DEFINITE PROJECT REPORT
WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

SECTION 206
LAKE BELLE VIEW
AQUATIC ECOSYSTEM RESTORATION PROJECT

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HYDROLOGY AND HYDRAULICS

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DEFINITE PROJECT REPORT
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SECTION 206
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APPENDIX H
HYDROLOGY AND HYDRAULICS

This appendix provides a hydrologic assessment of the area and summarizes the hydrologic and hydraulic evaluation of various project features considered as part of the Lake Belle View Aquatic Ecosystem Restoration Project. This includes all features considered throughout the feasibility phase of the environmental management project.

1. INTRODUCTION AND LOCATION OF SITE

Lake Belle View is a shallow millpond located approximately 20 miles southwest of Madison on the Sugar River in the Village of Belleville, Dane County, Wisconsin. The Sugar River watershed above Lake Belle View is approximately 172 square miles. Two river channels (Sugar River and West Branch Sugar River) converge several miles upstream of Lake Belle View. The Sugar River watershed is highly agricultural and experiencing rapid urban growth. The project area includes a lake, floodplain forest, and various wetland communities totaling in 133 acres. The lake itself averages 2 feet in depth and has a surface area of approximately 93 acres. Bordering the project area are a park, residences, roads, and farmland.

2. CLIMATE

Climatological data for this site are collected at the Madison WSO Airport gage. Temperature, precipitation, and snow depth data were recorded over a 53-year period from 1948 through 2000.

The climate of this area is typical of the Midwestern United States with warm, wet summers and cold, dry winters. The maximum average temperature of 78 degrees Fahrenheit occurs in July while the minimum average temperature of 3.7 degrees Fahrenheit occurs in January. The average annual precipitation is 32.0 inches with a standard deviation of 5.3. The average annual snowfall is 44.6 inches with a standard deviation of 15.2. Monthly mean values appear in Table H.1 below.

Table H.1. Summary of monthly precipitation and snowfall, Madison, Wisconsin.

Month	Rain (inches)	Snow (inches)	Month	Rain (inches)	Snow (inches)
January	1.22	11.02	July	4.06	0.00
February	1.15	7.47	August	3.83	0.00
March	2.13	7.90	September	3.00	0.00
April	3.11	2.39	October	2.24	0.28
May	3.28	0.08	November	2.09	3.71
June	4.15	0.00	December	1.59	10.51

2.1 Evaporation

Evaporation of Lake Belle View is expected to be 28 inches to 30 inches per year [Ref. 7], which is considered negligible for all project alternatives. The average annual precipitation is 32 inches per year. Groundwater inflow is estimated to be 0.75 cfs (cubic feet per second) into the lake in the eastern diversion alternatives, or 1.5 cfs in the western diversion alternatives.

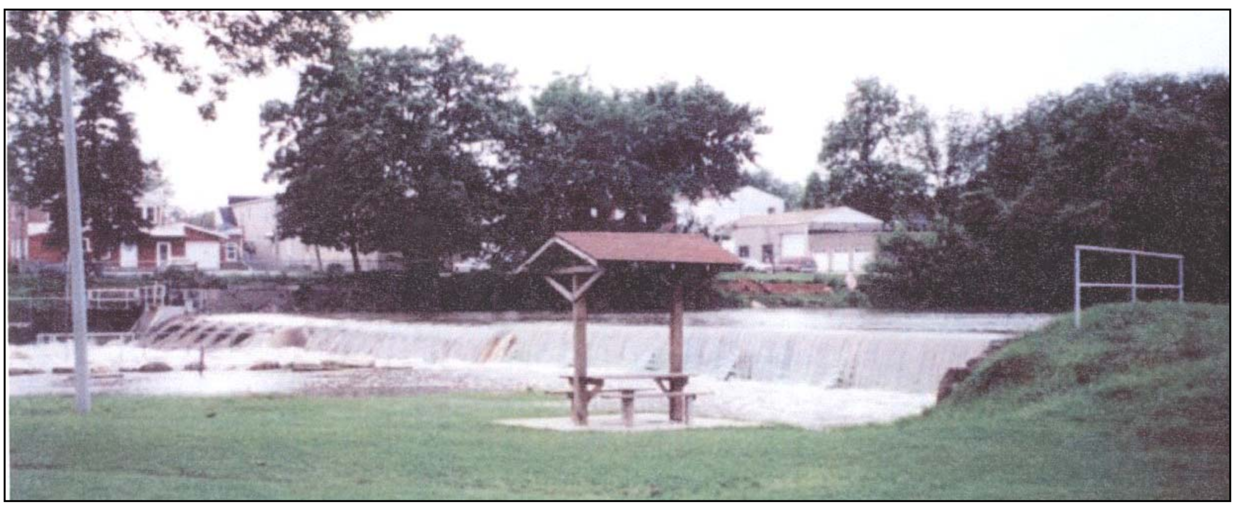
2.2 Wind-Driven Waves

Shoreline erosion is reduced by constructing gentle slopes on the interior (lake side) of a separation berm. Gentle slopes also reduce the amount of seepage through the separation berm and increase the diversity of wetland plant species. Establishment of vegetation on the slopes further reduces shoreline erosion and through seepage. Due to the prevailing wind direction, a separation berm on the eastern portion of the lake (Alternatives 1, 2, and 3) would experience higher wave-induced erosion than a separation berm placed on the western portion of the lake (Alternatives 4 and 5). Wave analysis indicates that the significant wave height is less than 0.5 foot, wind gusts of 40 mph produce waves of 1 foot, and wind gusts of 75 mph produce waves of 2 feet.

3. BELLEVILLE DAM

Belleville Dam
typical flow condition

Belleville Dam is a concrete structure approximately 15 feet high and 150 feet long. On the south side of the dam are two 6-foot-long lift gates. To the north of the gates is the principal spillway of the dam, which is 64 feet long at an elevation of 857.4 feet (above mean sea level). North of the principal spillway is the emergency spillway, which is divided into two sections. The first section, which is part of the main dam, is 64 feet long with an average elevation of 857.7 feet. The second section of the emergency spillway is a low, grassy area to the north of the concrete structure. This section is 134 feet long and has an elevation of 859.0 feet [Ref 2]. See Figure H.1 on the following page for a diagram of Belleville Dam with dimensions.



Belleville Dam: June 2, 2000 flood flow conditions
Approximate Flow: 1,800 cfs (33% exceedance probability)

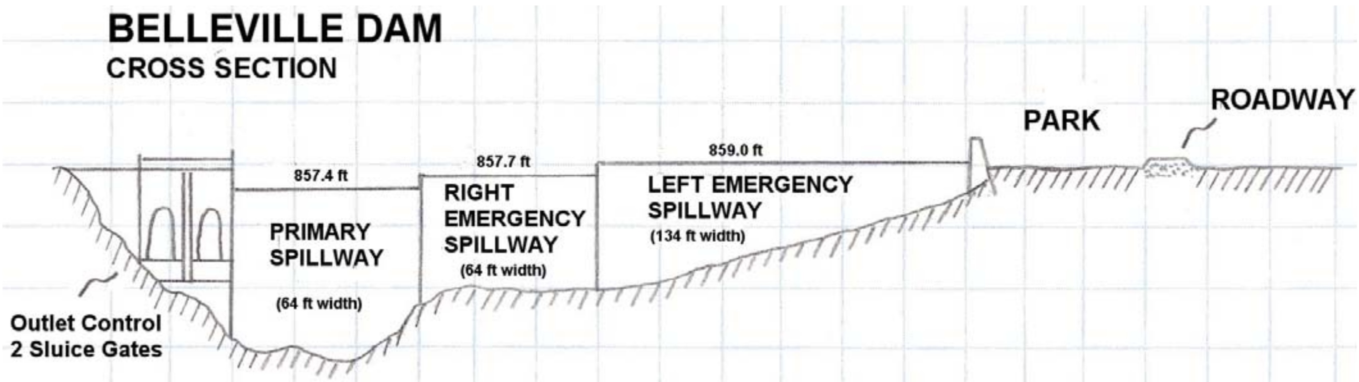


Figure H.1. Schematic drawing of Belleville Dam, Belleville, Wisconsin.

The total flow capacity of the dam, including the principal and emergency spillways but not the two lift gates, is 1,625 cfs. The capacity increases to 1,975 cfs with the two lift gates opened. Removing the stoplogs at the canal gate (or mill race) would allow for an additional 153 cfs discharge, making 2,130 cfs the maximum discharge capacity for Lake Belle View [Ref. 2].

Once the total flow capacity of the dam is exceeded, water passes around the northern abutment of the left emergency spillway and flows through the park to rejoin the Sugar River.

4. MILLRACE CHUTE

Belleville millrace: typical flow condition

Belleville millrace: 1997 flood flow

Located approximately 600 feet northeast of Belleville Dam, at the southeast corner of Lake Belle View, the Millrace Chute allows minimal flow to pass from the lake into the Sugar River. Of historical significance, this location was the former location of the Belleville Mill. In the "eastern diversion" alternatives of this 206 project, this location would be excavated to allow the Sugar River to bypass Lake Belle View. The bottom width of the new channel would be 65 feet, requiring a new bridge to be constructed that would allow access to the island park. In the "western diversion" alternatives, this location would serve as an outlet channel for lake level management and would remain unaltered.

If the stoplogs at the canal gate are removed, a maximum discharge of 153 cfs could be released during flood conditions. If the stoplogs are not removed during a flood, the lake level would rise slightly and send the 153 cfs over the dam. Lake levels would rise no more than 0.34 foot during a large flood if the stoplogs were not removed from the millrace.

5. SUGAR RIVER

5.1 Flood Conditions at Brodhead

The nearest gaging station to Lake Belle View is located more than 20 miles downstream of Belleville Dam, at Brodhead, WI. This gage is owned and maintained by the U.S. Geological Survey, Madison, WI and data recorded from this station can be accessed at: http://water.usgs.gov/wi/nwis/uv?05436500 . Hydrographs from 1914 to 2000 measured at the Brodhead gaging station can be found at this site. The drainage area at the gaging station is 523 square miles. The largest flood at Brodhead occurred on September 14th, 1915 with a peak flow of 10,600 cfs (see Fig H.2). This flow is approximately the 4% exceedance event (25-year recurrence interval). Other discharge frequencies are shown on Table H.2 on the following page.

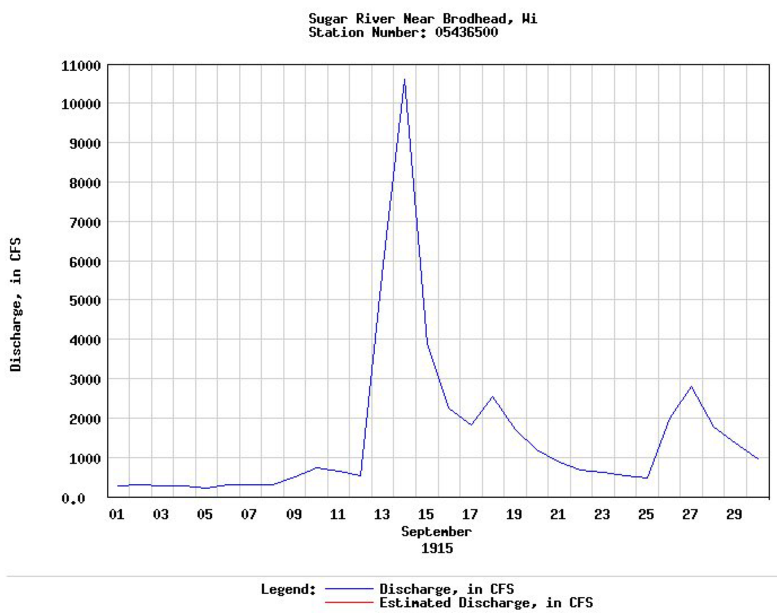


Figure H.2. Largest recorded flood at Brodhead gage (September 1915)

Table H.2. Flood discharges at gage station 05436500 on the Sugar River near Brodhead, Wisconsin (WRC skew = -0.181, SE_{100} = 15.0)

Annual Exceedance Frequency (%)	Recurrence Interval (years)	Discharge at Brodhead (cfs)
50.0%	2	3,390
20.0%	5	6,180
10.0%	10	8,360
4.0%	25	11,400
2.0%	50	13,900
1.0%	100	16,600

The above values were computed by the U.S. Geological Survey and published in 1992 [Ref. 4]. The U.S. Army Corps of Engineers computed new flow-frequency values using HEC-FFA in order to extend the period of record to 1914-1999 at Brodhead. The new frequency analysis yielded similar results to those listed in Table H.2 above (see Plate H-1).

5.2 Flood Conditions at Belleville

The drainage area at the Brodhead gaging station is 523 square miles, but is only 172 square miles at Lake Belle View. Since there is no gage station close to Lake Belle View on the Sugar River, a discharge-frequency curve was developed by scaling down the flows at Brodhead according to drainage area and plotting on log-probability paper (see Plates H-2 and H-3). MSA Professional Services developed the curves in June 1999 [Ref. 1]. Flood frequencies for Belleville appear in Table H.3.

Table H.3. Discharges for various flood frequencies on the Sugar River upstream of Lake Belle View.

Annual Exceedance Frequency (%)	Recurrence Interval (years)	Discharge Upstream of Lake Belle View (cfs)
80.0%	1.25	800
50.0%	2	1,500
20.0%	5	2,600
10.0%	10	3,600
4.0%	25	4,900
2.0%	50	5,900
1.0%	100	8,000
0.2%	500	11,890

Flood elevations listed on Plate H-4 were computed in 1978 using the hydraulic model HEC-2. The results were published as part of a FEMA Flood Insurance Study [Ref. 3] for Dane County, which was revised in 1986. In 1999, MSA converted the HEC-2 information to HEC-RAS and produced flood profiles that were very similar to the HEC-2 results. The RAS model was then modified (by MSA) to produce flood profiles for the initial eastern and western diversion plans of this 206 Project (see Project Alternatives section of this appendix for details). In 2002, USACE updated the HEC-RAS model to allow for greater lake-river separation and prolonged project life (see HEC-RAS Model section of this appendix for details).

5.3 Mean and Drought Conditions at Belleville

Since there is no gaging station at Belleville, the minimum flow is an estimate based off of the Flow-Frequency curves (Plates H-2 and H-3). Mean flow statistics at Brodhead are located on Plates H-5 and H-6. At the Highway 69 Bridge in Belleville, the estimated mean monthly flows appear in Table H.4 below.

Table H.4. Mean monthly discharge on the Sugar River at the Highway 69 Bridge in Belleville, Wisconsin.

Mean Monthly Discharge (cfs)											
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
97	142	222	151	120	117	98	85	98	93	101	90

The average annual discharge on the Sugar River in Belleville is 118 cfs. The lowest mean monthly discharge occurs in August with a discharge of 85 cfs. The lowest estimated drought condition flow is 50 cfs. All project alternatives consider this minimum flow in order to keep Lake Belle View at its normal pool during a drought. In the Eastern Diversion alternatives, the crest of the upper riffle structure should be set to a similar crest of the dam (857.4 ft NGVD); otherwise, the water level of Lake Belle View would drop.

Sugar River discharge in the Lake Belle View area was measured in August 2000 by the USGS [Ref. 5]. At that time, the river discharge was 114 cfs. It would be beneficial to establish a stage recorder or gage station at Belleville due to the differences in drainage area and flood peak timing between Belleville and the Brodhead gage. Downstream of the Highway 69 Bridge in Belleville, Wisconsin, would be a good location for a stage recorder or gage station, or a stage recorder could be placed at the crest of the dam and the discharge computed hydraulically.

6. PROJECT ALTERNATIVES

Five project alternatives considered in the Lake Belle View feasibility study are designed to improve aquatic habitat and enhance wetland habitat. The first three alternatives (Alternatives 1, 2, and 3) separate the river flow from the lake by using a separation berm in the northern and eastern portion of the lake. The eastern portion of the city park island (mill race location) would be excavated to provide for a channel with a minimum bottom width of 65 feet. The last two alternatives (Alternatives 4 and 5) direct the river flow through the western portion of the lake and towards the present dam. A separation berm is also used in these alternatives, but alternative 5 is a non-continuous berm that allows river flow to enter the lake as river levels increase. The western diversion alternatives require a form of fish passage to be implemented so that the Belleville Dam is no longer a barrier to fish migration. Diagrams of all five project alternatives appear below, followed by summaries of eastern diversion and western diversion alternatives.

6.1 Alternative 1

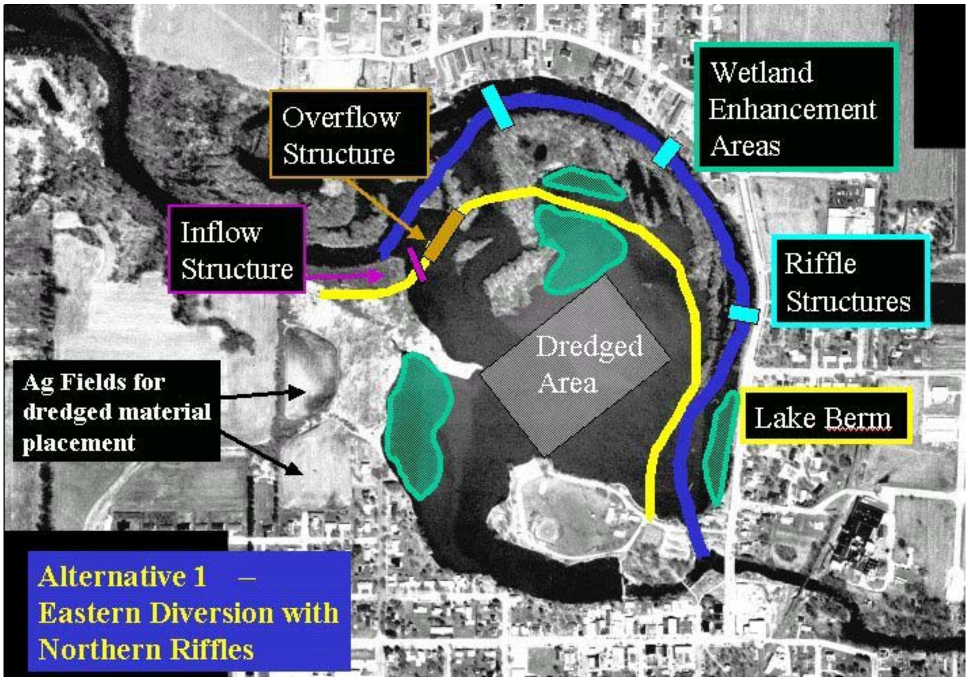


Figure H.3. Alternative 1 - Eastern diversion with northern riffles.

This alternative combines sediment removal, river diversion wetland enhancement and periodic drawdown. River restoration would include recreating the river channel by excavation along the northern and eastern lake perimeter, and reconnecting the river at the existing millrace just upstream of the Highway 69 Bridge. The excavated channel has a 65-foot bottom width and 3:1 sideslopes. A berm with an approximate 50-year crest elevation (862 ft NGVD) separates the lake from the river. An overtopping spillway is located in the berm at the northwestern portion of the lake. This spillway must be a minimum of 300 feet long with a crest elevation of 861 ft NGVD, which corresponds to the 25-year crest elevation. Wetland enhancement measures would be implemented primarily in the northern and western portions of the lake (see green shaded areas in Figure H.3). Inflow and outflow control structures also would be included to assist in management of water level within the lake, as well as providing the opportunity for periodic lake drawdown and replenishment of dissolved oxygen to the lake. Riffle structures would be placed along the northern shore, the northeastern shore, and the eastern shore in the newly excavated river channel to provide for grade control and fish passage. The channel bottom would be excavated to form a slope of 1-foot drop per 1,100 feet of length between the riffles. This is the natural slope of the Sugar River in this area [Ref. 3]. Rough fish control will be implemented though a combination of netting and a “carp gate” located upstream of the uppermost riffle structure. Significant riprap is needed for bank stability because flood flows are concentrated against the Highway 69 embankment. A total of 27,000 cubic yards of riprap was computed for this alternative. A profile diagram of this alternative appears on Plate H-7.

6.2 Alternative 2

Figure H.4. Alternative 2 - Eastern diversion with southern riffles.

This alternative is very similar to Alternative 1, except that the riffle structures are concentrated on the eastern shore in the newly excavated river channel to provide for grade control and fish passage. This alternative requires less riprap and channel dredging than Alternative 1 and is likely to be less expensive. Originally, a single riffle was examined, but a long rock ramp is less effective for fish passage than a series of smaller riffles. The channel bottom between the riffles would be excavated to form a slope of 1 foot drop per 1,100 feet of length, which is the natural slope of the Sugar River in this area [Ref. 3]. The excavated channel has a 65-foot bottom width and 3:1 sideslopes. A berm with an approximate 50-year crest elevation (862 ft NGVD) separates the lake from the river. An overtopping spillway is located in the berm at the northwestern portion of the lake. This spillway must be a minimum of 300 feet long with a crest elevation of 861 ft NGVD, which corresponds to the 25-year crest elevation. Rough fish control will be implemented though a combination of netting and a “carp gate” located in the northwestern portion of the lake. Significant riprap is needed for bank stability in the riffle structure area because flood flows are concentrated against the Highway 69 embankment. A total of 22,300 cubic yards of riprap was computed for this alternative.

6.3 Alternative 3

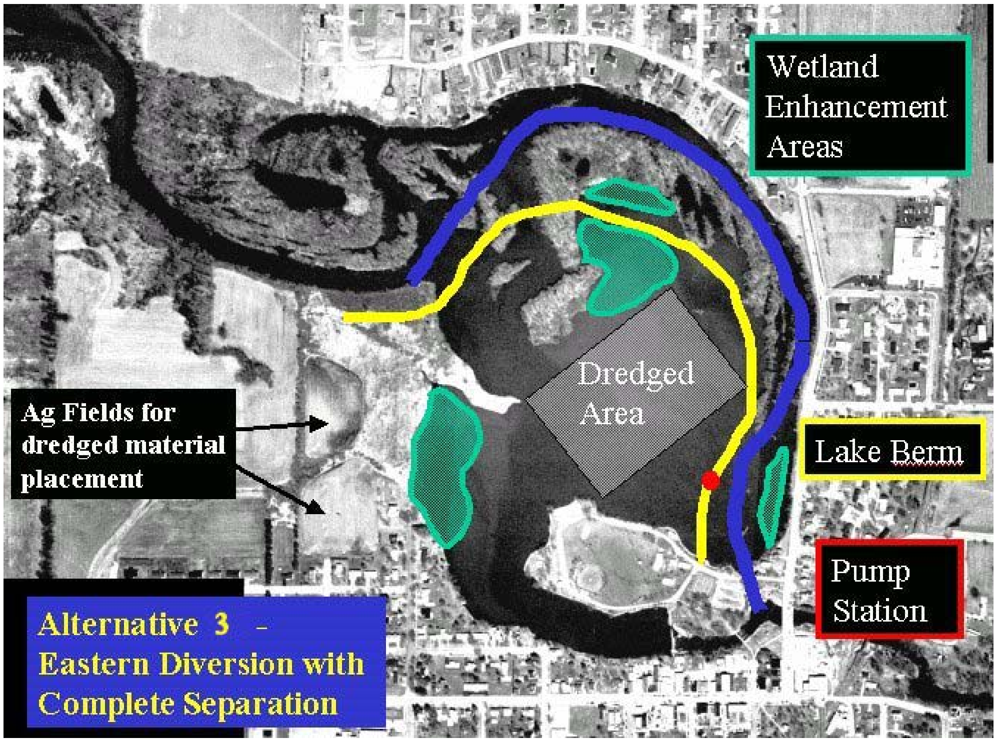


Figure H.5. Alternative 3 - Eastern diversion with complete separation.

This alternative provides for total separation of the lake and river. Because state requirements say that the 100-year flood profile may not be impacted, the separation berm can be no higher than the 25-year to 50-year elevation (861 ft to 862 ft NGVD). Once a large flood occurs, overtopping will begin at the northwestern part of the berm. Since this area does not have an overtopping spillway, it is expected that the berm would wash out in this location and need to be occasionally repaired. Inflow to the lake is accomplished using a pumping station in the southeastern portion of the lake. Seepage analysis indicates that 50 cfs total may seep from the lake to the river for all three eastern alternatives. This means that the minimum pump capacity needed to sustain the lake level would be 22,440 gallons per minute, with the pump running continuously. Complete separation means that sediments, nutrients, and rough fish would be excluded from the system. Dissolved oxygen may become depleted in winter, and added aeration may be necessary beyond the proposed pumping station. River restoration would excavate through the current millrace location, and let the river establish its own natural grade through the area. Future maintenance (adding riprap) would be necessary to control headcutting and bank sloughing. The excavated channel through the millrace location has a 65-foot bottom width and 3:1 sideslopes. Wetland enhancement measures would be implemented primarily in the northern and western portions of the lake (see green shaded areas in Figure H.5).

6.4 Alternative 4

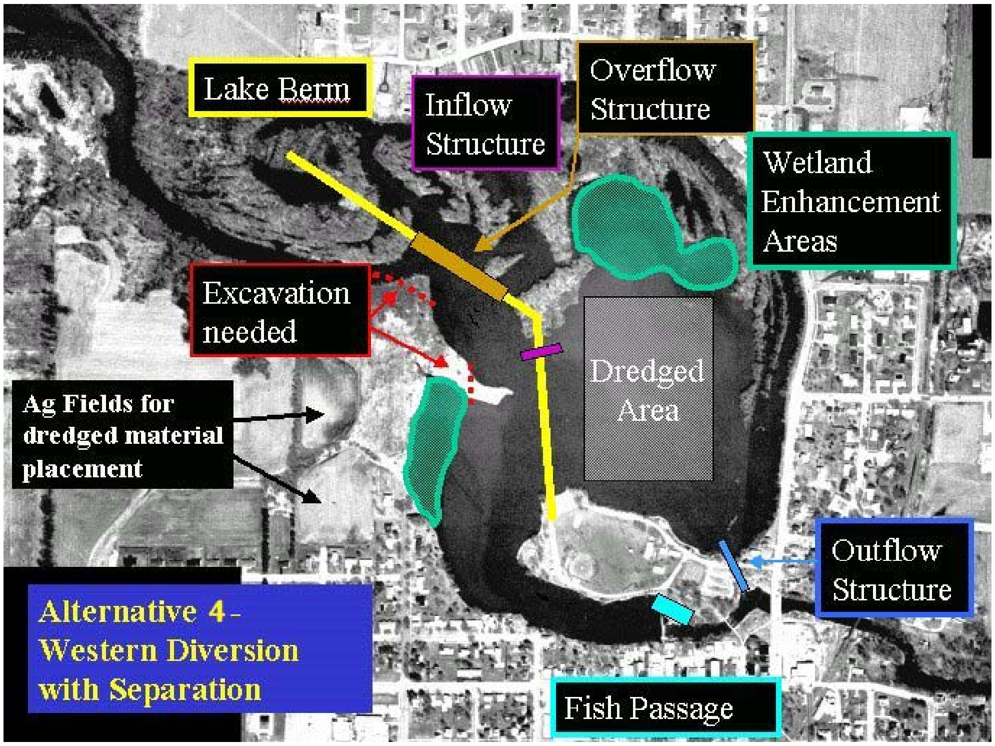


Figure H.6. Alternative 4 - Western diversion with separation.

This alternative includes sediment removal, river diversion, wetland enhancement and periodic drawdown. A berm with an approximate 50-year crest elevation (862 ft NGVD) separates the lake from the river. An overtopping spillway is located in the berm at the northern portion of the lake to help equalize lake levels during a large flood. This spillway must be a minimum of 300 feet long with a crest elevation of 861 ft NGVD, which corresponds to the 25-year crest elevation. Wetland enhancement measures would be implemented primarily in the northern and western portions of the lake (see green shaded areas in Figure H.6). Inflow and outflow control structures also would be included to assist in management of water level within the lake, as well as providing the opportunity for periodic lake drawdown. The current millrace would serve as an outlet structure. The inlet structure would be a "carp gate" installed in the separation berm. This gate would provide boat access between the river and the lake, would supply dissolved oxygen to the lake, and would help restrict rough fish access to the lake. Much less shoreline protection is needed in this alternative than the three eastern diversion alternatives. This alternative will need to implement a form of fish passage at the dam. Several types of fish passageways were studied, but only three were found to be economically feasible. Details of fish passage options appear in the "Fish Passage" section of this appendix.

6.5 Alternative 5

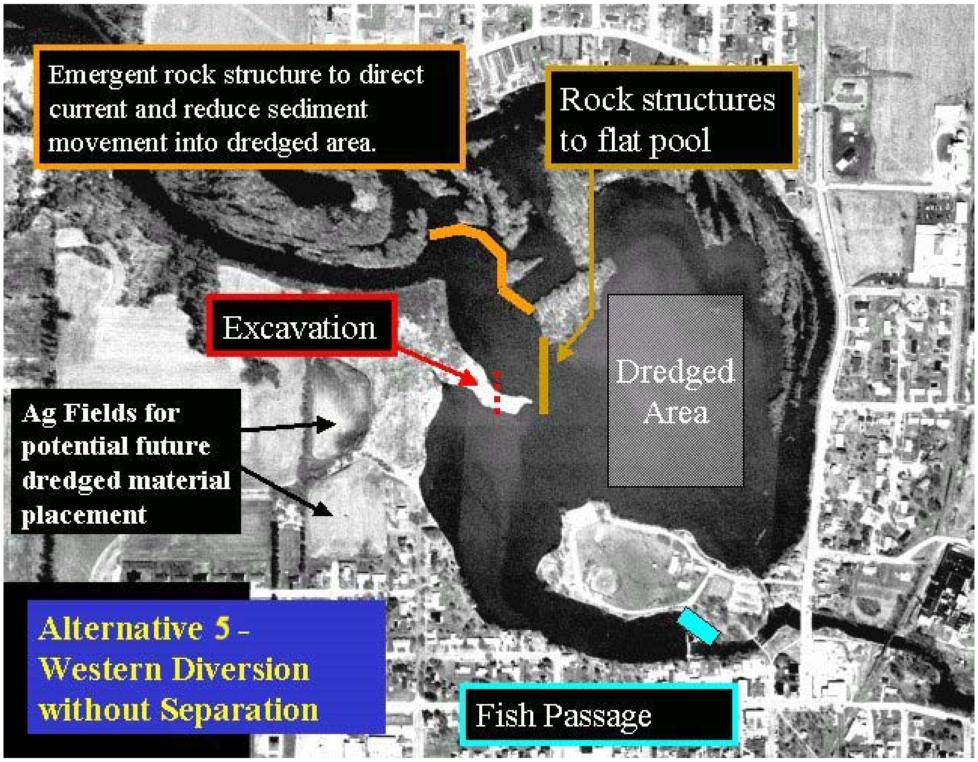


Figure H.7. Alternative 5 - Western diversion without separation.

This alternative is very similar to Alternative 4 except that the berm is not continuous. Rising flood levels are allowed to enter Lake Belle View. Nutrients, rough fish, and to some extent sediment, would be allowed to enter the lake throughout the year. The dredged area in the lake would have limited life due to ongoing sedimentation. The life of the dredged area is prolonged by the presence of flow diversion structures in the western part of the lake. The flow diversion structures are positioned to divert flows and bedload sediments along the west side of the lake and away from the dredged area in the lake (towards the dam). Sediment will not accumulate significantly in front of the dam as it is allowed to pass under the dam through two sluice gates. This alternative would not include channel excavation, inflow or outflow control structures, or an overtopping spillway. Riprap is only necessary on the flow diversion berms to keep them in place. Elsewhere in the lake, the change in flow conditions is not significant enough to cause erosion and require riprap. This alternative must implement some form of fish passage at the dam. Several types of fish passageways were studied, but only three were found to be economically feasible. Details of fish passage options appear in the "Fish Passage" section of this appendix.

6.6 Eastern Diversion Summary

All three eastern diversion alternatives re-create the river channel by excavation along the northern and eastern lake perimeter, and reconnecting the river at the existing millrace just upstream of the Highway 69 Bridge. The excavated channel has a 65-foot bottom width and 3:1 sideslopes (h:v). A berm with an approximate 50-year crest elevation (862 ft NGVD) separates the lake from the river. Because this route ponds water behind the berm of more than 6 feet on an annual basis, the berm is considered a dam by

State regulations from the park to the location of the middle riffle. In this section the berm must be built to higher specifications, having a crest of 864 ft NGVD.

An overtopping spillway is located in the berm at the northwestern portion of the lake (alternatives 1A and 1B only). This spillway must be a minimum of 300 feet long with a crest elevation of 861 ft NGVD, which corresponds to the 25-year crest elevation. This allows the lake to fill during large flood events, and meet the State of Wisconsin requirements that the 100-year flood profile not be impacted.

All three eastern diversion alternatives require significant riprap protection for bankline stability. The houses to the north of the lake would have their lakefront property converted to riverfront. The added velocities would tend to undercut the bankline to the outside of the channel bend, and would require riprap below the normal pool water surface elevation. Greater riprap protection is required along the eastern shoreline where the Highway 69 embankment is adjacent to the newly created channel.

On the eastern portion of the lake, the lake surface is higher than the water surface of the river at all times of the year. The normal pool of the lake would be 11 feet higher than the river at the southeastern portion of the lake, and 3 feet higher than the river at the northern portion of the lake (see profile on Plate H-7). The 11 foot head differential causes high pore pressures on the berm at the southeastern portion of the lake, and induces seepage through the berm. Seepage analysis has been performed on Alternative 1A resulting in 50 cfs of total seepage along the 3,000 foot length of berm. Seepage is discussed in more detail in the Appendix F - Geotechnical Considerations. The separation berm would have to be protected by riprap on the riverside to prevent scour and possible failure from flood flows. If the berm were to fail, Lake Belle View could be completely drained and significant maintenance would be required for repairs.

The crest elevation of the most upstream control point or riffle structure must be similar to the crest of the existing dam (857.4 ft NGVD) in order to maintain the normal pool elevation of the lake (857.7 ft NGVD). The crest should be no lower than 857.0 ft NGVD otherwise the lake level will be lower than the present lake level, resulting in greater demand for dredging and a lower expected life of the project. In the Eastern alternatives, water seldom overtops the Belleville Dam, as the dam would act as an emergency spillway when river discharges are above the 25-year flood discharge.

The riprap needed for shoreline and berm protection, the new channel excavation, and the construction of a new access bridge to the island are the main factors that make the eastern diversion alternatives more expensive than the western alternatives. The longer, wider fish passageway of the eastern alternative leads to more environmental benefits. Both Alternative 1B and Alternative 2 are considered “Best Buy” alternatives from those analyzed in the incremental analysis. Details of the incremental analysis are located in section 6 of the main report.

6.7 Western Diversion Summary

Both western diversion alternatives direct river flow along the western shoreline of Lake Belle View and to the Belleville Dam. The western shoreline is currently agricultural with residences located in the southwest and southern portions of the lake. These homes can expect waterfront conditions similar to what they have now. The same is true for the homes along the north shore. Homes that are outside of the 100-year floodplain will not be impacted as a result of the western diversion alternatives.

The western alternatives separate the lake from the river by using either a full separation berm (Alternative 4) or a partial separation berm (Alternative 5). For Alternative 4, the berm would extend northward from the northwestern tip of the city park island, with a crest elevation of 862 ft NGVD. The water level on either side of the berm would be equal at most times of the year, and would have a maximum head difference of 4 feet is possible during floods. This head difference will not require extra material to construct the berm, although wetland diversity would improve if a flatter slope were used on the lakeside of the berm. Inflow and outflow control structures allow for boat passage from lake to river, limit rough fish access to the lake, provide a supply of dissolved oxygen to the lake, and allow lake managers to periodically drawdown the lake. No inflow structure is possible with Alternative 5 because the partial berm allows nutrients, sediments, and rough fish to directly access the lake. Alternative 5 is a less expensive alternative, but it provides the fewest water quality and lake benefits.

There is no need to excavate a river channel with the western diversion alternatives. The flow of the river is directed towards the dam and is not allowed to circulate freely through the lake. Toe protection along the separation berm will be needed to prevent erosion and undercutting. Riprap will also be needed at the spillway overtop section of Alternative 4. Access to the island park will remain as it is now for the western alternatives. For both western alternatives, flood flows proceed over the dam as they would currently so no added riprap is necessary downstream of the dam.

The western diversion alternatives require a form of fish passage to be implemented so that the Belleville Dam is no longer a barrier to fish migration. Fish passage options exist only for western diversion alternatives because the eastern diversion channels themselves act as a fish passageway. Several types of fish passageways were studied, but only three were found to be economically feasible. Details of fish passage options appear in the "Fish Passage" section of this appendix.

The western alternatives are less expensive than the eastern alternatives because they require less riprap needed for shoreline and berm protection, less excavation of a new channel, and no construction of a new access bridge to the island. The shorter and narrower fish passageways of the western alternatives yield less environmental benefits. Both Alternative 2 and Alternative 4 are considered "Best Buy" alternatives from those analyzed in the incremental analysis. Details of the incremental analysis are located in section 6 of the main report.

7. PROJECT FEATURES

7.1 Fish Passage

Belleville Dam is approximately 15 feet high and poses a permanent barrier to fish migration on the Sugar River. All the alternatives of this 206 Study address this issue. Eastern diversion alternatives are formed by creating a channel that circumvents the lake and functions as a fish bypass channel. The excavated channel is 65 feet wide and is 1,000-3,000 feet long depending on which eastern alternative is considered. Fish passage is accomplished with three riffle structures that are each approximately 3 feet high.

Western diversion alternatives use smaller fish passage bypass channels using a series of riffles. The channel bypass is approximately 10-15 feet wide and is 380-450 feet long depending on which fish bypass option is considered. The riffle crests are placed in a series of 1-foot steps from below the dam to upstream of the dam (see Figure H.8 for profile).

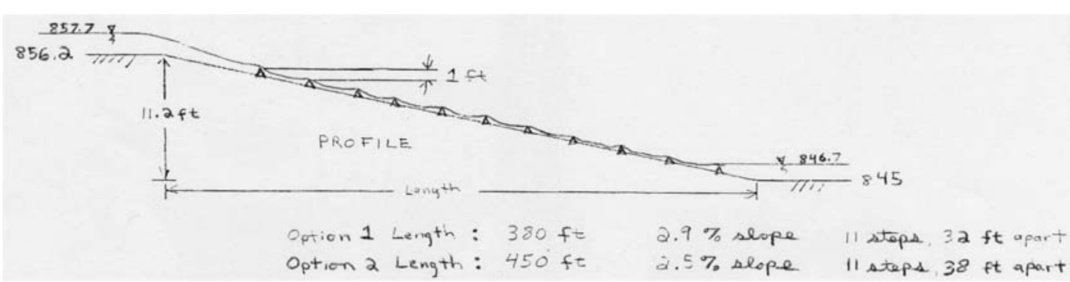


Figure H.8. Profile of Fish Bypass Channel.

It is best to place the exit of the bypass channel as close to the dam as possible because fish are attracted to the sound of rushing water. See photo of bypass channel exit (Figure H.9). Several types of fish passageways were studied for the western diversion alternatives, but only three were found to be economically feasible. A layout of the three bypass options considered is shown on Figure H.10.

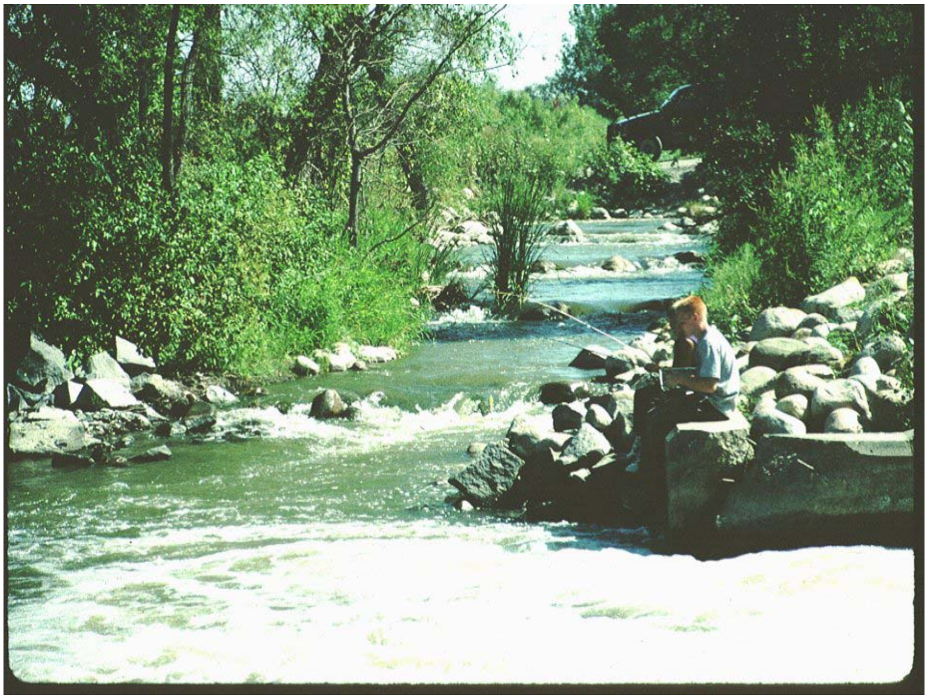


Figure H.9. Photo of exitway of fish bypass channel.

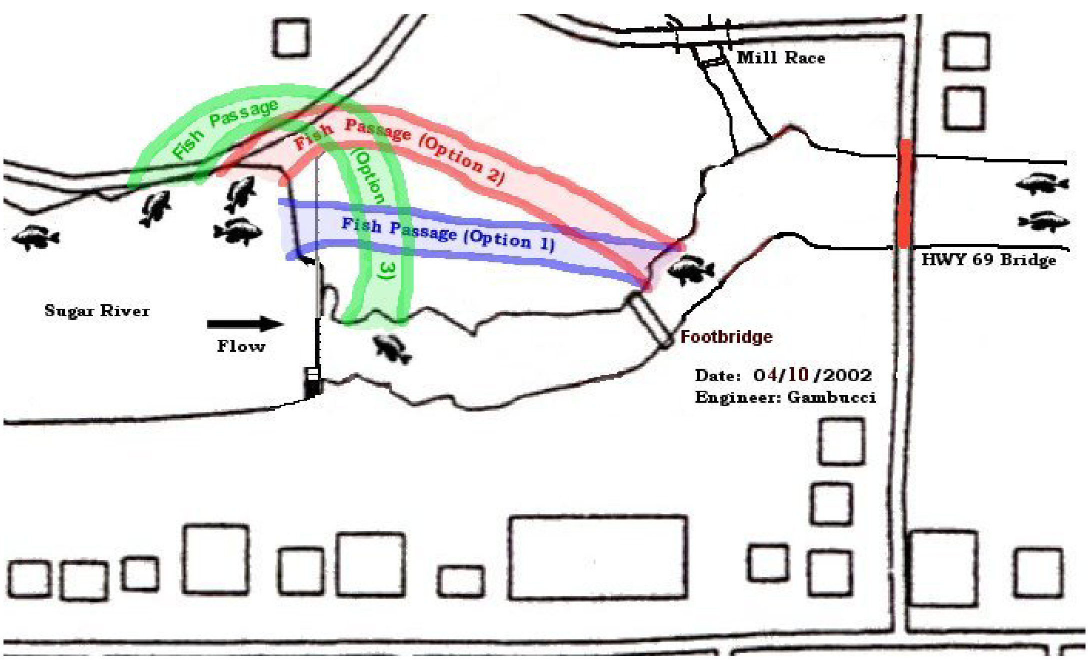


Figure H.10. Three potential locations for fish bypass channels at Belleville, Wisconsin.

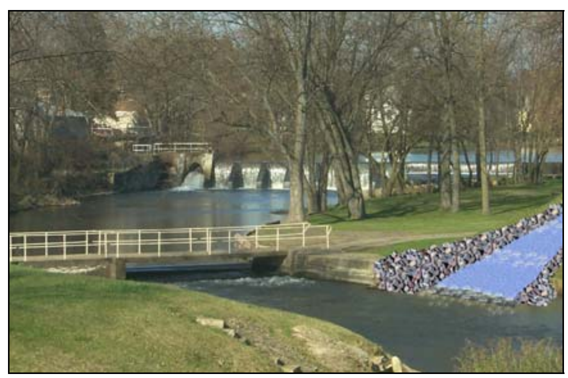
Fish bypass channel design is based off of the following parameters: vertical elevation drop is 9 feet, slope from riffle crest to riffle crest is 4% maximum and preferably less than 3%, and the channel section passes no more than 50% of the flow of the river during drought conditions. Drought conditions are estimated to be 50 cfs minimum, so 25 cfs is used for bypass channel section design. To adequately supply enough depth for fish passage during low flow periods, the fish bypass channel should be 10 feet wide with 3:1 sideslopes (h:v) and have an upper riffle crest of 856.7 ft NGVD (1.0 foot lower than the flat pool elevation of the lake). The option 3 bypass channel positions the exit channel closer to the dam where fish are attracted by the noise of rushing water. This method of fish bypass has been successfully implemented at several dams including the Rapid City Dam, Manitoba, Canada [Ref. 6].

Below is a conceptual photo of how the Belleville Dam would look if the Option 1 fish passage bypass channel were constructed:

Belleville Dam

Sugar River downstream of footbridge

Belleville Dam with fish bypass Option 1



Exiting flow of fish bypass Option 1

Figure H.11. Conceptual photo of fish bypass Option 1.

Fish bypass channel Option 1 is cut straight through the emergency spillway of the dam. This could be quite costly and channel-damaging discharges may flow down the fish passageway during flood discharges. Option 2 is routed around the emergency spillway of the dam to the north. The length of channel is slightly longer (450 ft vs. 380 ft) and it may cut into an existing park road. Flow enters the Option 3 bypass channel 100 feet upstream of the dam, flows around the emergency spillway to the north of the dam, and exits near the tailwater of the dam. Bypass options 1 & 2 exit below an existing footbridge (400 feet downstream of the dam).

Limiting the amount of flow that is allowed down the fish passageway is important during a flood to reduce the likelihood of damage to the riffle structures. Limiting the flood inflows can be accomplished using a stoplog structure or other gated control structure at the upstream extent of the fish passageway. This structure was not designed during the feasibility phase of this Section 206 study. Should a fish passage bypass channel be chosen as the recommended plan, the flow limiting structure would be designed during the Design & Specifications phase of this project.

Other methods of fish passage were investigated including a rock ramp structure and a modified crest of the dam. The rock ramp is a sloped pile of stone behind the dam, sloped so that fish may swim up and over the crest of the dam. The steepest slope useful for fish passage over one continuous rock ramp is 10:1 (h:v). Since Belleville Dam is 15 feet high, the rock ramp concept would require a very large amount of rock. At low flows the rock may be too porous to sustain swimable depths for fish. Due to the amount of rock and questionable effectiveness, the rock ramp concept was not considered further. The modified dam crest concept was investigated further and rock volumes were computed. The total rock necessary was significant (5,085 cubic yards), as would be the cost to modify the dam. This design also would eliminate the ability for lake managers to draw down the lake. For these reasons, it was decided that the fish bypass channels were the less costly and more effective methods of fish passage.

7.2 Wetland Enhancement/Carp Gate

Critical elements of enhancing wetlands are (1) rough fish control, (2) allowing periodic fluctuations in water surface elevation, and (3) reducing shoreline erosion caused by wind-driven waves.

Restricting the number of carp that enter can be accomplished by completely separating the lake from the river or by using a carp gate. Complete separation may lead to low dissolved oxygen in the lake and resulting fish kills. Separation also makes management of the lake level possible only through the use of a pump. Carp gates limit adult carp from entering the lake and can also function for boat passage between the lake and the river (assuming a separation berm is constructed). The gate is buoyant and is hinged at the bottom so that boats may pass over the gate. Since carp are vertical jumpers, the gate is positioned at an angle underwater, so that adult carp are prevented from entering the lake. The carp gate concept was originated from Art Techlow III, et al., WDNR, at Lake Butte des Morts, Wisconsin. A photo of a carp gate appears in Figure H.12 below.

Figure H.12. Photo of carp gate at Lake Butte des Morts, Wisconsin.

The wetland enhancement benefits of the Lake Butte des Morts breakwater and carp gate are impressive. The success of the carp gate relies upon the migratory habits of carp. Before winter, the gate is pinned to the bottom of the channel so that carp may exit the protected area as they search for deeper, warmer portions of Lake Butte des Morts. In early spring, the gate is raised to prevent larger carp from entering the protected area.

For Lake Belle View, the carp gate concept may not be as successful as for Lake Butte des Morts because the Lake Belle View itself would be the deepest and warmest area for fish to over-winter in. Other methods of carp control will occasionally be needed for Lake Belle View, which may include netting, periodic draining of the lake, encouragement of commercial harvest, etc. Other methods of carp control will have to be investigated even with a total separation berm in place because during larger floods, carp gain direct access to the lake once the spillway on the berm is overtopped (4% annual frequency of occurrence).

Carp gates have two other functions beyond rough fish control: they operate as boat passage structures and as inflow structures providing dissolved oxygen to the lake. A stoplog, miter gate, or bulkhead could be added to the carp gate channel to allow lake managers to seal off the inflow to the lake. This would allow lake levels to be lowered through a separate outlet structure in the lake (either the millrace outlet or the sluice gates of the dam, depending on the chosen project alternative - western diversion or eastern diversion). With the outlet gates open and inflow to the lake restricted, the lake can be lowered periodically for wetland enhancement or drained completely for emergency maintenance of wetland areas around the lake or carp control.

8. HEC-RAS MODEL (See Figure 1.13 for Flood Profile Results)

Flood profiles are generated using hydraulic models such as HEC-2 or HEC-RAS. In 1978 a FEMA Flood Insurance Study was published for Dane County, which included the Belleville area [Ref. 3]. This FIS was revised in 1986. HEC-2 was used at that time to produce flood profiles (Plate H-4). In 1999, MSA converted the HEC-2 information to HEC-RAS and produced flood profiles that were very similar to the HEC-2 results. Then the RAS model was modified (by MSA) to produce flood profiles for initial eastern and western diversion plans for the Lake Belle View restoration project.

In 2002, USACE updated the HEC-RAS model to allow for greater lake-river separation. Thirty-One cross sections are used in the model, including four bridge sections. In addition to cross section changes to the MSA model, other modifications were made including slightly different roughness coefficients, expansion and contraction coefficients, and bottom slope used for the downstream boundary condition. These parameters will be discussed in more detail in following paragraphs. Flood profile results for the eastern alternative (alt 1) are given on Figure H.13. Western alternatives were not modeled as it was judged that they were less likely to impact the 100-year flood profile; model results found that the eastern diversion alt 1 did not increase the 100-year flood profile, meeting state requirements. When a recommended plan is chosen, a final HEC-RAS model should be run using more current survey data than that available from the FIS study [Ref. 3].

8.1 Parameters

Roughness coefficients in the original model were chosen as 0.035 for the main channel. The 2002 RAS model uses a Manning n value of 0.030 for the main channel. This adjustment was made after surveying field conditions, and finding the main channel free of most debris and had a clean silt substrate.

Expansion and contraction coefficients in the original model were chosen as 0.3 and 0.5 at every section throughout the model. The 2002 RAS model uses 0.1 and 0.3 for gradual transitions or straight reaches, and uses 0.3 and 0.5 at bridge sections.

The downstream boundary condition of the original model is a normal depth computation with a 0.00006 ft/ft slope. The 2002 RAS model uses a slope of 0.0009091 ft/ft, which is the natural bottom slope of the Sugar River in the Belleville area (based off the 1978 FIS report [Ref. 3]).

These parameters were run first using unmodified model cross sections to simulate current flood profiles. The flood profiles were very similar to those of the original FIS study.

8.2 Flood Profiles

Flood profiles were computed for the Alternative 1 only. Western alternatives were not modeled as it was judged that they were less likely to impact the 100-year flood profile, and the eastern diversion Alternative 1 did not increase the 100-year flood profile. When a final recommended alternative is chosen, another HEC-RAS model will be run using updated survey data than what was available from the 1978 FIS study [Ref. 3]. Flood profile results are shown in Figure H.13 below.

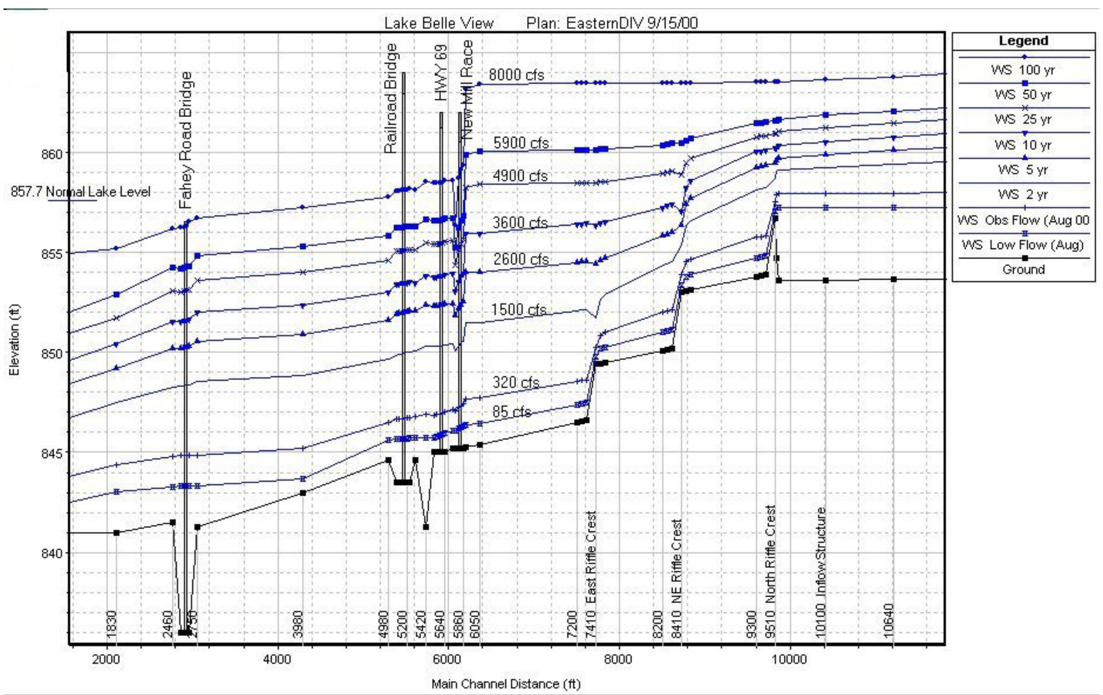


Figure H.13. Flood frequency profiles along the Sugar River (Alternative 1).

The overtopping spillway is located at the northwestern part of the lake, and is designed with the highest crest possible that will not raise the profile of the 100-year flood. This crest elevation was found to be 861 ft NGVD, which corresponds to the 25-year elevation. This separation limits the amount of sediment and nutrients that can enter the lake and will increase the overall project life. According to the 2002 RAS model results, a 25-year spillway crest with a 50-year separation berm does not raise the 100-year flood profile. This is necessary to meet State of Wisconsin requirements.

8.3 Low-Flow Profiles

Low-flow profiles were run using the 2002 RAS model to make certain that adequate depths were available in the diversion channel for fish passage during drought conditions. These results are also important to verify that normal pool elevations of Lake Belle View will be maintained during a drought. Low flow profiles are shown in Figure H.13.

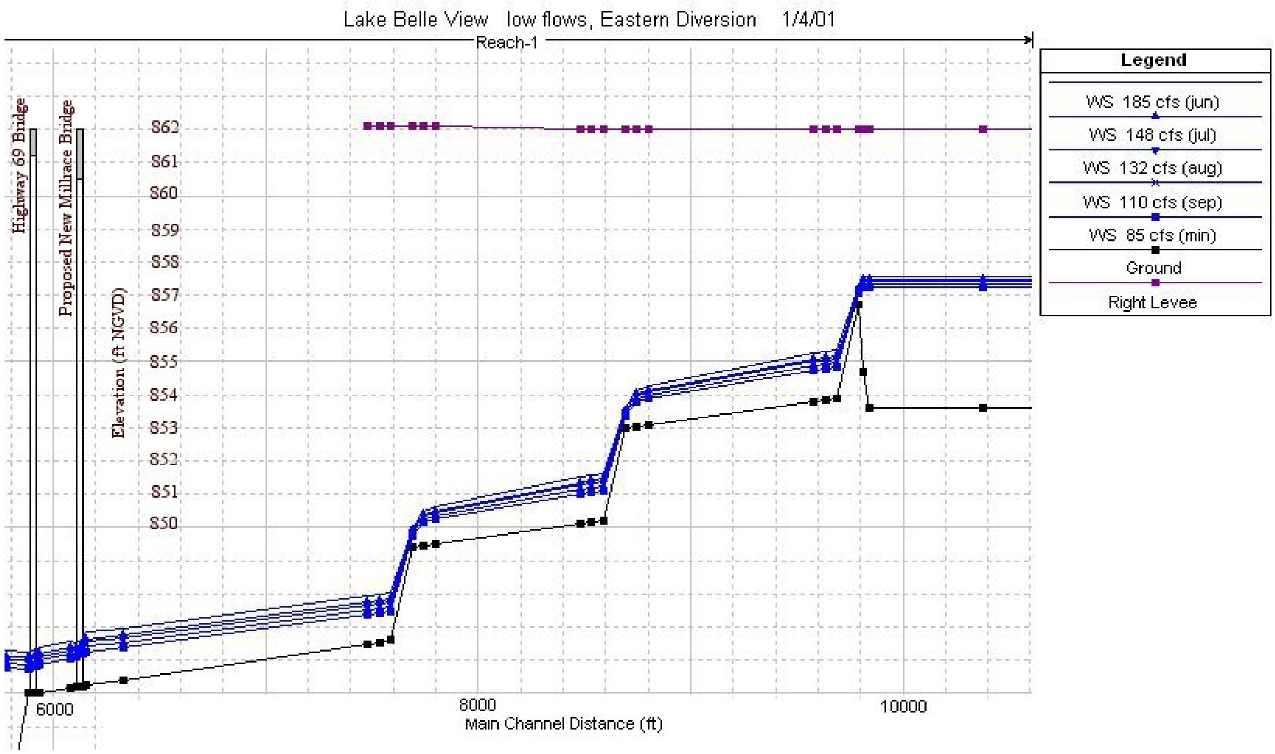


Figure H.14. Low-flow profiles along the Sugar River (Alternative 1).

8.4 Future Model Improvements

The cross sections and bottom slopes used in the feasibility phase of this Section 206 project are considered appropriate to choose a recommended alternative. The bottom slope and channel cross sections of the Sugar River are based off of the 1986 revised FIS survey [Ref. 3]. Additional surveying is necessary once the recommended alternative is chosen and the project proceeds into the plans and specifications phase. At that point, it is recommended to run a final HEC-RAS model of flood profiles and adjust design elevations accordingly.

9. REFERENCES

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