Filing for water rights on the dead storage volume in the lake could be an involved process.
7. WWDC may help fund initial installation but will not help fund continued operation costs.

Total Project Cost $ 5,401,000 (Initial installation and approximate operation costs for 30 years)
Alternative: Multiple Elevation Inlet Gates

Description:
This option does not try to reduce the amount of sediment arriving at the outlet. A new control gate structure would be built which would allow for the withdrawal of water at multiple elevations. In high water years this would allow for the withdrawal of water from above the sediment.

Construction Overview:
The existing outlet pipes would have to be cleaned and repaired. The existing outlet control gates would be removed and a new concrete structure would be constructed. Over time sediment would continue to build up over the lower gates which would require continued periodic excavation or dredging as described above.

Advantages:
1. After proper cleaning and repairs the existing outlet pipes could continue to be used.
2. If the new inlets are properly designed this alternative allows for the existing maximum release rate of 370 cfs.
3. By releasing from upper inlets in high water years the sedimentation in the downstream canal will be greatly reduced.

Disadvantages:
1. This alternative does not reduce the amount of sediment arriving at the outlet.
2. This alternative will require initial cleaning and repairs to the existing outlet pipes.
3. This alternative requires continued funding diligence. The PCLHID must establish and maintain an account to pay for regular sediment removal from the lower gates. WWDC funding will not be available for this continued expense.

Total Project Cost = $394,000 (Installation + cleaning in Year 10 and 20)
Alternative: Pinch Valves

Description:
This option involves cleaning all four outlet pipes and repairing two of the existing slide gates. New 36” pneumatically operated pinch valves will be installed on the two remaining outlet pipes. These pinch valves can be opened even when covered with sediment by releasing air pressure and letting the valve bladders deflate.

Construction Overview:
The pinch valves will require special made spools to connect to the existing outlet pipes. Protected air operating hoses will be run up the face of the dam to above the high water line so that the pinch valves may be operated by a truck mounted air compressor regardless of the water level.

Advantages:
1. Low operation costs.
2. Pinch valves can be opened regardless of sediment buildup.

Disadvantages:
1. Pinch valve bladders have a limited lifespan and can be damaged or punctured by weather or sharp objects if not protected.
2. Getting the valves open does not ensure that water will flow if sediment has built up.
3. This option does not try to reduce the amount of sediment being deposited.

Total Project Cost = $204,000
Alternative: Small Floating Sand Pump

Description:
This option tries to solve the problem of sediment deposition preventing the existing slide gates from working properly. By removing sediment from around and on top of the outlet structure the slide gates should continue to work properly. An agitating sand pump would stir up the sediment, suck it up, and discharge the sediment to a designated disposal site. This sand pump would be portable and could be stored offsite when not in use.

Construction Overview:
This option involves very little construction. The existing outlet pipes would be cleaned and the slide gates repaired. The pump would be purchased and operated on a yearly basis to ensure the slide gates continue to operate properly.

Advantages:
1. Low initial costs.
2. The existing outlet pipes and slide gates could continue to be used.
3. Pump is portable and storage offsite prevents damage from weather and vandalism.
4. Sand pump could also be used to wash the outlet structure in low water years.

Disadvantages:
1. This option requires initial cleaning and repairs to the outlet pipes and slide gates.
2. This option does not try to reduce the amount of sediment arriving at the outlet.
3. Sand pump will require operators.
4. A spoils area must be identified and grading equipment may be necessary to spread sediment at this location.
5. WWDC will not contribute funding to this solution.

Total Project Cost = $115,000
Alternative: Earthen Berm Sand Trap Trench

Description:
Construct a sand trap trench by building a 10 foot high earthen berm parallel to the face of the dam. The length of the berm and the distance from the face of the dam will be designed so that water entering from the north end will behave as if it is a settling basin. There is a spillway inlet across the north end of the sand trap trench with a top elevation of 7251.9. The bottom and inside slopes of the sand trap trench are paved with concrete to provide a hard surface for cleaning. A concrete ramp will provide access to the bottom of the trench.

Construction Overview:

Advantages:
1. After proper cleaning and repairs the existing outlet pipes could continue to be used.
2. This alternative tries to reduce the amount of sediment arriving at the outlet structure.
3. The concrete bottom and walls of the trench allow for easy cleaning and gauging of sediment buildup.
4. The top of the earthen berm could be used for cleaning the trench from above and as a fishing pier.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing control gates and outlet pipes.
2. Periodically the sediment will need to be removed from the sand trap trench by either heavy equipment or dredging. This cleaning cost will not be shared by the WWDC.

Total Project Cost = $344,000
Alternative: Sheet Piling Sand Trap Trench

Description:
Build the same kind of sand trap trench as described in the earthen berm sand trap trench only use driven sheet piles to form the trench walls. A concrete trench bottom and access ramp in the southern end will provide for easy cleaning. Shorter sheet piles will form the inlet into the north end of the trench.

Construction Overview:
Interlocking sheet piles will be driven to an appropriate depth to resist toppling. A concrete trench bottom and access ramp will then be poured in place.

Advantages:
1. Same as Earthen Berm Sand Trap Trench

Disadvantages:
1. Same as Earthen Berm Sand Trap Trench

Total Project Cost = $372,000
Alternative: Modified Sheet Piling Diversion Wall

Description:
A simplified version of the Sheet Piling Sand Trap Trench in which only the western wall is built along with a sheet piling wall along the south end of the trench. The bottom of the trench and the face of the dam are left unpaved. The inlet sill in the northern end of the trench will be constructed of locally available riprap or other stable material.

Construction Overview:
Again sheet piles will be driven with a crane or other heavy equipment.

Advantages:
1. Same as Sheet Piling Sand Trap Trench only less expensive to construct.

Disadvantages:
1. Same as Sheet Piling Sand Trap Trench only less convenient to clean.

Total Project Cost = $321,000
Alternative: Shortened Modified Sheet Piling Diversion Wall

Description:
Same as Modified Sheet Piling Diversion Wall only sheet pilings do not extend all the way to lake high water level. Instead the sheet piles only extend 6-8 feet above the lake bottom in order to block the majority of the sediment migration toward the outlet structure.

Construction Overview:
Same as Modified Sheet Piling Diversion Wall.

Advantages:
1. Same as Modified Sheet Piling Diversion Wall only lower material and construction costs.

Disadvantages:
2. Same as Modified Sheet Piling Diversion Wall.

Total Project Cost = $109,000
Alternative: Cast-In-Place Concrete Diversion Wall

Description:
Same as Shortened Modified Sheet Piling Diversion Wall only walls are constructed as cantilevered concrete retaining walls.

Construction Overview:
This alternative assumes the walls will be formed up, reinforced, and poured in place. However, equivalent pre-cast wall sections may be substituted if the Board so desires.

Advantages:
1. Same as Shortened Modified Sheet Piling Diversion Wall only lower construction costs.

Disadvantages:
1. Same as Shortened Modified Sheet Piling Diversion Wall.

Total Project Cost = $96,000
Alternative: Slide Gate “Garages”

Description:
This option involves cleaning and repairing the existing control gates and outlet pipes and then constructing protective structures over the gates. In theory these structures, or “garages”, would allow for the gates to open even when they are buried in sediment. The hope is then that water in the lake will have enough head to flush the sediment through the outlet pipes and into the downstream canal where it could be removed as necessary.

Construction Overview:
The existing control gates and outlet pipes would be cleaned and repaired. “Garages” will have to be designed and constructed to sustain heavy sedimentation loading yet still allow adequate flow to enter the outlet pipes.

Advantages:
1. After proper cleaning and repairs the existing outlet pipes could continue to be used.
2. If the garages are properly designed this alternative allows for the existing maximum release rate of 370 cfs.
3. Low cost solution.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing outlet pipes.
2. This option does not try to reduce the amount of sediment arriving at the outlet structure.
3. Even with open gates sediment may not flush through the existing outlet pipes which would now be harder to clean.
4. Continued sedimentation problems in downstream canal.

Total Project Cost = $162,000
Alternative: Vertical Knife Gates

Description:
The outlet structure would be modified so that two of the existing slide gates would be replaced with vertically oriented knife gates. These knife gates would be opened and closed by operating stems which run up the face of the dam similar to the existing operating stems.

Construction Overview:

Advantages:
1. Same as for Deep Water Intake Pipes (370 cfs).

Disadvantages:
1. Same as for Deep Water Intake Pipes (370 cfs).
2. Reduces water release rate into downstream canal to 140 cfs.

Total Project Cost = $217,000
Alternative: Eccentric Plug Valves

Description:

Construction Overview:

Advantages:
1. After proper cleaning and repairs the existing outlet pipes could continue to be used.

Disadvantages:
1. This alternative will require initial cleaning and repairs to the existing control gates and outlet pipes.
2. This option only moves where the sedimentation problem occurs.
3. Continued pump operation and maintenance costs and the cost of removing sediment from the downstream canal will not be shared by the WWDC.
4. Sediment pump will require monitoring while in operation and grading equipment will be necessary to grade sediment at its final location.

Total Project Cost = $115,000
Alternative: Intake “Silo”

Description:
Construct a large concrete enclosure over two of the existing slide gates. This concrete “silo” would extend to above the lake high water line with six vertical headgates to control the lake release rate. The operating stems of the vertical canal headgates would extend to the top of the “silo”. The area between the “silo” and the dam would be backfilled to provide strength to the tall structure and to provide access to the operating handles.

Construction Overview:
The “silo” could either be cast-in-place or pre-cast. The vertical gates could be any standard canal headgate that is able to withstand the hydrostatic pressures of this application.

Total Project Cost = $268,000
Alternative: Modified Intake “Silo”

Description:
Same as the Intake “Silo” only a scaled down version. The structure would only extend to just above the 1908 water right. The existing slide gates would be used to control the release rate when the lake water level is above the 1908 elevation. The area between the “silo” and the dam would not be filled to save costs. Access to the operating handles would be by climbing a ladder to the top of the “silo”.

Construction Overview:
Again either a cast-in-place or pre-cast structure would be acceptable.

Advantages:
1. Same as Intake “Silo” only lower construction costs.

Disadvantages:
1. Same as Intake “Silo” only the top is not accessible during high water years.
2. During high water years some bouys or markers may be necessary to prevent boaters from hitting the partially submerged structure.

Total Project Cost $163,000
APPENDIX B

Cost Estimates
Alternative: Small Floating Sand Pump

- This cost estimate must include the cost of the equipment plus the operational costs for the next 30 years.
- The operation costs assumes a continued steady sediment deposition rate of 500 cubic yards per year.

Equipment & Operation Costs:
1. Purchase a small floating sand pump = $ 8,000
2. Purchase a small boat for operators = $ 1,000
3. Fuel costs
   50 gal/year X $ 2.50 /gal X 30 year = $ 4,000
4. Wages for 2 operators
   $250 /day X 2 days/year X 30 years = $ 15,000
5. Offsite storage of sand pump & boat
   $ 1,000 /year X 30 years = $ 30,000
6. Initial cleaning and repairs to existing control gates and outlet pipes = $ 30,000

   Equipment & Operation Costs = $ 88,000

Additional Costs per WWDC Formula:

   Equipment & Operation Costs = $ 88,000

   + Final Design = $ 2,000
   + Permitting & Mitigation = $ 1,000
   + Legal Fees = $ 1,000
   + ROW & Easements = $ 10,000 (waste site)

   Subtotal $ 14,000

   + Construction Engineering = $ 0 $ 88,000

   + Contingencies (15%) = $ 13,000 $101,000

   + Subtotal $ 14,000
   Total Project Costs = $115,000

TOTAL PROJECT COSTS = $115,000

- WWDC will NOT participate in any of this total project cost since it is considered maintenance. WWDC also does NOT finance maintenance so the PCLHID will have to locate another loan source.
- If PCLHID’s portion is financed for 30 years at 6% interest and distributed to all 10,400 Type A & Type N shares, the annual increase per share will be $ 0.80
Alternative: Cast-In-Place Concrete Diversion Wall

* Since the soil bearing pressure of the lake bottom is unknown, assume a typical cantilevered retaining wall cross-section. This is probably a conservative assumption since the water levels should remain equal on both sides of the wall resulting in very little lateral pressure for the wall to resist.

2002 RS Means Heavy Construction Cost Data, 16th Annual Edition provides the following cost estimate:

Reinforced concrete cantilever, incl. excavation, backfill, & reinf.
6’ high, 33º slope embankment $ 183 / L.F.

Because of Lake Hattie’s remote location and the limited quantity of concrete needed this estimate assumes a cost of $ 250 / L.F. of retaining wall.

Construction Cost of Cast-In-Place Retaining Wall =

$ 250 / L.F. X 200 L.F. = $ 50,000

Additional Costs per WWDC Formula:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Cost</td>
<td>$ 50,000</td>
</tr>
<tr>
<td>+ Final Design</td>
<td>$ 20,000</td>
</tr>
<tr>
<td>+ Permitting &amp; Mitigation</td>
<td>$ 10,000</td>
</tr>
<tr>
<td>+ Legal Fees</td>
<td>$ 3,000</td>
</tr>
<tr>
<td>+ ROW &amp; Easements</td>
<td>$ 0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$ 33,000</td>
</tr>
<tr>
<td>+ Construction Engineering</td>
<td>$ 5,000</td>
</tr>
<tr>
<td></td>
<td>$ 55,000</td>
</tr>
<tr>
<td>+ Contingencies (15%)</td>
<td>$ 8,000</td>
</tr>
<tr>
<td></td>
<td>$ 63,000</td>
</tr>
<tr>
<td>+ Subtotal</td>
<td>$ 33,000</td>
</tr>
<tr>
<td>Total Project Costs</td>
<td>$ 96,000</td>
</tr>
</tbody>
</table>

**TOTAL PROJECT COSTS = $ 96,000**

- WWDC will participate in 50% of this total project cost thereby reducing PCLHID’s portion to $ 48,000.
- If PCLHID’s portion is financed for 30 years at 6% interest and distributed to all 10,400 Type A & Type N shares, the annual increase per share will be $ 0.34
Alternative: Modified Intake “Silo”

- A pre-cast concrete rectangular “silo” will be utilized to reduce the cost of onsite forming and reinforcing.
- All four (4) of the existing slide gates should be repaired even thought the intake “silo” will only cover two (2) of the gates.

Construction Costs:
1. Clean & Repair all four existing slide gates and clean outlet pipes = $ 30,000
2. Pre-cast concrete rectangular “silo” delivered to site = $ 20,000
3. Modifications to existing concrete outlet structure + installation of “silo” = $ 30,000
4. 36” Canal Gates delivered $2,000 each × 6 canal gates = $ 12,000
5. Installation of Canal Gates = $ 2,000
6. Construction Cost = $ 94,000

Additional Costs per WWDC Formula:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Cost</td>
<td>$ 94,000</td>
</tr>
<tr>
<td>Final Design</td>
<td>$ 30,000</td>
</tr>
<tr>
<td>Permitting &amp; Mitigation</td>
<td>$ 10,000</td>
</tr>
<tr>
<td>Legal Fees</td>
<td>$ 3,000</td>
</tr>
<tr>
<td>ROW &amp; Easements</td>
<td>$ 0</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$ 43,000</td>
</tr>
<tr>
<td>Construction Engineering</td>
<td>$ 10,000</td>
</tr>
<tr>
<td>$104,000</td>
<td></td>
</tr>
<tr>
<td>Contingencies (15%)</td>
<td>$ 16,000</td>
</tr>
<tr>
<td>$120,000</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td>$ 43,000</td>
</tr>
<tr>
<td>Total Project Costs</td>
<td>$163,000</td>
</tr>
</tbody>
</table>

**TOTAL PROJECT COSTS = $163,000**

- WWDC will participate in 50% of this total project cost thereby reducing PCLHID’s portion to $ 81,500.
- If PCLHID’s portion is financed for 30 years at 6% interest and distributed to all 10,400 Type A & Type N shares, the annual increase per share will be $ 0.57