DIAGNOSTIC\FEASIBILITY STUDY REPORT
RAVINE LAKE
BEADLE COUNTY, SOUTH DAKOTA

SOUTH DAKOTA CLEAN LAKES PROGRAM
DIVISION OF WATER RESOURCES MANAGEMENT
SOUTH DAKOTA DEPARTMENT OF WATER AND NATURAL RESOURCES
JULY, 1990
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INTRODUCTION

The purpose of this report is to provide information gathered from a Diagnostic/Feasibility Study of Ravine Lake. The study was conducted from June, 1988 through September, 1989 and involved the cooperation of the South Dakota Department of Water and Natural Resources, and the City of Huron, South Dakota.

Excessive nutrient inflow and poor water quality have plagued Ravine Lake for many years and have resulted in declining recreational use. The study was initiated at local request to identify and assess the current status of the lake, determine water quality problems and pollution sources, and develop specific restoration alternatives. This report presents the results of data analyses, identification of significant lake impairments, and recommendations for restoration.

STUDY SITE DESCRIPTION

Ravine Lake has a surface area of 83 acres, a mean depth of approximately 7 feet and a maximum depth of 13 feet. The lake has been assigned the South Dakota beneficial uses of: warm water semipermanent fish life propagation, immersion recreation, limited contact recreation, and wildlife propagation and stock watering.

The Ravine Lake watershed contains 85,560 acres of the Northern Great Plains ecosystem of east central South Dakota. Figure 1 is a map of the Ravine Lake watershed. The watershed occurs entirely in Beadle County, South Dakota. The Ravine Lake watershed is approximately 24 miles long and 6 miles wide with its long axis on a northwest to southeast orientation. The principal receiving water body is Ravine Lake, a city-owned impoundment of Broadland Creek. The discharge from Ravine Lake drains to the James River. Huron, South Dakota, the primary user of the lake, lies directly west of Ravine Lake. In 1981 the estimated population within a 65 mile radius of the lake was 130,160.

The Ravine Lake watershed consists of flat to gently undulating glaciated uplands in the James Basin of the Central Lowlands Physiographic Province. Local topographic relief is generally less than 20 feet. Pierre shale of Cretaceous age forms the bedrock of the area and is mantled by an average of 75 feet of
Ravine Lake

77,178 acres

Figure 1  Ravine Lake Watershed
Pleistocene glacial till. The till contains a mix of clay, silt, sand, gravel, and boulders. Soils are generally deep, well-drained loamy soils formed in glacial drift.

The Ravine Lake watershed has a continental climate with extremes of hot and cold, and rapid fluctuations of temperature. The average annual temperature is 45°F and the average annual precipitation is approximately 20 inches. Agriculture is the primary enterprise of the watershed. Land use is estimated to be 51 percent cropland and 49 percent rangeland or pasture.

WATER QUALITY STANDARDS

The water quality standards for the State of South Dakota are based on the highest ranking beneficial use assigned to a body of water. The highest beneficial use assigned to Ravine Lake is warmwater semipermanent fish life propagation waters. Other beneficial uses assigned to Ravine Lake include immersion recreation, limited contact recreation, and wildlife propagation and stock watering. The water quality standards for Ravine Lake are listed in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Chlorine Residual</td>
<td>&lt;0.02 mg/l</td>
</tr>
<tr>
<td>Un-Ionized Ammonia Nitrogen</td>
<td>&lt;0.04 mg/l</td>
</tr>
<tr>
<td>Total Cyanide</td>
<td>&lt;0.02 mg/l</td>
</tr>
<tr>
<td>Free Cyanide</td>
<td>&lt;0.005 mg/l</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>&gt;5.0 mg/l</td>
</tr>
<tr>
<td>Undissociated Hydrogen Sulfide</td>
<td>&lt;0.002 mg/l</td>
</tr>
<tr>
<td>pH</td>
<td>&gt;6.5 units and</td>
</tr>
<tr>
<td></td>
<td>&lt;8.3 units</td>
</tr>
<tr>
<td>Suspended Solids</td>
<td>&lt;90 mg/l</td>
</tr>
<tr>
<td>Temperature</td>
<td>&lt;90°F</td>
</tr>
<tr>
<td>Polychlorinated Biphenyls</td>
<td>&lt;0.000001 mg/l</td>
</tr>
<tr>
<td>Fecal Coliform Organisms</td>
<td>&lt;200 per 100 ml*</td>
</tr>
</tbody>
</table>

*Based on geometric mean based on a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period, and they may not exceed this value in more than 20 percent of the samples examined in this 30-day period. A sample may not exceed 400 per 100 ml in any one sample from May 1 to September 30.
METHODS AND MATERIALS

Water samples were collected at 10 individual sampling sites in the Ravine lake Study Area. Figure 2 is a map of the sampling sites for the study. Site 1 was the outlet near the spillway of the dam. Sites 2 - 5 were tributary sites in the watershed of Ravine Lake. Sites 6 and 7 were in-lake sites. Sites SD1, SD2, and SD5 were storm sewer discharge outlets which drain directly into Ravine Lake. The Location of each of the sampling sites is as follows:

Site 1 - Located at the outlet structure near the spillway on the east side of the dam. Latitude: 44° 22' 03"N. Longitude: 98° 12' 04". Site 1 samples are representative of the water quality of the outflow of Ravine Lake.

Site 2 - Located 3/4 mile east of Highway 37 on the section line road forming the south boundary of Section 31 at the confluence of the northeast tributary and the section line road. Latitude: 44° 23' 07"N. Longitude: 98° 11' 59". Site 2 samples are representative of water quality for the portion of the watershed drained by the northeast tributary.

Site 3 - Located approximately 4/5 mile north of the Huron City Limits on Highway 37 at the confluence of the main tributary and Highway 37. Latitude 44° 23' 50"N. Longitude: 98° 12' 50". This site was selected to collect data from the major tributary leading to Ravine Lake.

Site 4 - Located 2,560 feet west of Highway 37 on the section line road forming the north boundary of Section 25 at the confluence of the North Branch of the main tributary and the section line road. Latitude: 44° 23' 59"N. Longitude: 98° 12' 53". This site provided loading data for an arm of the main tributary which flows through an area of concentrated animal feeding operations.

Site 5 - Located approximately 1/3 mile east of Highway 37 on the section line road forming the north boundary of Section 30 at the confluence of the north tributary and the section line road. Latitude: 44° 23' 58"N. Longitude 98° 12' 26". This site provided data for the portion of the watershed drained by the north tributary.

Site 6 - Located near the Burlington Northern railroad
Figure 2  Ravine Lake Monitoring Sites
trestle on Ravine Lake. Latitude 44° 23' 01"N, Longitude 98° 12' 21". This site provided in-lake data for the northern portion of Ravine Lake.

Site 7 - Located approximately near the north side of the bridge where Highway 14 crosses Ravine Lake. Latitude 44° 22' 15"N, Longitude 98° 12' 11". This site provided in-lake data for the southern portion of Ravine Lake.

Site SD1- Located approximately 1\4 mile east of highway 37 on the section line road along the northern border of section 31, near the west shore of Ravine Lake. Latitude 44° 23' 07"N, Longitude 98° 12' 33". This site provided data for storm drain #1.

Site SD2 - Located on the west shore of Ravine Lake near the Burlington Northern railroad trestle. Latitude 44° 22' 50"N, Longitude 98° 12' 23". This site provided data for storm drain #2.

Site SD5 - Located approximately on the west shore of Ravine Lake, east of the corner of Second St. and East Center St. in Huron, South Dakota. Latitude 44° 22' 07"N, Longitude 98° 12' 18". This site provided data for storm drain #5.

As listed in the following table (Table 2), the sampling period for this study extended from March 19, 1988, through July 10, 1989. During that period, a total of 173 samples were collected from the ten sites.

<table>
<thead>
<tr>
<th>SITE #</th>
<th>SAMPLE TIME PERIOD</th>
<th># OF SAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM:</td>
<td>TO:</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3/19/88 - 7/10/89</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>4/15/88 - 5/23/89</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>4/15/88 - 7/10/89</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>4/15/88 - 5/1/89</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>4/4/88 - 5/16/89</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>4/12/88 - 6/14/89</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>4/12/88 - 6/21/89</td>
<td>28</td>
</tr>
<tr>
<td>SD1</td>
<td>3/14/89 - 4/19/89</td>
<td>6</td>
</tr>
<tr>
<td>SD2</td>
<td>3/20/88 - 7/10/89</td>
<td>9</td>
</tr>
<tr>
<td>SD5</td>
<td>7/26/89 - 7/10/89</td>
<td>16</td>
</tr>
</tbody>
</table>

Total Samples: 173

The schedule for the collection of water quality samples at the three in-lake sites was comparable to that used at other D/F Study projects. At each of the sites two samples were collected.
per month from April through September, and one sample was collected per month from October through March except during unsafe ice periods. This sampling schedule was adhered to as nearly as possible throughout the project period. Occasionally, due to drought conditions in the watershed, there was no flow at some of the tributary sites. Under average conditions, samples are collected at the surface and bottom at each site. However, because of the relatively shallow depth of Ravine Lake - average depth approximately 7 feet - only surface samples were collected. The "surface" sample is actually a grab sample collected approximately 6" below the water surface.

The laboratory analyses were conducted by the South Dakota State Health Laboratory in Pierre, South Dakota. Field sample collection and analyses were done by Floyd Kallenburger, a local resident.

The raw water quality data was compiled by the Water Resources Management Division of the Department of Water and Natural Resources. Water quality data was loaded onto computer files and was analyzed for trends. A minimum, mean, and maximum were calculated for each of the parameters.

The water quality parameters that were sampled for at each of the three in-lake sites are shown in Table 3. A description of each of the parameters may be found in Appendix A.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter</th>
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</thead>
<tbody>
<tr>
<td>Water Temperature</td>
<td>Total Solids</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>Total Dissolved Solids</td>
</tr>
<tr>
<td>Secchi Disk</td>
<td>Total Suspended Solids</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>Ammonia</td>
</tr>
<tr>
<td>Field pH</td>
<td>Nitrates + Nitrites</td>
</tr>
<tr>
<td>Fecal Coliform Bacteria</td>
<td>Total Kjeldahl Nitrogen</td>
</tr>
<tr>
<td>Specific Conductance</td>
<td>Total Phosphorus</td>
</tr>
<tr>
<td>Laboratory pH</td>
<td>Orthophosphate</td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>Unionized Ammonia</td>
</tr>
</tbody>
</table>

A sediment survey was completed for Ravine Lake during February of 1986. Cross sections of the lake depicting water depth and sediment depth were taken at 100 ft. intervals for a distance of 700 feet north of the dam. Points for each cross section were taken at 100 foot intervals. The cross sections may be found in Appendix B.

Two elutriate samples were collected in the spring of 1988 and sent to the U.S. Army Corps of Engineers Laboratory in Omaha, Nebraska, for analysis. One sample was from the northern portion of the lake and one sample was from the southern portion of the lake. An elutriate sample is a sediment sample which is analyzed for toxic chemicals and/or metals. Results of the elutriate samples may be seen in Appendix C.
RESULTS AND DISCUSSION

A review of the water quality samples from the two in-lake sites produced somewhat predictable results. Most of the sample concentrations of the parameters tested were within the legal limits set by the Surface Water Quality Standards of the State of South Dakota (Table 1). However, factors such as Secchi Disk for determining water clarity and total phosphorus concentrations are not subject to standards limitations. Therefore, a simple review of standards violations is somewhat misleading.

Generally, the established standards for the concentrations of selected parameters are based upon the results of a 24-hour representative, composited sample. The numerical value of a parameter found in any one grab sample collected during the period may not exceed 1.75 times the applicable criterion. As an example, any single grab sample that yields a suspended solids number in excess of 157.5 mg/l is in violation of the standards (90 mg/l x 1.75). Also, the standard for pH states that the applicable criterion is to be maintained at all times, without exception. For Ravine Lake, the pH should not be below 6.5 units or above 8.3 units. All of the water quality samples collected for this project were individual grab samples. For a summary of the results of the sample analysis for each site please refer to Table 4. The results of the water quality sampling analyses for the Ravine Lake Diagnostic/Feasibility are in table form in Appendix C.

Based on the results of the data evaluation, the parameters of concern for Ravine Lake are dissolved oxygen, fecal coliform bacteria, pH, unionized ammonia, and phosphorus. Each one of these parameters exhibits either violations of existing standards and/or may be responsible for limitations on beneficial uses. The following discussion details the rationale for focusing on each parameter.

Dissolved Oxygen

The dissolved oxygen standard was exceeded on at least one occasion during the sampling period at site 3 on June 6, 1989. As noted above, the standard for dissolved oxygen is 5 mg/l. The concentration on June 6, was 1.1 mg/l. Low concentrations of dissolved oxygen are responsible for fish kills. During summer, water containing less that 3.5 mg/l of dissolved oxygen is lethal to most northern fishes. Decreases in dissolved oxygen can be attributed to the respiration of plants, animals, and the aerobic bacteria of decay (Cole, 1983).

Fecal Coliform Bacteria

Fecal coliform organisms are the bacteria which inhabit the digestive systems of warm-blooded animals. The presence of these bacteria in water is indicative of human or animal waste. The water quality standards for fecal coliform bacteria state that a
<table>
<thead>
<tr>
<th>SITE</th>
<th>OF SAMPLES</th>
<th>SITE</th>
<th>TEMP</th>
<th>ATEMP</th>
<th>SECCII</th>
<th>DISOS</th>
<th>FECAL</th>
<th>COND</th>
<th>LABPH</th>
<th>TALKAL</th>
<th>TSOL</th>
<th>TDSOL</th>
<th>TSOL</th>
<th>ANION</th>
<th>NITRO</th>
<th>TKN</th>
<th>N_H</th>
<th>TP4</th>
<th>OP4</th>
<th>OPO4</th>
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<td>SD-1</td>
<td>6 MINIMUM</td>
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<td>16</td>
<td>2.00</td>
<td>9.90</td>
<td>0</td>
<td>356</td>
<td>7.71</td>
<td>69</td>
<td>299</td>
<td>250</td>
<td>2</td>
<td>0.02</td>
<td>0.10</td>
<td>0.32</td>
<td>0.058</td>
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<td></td>
<td>MEAN</td>
<td>41</td>
<td>63</td>
<td>2.00</td>
<td>12.60</td>
<td>900</td>
<td>1500</td>
<td>8.04</td>
<td>444</td>
<td>1255</td>
<td>1191</td>
<td>516</td>
<td>0.60</td>
<td>0.90</td>
<td>1.94</td>
<td>0.461</td>
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<td>0.0042</td>
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<td>9 MINIMUM</td>
<td>26</td>
<td>34</td>
<td>1.80</td>
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<td>8.44</td>
<td>316</td>
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<td>0.96</td>
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<td>296</td>
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<td>14.20</td>
<td>3.77</td>
<td>0.508</td>
<td>0.300</td>
<td>0.0493</td>
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<td>16</td>
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<td>7.50</td>
<td>0</td>
<td>470</td>
<td>7.12</td>
<td>65</td>
<td>390</td>
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<td>0.11</td>
<td>0.22</td>
<td>0.024</td>
<td>0.005</td>
<td>0.0003</td>
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<td>6.79</td>
<td>34</td>
<td>539</td>
<td>278</td>
<td>2</td>
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<td>40</td>
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sample may not exceed a count of 400 per 100 ml in any one grab sample from May 1 to September 30. A total of 18 samples had counts of equal to or greater than 400 colonies per 100 ml of sample. SD-1 had 1 sample, SD-5 had 3 samples, site 1 had 6 samples, site 2 had 4 samples, site 3 had 1 sample and site 5 had 2 samples out of compliance with the standard for fecal coliform bacteria. Possible sources of this bacteria in Ravine Lake include wild mammals or birds, domestic animals or livestock, or a malfunctioning sewer system for homes near the lake or a leak of a sewer line to the storm sewer system.

**pH**

As noted above, the water quality standard for pH states that the pH must fall in a range between 6.5 and 8.3 units. The laboratory pH measurements were not below the minimum standard at any of the sites. The maximum pH standard was exceeded during the sampling period at 5 of the sampling sites. SD-2 had 3 samples, site 1 had 7 samples, site 3 had 10 samples, site 6 had 16 samples, and site 7 had 24 samples greater than 8.3 units of pH. The maximum pH measurement obtained at any site was 9.11. Limited evidence indicates that pH in excess of 8.3 units may cause minor eye irritation in swimmers. The high pH values may be the result of soil composition in the watershed. Vegetation (algae or macrophytes) can also cause elevated pH. The photosynthetic processes of plants can result in a rise in pH (Cole, 1983).

**Total Suspended Solids**

The Water Quality Standard for suspended solids at Ravine Lake is 90 mg/l. As noted earlier, when dealing with individual grab samples the standard concentration may be multiplied by 1.75 for an allowable concentration of 157.5 mg/l. Approximately 18 percent of the samples during the study were in excess of 157.5 mg/l. The mean concentration of all of the in-lake samples (site 5 and site 6) was 95 mg/l. Concentrations of suspended solids at this level impair recreation by giving the water a muddy appearance and subsequent reduced appeal. High concentrations of suspended solids may also adversely effect sight feeding species of fish, reduce oxygen intake by clogging gills and inhibit the growth of desirable aquatic plants by reducing light transmission.

**Un-ionized Ammonia**

The un-ionized ammonia standard for Ravine Lake is 0.04 mg/l. The standard concentration of un-ionized ammonia was exceeded in one sample at site SD-5 and one sample at site 3. Un-ionized ammonia is the fraction of total ammonia that is highly toxic to fish. The level of un-ionized ammonia is directly related to temperature and pH.
Phosphorus

The State of South Dakota does not include phosphorus in the water quality standards. In spite of this fact, the concentration of total phosphorus in Ravine Lake is extremely high. The average in-lake concentration of total phosphorus is approximately .7 mg/l. When phosphorus concentrations exceed .025 mg/l, nuisance growths of aquatic vegetation may occur (EPA 1976). Sources of phosphorus in a lake may be human or animal waste, fertilizer, detergent, run off from the land, and point source pollution. Total phosphorus concentrations in Broadland Creek ranged from 1.320 mg/l to a high of 7.100 mg/l during a period from April to July of 1988. These high concentrations coincided with a discharge from drain tile into Broadland Creek. The material discharging from the drain tile is believed to have been effluent from the wastewater treatment facility belonging to Huron Dressed Beef. Corrective measures have been taken to ensure that this discharge will not occur in the future. Huron Dressed Beef has constructed a zero discharge treatment facility so that all effluent will be disposed of on their own property.

Oil and Grease

Of the two elutriate samples collected in Ravine Lake, the elutriate water sample collected in the south end of the lake contained 8.6 mg/l of oil and grease. The South Dakota Standard for oil and grease is 10 mg/l. The source of the material may be from storm sewer discharge, an auto salvage business on the lake shore, a point source, or a spill.

CONCLUSIONS

The water quality of Ravine Lake is generally poorer than most eastern South Dakota prairie lakes. Nutrient concentrations are high both in the lake and the tributaries which feed the lake. Suspended solid concentrations are excessive and may indicate sedimentation of the lake basin.

The primary source of water to Ravine Lake is Broadland Creek. Broadland Creek is also the source of the majority of the nutrient and sediment pollution to the lake. Huron Dressed Beef was a point source to the lake at least during the spring of 1988 (EPA 1989). The problem has been corrected and no further discharge from Huron Dressed Beef is anticipated. Both an urban and agricultural nonpoint pollution problem is suspected in the lake and its watershed. The City of Huron has 5 discharge points from the storm sewer system which contribute nutrient and sediment to Ravine lake. Storm drain #5 seems to have a constant discharge even during extended dry periods. The source of this water was not determined during the course of the study. The storm sewer concentration while significant, does not account for the major loading of pollution to the lake.
Due to the size of the Broadland Creek watershed and the concentrations of nutrients in the samples, it is apparent that most of the loadings enter the lake from Broadland Creek. Some potential sources of nutrients to the lake in the Broadland Creek watershed include runoff from agricultural land, runoff from the golf course, feedlot runoff, and airport runoff. The only point source identified in the watershed was Huron Dressed Beef. Huron Dressed Beef is not expected to be a source of pollution in the future due to the construction of the new waste water treatment facility.

RESTORATION ALTERNATIVES

The alternatives considered for restoration of Ravine Lake include the following:

1. No action
2. Broadland Creek hydrologic unit plan
3. Reroute storm drain discharge
4. Selective dredging
5. Dewatering of reservoir
6. Land based removal of sediment

No Action

If the no action alternative is selected, the lake will not improve. The large concentration of nutrients currently in the lake will continue to cycle through the system. The lake will continue to degrade and algae or emergent macrophytes may take over the lake. Odor problems may develop due to decaying organic material. Recreation will be increasingly impaired.

Broadland Creek Hydrologic Unit Plan

If the Broadland Creek hydrologic unit plan alternative is selected, the pollution problems in the watershed will be identified and an implementation strategy will be developed. The City of Huron may contact the Beadle County Conservation District and request a hydrologic unit plan be completed for the Broadland Creek watershed and Ravine Lake. With the help of the Department of Agriculture, Soil Conservation Service, a series of public hearings will be held to get input from the landowners, and other interested parties. A strategy for the implementation of corrective measures will be the final product of this process. This is one of the requirements for eligibility for Section 319, Nonpoint Source, and federal assistance from the Environmental Protection Agency.

Reroute Storm Drain Discharge

If the Reroute Storm Drain Discharge alternative is selected, engineering plans and specifications will need to be developed. This alternative will eliminate the effect of the nutrients from
the storm drains. The source of the continual discharge to storm drain number 5 is unknown. This alternative may not have an acceptable cost to benefit ratio. This alternative needs further study before implementation.

Selective Dredging

If selective areas in the lake basin are dredged, there will be several improvements. Fish habitat will be enhanced and the threat of summer and winter fishkill will be reduced. There will be better control of macrophytes in the dredged areas. Selective dredging is less expensive and less time-consuming than whole lake dredging. Fewer sediment disposal ponds would need to be constructed. Suspended solids may remain a problem, depending on how much sediment is removed, due to resuspension of the remaining sediment by wind or recreation activities. If dredging is concentrated in areas with greatest sediment accumulation that is prone to wind and wave action, improvements would be most noticeable. In addition, dredging thick layers of sediment would improve dredging efficiency. Hydraulic residence time may be increased with dredging. This will result in slower flushing time. The cost of operation for an eight inch dredge is estimated to be approximately $175,000 per year.

Dewatering of Reservoir

If the Dewatering the Reservoir alternative is selected, the removal of water from the lake basin would probably be accomplished by the use of a pump. The volume of Ravine Lake is approximately 556.1 acre-feet. This volume of water could feasibly be removed by the use of a high capacity pump. Pumps are available for lease that will pump up to 10,000 gallons per minute. The cost of leasing a pump will depend on the size of the pump. For a 12 inch diesel pump the rental cost is approximately $5,000 to $7,000 per month. Shipping cost for a pump of this size will be approximately $4,000. It would take a pump of this size approximately 1.5 months to dewater Ravine Lake. Ideally, the lake basin should remain dry for one summer and one freeze-thaw cycle.

Several potential benefits will occur by the use of this alternative. By exposing the bottom of the lake, the sediment will consolidate and lake volume will increase slightly. The consolidation of sediment is considered to be permanent and the material will not rise back up. The rich organic surface of the sediment will be oxidized and this may reduce release of nutrients to the water from the sediments. Aquatic macrophytes may be controlled using this method. Any subsurface pollution sources may be detected and corrected during the period that the lake is dewatered. Total removal of the rough fish population could be accomplished during the drawdown, however, rough fish would eventually return to the lake. After the lake basin is allowed to refill, the lake may be restocked with more desirable species of game fish. Some rip-rap is needed on the north end of
the lake. This alternative would make the riprapping easier to accomplish and therefore cheaper. The lake is currently extremely eutrophic and high in nutrient concentration. This alternative will allow for the rapid removal of the nutrient rich water all at once. Higher quality water will replace the existing water in the reservoir (Cooke, 1986 and Wisconsin DNR, 1975).

There are several potential negative factors involved with this alternative. Potential failure of the reservoir to promptly refill is one of the risks of dewatering the reservoir. Drought is always a potential problem in South Dakota. Blooms of algae have been reported after reflooding of lakes which have been dewatered. Care must be used in game fish salvage operations during drawdown to avoid a fishkill. The lake basin may be taken over by noxious weeds during drawdown but the weeds would be drowned out during reflooding. Also chemical weed control may be used if necessary. The soft, flocculent sediment may crust over creating a hazard to people attempting to walk across the lake basin.

Land Based Removal of Sediment

If the Dewatering of the Reservoir is selected, land based removal of the sediment is a possibility. Rather than attempting to remove all of the soft sediment from the lake, a series of deep pools may be constructed. These pools would increase recreation potential in the lake and provide fish habitat. The advantage of land based removal of sediment is that it can be accomplished with conventional equipment such as draglines, bulldozers or scrapers. The dry sediment may be transported and disposed of immediately by trucks. The sediment may be removed after it dries or in the winter. The City may remove as much sediment as it desires or can afford and locate the pools in the lake basin at whatever location they desire. In addition, fish habitat structure may be constructed, such as rock piles, ditches, or walls.

RECOMMENDATIONS

Based on the information collected in the course of this study and an evaluation of historical baseline data, the Water Resources Management Division of the Department of Water and Natural Resources recommends that restoration activities of Ravine Lake be accomplished using the following restorative alternatives.

1. Broadland Creek Hydrologic Unit Plan
2. Dewatering of the Reservoir
3. Land Based Removal of Sediment
The reason for the selection of the Broadland Creek Hydrologic Unit Plan alternative is to address the pollution entering the lake from the watershed. This alternative is the most cost effective and practical method of dealing with the problem. This method will allow the landowners to have a voice in the implementation of management practices to reduce the sediment and nutrient load to the creek and ultimately to the lake. The inflow of nutrients and sediment from Broadland Creek is by far larger than the input from the City storm drains due to the amount of land drained by Broadland Creek. The City may also wish to consider urban best management practices (BMP’s) to control the water quality in the storm runoff to the lake. Urban BMP’s may be incorporated into the hydrologic unit planning process for the watershed. Some urban BMP’s include sediment traps for areas which contribute large amounts of sediment to the storm sewer runoff, an aggressive street sweeping program, and an inspection of the sanitary sewer system to insure that the system is not leaking into the storm sewer system.

There are several reasons for choosing the Dewatering the Reservoir alternative. This method is much more cost effective for Ravine Lake than a dredging project. This alternative will improve the recreation potential of the lake faster than the hydrologic unit alternative alone. The water in the lake has extremely high concentrations of nutrients and it will take a much longer period of time to clean itself by natural flushing. The riprap installation will be easier on the north end of the lake if the lake is dewatered. The loss of availability of lake water for irrigation on the golf course is a local problem which should be considered by the City. The primary goals of this alternative are to remove the nutrient rich water from the lake, consolidate the sediment and increase lake volume, and to oxidize the organic material on the surface of the sediment layer. Other goals may include rough fish removal and game fish restocking, macrophyte control, construction activities such as riprap of eroded shoreline areas or possibly swimming beach construction.

The Land Based Removal of Sediment alternatives was selected to improve the fish habitat in the lake and to reduce the threat of fishkill in Ravine Lake. The addition of structure to the lake will improve the fishing in the lake. The sediment removal may be conducted by the City to the extent that the City wishes. The State recommends a series of deep pools at intervals along the length of the reservoir. This will increase the area which fish may winter in and increase area for recreational fishing.

The City may select any of the restoration alternatives listed and described in this report or choose to take another plan of action. The restoration alternatives are presented to the City as a group of options based on the watershed and water quality information available.
REFERENCES


Wisconsin Department of Natural Resources. Survey of Lake Rehabilitation Techniques and Experiences., 1974.
APPENDIX A. DESCRIPTIONS OF WATER QUALITY PARAMETERS
WATER QUALITY PARAMETERS

1. Laboratory Analysis:
   a. **Fecal coliform** (organisms/100ml) can indicate fecal contamination and thus potential human health hazards. Fecal coliform bacteria are bacteria which live in the digestive tract of warm-blooded animals. These bacteria are considered to be an indicator of sewage pollution or livestock manure. Fecal coliform bacteria are not found in the digestive tract of cold-blooded animals such as fish, amphibians or reptiles. Some fecal coliform will exist in nature from the fecal material of wild animals or birds.

   b. **Biochemical oxygen demand** (BOD) (mg/l) is used to measure the organic content in polluted waters. BOD is a measurement of the potential for oxygen removal from the water and an indicator of organic pollution. As organisms die, the process of decomposition by bacteria removes dissolved oxygen from the water. The more nutrient rich the environment, the more potential for growth of aquatic organisms; hence, there will be more bacterial decomposition.

   c. **Laboratory pH** (su) is a measurement of the hydrogen ion activity which directly affects the toxicity (solubility) of heavy metals in water, among other items. The pH scale is a number range between 1 and 14, with 7 being neutral. Any value less than 7 is considered acidic and any value greater than 7 is considered basic.

   d. **Suspended solids** (mg/l) can indicate the sediment load into a body of water and possible problems to the biological community. Suspended solids does not include a measure of larger particles that are moved along the stream bed during high flows.

   e. **Total solids** (mg/l) are used to determine dissolved solids by subtracting suspended solids from total solids. Dissolved solids may have a detrimental affect on the biological community.

   f. **Ammonia-nitrogen** (mg/l) is a product of the first oxidative step in degrading organic material. It is directly available to plants as a nutrient for growth. Ammonia can be used as evidence of organic pollution and the unionized fraction of ammonia is toxic to fish.
g. Nitrate-nitrogen (mg/l) constitutes the inorganic nitrogen fraction which is used by phytoplankton. Nitrate-nitrogen also indicates pollution from animal wastes, fertilizers or nitrogenous organic matter which are used by algae. It gives an indication as to what may be causing pollution in a lake (i.e., fertilizers, animal wastes, nitrogenous organic matter).

h. Total Kjeldahl Nitrogen (mg/l) is used to measure both ammonia and organic nitrogen. Ammonia is subtracted from TKN and results in the organic nitrogen fraction which can be broken down to nitrogen compounds which are utilized by phytoplankton.

i. Total phosphorus (mg/l) represents all of the phosphorus found in the water sample. Not all of the phosphorus is immediately available to aquatic plants and algae. Phosphorus is an element which is essential to all life and is the least available to living organisms. For this reason, phosphorus is commonly the limiting factor for biological productivity. When phosphorus concentrations are high, nuisance growth of aquatic plants or algae may result.

j. Ortho-phosphorus (mg/l) is analyzed because it is phosphorus which is immediately available to algae.

2. Field Analysis:

a. Water temperature (F or C) is taken since it has considerable effect on the chemical processes in a lake. Also, temperature is important to fish life and other aquatic species.

b. Field pH (su) measures the hydrogen ion activity which can affect the toxicity of heavy metals in the water, as well as other factors.

c. Dissolved oxygen (mg/l) is an indicator of the overall health of the lake and it is needed to sustain most aquatic animal life.

d. Climatic conditions - wind, precipitation, air temperature (F or C).

e. Visual observations - septic conditions, odor, water color, turbidity or anything unusual (e.g. dead fish).

f. Tributary flow depth (ft.) to calculate flows entering the lake.
g. The following additional measurements are taken for in-lake analysis: water depth, oxygen profiles, composite sampling at various lake depths (surface, mid-depth, and bottom), chlorophyll a, secchi disc (visibility) and phytoplankton identification.

3. In-lake Sediment Sampling

a. Corps of Engineers elutriate test for some of the above mentioned parameters plus selected pesticides: such as endrin, DDT, parathion, etc., is used to determine what is in the sediments.

b. Sediment topographic surveys and sediment depth measurements are used to determine sediment volumes in the lake.
APPENDIX B. CROSS SECTIONS OF RAVINE LAKE
RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1980

DEPTH

WATER PROFILE

SEDIMENT PROFILE

300

1200

1100

1000

900

800

700

600

500

400

300

200

100

0

-10

-15

-20

0

100

200

300

400

500

600

700

800

900

1000

1100

1200

FEET
RAVINE LAKE CROSS-SECTIONS

FEBRUARY 1986

DEPTH

WATER PROFILE

SEDIMENT PROFILE

FEET

0 100 200 300 400 500 600 700 800 900 1000 1100 1200

-20 -15 -10 -5 0
APPENDIX C. WATER QUALITY DATA AND ELUTRIATE RESULTS
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<th>FERAL</th>
<th>COMB</th>
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**RAVINE LAKE SIMPLE CONCENTRATIONS 1980 - 1989**