Rum River Dam Improvements

Report on Concept Development and Initial Feasibility Analysis

Prepared for the City of Anoka, Minnesota

March 12, 2025

Contents

Tables

Figures

Abbreviations

°F	degree(s) Fahrenheit
AACE International	Association for the Advancement of Cost Engineering
AASHTO	American Association of State Highway and Transportation Officials
AC	alternating current
ADA	Americans with Disabilities Act
AERP	Aquatic Ecosystem Restoration Program
AMU	Anoka Municipal Utility
Barr	Barr Engineering Co.
BO	boron–oxygen-fused
Braun	Braun Intertec Corporation
BRIC	Building Resilient Infrastructure and Communities
BTS	Bettenburg, Townsend and Stolte
Btuh	British thermal unit(s) per hour
Calibre	Calibre Engineering
CatEx	categorical exclusion
CFR	Code of Federal Regulations
cfs	cubic foot/feet per second
CIP	cast-in-place
City	City of Anoka
City Hall	City of Anoka City Hall
CMU	concrete masonry unit
CO_2e	carbon dioxide equivalent

CSAH	County State Aid Highway
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
DC	direct current
DOI	U.S. Department of the Interior
EA	environmental assessment
EAW	Environmental Assessment Worksheet
EIR	Energy Infrastructure Reinvestment
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
FONSI	Finding of No Significant Impact
FSI	Freestyle Surface Index
ft^2	square foot/feet
GDR	Geotechnical Data Report
GHG	greenhouse gas
GIR	Geotechnical Interpretive Report
gpm	gallon(s) per minute
H	head
HA	Hakanson Anderson Civil Engineers and Land Surveyors
HDPE	high-density polyethylene
HDR	HDR Engineering, Inc.
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HMA	Hazard Mitigation Assistance
HPU	hydraulic power unit
H:V	horizontal:vertical *(slope)*
HVAC	heating, ventilation, and air conditioning
ICF	International Canoe Federation
IDF	inflow design flood
IRA	Inflation Reduction Act
kVA	kilovolt-ampere(s)
kW	kilowatt(s)
kWAC	kilowatt(s) alternating current
kWh	kilowatt-hour(s)
L	length
lb	pound(s)
LED	light-emitting diode
Legend	Legend Technical Services, Inc.
LiDAR	light detection and ranging
LNTP	limited notice to proceed
LOMR	Letter of Map Revision
LRFD	Load and Resistance Factor Design

LRRWMO	Lower Rum River Watershed Management Organization
LSOHC	Lessard-Sams Outdoor Heritage Council
LWCF	Land and Water Conservation Fund
MCD	Minnesota Conservation Department
MEPA	Minnesota Environmental Policy Act
mi^2	square mile(s)
MMPA	Minnesota Municipal Power Agency
MnDNR	Minnesota Department of Natural Resources
MnDOT	Minnesota Department of Transportation
MPARS	MnDNR Permitting and Reporting System
MPCA	Minnesota Pollution Control Agency
MROW	Midwest Reliability Organization West
msl	mean sea level
MSP	Minneapolis-Saint Paul
MW	megawatt(s)
MWh	megawatt-hour(s)
NAVD88	North American Vertical Datum of 1988
NCBD	North Central Business District
NEPA	National Environmental Policy Act
NFPA	National Flood Insurance Program
NGVD29	National Geodetic Vertical Datum of 1929
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NREL	National Renewable Energy Laboratory
OEM	original equipment manufacturer
OHF	Outdoor Heritage Fund
O&M	operations and maintenance
OPCC	opinion of probable construction cost
ORNL	Oak Ridge National Laboratory
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PLC	programmable logic controller
ppm	part(s) per million
PMT	Project Management Team
PPA	Power Purchase Agreement
psf	pound(s) per square foot
PSI	Power Surface Index
PV	photovoltaic
RCP	reinforced concrete pipe
RGU	responsible governmental unit
RTP	Recreational Trails Program
SAFHL	St. Anthony Falls Hydraulic Laboratory
SDS	State Disposal System
SHPO	(Minnesota) State Historic Preservation Office
SPCC	Spill Prevention, Control, and Countermeasures

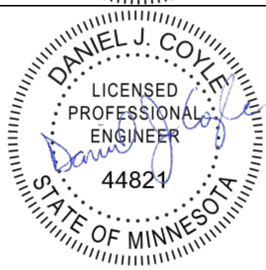
SRV	Soil Reference Value
Stanley	Stanley Consultants
SWPPP	Stormwater Pollution Prevention Plan
USACE	United States Army Corps of Engineers
USC	United States Code
USDOT	United States Department of Transportation
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UV	ultraviolet
V	volt(s)
VAC	volt(s) alternating current
WCA	Wetland Conservation Act
WDC	watt(s) direct current
WIFIA	Water Infrastructure Finance and Innovation Act

Appendices

This page intentionally left blank

Certification Sheet

<table>
<tr>
<td>
</td>
<td>I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.
Signature: ____________________ Typed or Printed Name: __Martin J. Weber________
Date: ___March 12, 2025________ License No. __20419________________________

Discipline(s) covered by the seal: Dam Engineering</td>
</tr>
<tr>
<td>
</td>
<td>I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.
Signature: ____________________ Typed or Printed Name:_Daniel J. Coyle_________
Date: __March 12, 2025___________ License No. __44821_______________________

Discipline(s) covered by the seal: Bridge and Municipal Engineering</td>
</tr>
</table>

Executive Summary

The City of Anoka (City) retained HDR Engineering, Inc. (HDR) and Kimley-Horn to perform a feasibility study for improvements for the Rum River Dam. HDR and its subconsultant, Calibre Engineering (Calibre), were responsible for examining the dam itself and Kimley-Horn was responsible for examining the bridge across the river and integration of the project with adjacent City amenities. Kimley-Horn also served as the overall manager of the project. The Project Management Team (PMT) included representatives from City staff, Anoka Municipal Utility (AMU) staff, Kimley-Horn, and HDR.

The Rum River Dam is located adjacent to Anoka City Hall, approximately ¾ mile upstream of the confluence between the Mississippi and Rum Rivers. The dam consists of an overflow spillway, Tainter gate spillway bay (which also forms the left abutment), and a right abutment.

The overflow spillway currently features timber flashboards that are used to raise the overflow elevation by approximately 3 feet and create a recreational pool upstream of the dam. City staff removes the flashboard system each fall and reinstalls it in the spring.

The PMT held a series of meetings during spring and summer 2024 to discuss prospective alternative dam improvement features. The design team (HDR and Kimley-Horn) supported PMT meetings through consideration of alternatives and development of conceptual designs. . The design team also gathered background information and site data to inform the alternatives evaluation. A water allocation model was also developed to illustrate how Rum River flows could be distributed between the alternative dam features.

Five prospective dam improvement features were evaluated. Detailed descriptions of each of the selected features are provided in this report and are summarized as:

- **Spillway crest gates:** Obermeyer ™ (or similar) gates of equal height to the existing wooden flashboards were identified as prospective replacement of the wooden flashboards. These gates consist of a steel plate supported by a pneumatic rubber bladder. The gates are raised or lowered by inflating or deflating the bladder via a compressed-air system located on shore. The gate control system can be programmed to automatically adjust to maintain a constant pool level.
- **Recreational vessel passage:** Although various systems exist, the system which at the time of this report appears more viable in comparison to others is a conventional lock. The existing Tainter gate and stilling basin bay provide convenient infrastructure that can be modified to serve as a lock and continue to serve as a high-capacity spillway during larger river flow events. Modifications would include replacement of the Tainter gate with a crest gate, bolstering of existing concrete walls, addition of a downstream miter gate, and lock filling/emptying system. The intent of the lock would be that it is capable of passing two pontoons (or similar-sized recreational vessels) at a time.
- **Fish passage:** Two types of fish passage features were evaluated, a structural fish ladder and natural rock rapids. The natural rock rapids feature type was identified as likely more biologically viable at the time of this report in comparison as it would likely

be more effective for Midwestern fish species. Ideally, the fish passage feature would be located adjacent to the recreation feature because the two features require similar slopes, and this could result in potential construction cost savings in comparison to other locations.

- **Recreation feature:** Analysis of the river hydraulics indicated that there appears to be ample streampower within the river to support whitewater activity. Because of the approximate 12-foot drop across the Rum River Dam, a recreation channel would contain multiple features in series to provide varying experiences, e.g., surfers, kayakers, tubers, etc. Water recreation features are known to attract regional users and tourists for events such as festivals and competitions. The feature could also be used as a swiftwater rescue training facility for example by EMS entities.
- **Hydropower:** Two hydropower configurations were evaluated—high (600-kilowatt [kW]) capacity and reduced (60 kW) capacity. Energy production estimates were coupled with high-level capital cost and economic estimates to derive the approximate payback period for the two options. Based on conditions at the time of this report, both options resulted in payback periods in excess of 50 years. Absent capital funding assistance or generation incentives, this payback period was deemed economically unviable by the PMT. Construction and operation of hydropower development (and the dam) would be regulated by the Federal Energy Regulatory Commission (FERC). The FERC process can be both lengthy and costly.

Because hydropower is deemed unviable at the time of this report, high-level evaluations of other renewable-energy sources were performed:

  - **Solar:** Photovoltaic (PV) system installations were evaluated at four locations in the vicinity of the Rum River Dam. The most promising location appears to be the parking ramp near City Hall. The PV system could be installed as part of the planned expansion of the existing City parking ramp, i.e., rooftop system. This PV system would have an approximate capacity of 300 kW and produce annual energy of approximately 560 megawatt-hours (MWh).
  - **River heat exchanger:** City Hall currently uses fuel-fired heating equipment and direct-expansion refrigerant-based equipment cooling. These existing mechanical systems could be replaced with heat pumps that could use river water as a heat exchanger. Approximately 750 gallons per minute (gpm) of river water would be required. Further examination of the heat exchanger concept may prove beneficial as existing City Hall mechanical systems age and planning for their replacement begins.

Construction

It is anticipated that construction of dam improvements would occur in three phases and span two construction seasons (2 years). Cofferdams will be required to divert Rum River flows and provide dry work areas for construction. It appears that portions of cofferdams can be designed to serve as permanent elements for certain features, thus saving on capital costs. However, early contractor involvement in some form may prove beneficial in refining construction durations and overall schedule.

Opinion of Probable Construction Cost

Based on what is known at the time of this report, the opinion of probable construction cost (OPCC) was developed based on crew wage projects, quotes, and unit costs and is estimated at approximately $37 million (2024 dollars). According to the Association for the Advancement of Cost Engineering (AACE International) and the present maturity of project definition, the OPCC is considered as a Class 4. As such, the OPCC accuracy range is +50 percent to -30 percent.

Funding

Many funding sources may be available to reduce the City's burden. These are detailed in the main body of this report.

Permitting

It is anticipated that construction of the project would require permits or approvals from the following agencies (however, additional permit needs may surface):

- United States Army Corps of Engineers (USACE)
- Federal Emergency Management Agency (FEMA)
- United States Fish and Wildlife Service (USFWS)
- Minnesota State Historic Preservation Office (SHPO)
- Minnesota Department of Natural Resources (MnDNR)[1]
- Minnesota Pollution Control Agency (MPCA)
- Lower Rum River Watershed Management Organization (LRRWMO)
- Anoka County
- City of Anoka

[1] The MnDNR was provided with an earlier draft of this report and provided preliminary comments which were addressed by the design team.

1 Introduction

This introductory section presents the project scope of work, limitations, and public safety risk.

1.1 Scope of Work

The scope of work (extracted from the consulting agreement) is included in Appendix H.

1.2 Limitations

This work was performed in a manner consistent with that level of care and skill ordinarily exercised by other members of the profession under similar conditions. Any conclusions, opinions, and recommendations contained in this report are based on a limited number of observations, data or information received and relied-upon as-is, and readily known conditions at the time of this report. It is possible that current conditions differ from those assumed or conditions could vary subsequent to this report. HDR makes no other representation, guarantee, or warranty, express or implied, regarding the services, communication (oral or written), report, opinions, feasibility observations or instrument of service provided.

The assessment of the general condition of the dam and conceptual modifications to the dam contained in this report are based on available data and visual inspections. Detailed investigations and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of this report.

The condition of the dam will vary over time depending on numerous and constantly changing internal and external conditions. It would be incorrect to assume that the reported condition of the dam will continue to represent the condition of the dam at some point in the future and HDR does not represent or guarantee the safety or stability of the dam or related structures.

Detection of hidden, covered, inaccessible, or internal structural or material defects, corrosion, or damages in components, embedment, reinforcing, anchorages and parts of equipment, structures, or mechanisms being inspected that are not readily discernible by external visual inspection were not included as part of this scope or report. Additionally, no structural or geotechnical engineering investigations or evaluations are part of the scope of this study. Only a site visit and limited field inspection were performed, as well as a review of the existing (limited) design information that was available. As a result, only obvious structural or geotechnical deficiencies may be identified.

Any opinions of probable project cost or probable construction cost are made on the basis of information made available, experience and qualifications, and HDR's professional engineering judgment. However, since HDR has no control over the cost of labor, materials, equipment or services furnished by others, or over the contractor(s') methods of determining prices, or over competitive bidding or market conditions, HDR does not guarantee that proposals, bids, or actual project or construction cost will not vary from the opinions of probable cost prepared by HDR.

1.3 Public Safety Risk

River recreation and sports are some of the fastest-growing sports in America and there is a growing trend among many towns and cities to create river parks in their own backyards.

One of the main drivers for whitewater parks is to create a boater bypass as an alternative to the potentially dangerous hydraulics and drop associated with a typical dam. In this case, the bypass channel would be designed with features such as flow control to modulate the amount of water in the bypass canal, as well as a low-slope, low-flow channel in which risks of whitewater, such as foot entrapment or pinning, may be reduced. Such a channel can decrease risk associated with the existing dam; however, HDR does not represent, guarantee or warrant that a boater bypass or any improvement feature is safe or without risk (public safety or otherwise).

Low head dams such as the Rum River Dam (as it exists today) can pose a risk to the public due to recirculating currents that can develop downstream of spillways and trap recreational users. Despite safety measures that may be incorporated into the dam, including supplemental features, there always remains a potential risk associated with public use of any feature that is open to the public.

2 Background

This section presents the project background.

2.1 Project Description

This section presents a description of the project.

2.1.1 Dam

The Rum River Dam is owned and operated by the City of Anoka. The City also controls the flowage easements associated with the facility. As shown on Figure 2-1 and from right to left looking downstream, major dam components include: the right (west) abutment, overflow spillway, and Tainter gate bay. Further descriptions of these features follow.

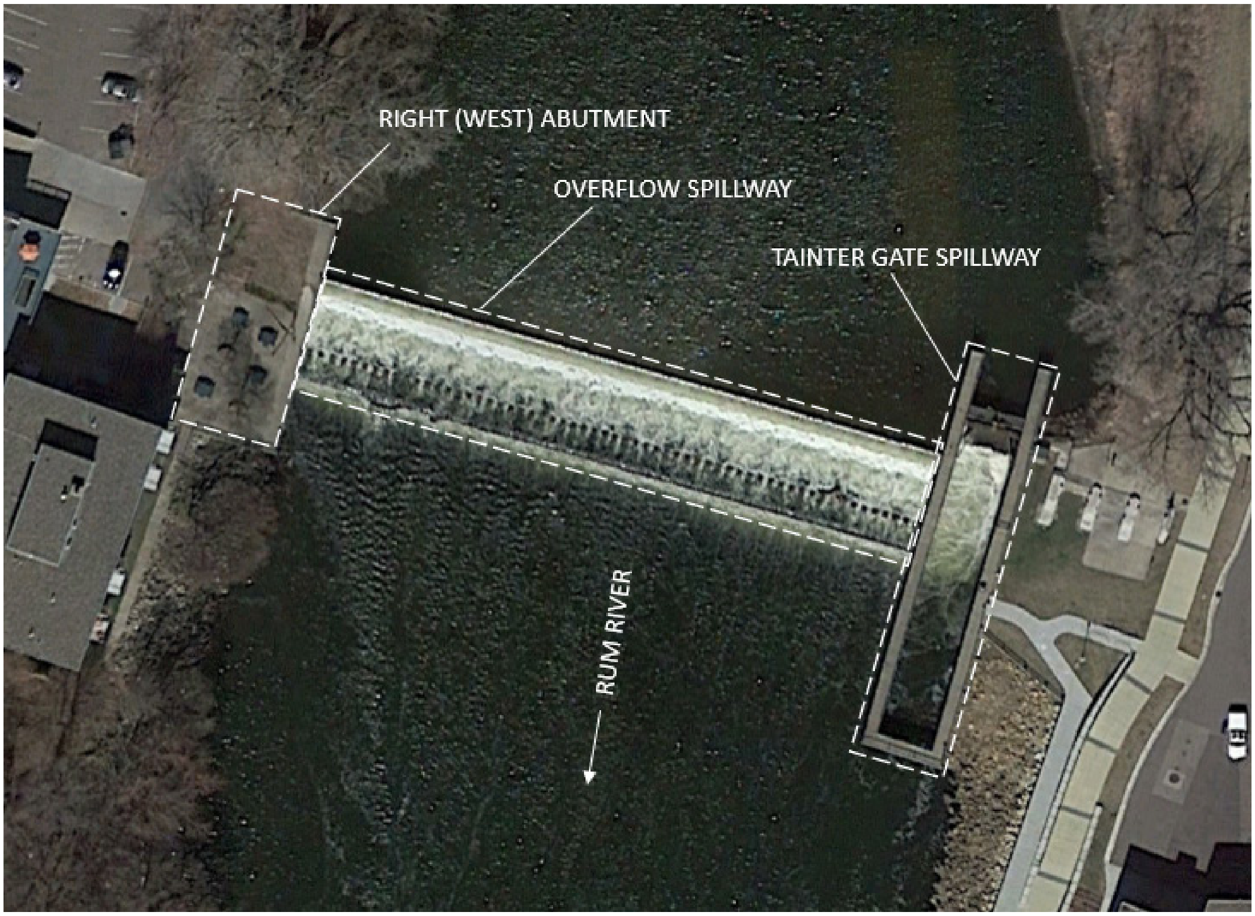


Figure 2-1. Major dam components

Right (West) Abutment. The right abutment provides the transition from the dam to the adjacent higher ground and is effectively a reinforced concrete “box” infilled with earth. The “box” is formed by a series of intertied reinforced concrete retaining walls and slabs founded on a grid of timber piles driven into the underlying soil.

Overflow Spillway. The main portion of the dam is a 236-foot-long overflow spillway consisting of an 18-inch-thick reinforced concrete apron supported by 24-inch-wide reinforced concrete buttresses spaced at approximately 17 feet 8 inches. Both the apron and buttresses are founded on a 3-foot-thick, 41-foot-long reinforced concrete base slab founded partially on engineered earthen fill and native soil.

The crest of the concrete spillway is at elevation 841.35 (see Section 2.2 for a discussion on vertical datums). Flashboards (timbers and steel support system) are used to raise the overflow elevation by approximately 3 feet, i.e., the crest of the wooden flashboards is at Elevation 844.24. City staff remove flashboards each fall and reinstall them in the spring.

Water flowing over the spillway falls onto a reinforced concrete “stilling basin” that serves to dissipate some of the water’s energy before it enters the natural river channel. The stilling basin is 26 feet long and includes a series of baffle blocks and an end sill.

Two rows of steel sheet pile that span the length of the spillway serve to reduce seepage beneath the dam and reduce the risk of scour. Seepage cutoff walls are located 1 foot and 20 feet downstream of upstream end of the spillway base slab. A reinforced concrete key is located at the downstream end of the stilling basin to further reduce the potential for scour.

The spillway was also provided with a foundation drain system to reduce uplift pressures acting on the base slab and stilling basin. Piezometers were installed to monitor the foundation pressures and effectiveness of the drain system. A cross section of the spillway is provided in Figure 2-2.

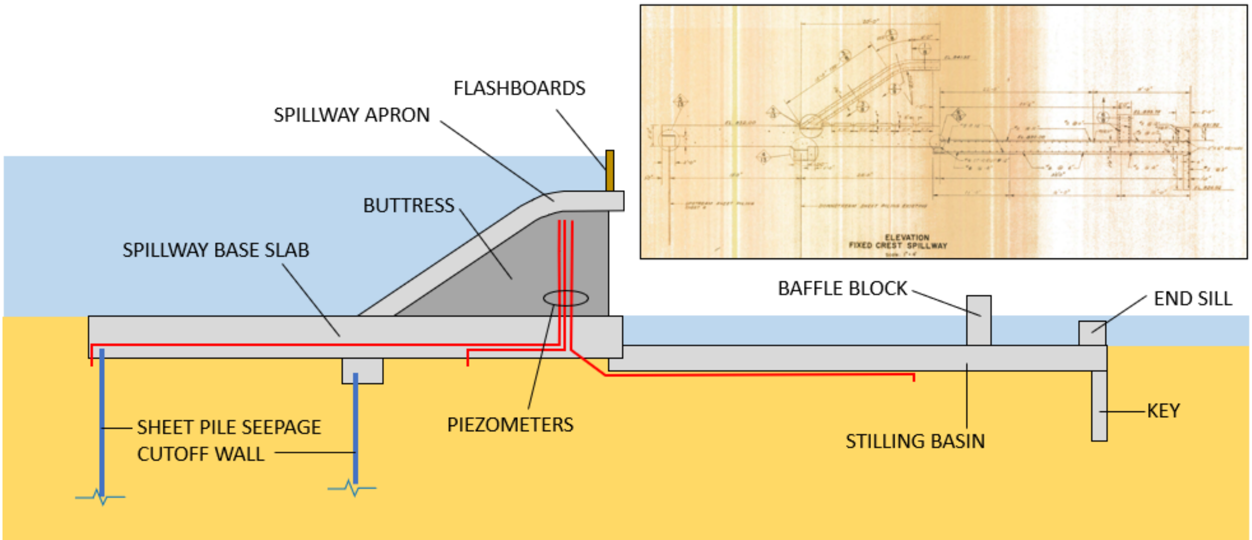


Figure 2-2. Spillway cross section

Tainter Gate Spillway. Supplemental spillway capacity for the dam is provided by the Tainter gate spillway that also forms the left (east) abutment. The 20-foot-wide bay is formed by two 5-foot-wide reinforced concrete walls founded on a 4-foot-thick reinforced concrete base slab. The top elevation of the walls begins at elevation 849.75 and steps down twice ending at elevation 841.75 at the downstream end. The Tainter gate is seated on a reinforced concrete ogee-shaped spillway with a crest elevation of 835.00 feet. Water flowing over the spillway enters an energy dissipating stilling basin with a floor elevation of 820.00 feet. The Tainter gate spillway structure is founded directly on engineered earth fill and native soil.

The Tainter, or radial, gate is of standard construction, i.e., structural steel skin plate mounted on a steel stiffening/support girders connected to struts or arms. The arms pivot about trunnion pins anchored to the adjacent concrete walls. The gate is 20 feet wide and approximately 10 feet tall. A chain, drum-type electric hoist is used to raise and lower the gate. A cross section of the Tainter gate bay is presented in Figure 2-3.

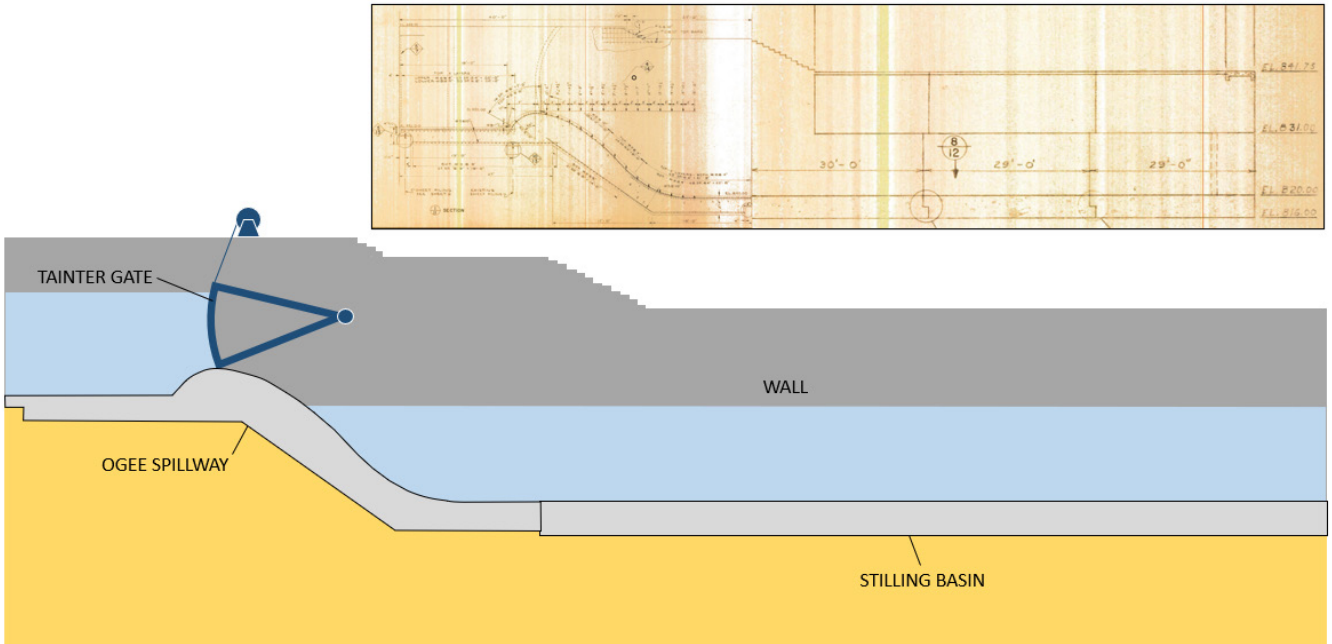


Figure 2-3. Tainter gate spillway cross section

2.1.2 Trails and Surroundings

The existing Rum River Regional Trail (see Figure 2-4) runs along the east side of the Rum River and connects with the Mississippi River Regional Trail and Central Anoka County Regional Trail. The trail is a mixed-use biking and hiking trail that stretches to the Anoka/Isanti County border. Through previous planning efforts, additional pedestrian and bicycle connections have been proposed along the west side of the river, moving north under the Main Street bridge, and further connecting to a proposed River Crossing Bridge. Existing and programmable light-emitting diode (LED) lighting on the Main Street bridge helps to set a tone for nighttime activity in the area and will give cues to an appropriately lit public realm environment along the west side and river crossing.

This project provides an opportunity to increase connectivity and access to the Rum River as a recreational resource, and further capitalize on Anoka's great support and promotion of community through downtown programming, activation, and event opportunities. Anoka Riverfest, Food Truck Festival, Halloween, and Winter holiday events; weekly classic car shows, concerts in the parks, and farmers' markets; and a new social district are all examples of how Anoka residents, businesses, and visitors come together as a community on a regular basis.

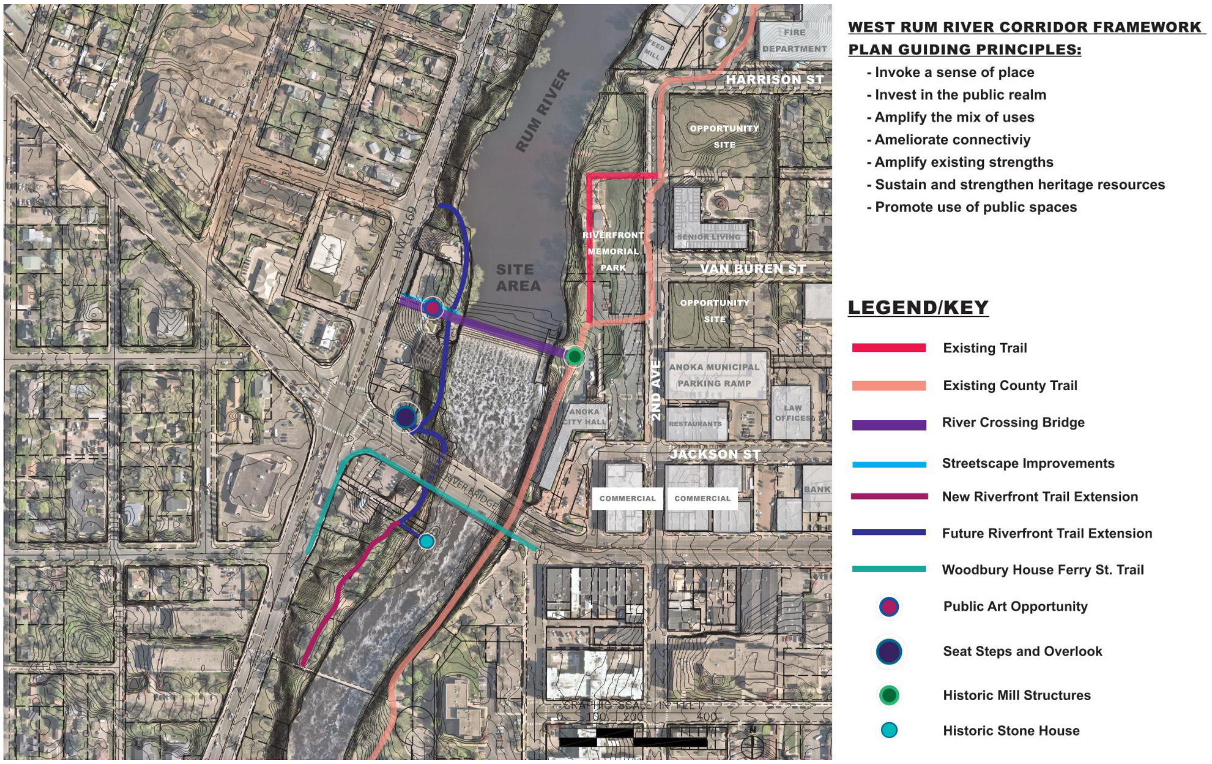


Figure 2-4. Trails in vicinity of dam

2.2 Vertical Datum

The Flood Insurance Study (FIS) (FEMA 2015) references the North American Vertical Datum of 1988 (NAVD88). In the same document, FEMA reports a mean conversion factor of +0.233 foot when converting from the National Geodetic Vertical Datum of 1929 (NGVD29) to NAVD88, i.e., add 0.233 foot to NGVD29 to get the equivalent NAVD88 elevation.

Although the dam's construction drawings (Barr 1968a) and Operations and Maintenance (O&M) Manual (Barr 1972) do not provide the project's vertical datum, it may be reasonable to assume those to be NGVD29 (however this is not known with certainty). For the purposes of this report, a distinction or differentiation between the two datums is not made. However, should any of the dam improvements project move forward or into design, it will be important and is recommended that this issue be resolved.

2.3 Available Information

The following available information was used to inform this study:

- Construction Drawings (Barr 1968a) - see Appendix A1
- Construction Specifications (Barr 1968b)
- Soil Borings (Soil Exploration Company 1962)
- Operation and Maintenance Manual (Barr 1972)

- 2023 Dam Inspection Report (Barr 2023)

Information requests were submitted to the City, MnDNR, and Barr Engineering Co. (Barr), but no other salient original design information (e.g., design report, computations, etc.) was provided to HDR or is known to exist.

2.4 Geology

This section presents bedrock and surficial geography for the project area derived through desktop review of information made available to HDR.

2.4.1 Bedrock Geology

Bedrock under the project site can range in depth from 150 to 200 feet and consists of the Cambrian Tunnel City Group (Setterholm 2013). Figure 2-5 illustrates a bedrock geology map and a cross section that passes about ½ mile northeast of the site. The plan view map shows the site in the Tunnel City Group; however, the thickness of the unit[2] at the site is unknown. The cross section shows the Tunnel City Group pinching out below the Rum River and overlying the Wonewoc Sandstone, which overlies the Eau Claire formation. The Tunnel City Group is differentiated into two formations. The stratigraphically lower formation, which appears likely to underlie the site, is the Lone Rock Formation, which is further divided into the Reno, Tomah, and Birkmose Members. Descriptions of each unit are provided below after Setterholm (2013):

- **Tunnel City Group (Ꞓtc[3]):**
  - **Lone Rock Formation**
    - **Reno Member:** Pale yellowish green, very fine- to fine-grained, glauconitic, feldspathic sandstone with thin, greenish-gray shale partings. The sandstone is well sorted and contains thin zones with dolomitic intraclasts.
    - **Tomah Member:** A thin unit composed of interbedded, grayish-yellow-green, feldspathic siltstone, very fine-grained sandstone, and pale green shale; sparsely glauconitic.
    - **Birkmose Member:** Grayish-yellow-green, fine-grained sandstone that is cemented by dolomite. It is highly glauconitic and contains abundant dolomitic intraclasts.
- **Wonewoc Sandstone (Ꞓw):** Fine- to coarse-grained, moderately sorted to well sorted, light gray, quartz sandstone. The upper part is the coarsest-grained; the lower part is finer-grained, better sorted, and progressively finer-grained toward its base. The very fine-grained sandstone in the lower part is feldspathic. The sandstone contains abundant brachiopod valves locally along bedding planes (Runkel et al. 1998). Thickness: 75 to 80 feet.

---

[2] A rock "unit" is a mass of rock that has identifiable characteristics and is named for use by geologists for mapping purposes.

[3] This and similar geologic unit symbols are commonly used in geologic maps.

- **Eau Claire Formation (Ꞓe):** Yellowish gray to pale olive-gray, very fine-grained, feldspathic sandstone, siltstone, and shale. The upper part is predominantly shale and siltstone, and the lower part is predominantly glauconitic sandstone and siltstone (Mossler 1992). Thickness: 125 to 200 feet.

Figure 2-5 shows a normal fault about ½ mile northwest of the site, with a southwest–northwest trend and a down-to-the-west disposition that terminates in a perpendicular normal fault about 2 miles northeast of the site. These faults are part of the Douglas Fault zone and predate Quaternary deposition. The site lies on the upthrown block and the cross section on Figure 2-5 indicates vertical offset of about 150 feet.

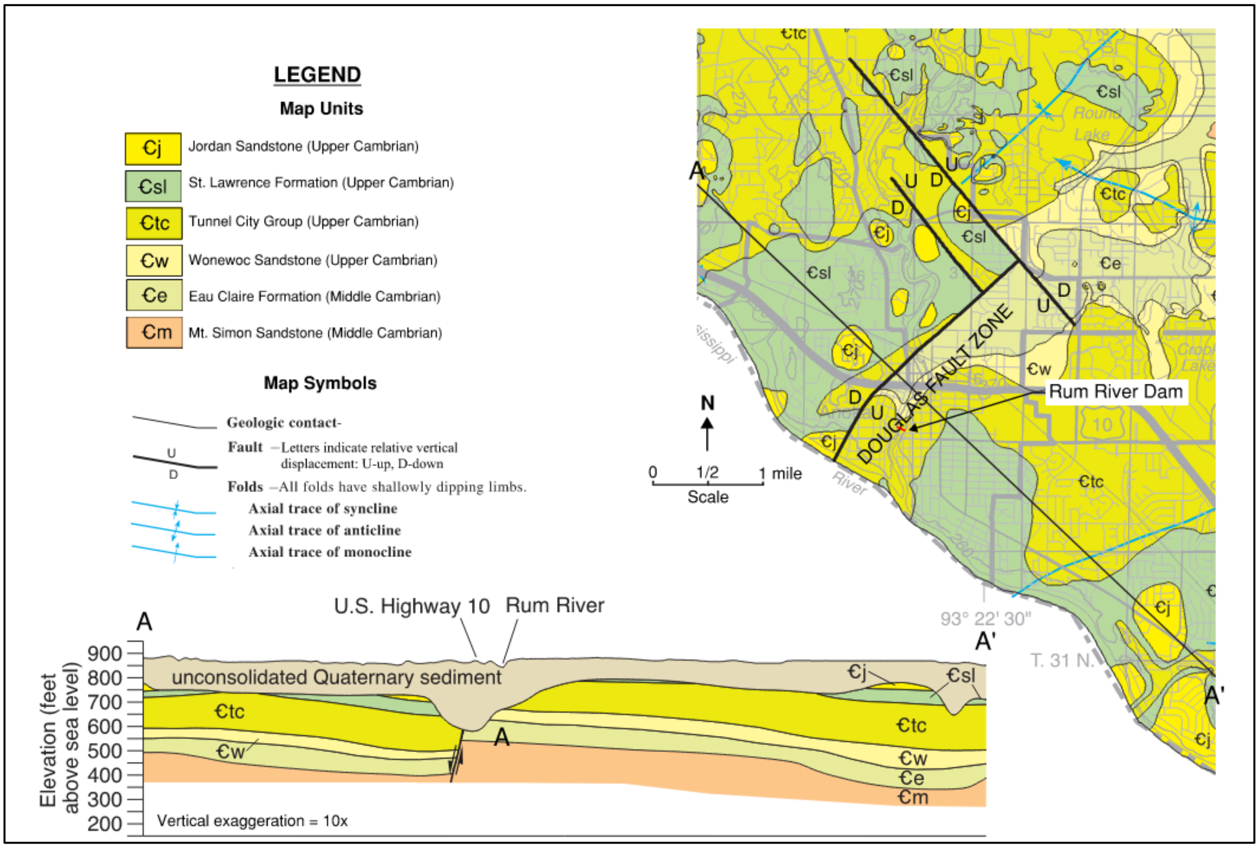


Figure 2-5. Bedrock geology

2.4.2 Surficial Geology

The thick sequence of soil above the bedrock is made up of several units spanning the: Hudson, Wisconsin, Pre-Wisconsin, and previous glaciation episodes. Figure 2-6 shows a surficial geology map and a cross section that passes about ½ mile north of the site. The plan view map shows the site in the Richfield terrace member (Qwr) of the West Campus Formation, which is sand and gravelly sand about 50 to 70 feet above the modern floodplain. The Cromwell Formation underlies the West Campus formation and is mostly reddish and sequence of sand and gravel (Qsc, Qse) interbedded with sandy till (Qcr, Qce) below a lacustrine layer of clay and silt and/or clayey till to sandy till (Qlc). Below the Cromwell Formation are several units of the Pre-Wisconsin episode that are yellow-brown to gray or red-brown to gray and interbedded loamy till (Qxt), sandy till (Qrt, Qvt), and sand and gravel (Qsp).

Because of the nature of glacial deposits, which can be both interbedded and interfingered, the soil type can change significantly both vertically and horizontally. Therefore, the section shown in Figure 2-6 is not likely to be an exact representation of the soil at the site but is illustrative of the type and variability of soil deposits that could be present above bedrock. An illustrated cross section created by Barr (1963) to support preliminary design of the dam as it exists today is presented in Figure 2-7.

From 1962 to 1968 five borings were drilled in the vicinity of the old dam structure by Soil Exploration Company (1966) and Soil Engineering Services (1966, 1968a, 1968b) to depths varying from 72 to 93 feet. During the drilling process three attempts appear to have been met with refusal on wood, boulders, or concrete and which needed to be re-drilled to achieve the target depth; materials associated with refusal appear likely to be fill placed as part of original dam construction. The uppermost unit encountered in all borings was a gray medium to coarse sand with fine gravel that ranged in depth from about 10.5 to 33.0 feet. Below this unit was a mix of interbedded sandy/silty/clay loam or loamy sand with lenses of medium- to coarse-grained sand. Fine gravel was noted throughout, and the color varied from gray to brown to red and greenish gray. At 63 feet one boring noted that the fine loamy sand appeared to be loosely cemented sandstone with some shale and limestone interbedding that resembled the St. Lawrence Formation (Soil Engineering Services 1968a). It is unlikely that bedrock would be encountered at such a shallow depth and because the St. Lawrence Formation overlies the Tunnel City Group. It could be that the boring may have encountered a boulder that was deposited contemporaneously with the Quaternary sediment.

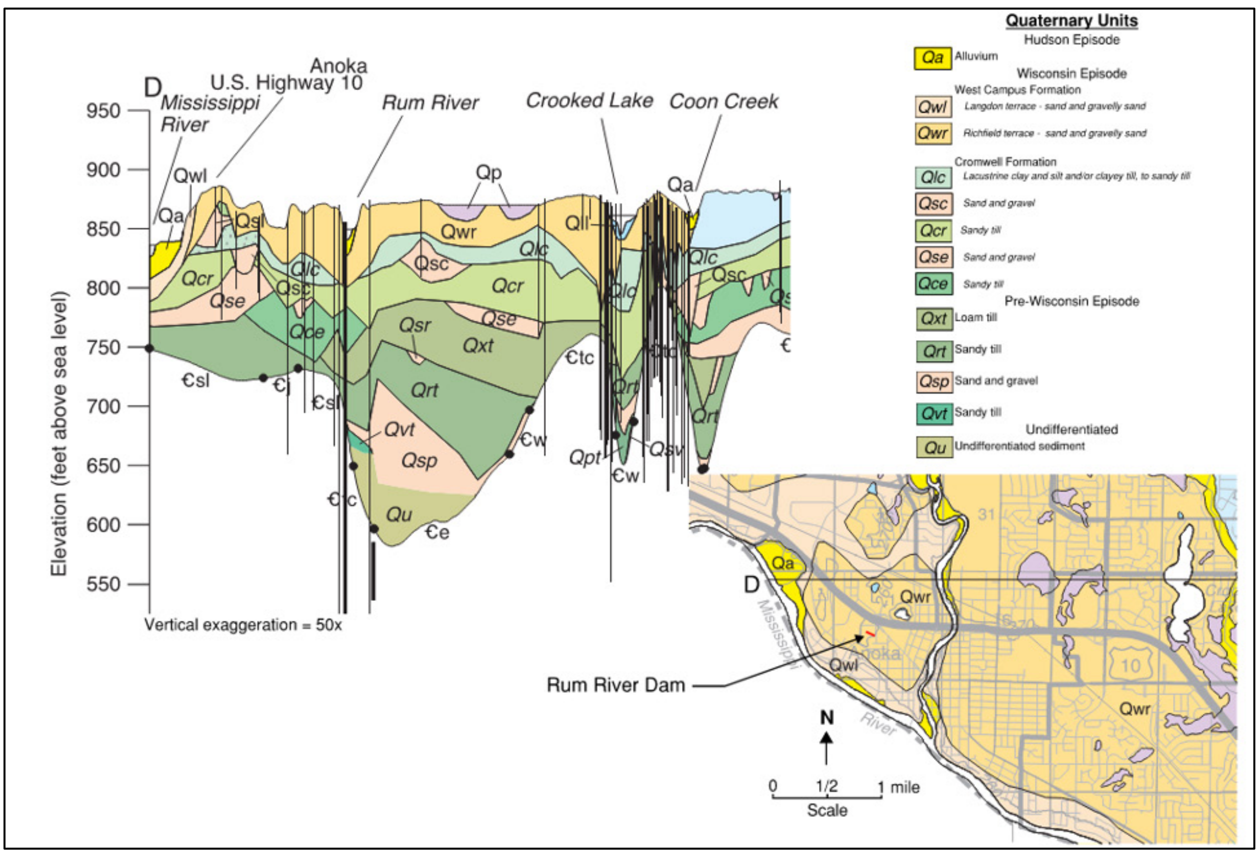
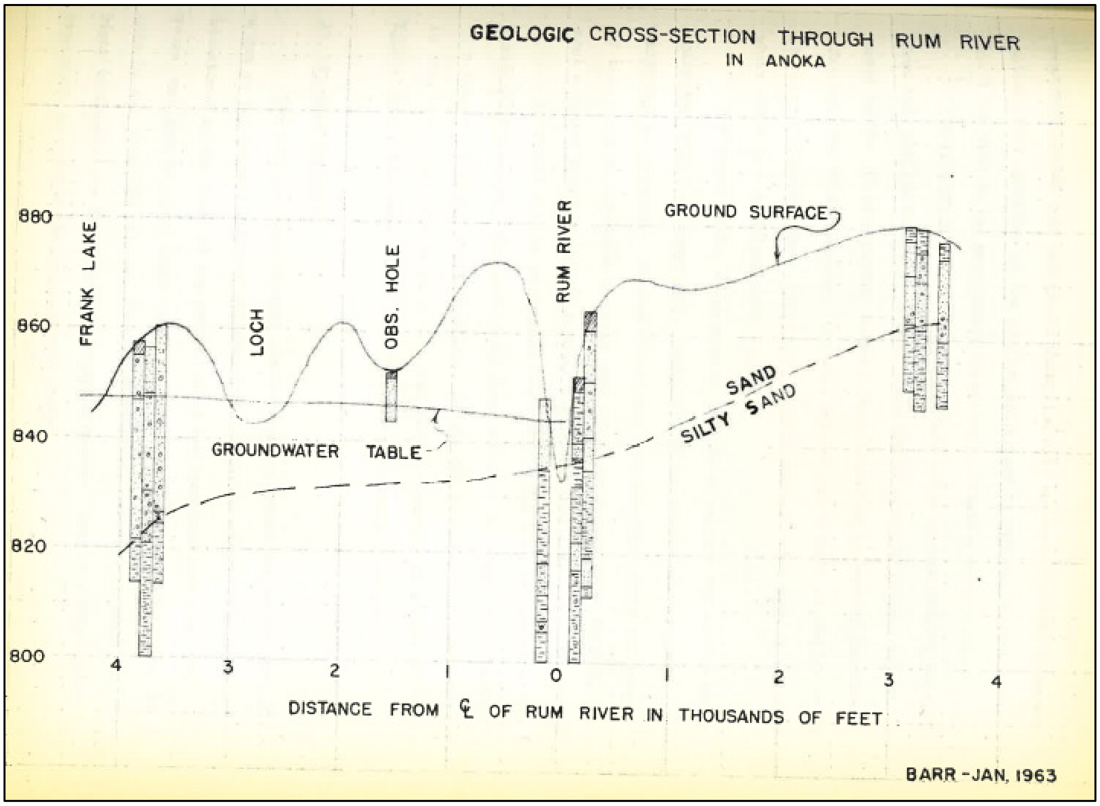


Figure 2-6. Quaternary geology



Source: Barr 1963.

Figure 2-7. Geologic cross section near CSAH 10

2.5 Recent Dam Inspection Findings

Table 2-1 presents recommendations that were included in the most recent inspection report (Barr 2023). At the time of this report, the City indicates it has not implemented these recommendations.

Table 2-1. Recent dam inspection recommendations

Index	Location	Recommendation	Priority
1	Right embankment/ abutment (downstream)	Place a crack gage to measure to the nearest 0.1" and record changes every year. Remove tree root passing through expanded joint and any nearby trees that may have roots behind the wall.	High
2	Stilling basin slab	Evaluate the scour potential and determine a remediation to address the scour and protect from further deterioration, if necessary.	High
3	Right embankment/ abutment	Remove and reinstall concrete slab behind abutment wall so it has positive drainage away from wall.	Medium
4	Stilling basin baffle blocks 1, 2, 3, 4, 41, 42, and 43	Evaluate the scour potential and determine a remediation to address the scour and protect from further deterioration, if necessary.	Medium
5	Stilling basin baffle blocks 8, 49, 51, and 52	Evaluate if missing baffle blocks are required and design appropriate mitigation as needed.	Medium
6	Right embankment/abutment (upstream)	Remove vegetation within 15' upstream of upstream abutment wingwall.	Low
7	Spillway underside Bays 3, 5, and 9	Develop a plan to document and inspect the spalling to determine the rate of change and then the development of a long-term plan.	Low
8	Spillway upstream face Stations 1–4	Develop a plan to document and inspect the spalling to determine the rate of change and then the development of a long-term plan.	Low

2.6 Piezometer Readings

As discussed earlier, several piezometers were originally installed within the dam to measure uplift pressures acting on the dam foundation. HDR understands that the City has not recorded piezometer levels in recent years and no readings were included in the most recent Dam Inspection Report (Barr 2023).

Readings up to 1995 were included in the 1996 evaluation report (Stanley 1996) and are shown in Figure 2-8 and Figure 2-9. These piezometer readings were used to inform the stability analyses of the dam discussed in Section 2.8.

A cursory review of the available piezometer readings indicates that other than some short-term higher levels, water pressures have been relatively steady over time for which they exist; except for Piezometer 2 in Buttress 1 that shows a significant increase beginning in approximately 1996. Although the numbering of the buttresses and piezometers within each buttress is not indicated on the drawings, it is believed that Buttress 1 is the farthest left (east).[4]

Regardless of the disposition of dam improvements, it is recommended that the City begin taking piezometer readings and evaluating results on a regular basis. Piezometers should be flushed[5] if erroneous readings are suspected.

[4] See piezometer arrangement shown on Sheet 19 of 19 (Barr 1968a).

[5] “Flushing” basically consists of injecting water into piezometer until water flows out the top of the piezometer.

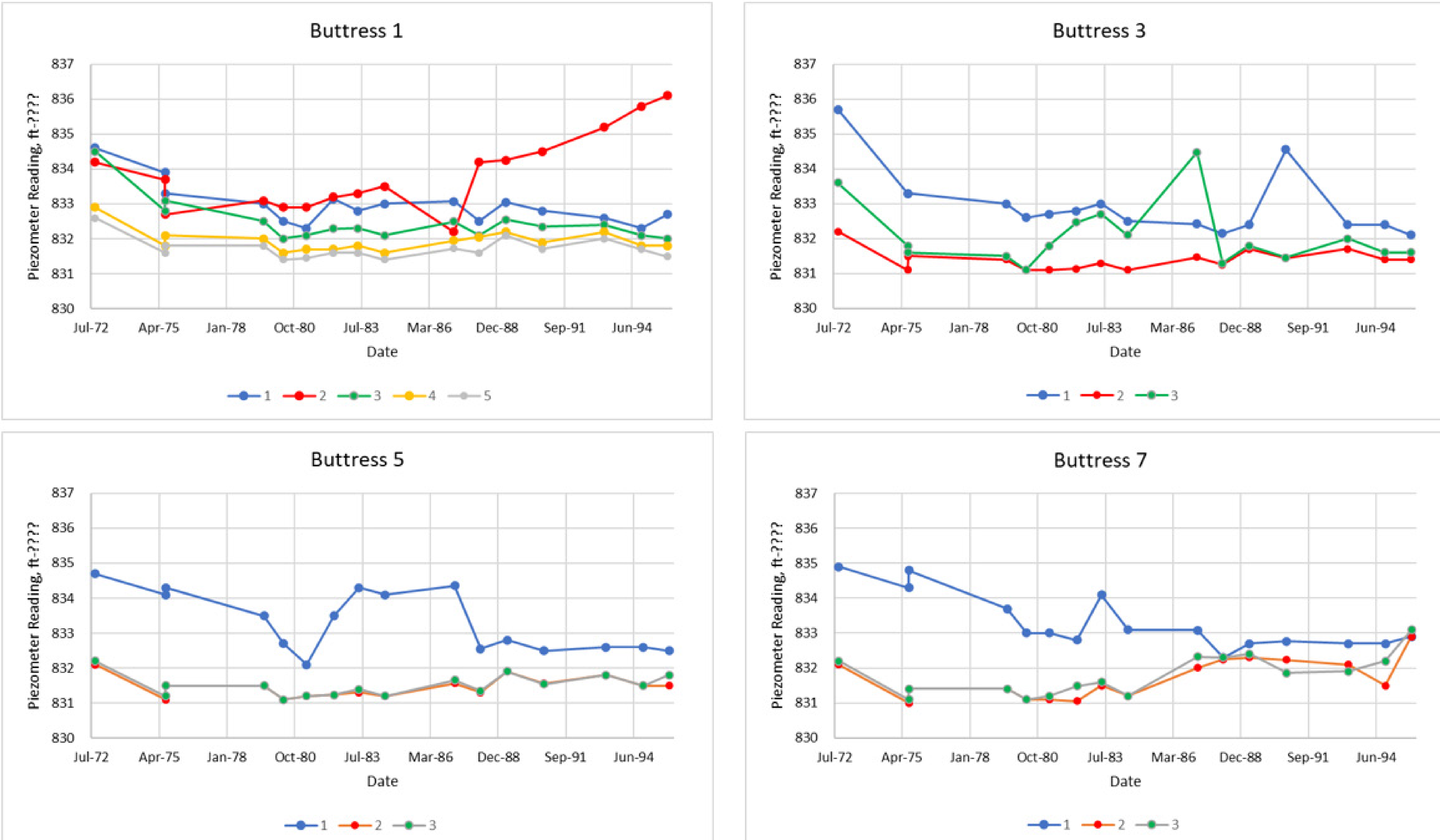
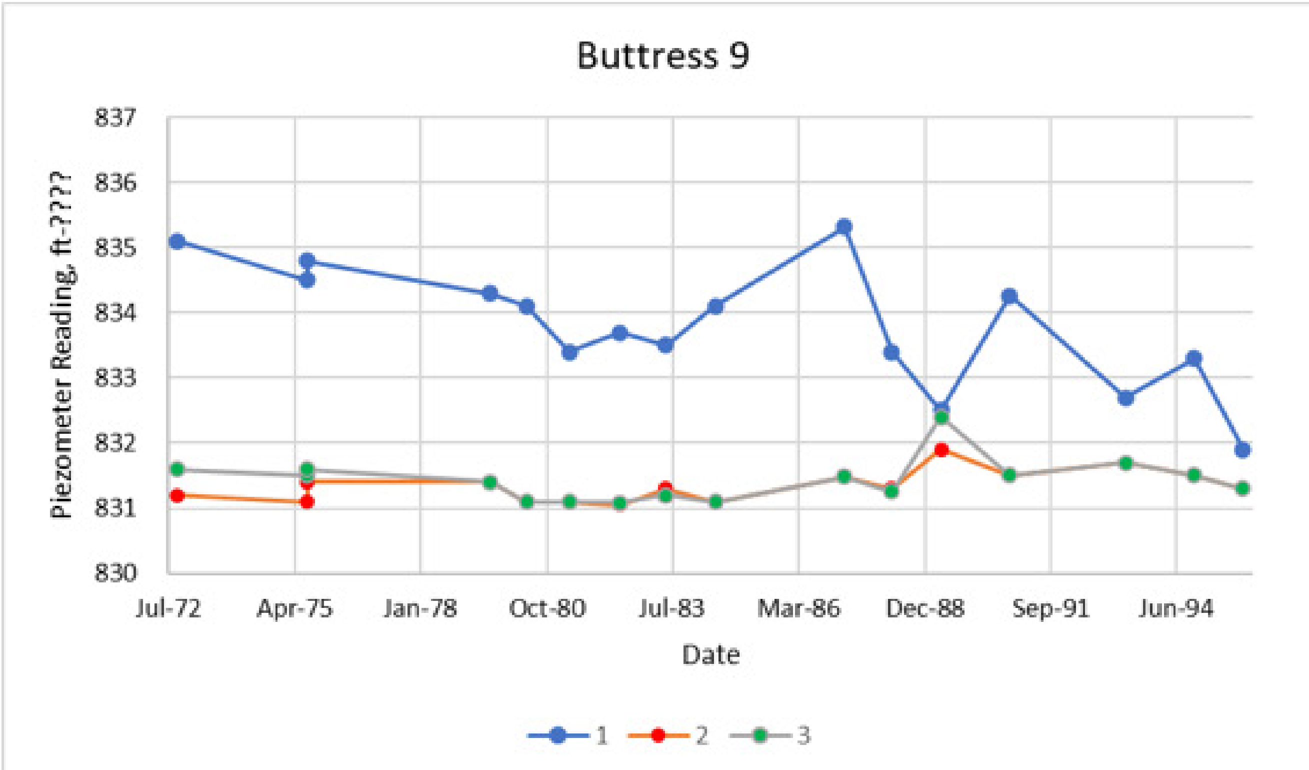
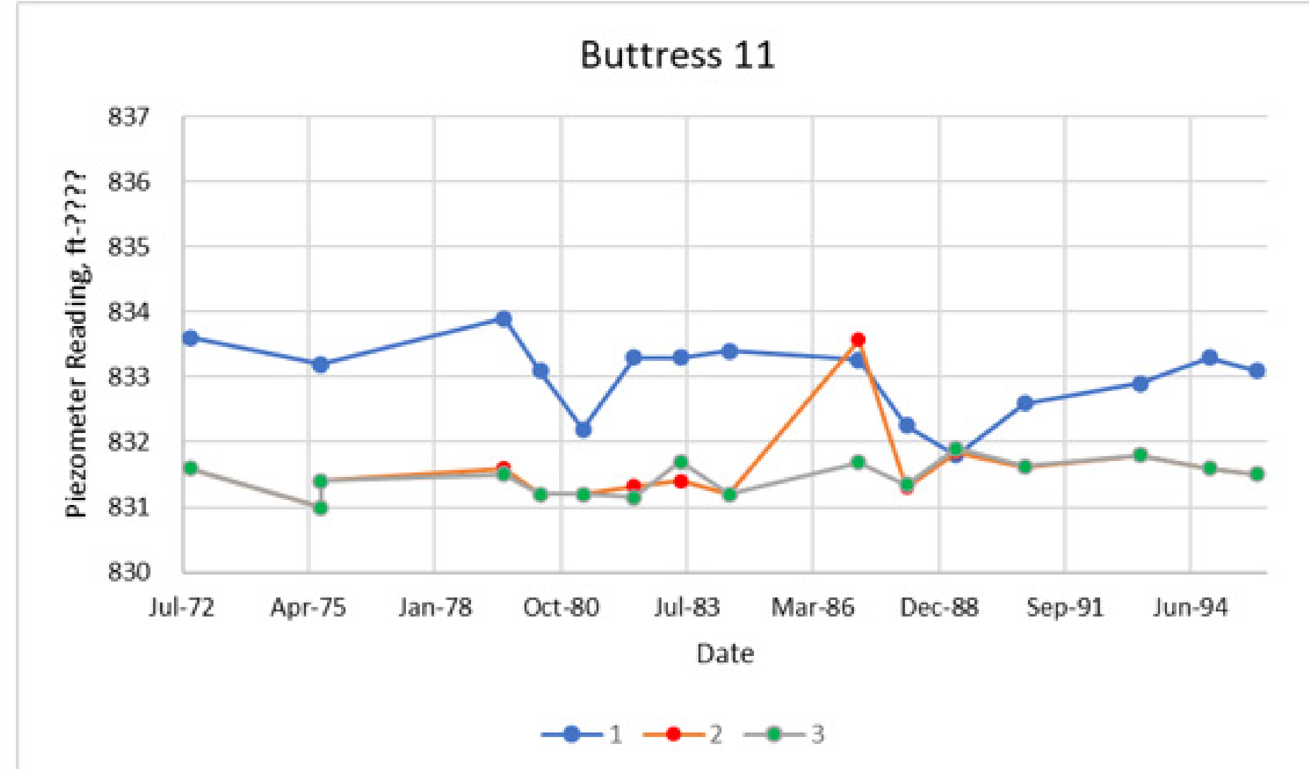


Figure 2-8. Piezometer readings through 1995





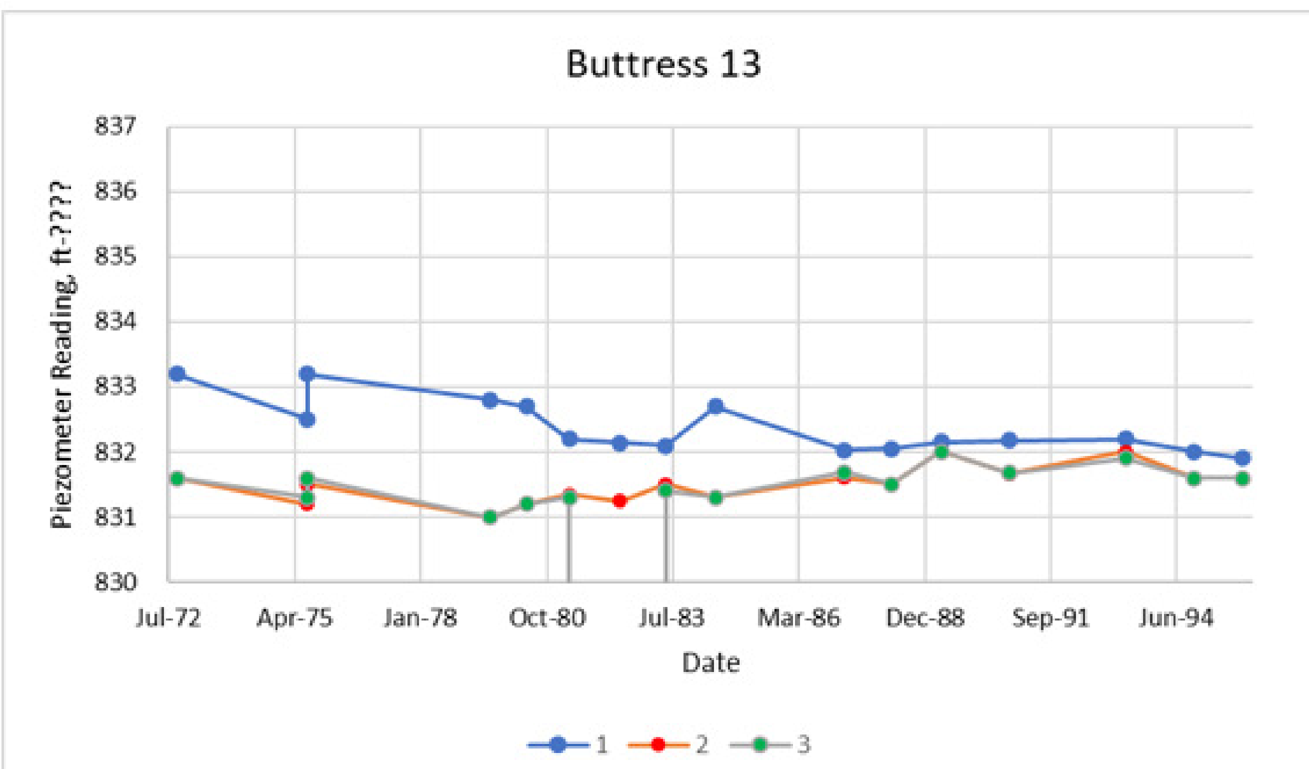


Figure 2-9. Piezometer readings through 1995 (continued)

2.7 Dam Hazard Classification

Hazard classifications[6] (as defined by the State of Minnesota [2024]) are described below:

- **Class I:** any loss of life or serious hazard, or damage to health, main highways, high-value industrial or commercial properties, major public utilities, or serious direct or indirect, economic loss to the public.
- **Class II:** possible health hazard or probable loss of high-value property, damage to secondary highways, railroads or other public utilities, or limited direct or indirect economic loss to the public other than that described in Class III.
- **Class III:** property losses restricted mainly to rural buildings and local county and township roads which are an essential part of the rural transportation system serving the area involved.

According to the National Inventory of Dams (USACE 2024), the Rum River Dam is currently classified as a Class III (low hazard) structure. The hazard classification of the dam should be confirmed or reevaluated in support of dam improvements as it has the potential to change, and a change to the hazard classification may in-turn affect detailed design considerations.

2.8 Existing Spillway Structural Stability

As indicated earlier in the report, no original design computations are known to exist for the dam. Therefore, HDR performed preliminary analyses to assess the structural stability of the existing spillway. Sliding and overturning stability were evaluated for normal conditions only. Note that these analyses are preliminary only and would be revisited in subsequent stages of design.

2.8.1 Criteria

Additional load cases would be considered in future stages of design. For the purposes of this study, FERC (2024) stability criteria were applied as tabulated below. Note also in the table:

- Normal conditions = normal pool and normal tailwater
- Unusual conditions = flood loading or ice loading
- Extreme conditions = earthquake

Table 2-2 below presents sliding stability criteria.

[6] Hazard classification is not a measure of the quality of a dam's design or construction, but rather a measure of the potential consequences should the dam fail. A dam's hazard classification serves as the basis for certain design requirements and operational dam safety requirements.

Table 2-2. Sliding stability criteria

Loading condition	Recommended sliding factor of safety	
	High or significant hazard potential	Low hazard potential
Normal	3.0	2.0
Unusual	2.0	1.25
Extreme	1.3	> 1.0

FERC is somewhat vague regarding overturning stability for normal loading conditions and therefore USACE (USACE 2005) criteria were applied. Said criteria require 100 percent of the structure base to be in compression or, in other words, the resultant force must be located within the middle one-third of the base.

2.8.2 Analysis

Preliminary stability analyses were completed for six scenarios, all under normal loading conditions. Three scenarios included effects of sedimentation and three did not. The results of the six scenarios, including sliding and overturning stability, are shown in Table 2-3. In all cases the dam was found to be adequate. Stability analyses are included in Appendix C1.

Table 2-3. Spillway stability results

Criterion	Recommended factors of safety		Calculated factors of safety					
	High hazard	Low hazard	A	B	C	D	E	F
Sliding	3.0	3.0	10.2	10.2	6.76	5.3	5.3	3.2
Overturning resultant location	Middle ⅓	Middle ⅓	Middle ⅓	Middle ⅓	Middle ⅓	Middle ⅓	Middle ⅓	Middle ⅓

Scenarios A, B, and C include sedimentation on the upstream side of the dam as silt pressure, based on the Dam Inspection Report (Barr 2023). In general, the additional weight of the sediment compared to the weight of water provides a net benefit to sliding stability but does impact the resultant force location because of the sediment's lateral load. Scenarios D, E, and F exclude the effects of sediment and provide more conservative values for sliding factors of safety.

2.9 Existing Utilities

Readily known utilities in the project area include sanitary sewer, electrical, and storm sewer. Based on what is known at the time of this report these utilities do not appear to present major issues that would directly affect feasibility or alternatives analyses. However, coordination with utility owners and subsurface investigations to increase confidence in utility locations should be considered in detailed design, and certainly performed at time of construction. A summary of known utility information is provided in the following sections.

2.9.1 Sanitary Sewer

Figure 2-10 on the following page shows the location of the existing 21-inch-diameter reinforced concrete pipe (RCP) sanitary sewer[7] that runs parallel to the river between the dam and City Hall. Figure 2-10 was taken from construction drawings prepared by Hakanson Anderson (HA 2012).

[7] The East Rum River Interceptor Sewer was designed by E.C. Rather and Associates and constructed in 1961.

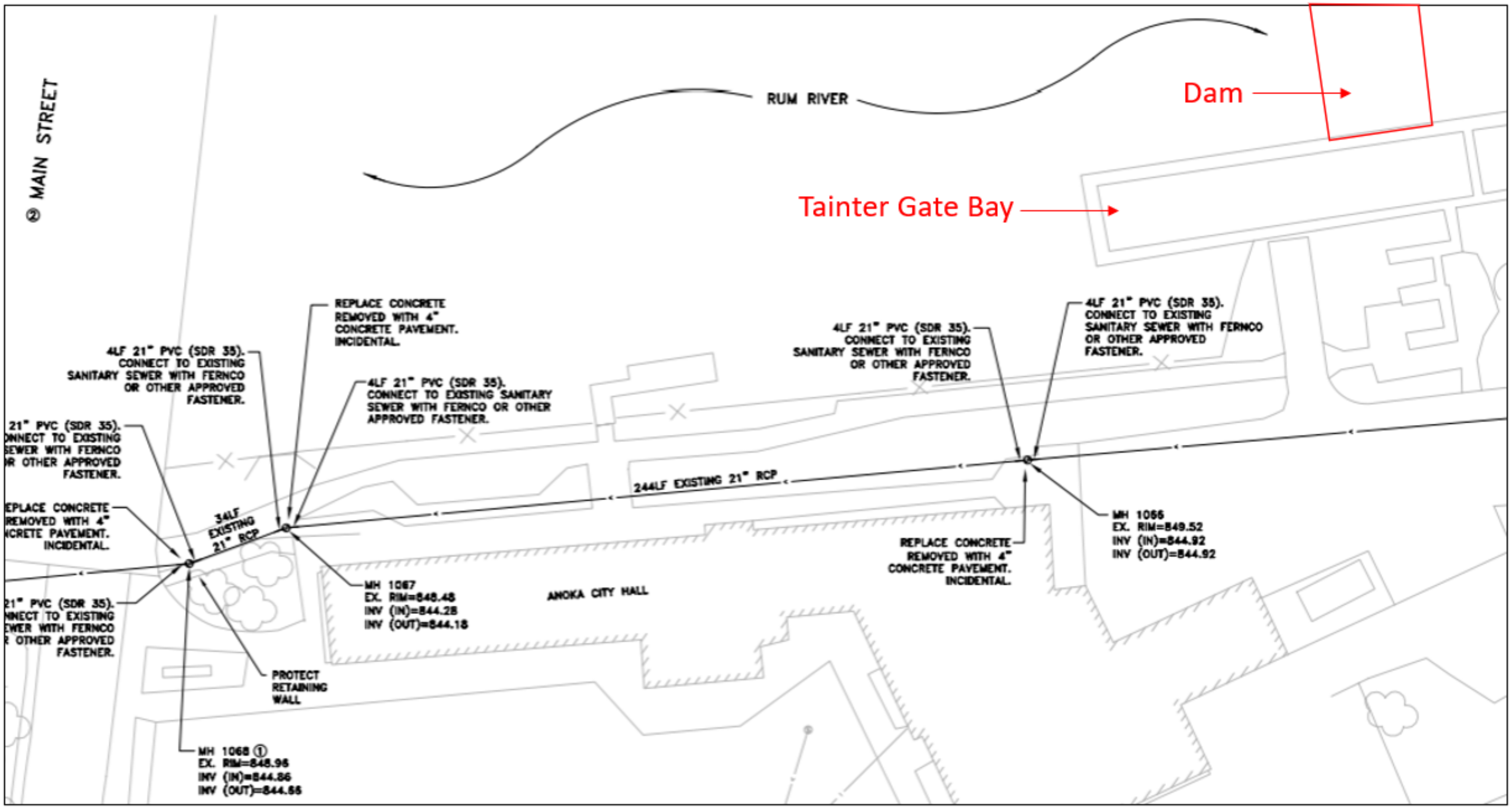


Figure 2-10. Plan of sanitary sewer location

2.9.2 Electrical

A map of the AMU existing electrical services in the vicinity of the Rum River Dam is provided in Figure 2-11.

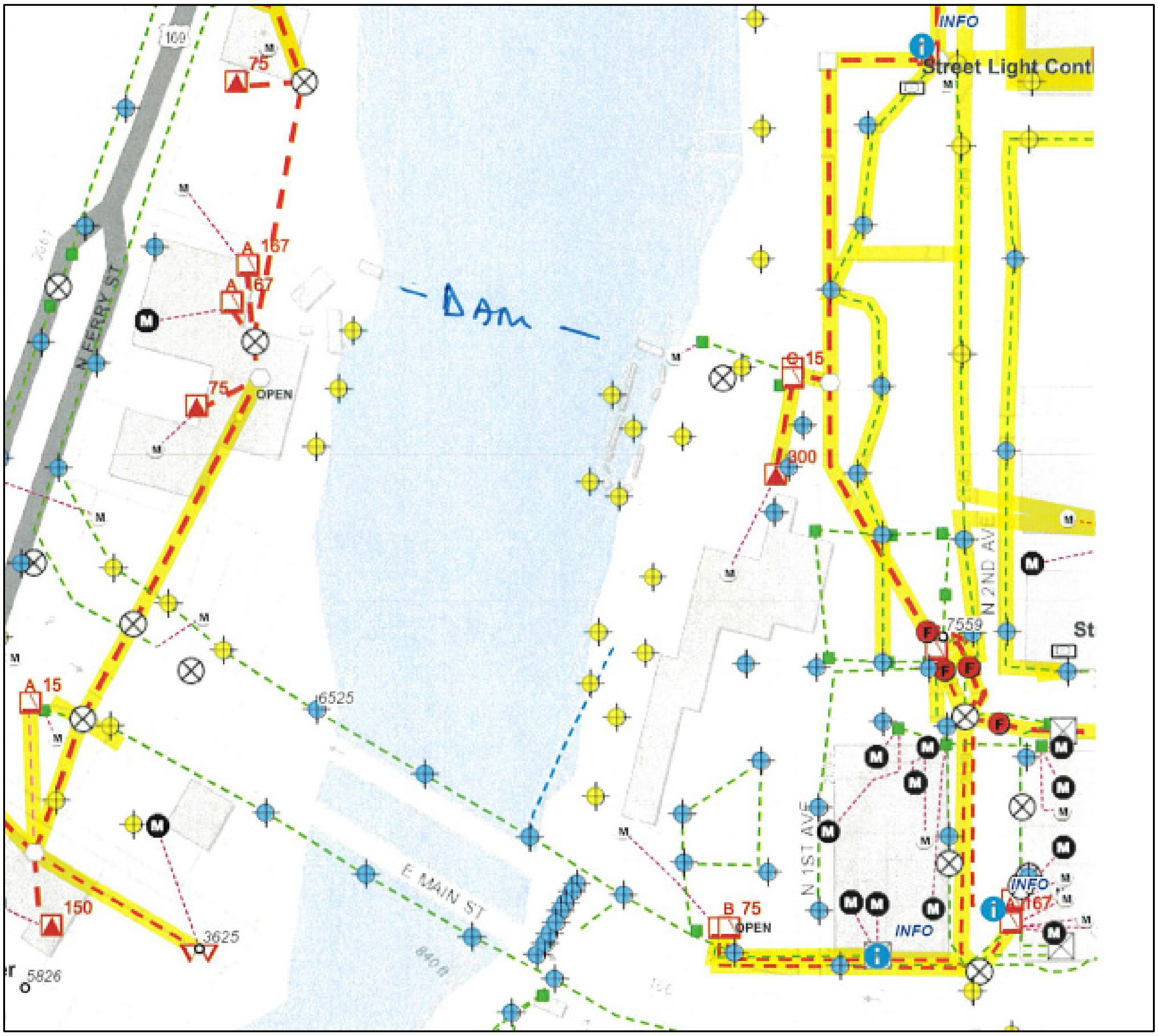


Figure 2-11. Existing electrical services

2.9.3 Storm Sewer

Based on review of existing stormwater construction drawings on the east side of the river (Kimley-Horn 2016), it appears that storm sewer facilities exist on the east side of City Hall, i.e., along 2nd Avenue, and may not present construction impacts. Based on review of existing stormwater construction drawings on the west side of the river (MnDOT 2001), there appears to be a 12-inch-diameter outfall to the Rum River on the west side of the river, just upstream of the building at 2040 North Ferry Street. It does not appear that construction would impact this outfall. Additional 12- and 30-inch diameter outfalls (including one from a Vortech treatment structure) are present on the west side of the river between the dam and the Main Street bridge. Both may be impacted by construction of the recreation feature and associated cofferdam. The location and interrelated effects of sewers and all utilities should be confirmed at time of final design and certainly before any construction commences.

2.10 Existing Adjacent Structures

This section describes existing adjacent structures in the project area.

2.10.1 East Bank Retaining Walls

Figure 2-12 shows the original retaining wall design from Bettenburg, Townsend and Stolte (BTS) (1954).

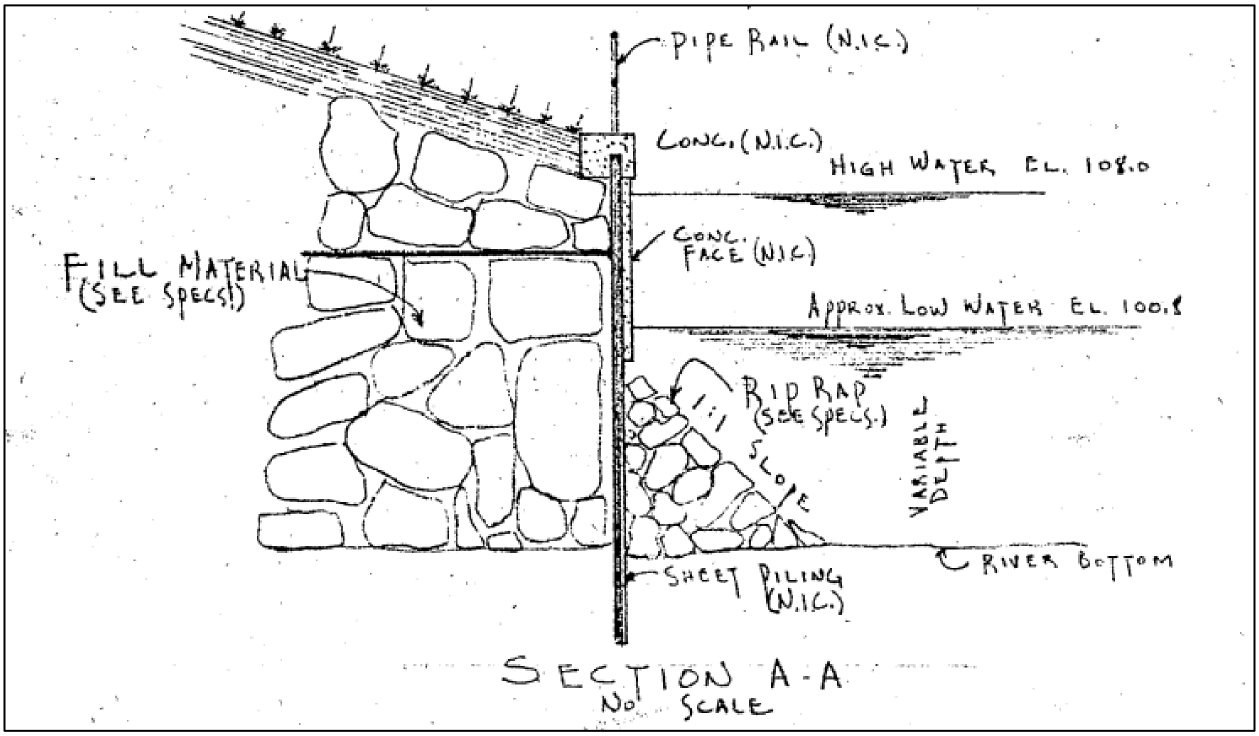
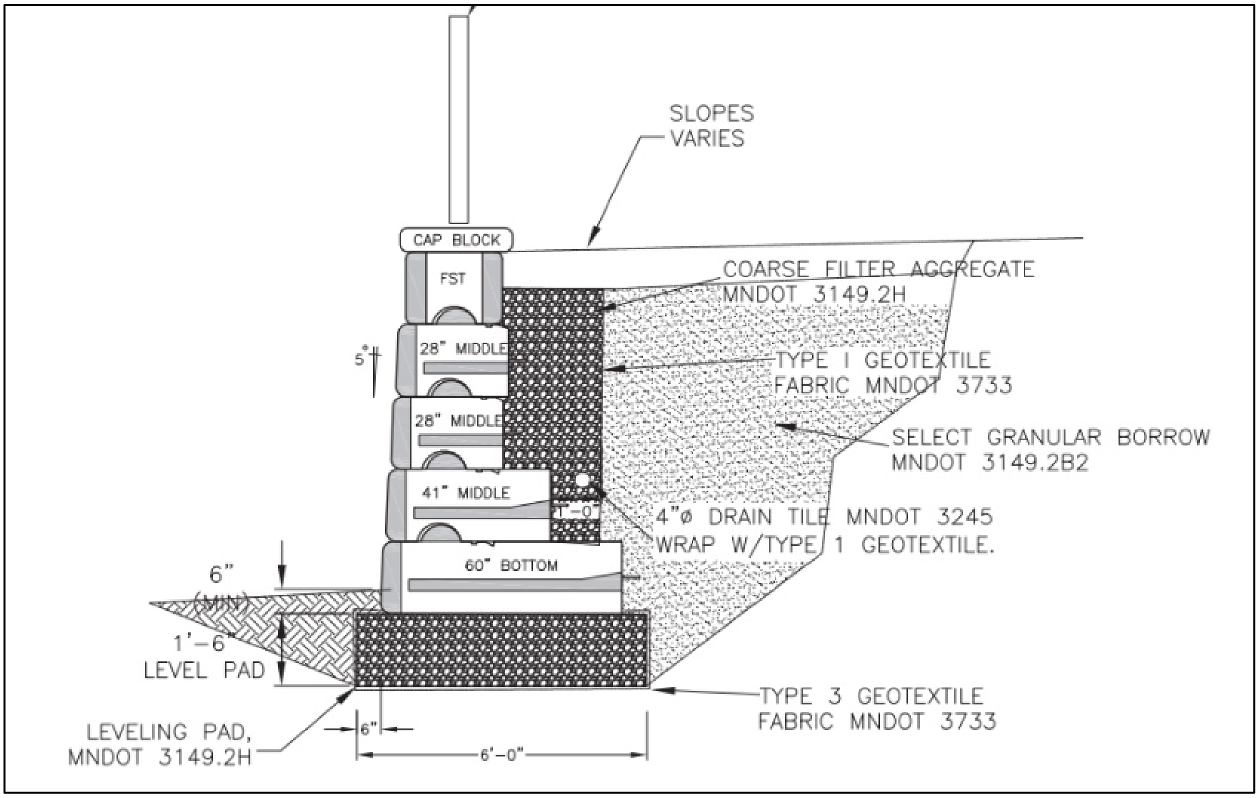


Figure 2-12. East bank retaining wall (original)

As part of a larger project in 2016, the east bank retaining wall was reconstructed (and/or modified) and featured the use of a Redi Rock retaining wall system. See Figure 2-13, taken from design drawings by Stantec (2016).



Source: Stantec 2016.

Figure 2-13. East bank retaining wall

2.10.2 Stone House

The “Giddings” Stone House is an historic monument located on a sandbar in the Rum River just downstream of the Main Street bridge in Anoka’s downtown district (see Figure 2-14). Built in the early 1900s, the Stone House is the last remaining structure out of the original three that were constructed. As part of the plan to enhance recreational opportunities along the river through the development of an expanded trail network, the City is looking to reconnect the Stone House site to the west bank of the river and potentially to the trail network. Historically a stone arch bridge connected the Stone House site over a side channel to the west bank of the river, but that has since been washed away by the river. The City is pursuing a project that includes a replacement bridge concept that would be developed and would need to be evaluated for hydraulic impacts within the floodplain to comply with MnDNR Public Water Works Permit requirements or FEMA/other requirements.

Figure 2-14. Rum River Stone House

2.10.3 Boat Dock and Mooring System

The City constructed the “Port of Anoka”, a boat dock and mooring system downstream of the dam in 1998 (see Figure 2-15). The system includes an Americans with Disabilities Act (ADA) accessible ramp leading to a modular floating dock system. The ramp or gangway is of aluminum construction. The ramp and modular dock are supported by structural steel and reinforced concrete “dead men.” Several of the structural members and dead men are founded on helical soil anchors.

Figure 2-15. “Port of Anoka” boat dock and mooring system

2.10.4 Bridges

Figure 2-16 shows the location and names of Rum River bridges in the vicinity of the Rum River Dam. Table 2-4 presents lowest structural members elevations of these bridges based on survey by Hakanson Anderson (HA 2019). Based on this available information, the minimum clearance between the upstream bridges and normal summer pool (i.e., with flashboards installed) is approximately 10 feet.

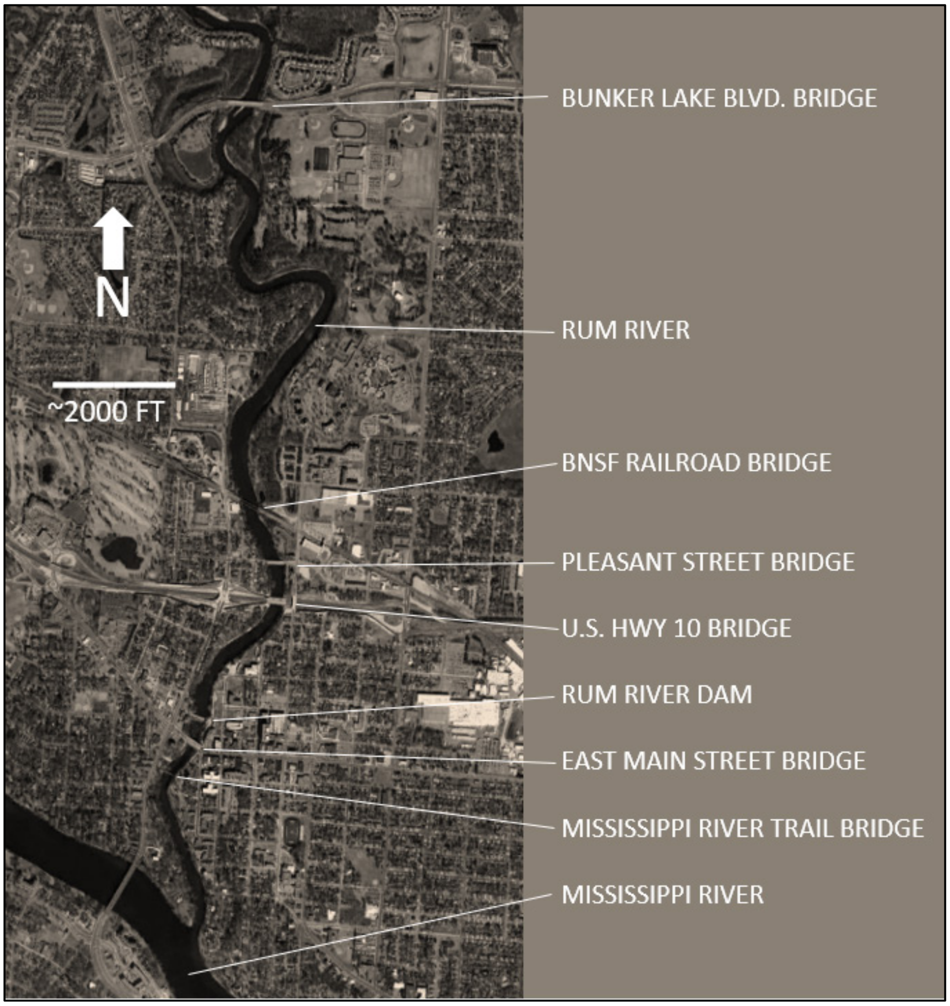


Figure 2-16. Project area bridges

Table 2-4. Bridge low chord elevations

Bridge	Low elevation (ft)
Bunker Lake Blvd. (CSAH 116)	863.2
Pleasant Street (CSAH 30)	863.2
U.S. 10	855.5

2.10.5 Boat Channel

The City maintains a recreational boat channel in the Rum River between the dam and the Mississippi River. The most recent restoration project, completed in 2024, included channel excavation from just south of the pedestrian bridge over the Rum River to just north of the confluence of the Mississippi River. Previous restoration projects were completed in 2008 and 2023, included channel excavation from the dam downstream to just south of the pedestrian bridge over the Rum River between Monroe and Madison Avenues. As shown on Figure 2-17, the typical channel section is trapezoidal in shape with a bottom width of approximately 40 feet. The channel provides for a normal water depth of approximately 4 feet.

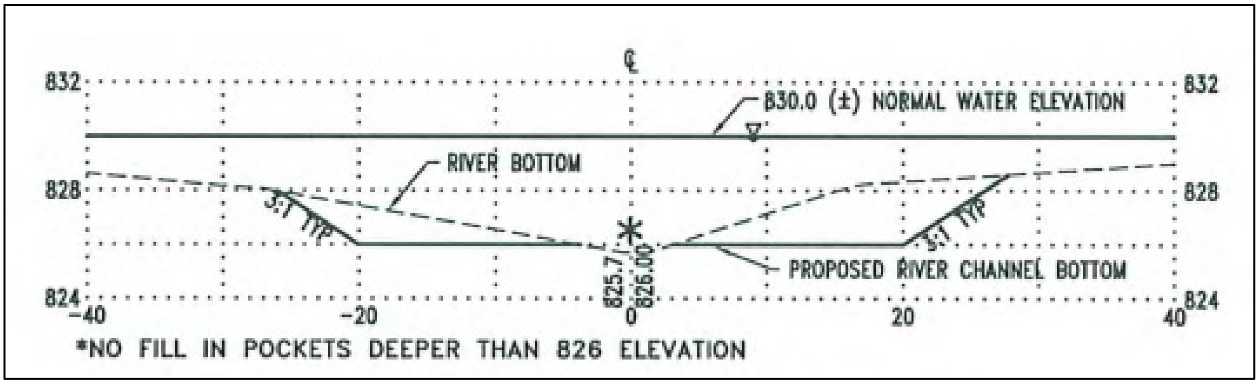


Figure 2-17. Typical boat channel section

2.11 River Sediment

Based on the sounding program results reported in the most recent Dam Inspection Report (Barr 2023), it appears that approximately 6 feet (depth) of sediment[8] is present upstream of the spillway. River sediment may have environmental and permitting implications and regulatory authorities or agencies may influence the need for sediment testing, sediment transport analyses, and disposition of sediment removed in conjunction with construction activities. No testing results for upstream sediment are known to exist, but there has been historical sediment testing downstream of the dam as summarized below (but which may require updating at time of final design and construction).

Sampling and testing of Rum River (downstream of the dam) bed material has been performed in the past to support dredging projects. Results from the 2008 investigation (Braun 2008) indicated the following:

- No polychlorinated biphenyls (PCBs), total organic carbon, cadmium, chromium (hexavalent), mercury, or selenium were reported.
- Several metals (arsenic, chromium [total], copper, lead, nickel, and zinc) were present above the method reporting limits. All these parameters are naturally occurring metals, and the concentrations were at ambient (natural) levels.
- None of the concentrations exceeded the Level 2 Soil Reference Value (SRV) concentrations and therefore, in accordance with MPCA (2007)[9], the dredged sediment is suitable for use or reuse on properties with an industrial use category. Although the copper concentrations are at natural levels, it is recommended that dredged sediment not be used in a residential or recreational environment without approval from MPCA.

Sediment sampling and testing were again performed in 2023. Laboratory results from Legend (2023) indicated the following:

- Boron–oxygen-fused (BO) polycyclic aromatic hydrocarbons (PAHs) or arsenic were identified above laboratory reporting limits.

---

[8] Measured relative to the top of the upstream spillway base slab at elevation 832.

[9] The most recent edition of MPCA's "Managing Dredged Material in the State of Minnesota" is April 2024.

- Copper was identified at concentrations ranging from about 1.5 to 3.0 parts per million (ppm). These concentrations were at naturally occurring levels. In addition, these levels were well below the Residential SRV of 100 ppm.
- The dredged material was considered unregulated fill and will not require special handling or disposal.

3 Rum River Hydrology and Hydraulics

This section discusses background data and considerations related to flows in the Rum River. This information is critical as it informs the conceptual designs and evaluations of alternative dam improvements presented in subsequent sections of the report; and additional or more detailed analyses would be recommended at the time of final design.

3.1 Gage Data

The United States Geological Survey (USGS) (2024a) operates a streamflow gage (05286000) on the Rum River near St. Francis, Minnesota. The gage is located approximately 22 river miles north (upstream) of the dam and has a drainage area of 1,360 square miles (mi^2). Mean daily streamflow data are available from the gage dating back to 1929 and without interruption back to 1933.

The drainage area of the Rum River at the dam is 1,573 mi^2 (per USGS 2024b); see Appendix C1. To estimate river flows at the dam, USGS gage flows were adjusted as follows. This method matches that used by FEMA (2015).

$$Q_{dam} = Q_{gage} (A_{dam} / A_{gage})^{0.6} \text{ (Equation 1)}$$

$$Q_{dam} = 1.09\, Q_{gage} \text{ (Equation 2)}$$

Where:

- Q_{dam} = river flow at dam, cfs
- Q_{gage} = river flow at gage, cfs
- A_{dam} = drainage area at dam, mi^2
- A_{gage} = drainage area at gage, mi^2

HDR applied the above adjustment factor to estimate daily flows at the dam. The streamflow data set used for the balance of this study is based on the most recent 20 years of data, i.e., from October 1, 2012 through September 30, 2023. Typically, the full or available period of record of a gage is used. However, use of more recent data may be appropriate to coarsely to account for changes in climate and hydrologic (runoff) conditions in more recent years. For example, the daily average Rum River flow over the complete period of record is 760 cubic feet per second (cfs), but is 934 cfs for the most recent 20 years: an increase of approximately 23 percent. Table 3-1 presents annual and monthly streamflow statistics.

Table 3-1. Rum River streamflow statistics (2012–2023)

Period	Daily average river flow, cfs		
	Min	Max	Mean
January	144	1,439	356
February	134	2,669	329
March	121	6,787	873
April	256	10,335	2,061
May	390	8,369	1,835
June	190	7,600	1,379
July	112	5,810	842
August	100	3,833	700
September	132	4,712	711
October	182	6,348	916
November	208	3,778	716
December	144	3,031	467
Annual	100	10,335	934

Another method to assess river flow is known as "flow duration" analysis, where daily data is sorted to determine the amount of time (expressed in percent) that a given flow can be expected to be exceeded. Figure 3-1 below presents flow duration curves on an annual and seasonal basis. As an example, the median (50 percent) flows are approximately 590 cfs, 740 cfs, and 460 cfs on annual, summer, and winter bases, respectively. Note that the y-axis (river flow) is abbreviated to show the lower range of flows, which is the primary focus of this study.

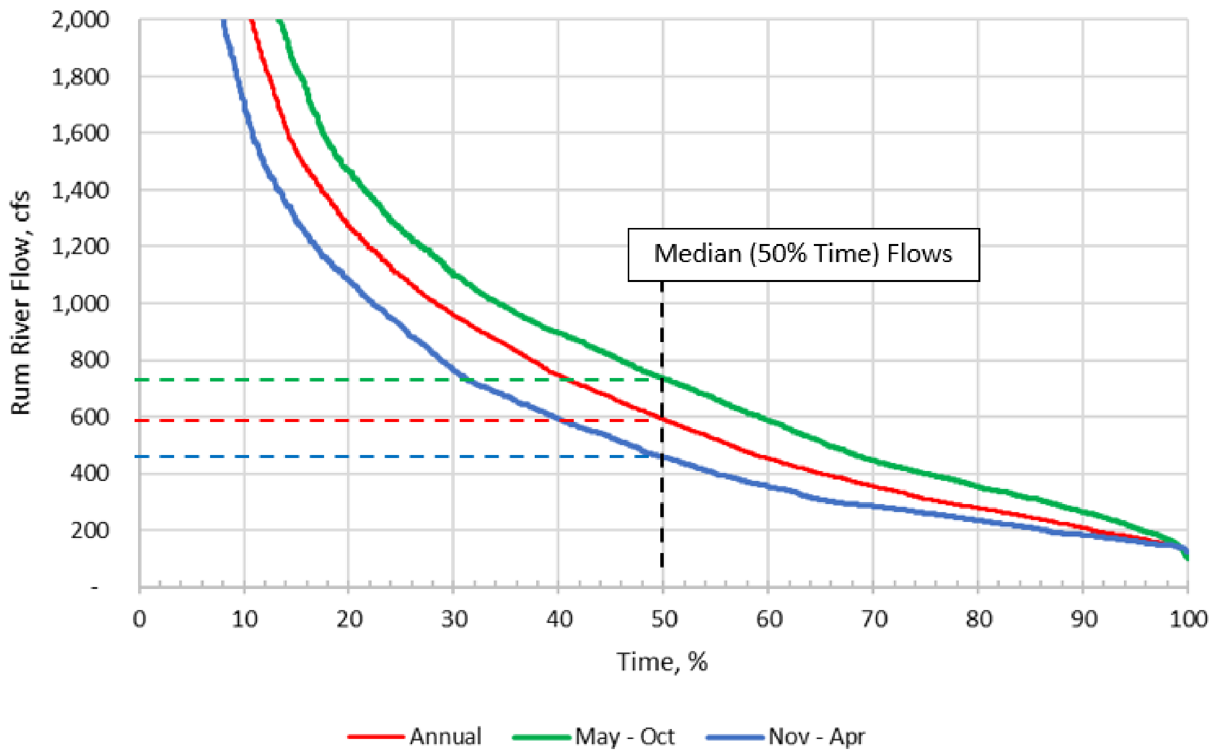


Figure 3-1. Flow duration curve

3.2 Extreme Events

In a memorandum to the City, Hakanson Anderson Associates (HA 1999) reported the following historic Mississippi River flood elevations (Table 3-2):

Table 3-2. Historic Mississippi River Flood Events

Year	Elevation, ft	Cause
1952	841.2	Runoff
1957	841.5	Ice jam
1965	844.3	Ice jam
1965	843.4	Runoff
1969	841.3	Ice jam
1984	842.2	Ice jam
1997	840.6	Runoff

Data in Table 3-3 below are from FEMA's FIS (2015). The flood of record reported in the O&M Manual (Barr 1972) is 11,400 cfs, which occurred during the flood events of 1965. The 11,400 cfs value is instantaneous, which is larger than the prorated mean daily flow of 10,790 cfs at the dam recorded on that day (USGS 2024a). Since 1965, river flow has approached that value once, in 2023.

Table 3-3. Rum River flood data

Recurrence interval, years	Rum River flow, cfs		Water elevation, ft-NAVD
	Upstream of dam	Downstream of dam	
10	9,080	845.8	840.3
50	13,300	847.1	843.9
100	15,300	848.0	845.2
500	19,800	850.2	848.9

3.3 Spillway Capacity

A spillway "rating" refers to the relationship between headwater (or pool) elevation versus discharge (or flow). The Rum River Dam's spillway rating curve presented on Figure 3-2 is reproduced from the dam's O&M Manual (Barr 1972). This represents the maximum spillway rating, i.e., flashboards are down and Tainter gate is fully open.

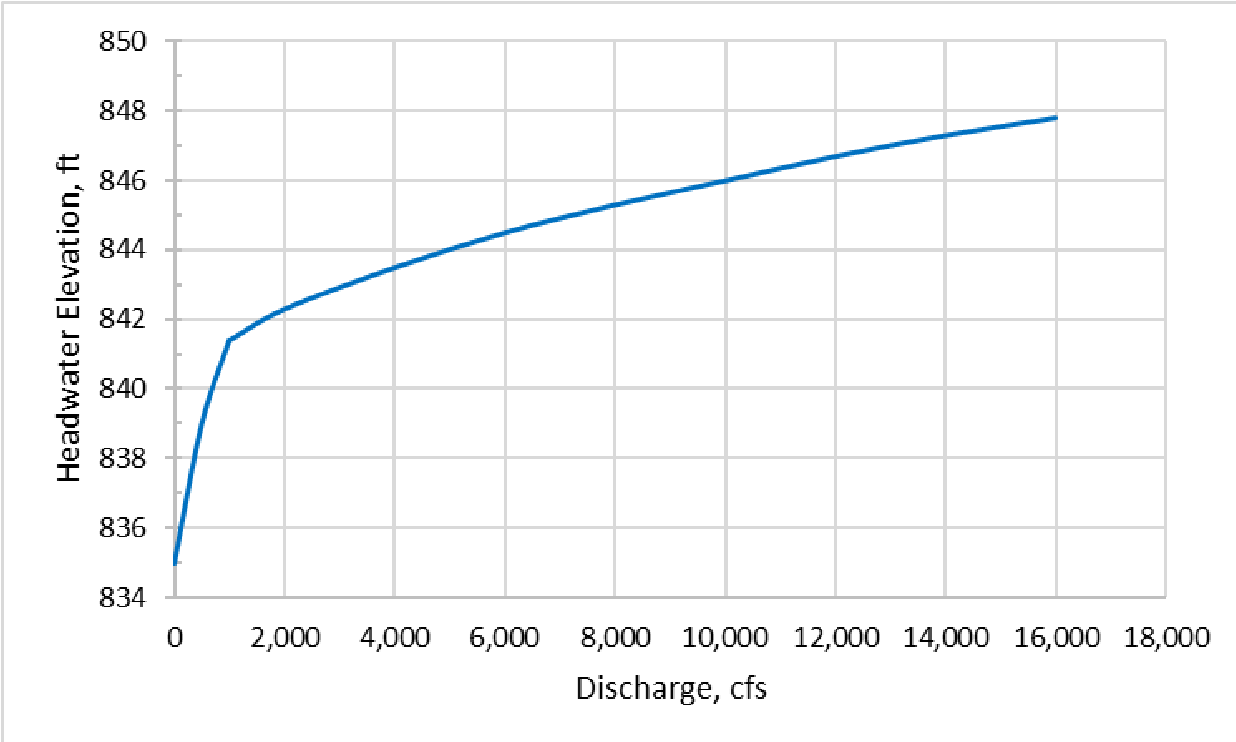


Figure 3-2. Spillway rating curve

The O&M Manual indicates that the dam was designed to safely pass up to 16,000 cfs (Barr 1972). The dam is currently under the authority of MnDNR. MnDNR does not define "safely" but HDR's experience is that this generally means the discharge associated with the maximum pool elevation does not overtop non-overflow portions of the structure or adjacent lands. Additionally, dam-safety officials commonly require a certain amount of freeboard[10] (i.e., safety allowance). The original grading plan for the dam (Barr 1968a) indicates an overtopping elevation of approximately 849 feet, which correlates to a spillway capacity greater than 16,000 cfs. Therefore, it appears that the stated spillway capacity of 16,000 cfs may be reasonable so long as the flashboards are not in-place and there is no substantive backwater/tailwater effects from either the Rum River or Mississippi River.

Related to "spillway capacity" is the inflow design flood (IDF). Although MnDNR does not have specific requirements on how to determine the IDF, the following description is offered for context:

> The Inflow Design Flood (IDF) is the flood flow above which the incremental increase in water surface elevation due to failure of a dam or other water impounding structure is no longer considered to present an unacceptable threat to downstream life and property. (FERC 2024)

The method to determine a dam's IDF can be complicated and commonly involves performing a dam failure analysis using computer modeling software such as the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS). The model is used

---

[10] Freeboard is the vertical distance between the water surface and the top of a structure.

to simulate flooding downstream of a dam with and without failure of the dam. The IDF is the point (river flow) at which the effect of the dam failure becomes insignificant with respect to potential downstream life loss and property damage. Because the IDF does not appear to have been explicitly determined, if is not clear if spillway capacity is adequate.

3.4 Tailwater Rating

The dam's "tailwater rating" is the relationship between river flow and water elevation downstream of the dam. Tailwater rating can affect a dam's spillway capacity, structural stability, hydropower potential, and recreational features.

The dam's tailwater rating curve presented on Figure 3-3 is reproduced from the dam's O&M Manual (Barr 1972). The curve reflects the flow conditions of the Rum River alone without backwater effects of the downstream Mississippi River.

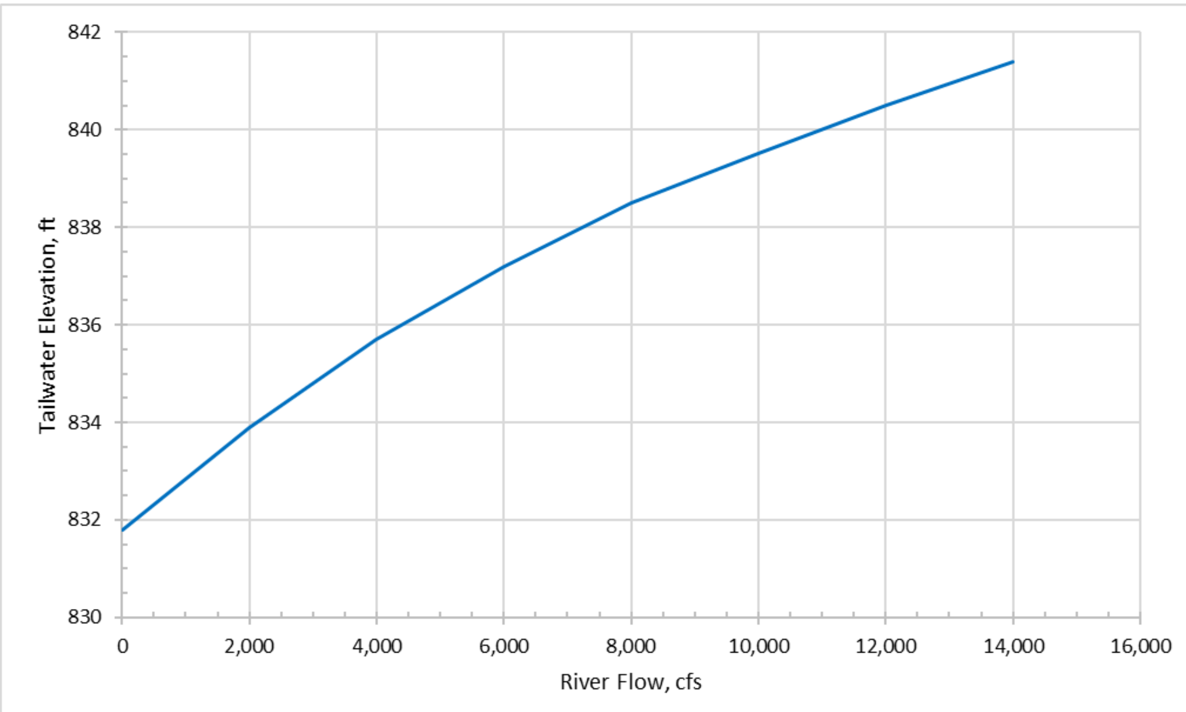


Figure 3-3. Rum River Dam tailwater curve

3.5 Minimum Aesthetic Flow

Water flow over the spillway is aesthetically pleasing, especially at night with the water cascade illuminated. However, flow in excess of what is required for aesthetic purposes reduces the water available to allocate to other prospective dam features. Figure 3-4 below is similar to the spillway rating curve (see Figure 3-2) but highlights smaller spillway depths, and a closed tainter gate, to better represent potential minimum spillway flows for aesthetic purposes, or "minimum aesthetic flow". Figure 3-4 applies the full existing spillway length of 236 feet.

The minimum aesthetic spillway flow can be variable, i.e., more on weekends, less after midnight, vary with inflow, etc. For the purposes of this report, a minimum aesthetic flow of 100 cfs (3 inches of flow over spillway) is assumed.

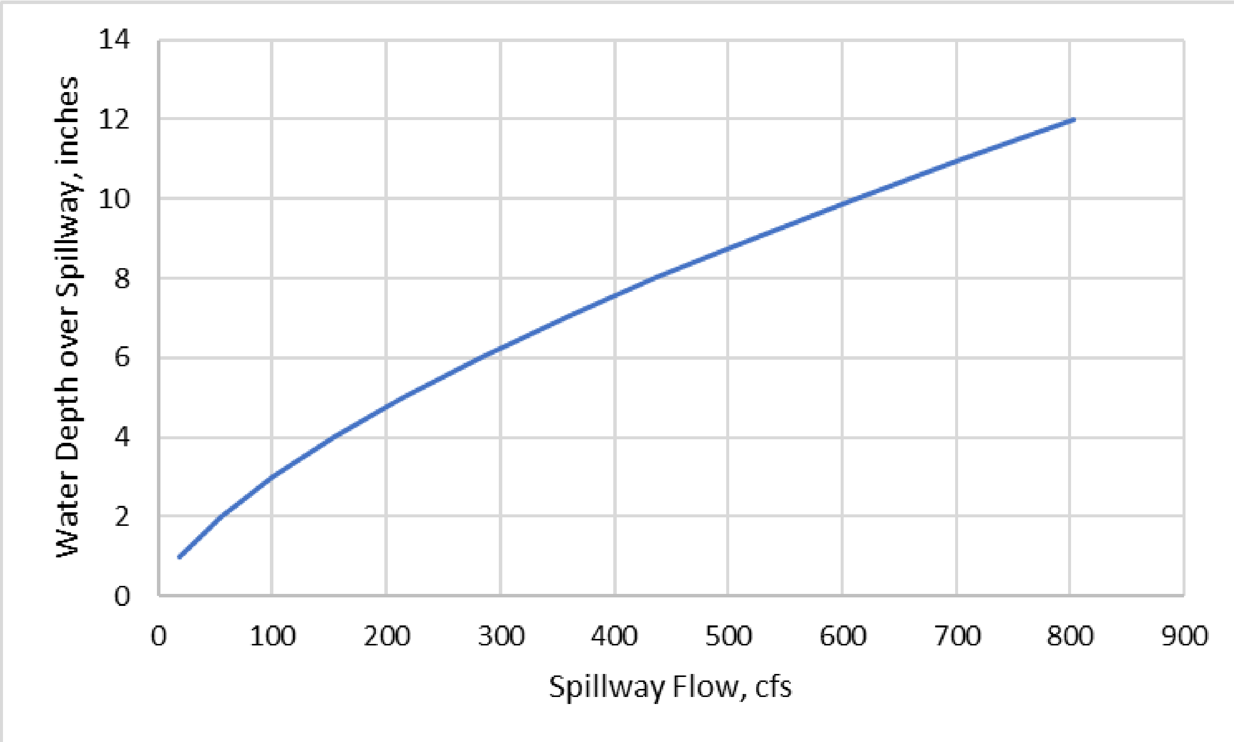


Figure 3-4. Aesthetic spillway flow vs. depth

3.6 Water Allocation Model

A spreadsheet model was developed to evaluate the general availability and allocation of water between the various prospective dam features. This model uses Rum River flow taken from USGS Gage 05286000, adjusted to reflect flows at the dam as described in Section 3.2. The resulting flow at the Rum River Dam is assigned to one of the following six features based on the following an initially assumed priority[11]:

- Fish passage
- Minimum aesthetic spill
- Lock
- River surfing/recreation
- Hydropower
- Remaining spill

The model user can assign operational criteria to each feature such as month, day of the week, time of day, and required flow. Beginning with fish passage, each feature's criteria are checked and if all criteria are met, water is allocated to the feature. The criteria[12] for each feature are listed below:

[11] Note the model allows for real-time changes to the priority order.

[12] Note that the model allows for real-time changes to the required flow and/or operational range for each feature.

1. Fish passage:
   - Required flow rate of 75 cfs or total river flow, whichever is less
   - Operational range (months)
2. Minimum aesthetic spill:
   - Remaining river flow after fish passage criteria are met or required flow of 100 cfs, whichever is less
   - Operational range (months, days of week, times of day)
3. Lock:
   - Remaining river flow after previous features' criteria are met or required flow, whichever is less
   - Required lock flow based on an assumed four lockages per hour
   - Required lock flow based on lock dimensions of 75 by 20 by 13 feet
   - Assume lock fills in 15 minutes
   - Operational range (months, days of week, times of day)
4. River surfing/recreation:
   - Remaining river flow after previous features' criteria are met or required flow of 300 cfs, whichever is less
   - Assume required flow for surfing, but flows less than required surfing flow are acceptable for other whitewater recreational activities
   - Operational range (months, days of week, times of day)
5. Hydropower:
   - Remaining river flow after previous features' criteria are met or required flow, whichever is less
   - Hydropower operation is constant as long as flows within the operating range are available
6. Remaining spill:
   - If all features are operating at their target flows, any remaining river flow is assigned to the overflow spillway

The model was used in a working session between members of City staff and the PMT. Variations of priority were evaluated, and the following priority was established:

1. Fish passage
2. Lockages
3. Recreation flow
4. Aesthetic flow

Note that hydropower was considered by the PMT to be infeasible at the time of this report (see discussion in Section 5.11).

The water balance model can be used in future phases of project development as a means to estimate whether the local hydrology and inflow can support proposed changes in operation to any of the above features.

4 Alternatives Selection Process

The design team consisted of HDR (and its subconsultant, Calibre) and Kimley-Horn. HDR was responsible for the dam proper, and Kimley-Horn was responsible for the bridge across the dam and integration of the project with adjacent City amenities. The Project Management Team (PMT) included representatives from City staff, Anoka Municipal Utility staff, Kimley-Horn, and HDR.

The PMT held a series of meetings to discuss prospective alternative dam improvement features. Conceptual designs of and considerations for alternative features were developed by the design team (HDR and Kimley-Horn) to support the PMT meetings. The PMT meetings were also supported by the background information and Rum River flow data discussed in Sections 2 and 3 of this report.

This section includes a brief description of the alternatives and details are provided in Section 5.

4.1 Alternatives Considered

The following alternative features were evaluated as part of the feasibility study:

- **Flashboard replacement:** replacement of existing flashboards with automatic crest gates or similar that are operable from shoreline control buildings
- **Recreational vessel passage:** means of allowing passage of recreational vessels to and from the Upper Rum River from and to the Lower Rum River and Mississippi River
- **Fish passage:** means of connecting the Upper Rum River to the Lower Rum River and Mississippi River for native fish species
- **River surfing/whitewater recreation:** establish a river surfing/whitewater recreational feature at the dam
- **Pedestrian, bicycle, and river access:** consideration for a bridge across the river and other improvements along the west side of the Rum River for pedestrian and bicycle access, access to and from Main Street, and access across the river, along the dam, creating a full pedestrian loop
- **Hydropower:** evaluate the potential for electrical generation through the addition of a hydropower facility at the dam

4.2 Alternatives Selection

On July 29, 2024, the PMT presented the culmination of the advanced engineering and planning concepts to the Anoka City Council at a regularly scheduled work session.

Following recommendations from the PMT, the City Council decided to advance all of the features except for hydropower[13].

5 Alternative Features

This section provides detailed descriptions of the features of each selected alternative.

5.1 Design Criteria

The following design criteria were adopted for the purposes of this study:

- Overall spillway capacity of the dam cannot be reduced
- IDF assumed to equate to the existing FEMA 100-year event or 15,300 cfs
- Target pool elevations are as follows:
    - Summer (May through October): 844.35
    - Winter (November through April): 841.35
- No new dam features are to extend past (west of) the existing west (right[14]) abutment
- New dam features may extend to the east (left) but may not adversely impact the existing sanitary sewer line or existing river/retaining wall

5.2 Operational Improvements

The primary operational improvement is replacement of the timber flashboard system with crest gates that will allow for; a) automatic pool level control, and b) manual control (from shoreline control building) to allow for special operating conditions such as river debris passage, etc. The automatic crest gates would eliminate the need for operators to install and remove the flashboards annually. The crest gate system is described in detail in Section 5.4 of this report.

A second potential operational improvement is the addition of a bridge over the overflow spillway. This would provide access over the spillway and crest gates and improve the ability of operators to remove or guide debris over the spillway. As this feasibility study advanced, the river-crossing bridge grew in complexity (see Section 5.8 for full description):

- The deck was raised to avoid impacting use of the recreation feature and navigation lock.
- The alignment was revised to provide better access to public ways on the east side of the river.

[13] As discussed in Section 6, hydropower development was found not viable at the time of this report and unattractive from a regulatory standpoint. However, the City Council requested that alternative renewable energy sources, such as solar or heat exchange, be evaluated in place of hydropower. Section 6 discusses these prospective alternative renewable energy sources.

[14] In river engineering terms, “left” and “right” refer to the direction when looking downstream.

- The load carrying capacity of the bridge was increased to allow for overlooks and small vehicle traffic.

Initially it was envisioned that the bridge would be supported by new piers found on the existing dam/base slab. Given the above complexities and lack of information on the dam foundation conditions, for the purposes of this report it is assumed that the bridge cannot be founded on the existing dam and instead would be supported by new piers constructed within the river (which may require assessment of FEMA floodway or other considerations in future design stages). With respect to operational considerations, the automatic crest gates should make passage of debris easier as the gates can easily be raised and lowered from shore. An operators’ bridge is not a necessity for crest gates – two examples are the St. Cloud Dam and Lock and Dam 1 in St. Paul.

5.3 Dam-Safety Improvements

Section 2.5 provides discussion of the results of the most recent dam inspection. The eventual general construction contract is envisioned by the PMT to include requirements to allow the future owner’s engineer access to the dam after the cofferdams are in place to perform a detailed inspection of dam elements including those that are normally submerged or inaccessible. Following the inspections, remediation measures would be developed as appropriate and ultimately implemented by the selected contractor will make necessary repairs with measurement and payment terms (i.e., unit adjustment prices) established in the bidding/contract documents. Based on what is known at the time of this report, repairs may include the following:

- Vegetation removal
- Concrete crack and spall repair
- Concrete baffle repair or replacement
- Concrete element replacement
- Scour/undermining repair, e.g., riprap, grouting, etc.
- Piezometer refurbishment or replacement
- Foundation drainage system refurbishment or replacement

5.4 Spillway Crest Gates

This section describes the spillway crest gates, including possible gate types, selected gate type, required dam modifications, and required systems and services. Spillway crest gates are necessary for control of the upstream seasonal pool, as well as managing the amount of water into the various proposed features.

5.4.1 Spillway Capacity

HDR created a spreadsheet tool to evaluate proposed versus existing spillway capacity. This tool allows one to adjust key spillway feature parameters such that the existing spillway capacity is not compromised. An example follows.

$$Q = C_d L H^{3/2} \quad \text{(Equation 3)}$$

Where:

- Q = flow, cfs
- C_d = weir coefficient
- L = length of spillway, feet
- H = head over spillway, feet

Regardless of the spillway crest shape (i.e., profile), the spillway length (L) and head (H) are constant. However, the weir coefficient varies with the shape or profile of the spillway crest and can range from approximately 2.7 to 3.4, which equates to an approximate variance in discharge of up to 25 percent.

To calculate the effect of a spillway modification on the overall capacity, an existing and post-construction discharge was calculated for each modification. The existing spillway rating curve presented in the O&M Manual (Barr 1972) was used to determine the dam's total discharge at the 100-year flood elevation of 848.43 ft (18,075 cfs).

Each section of the spillway to be modified was isolated, the Tainter gate bay, the section for recreation/fish passage, and the remaining spillway. Existing discharges for each section were either taken directly from the rating curve (Tainter gate) or ratioed by length.

To determine the discharge coefficient for each section, an iterative process was implemented using the weir equation (Equation 3). For each section, a unique discharge coefficient was found by iterating through the weir equation, until the computed discharge matched the existing discharge given by the rating curve.

The following assumed new features were used in the analysis. Table 5-1 provides results of the analysis.

- New crest gate system mounted directly on top of existing spillway and consist of two main spillway bays (in addition to the recreation/fish passage channel, which itself consists of two bays). Construction of the crest gate system will require a mounting system. For the purposes of this study, it was assumed the mounting system height is 6 inches. This increases the crest elevation, reducing discharge at any given pool elevation.

- The new crest gate system will be supported by 2 piers, one between each bay, and another to attach the gates to the existing Tainter gate wall. These 2-foot-wide piers result in a reduced effective spillway length due to their width and associated contraction losses in the flow as it passes around the piers. These two factors in addition to the conversion the section to a recreation/fish passage channel, combine to reduce the effective spillway length from 236 ft to 226.2 ft.

Without modification to the spillway crest, adding the piers and gate mounting system is estimated to increase the 100-year flood elevation from 848.4 ft to 849.9 ft. To remediate this loss of discharge capacity, spillway crest elevation modifications are required. With the 2-spillway bay configuration, the capacity can be increased to the required flowrate by lowering a single spillway section (approximately 76 ft in length) by approximately 1.85 ft, to a crest elevation of 840.0 ft (after installation of the crest gate mounts).

It is important to recognize that in future advancement of improvements, any new crest gate system will likely require examination of important regulatory aspects such as FEMA floodway considerations.

The spillway evaluation spreadsheet/computations are included in Appendix C3.

Table 5-1. Existing and proposed discharge at 100-year flood level

Feature	Length	Existing Flowrate	Discharge Coefficient	Post-Construction Flowrate
	ft	*cfs*	*--*	*cfs*
Tainter Gate	20	2,765	2.81	3,030
Rec/Fish Channel	73	4,737	N/A[1]	4,545
Bay 1	84.5	5,469	3.44	4,766
Bay 2	78.5	5,103	3.47	4,358[2]
Bay 2, Lowered Crest	78.5	5,103	3.47	5,733

[1] A hydraulic model was developed to analyze 100-year flows through the proposed recreation/fish passage channels.

[2] Without modification to the Bay 2 crest elevation, the post-construction dam would have a discharge deficit of approximately 1,375 cfs during the 100-year event.

5.4.2 Gate Types

This section describes gate types for the spillway crest gates, including hydraulic crest gates, pneumatic gates, and Obermeyer gates.

5.4.2.1 Hydraulic Crest Gates

Hydraulic crest gates consist of a steel gate leaf that rotates about a shaft anchored just above the dam crest. Steel plates (with integral heating systems in northern climates) are provided where the gate leaves meet a pier or abutment and provide a smooth bearing surface to reduce leakage. Gate actuation is provided by high-pressure oil/hydraulic fluid via piping routed within the dam crest or bridge above. The fluid is pressurized by a hydraulic power unit (HPU) located within a shoreline structure. The HPU includes an oil reservoir, redundant pumps, valving, and control system. Although vegetable-based hydraulic fluid can be used for hydraulic crest gates, a Spill Prevention, Control, and Countermeasures (SPCC) Plan would still be required.

As an example, the hydraulic crest gates at Coon Rapids Dam (Mississippi River in Coon Rapids, Minnesota) are approximately 7 feet high (see Figure 5-1).

Figure 5-1. Hydraulic crest gates at Coon Rapids Dam

5.4.2.2 Pneumatic Gates

Pneumatic gates, also known as “rubber dams,” feature a rubber/nylon tube or bladder mounted to the dam crest. The gate is actuated by compressed air via piping embedded in the dam crest. Air is pressurized by air compressors or blowers housed within a control building usually located on shore.

Figure 5-2 shows the pneumatic crest gates at Lock and Dam 1 on the Mississippi River in St. Paul. This gate system has been operated with success since the 1990s.

The predecessor to the Coon Rapids Dam hydraulic crest gates was a pneumatic system. In this case, the pneumatic gates were not relied upon to provide precise pool level control[15], i.e., the gates were generally fully inflated or fully deflated. The dam featured one hydraulic crest gate to provide that (precise pool level control) function. The Coon Rapids installation experienced ongoing problems with excessive wear and eventual leakage to the bladder material that normally occurred in the “fold” area where the bladder transitions from crest-mounted to pier-mounted (see Figure 5-3).

Some pneumatic gate installations have also experienced damage caused by ultraviolet (UV) radiation.

[15] When partially inflated, water flowing over pneumatic gates can result in a “moving V-notch” that makes precise pool level control difficult.

Figure 5-2. Pneumatic crest gates at Lock and Dam 1

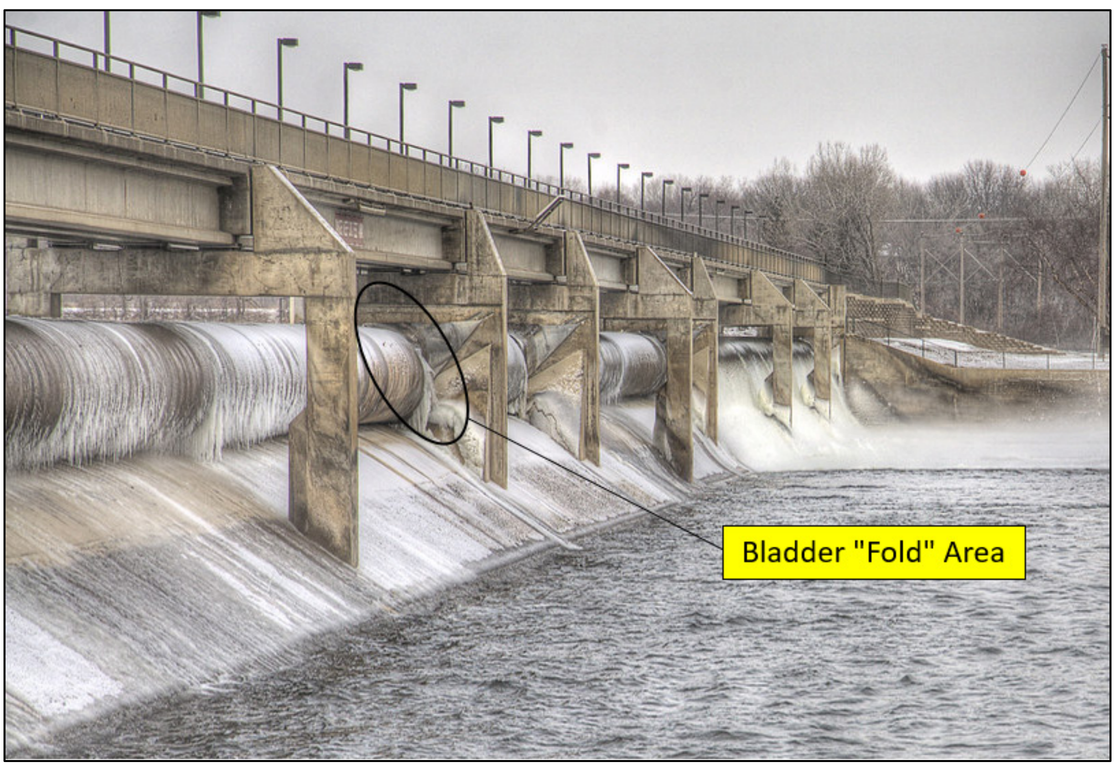


Figure 5-3. Former pneumatic gates at Coon Rapids Dam

5.4.2.3 Obermeyer Gates

Obermeyer Hydro, Inc. is a Colorado-based company that manufactures gates and other dam and flood protection products. Obermeyer's crest gates feature steel gate leaves that are hinged/mounted to the dam crest similar to hydraulic crest gates. However, Obermeyer gates are actuated by a pneumatic bladder similar to pneumatic crest gates. In this case, however, the bladders are not directly exposed to flowing water. Also, the bladders are not mounted to adjacent piers or abutments and therefore require no "fold" in the bladder fabric.

As discussed in Section 5.4.4, modifications to the dam crest will be required to accommodate the crest gate system. Also of note is that Obermeyer gates normally require annual testing/re-torquing of the mounting system anchor bolts.

Figure 5-4 shows the Obermeyer gates recently installed at the St. Cloud Dam (Mississippi River in St. Cloud, Minnesota).

Figure 5-4. Obermeyer crest gates at St. Cloud Dam

5.4.3 Selected Crest Gate Type

Obermeyer gates (or similar) were identified for advancement in this study. This type of gate is commonly used in the dams and hydropower industry, the technology appears proven through such installations and appears especially compatible for relatively short (in height) wooden flashboard replacement retrofit applications such as the Rum River Dam.

Note that subsequent phases of project development (including the bidding phase) can continue to consider alternative gate types[16].

5.4.4 Required Dam Modifications

The hinge of an Obermeyer gate is formed by an extension of the bladder fabric that is fastened to the gate leaf and secured to the dam crest with a bolted clamp. When Obermeyer gates are retrofitted onto concrete gravity spillways, it is common to remove a portion of the crest concrete to allow for placement of the air piping and electrical conduit. Concrete is then placed on the crest to embed the piping/conduit and form a ledge to protect the new gate hinge system. The crest of the Rum River Dam spillway is structural in nature (as opposed to mass concrete) and precludes application of the "demolition and rebuild" method. Instead, the crest slab would be built up to accommodate the Obermeyer gate based on and consistent with future structural analysis and dam stability requirements.

Piers and abutments would be provided with plates to provide a smooth surface for the gate leaves. The plate systems include heating systems to allow for winter operations. Stoplog slots would also be included to allow for unwatering of individual gate bays.

Figure 5-5 presents components of an Obermeyer gate and a conceptual arrangement on the existing spillway.

[16] For the Coon Rapids project, a separate gate procurement contract was used and was open to all gate types. Contract award was based on capital cost, required dam crest modifications, operability, O&M costs, energy usage, and environmental impacts.

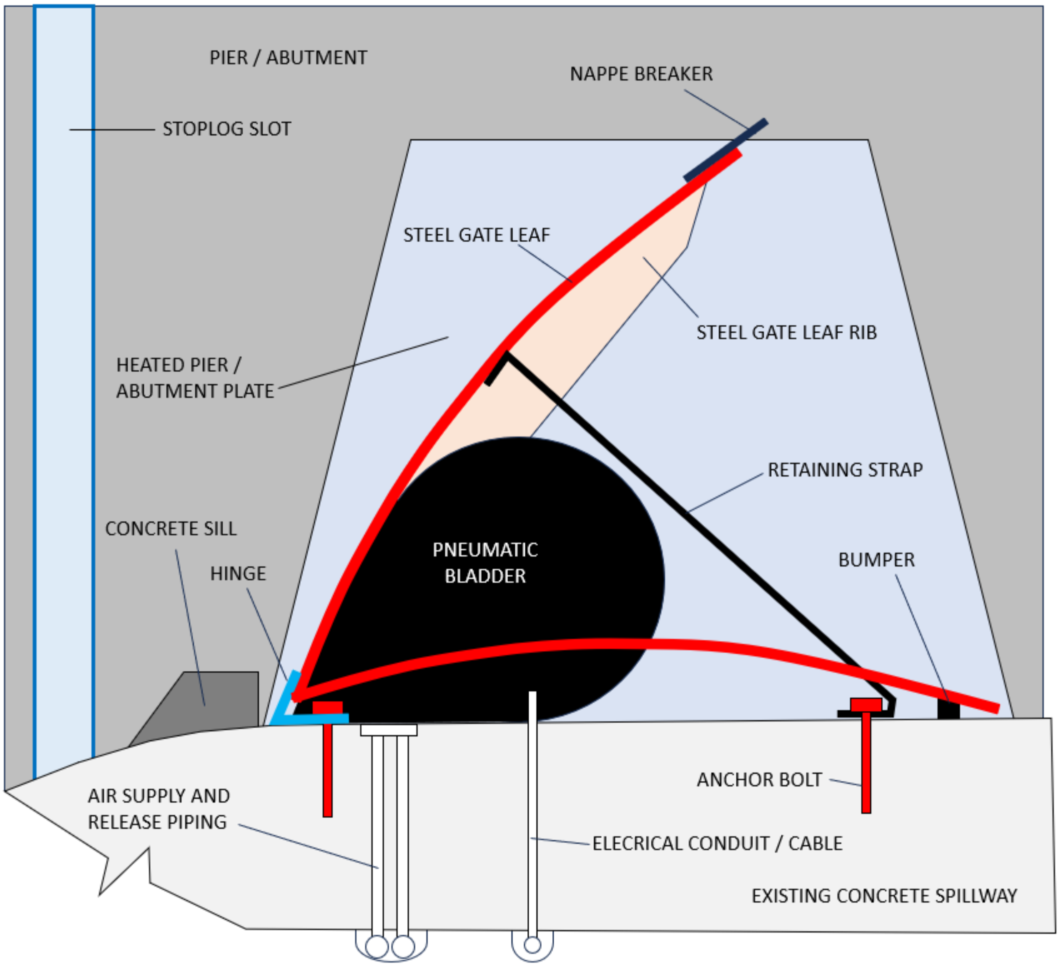


Figure 5-5. Conceptual crest gate details

5.4.5 Required Systems and Services

Obermeyer gates require an air system to inflate and deflate the air bladder that controls the weir height. The air system consists of an air compressor, air dryer, air filter, receiver tank, air supply piping, and air discharge piping. The air system components, which are controlled at the local air control panel, can be tied into a programmable logic controller (PLC). The air control panel, compressor(s), accessories, and receiver tank should be located within a nearby control house to protect the equipment from theft, vandalism, and harsh environmental conditions. Figure 5-6 presents the preliminary layout of the crest gate control building.

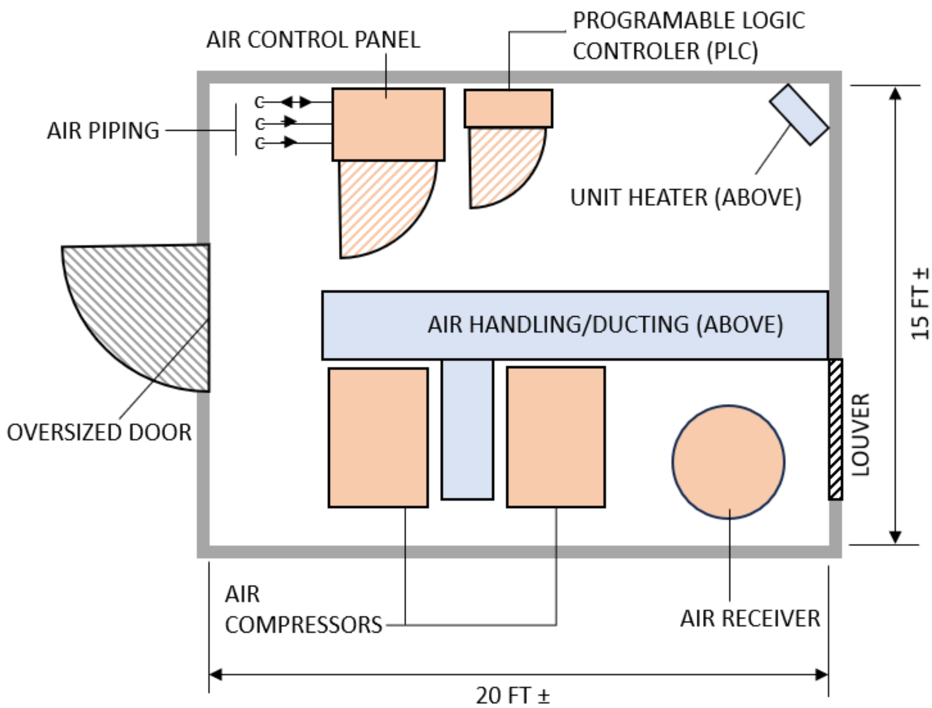


Figure 5-6. Conceptual crest gate control building layout

Air supply piping is routed from the control building's receiver tank to the gate bladders. The air supply piping attaches to the air bellows at a concrete blockout, spaced approximately every 20 feet along the crest. Separate piping is provided to remove air from the bladders, i.e., when lowering the gates (see Figure 5-6).

5.5 Recreational Vessel Passage

This section provides a summary of recreational vehicle passage, including alternative passage systems, design vessel selection, navigation logistics, required tainter gate spillway modifications, and lock operations.

5.5.1 Alternative Passage Systems

The following systems have been used to transfer boats between bodies of water with water surface elevation differences:

- **Manual portage:** As the name implies, this involves physically carrying a craft along a portage route and would be practical only for smaller craft, e.g., kayaks and canoes.
- **Hoists:** A dedicated hoist or crane with slings could be used to lift boats from below the dam to the upstream side of the dam and vice versa. Passengers on the boats would be required to temporarily exit the craft during the lifting operations. These systems require construction of a large crane system, would have significant O&M expenses, and would be visually imposing.
- **Ramps:** A ramp system would involve an inclined plane with carriages or cradles to support boats as they are transported up to higher elevations on the upstream side of

the dam. These systems would require a long, straight run to provide reasonable grades for operation, and like the hoist option would have significant O&M expenses.

- **Locks:** A lock system uses a water-filled chamber to raise or lower boats. The chambers typically have steel ("miter") gates to retain water within the chamber and open and close at each end to allow boat traffic to enter and exit. When closed, the gates form a seal against differential water surface elevations. Water levels are typically raised or lowered in the chamber by supplying or removing water through a piping and valve system, typically in the floor of the lock. Miter gates are normally not used to fill or empty lock chambers.

The lock option was identified as the preferred configuration for the following primary reasons:

- The lock alternative can take advantage of the existing Tainter gate bay infrastructure to reduce capital costs
- A lock system would be more straightforward and likely less expensive to operate and maintain than the other systems
- The lock configuration would likely provide a better boater experience (rapid transit without having to disembark from the boat)
- The lock configuration could transport multiple boats at one time
- Construction of a lock would have the smallest construction footprint

5.5.2 Design Vessel

A design vessel was determined based on discussions with the City, review of the Your Boat Club[17] inventory as presented on its website, and review of pontoon boat manufacturer data sheet. The design vessel selected for the recreational vessel passage feature is a pontoon boat with dimensions as follows:

- **Length:** 27.0 feet
- **Beam:** 8.5 feet
- **Height:** 11.0 feet (above water surface)
- **Draft:** 4.0 feet

Note that the above dimensions are in basic agreement with those of a previous navigation study (Fischer 1993).

5.5.3 Navigation Logistics

Although user-controlled operation of the lock is possible, it is recommended that lock operations be manually controlled by City or contracted staff. This would reduce the potential for accidents, injuries, craft damage, and general misuse.

[17] The Your Boat Club operates a boat rental facility out of Chandler Park located on the south/west shore of the Mississippi River approximately 0.4 mile downstream of the Rum River mouth.

The recreational navigation season will be dependent on weather, flow conditions, and ice conditions. For the purposes of this study, a season of April 1 through October 31 was assumed.

Days and hours of operation during the navigation season are to be determined, keeping in mind that operators would be required during these times. Days and hours of operation would ultimately be based on the popularity of the feature and experience gained in the initial years of operation.

5.5.4 Required Tainter Gate Spillway Modifications

To allow for recreational passage, modifying the Tainter gate spillway will be required. Feasibility-level analysis was performed to decide the best course of action to provide the required water level and flow control.

To reduce the number of modifications to the upstream ogee, it appears possible to install crest gates on or just upstream of the ogee. Using crest gates should reduce the amount of required spillway demolition. The spillway floor can be filled with concrete to embed the gate anchorage. Wiper walls (i.e., heated seal plates) will need to be installed on the gate bay piers/walls. An Obermeyer gate was selected for the upstream lock gate because it can function under head and be used as an emergency spillway gate if additional spillway capacity is required. Obermeyer gates have been used successfully in multiple lock installations in similar low head lock configurations. Having an Obermeyer gate as the upstream lock gate also provides consistency with other aspects of the dam improvement project, and future dam operations.

A previous study (Fischer 1993) concluded that exterior buttressing of the spillway walls was required to resist the additional water loads. It is theorized that the 1993 study included a requirement to maintain the 20-foot lock/spillway width. The current analysis corroborates that the existing walls are not structurally adequate to serve as lock walls. The current study allows for a narrower lock chamber, and it appears possible to thicken the inside of the walls by 1 foot, reducing the lock chamber width to 18 feet. This can be seen in Figure 5-7. Other lock features would be added to the lock wall additions for safety during the lock operations (bumpers, cleats, miscellaneous lock hardware, etc.).

Based on anticipated structural requirements and constructability considerations, it is assumed that a new miter gate bay would be constructed at the downstream end of the existing Tainter gate bay. Preliminary sizing of the miter gate estimates that the miter gates would be 1.5 feet deep and more than 10 feet long to close the channel at a target angle of approximately 30 degrees. The miter gate monolith would have to be longer than the miter gates to provide the required thrust resistance and provide for storage of the miter gates when in the open position. Plan and elevation views of the navigation lock are shown on Figure 5-7. The miter gates would likely be likely be actuated by a pressurized hydraulic system. The hydraulic cylinders would be located at the top of the lock wall as shown in the example of Figure 5-8.

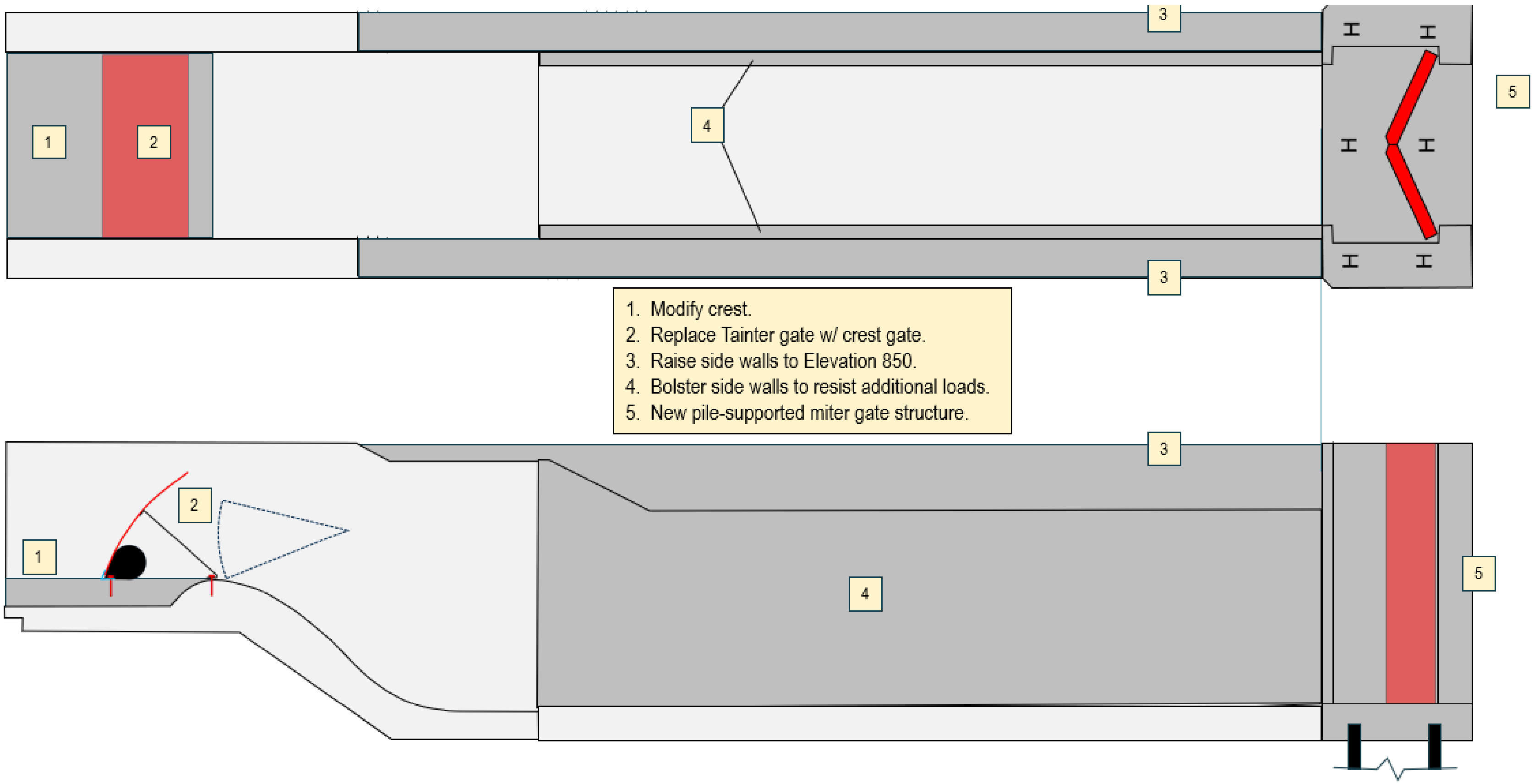


Figure 5-7. Plan and elevation views of navigation lock

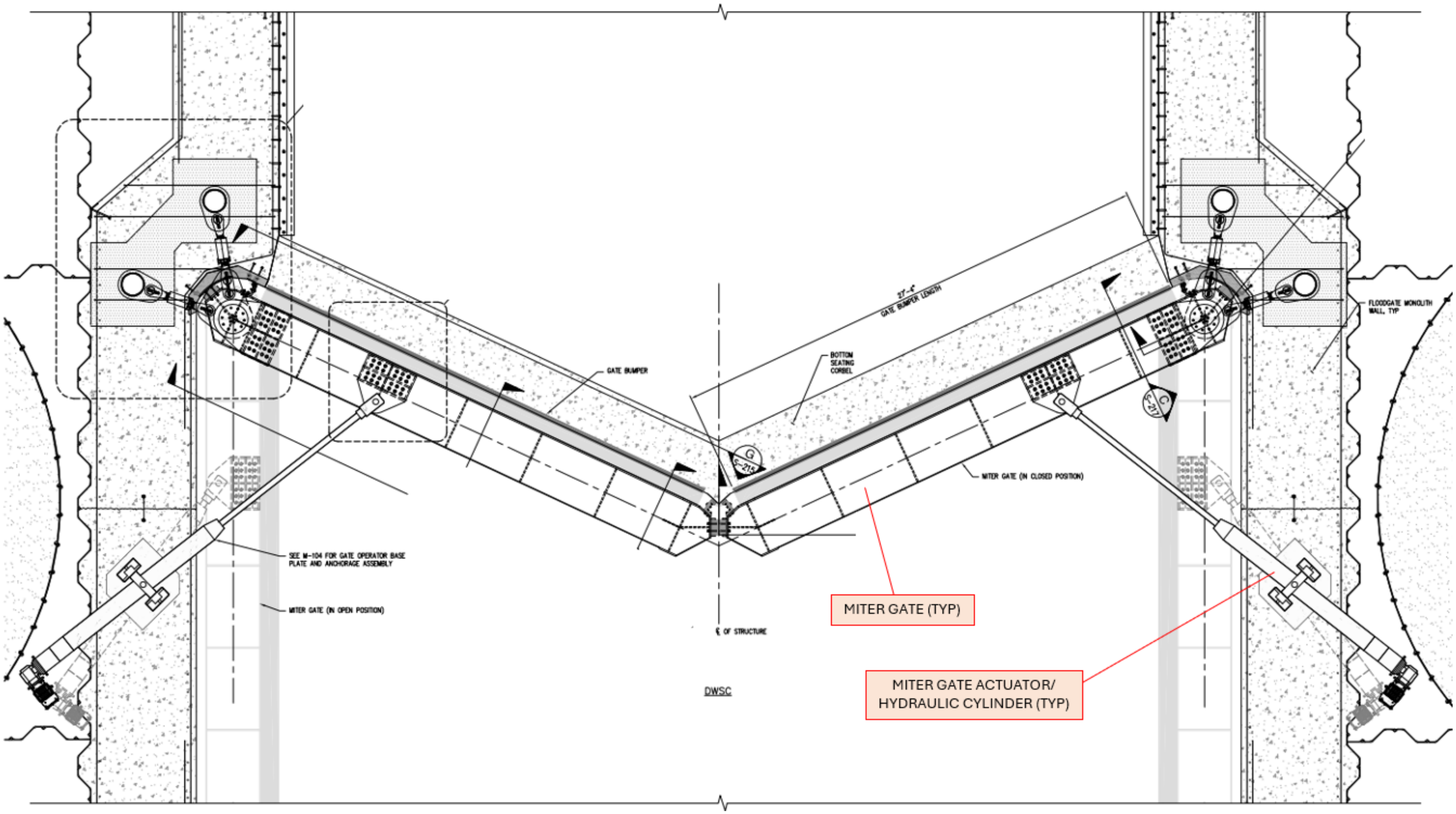


Figure 5-8. Example miter gate and actuation system

5.5.5 Lock Operations

One lockage is defined as closure of a single lock gate, filling/emptying of the lock chamber, and opening of a single lock gate to allow boat passage to continue along the river. One lockage is anticipated to take approximately 15 minutes, with filling/emptying operations taking about 9 minutes, and each gate operation taking about 3 minutes.

The filling and emptying system is anticipated to be integrated into a common culvert encased in concrete that runs on the outside of the riverside lock wall. The common culvert has two control points, an upstream valve for filling operations and a downstream valve for emptying operations. For lock operations, both valves would be closed, or one closed with the other open. Other than for maintenance flushing operations, both valves should never be open at the same time.

The filling and emptying system intake structure will be on the upstream side of the gated spillway and will include a trash guard to exclude debris from entering the system. Inside the screened intake, there will be a pipe entrance with two inline valves for filling operations. One of the two valves is an isolation valve for maintenance purposes. Similarly, the downstream end of the common culvert will have two inline valves for emptying operations with one valve being used for isolation.

The common culvert will branch into five pipes that enter the lock chamber through the west wall and just above floor level. Each branch will have four ports to disperse flow evenly into the lock and reduce the potential for turbulent flow conditions that could negatively impact vessels. Each port is oriented such that flow enters and exits horizontally. For filling operations, this orientation facilitates dissipating the energy and dissipating flow. For emptying operations, there will be some losses with this entrance configuration at each port; however, the culvert diameters are sufficient such that it does not pose an issue for the emptying system. As it relates to initially emptying the lock, final design should confirm that water velocities should be sufficient to remove accumulated sediment. Toward the end of emptying, water velocities will slow to settling velocities.

Inasmuch as this lock configuration and layout is consistent with typical lock design, future detailed design should consider and be based on more detailed hydraulic evaluations, which may necessitate CFD modeling or other approaches. Figure 5-9 shows a plan view of the conceptual lock filling and emptying system.

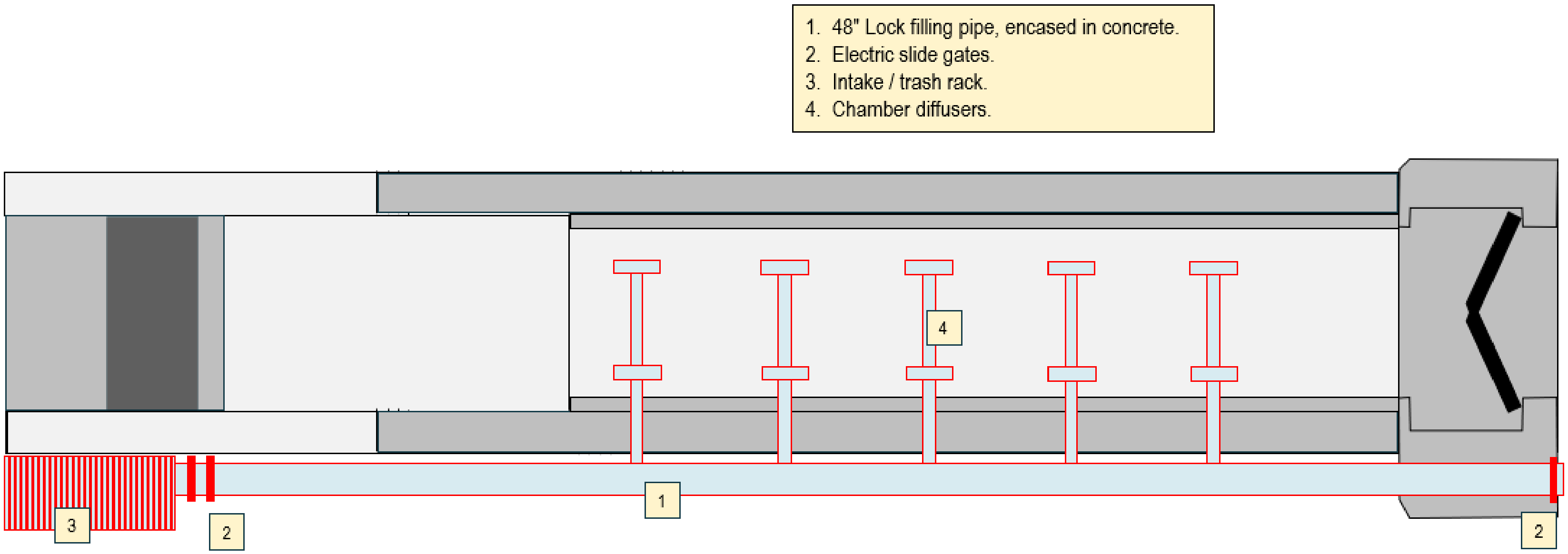


Figure 5-9. Plan view of lock filling/emptying system

It is anticipated that a single control building will be constructed to house the following:

- Air system to control upstream Obermeyer gate
- Hydraulic system to control downstream miter gate
- Space and controls for lock operator

Figure 5-10 shows a conceptual control building layout. The location of the lock control building will be established during the next phase of design. The building will be located to provide the lock operator with line-of-sight visibility to boats approaching from both upstream and downstream. The lock control building will also house controls for the eastside crest gate system. It is anticipated that the control building will be a concrete masonry unit (CMU) structure on the dam's east abutment, consisting of a spread footing below frost depth and slab on grade for the operating floor.

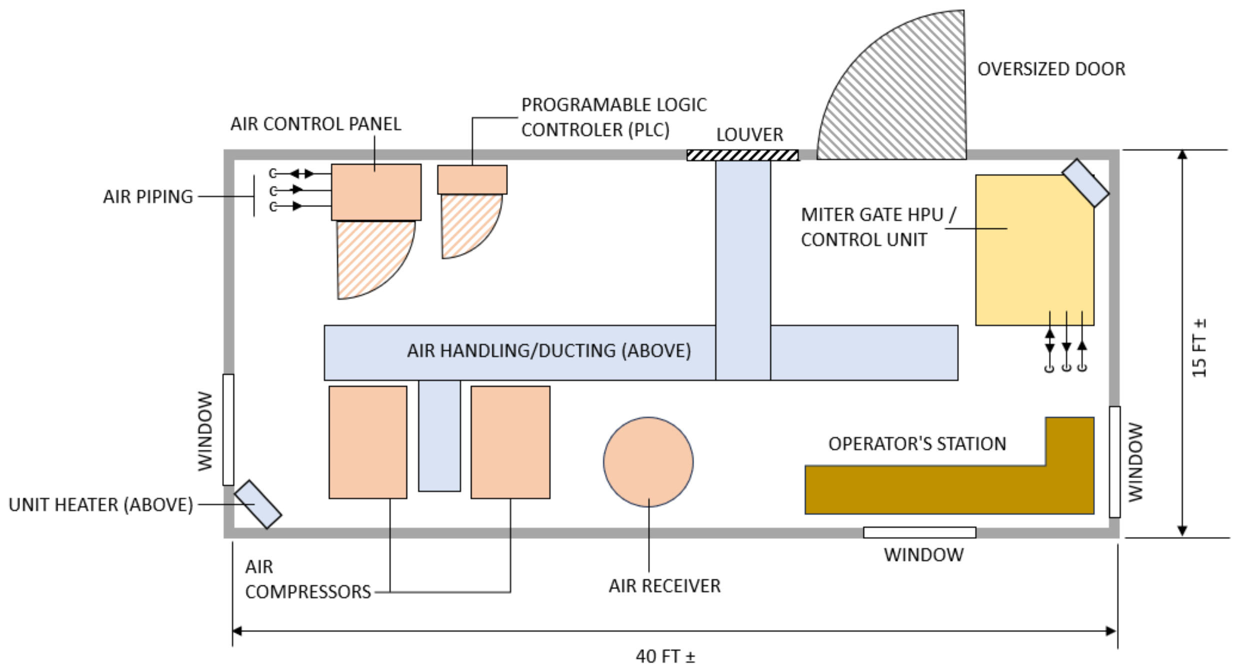


Figure 5-10. Control building conceptual layout

5.6 Fish Passage

This section describes fish passage in the project area, including types of passage, target species, invasive-species considerations, and the fish passage concept applied.

A fish passage feature could enhance public fishing opportunities of the Rum River both upstream and downstream of the dam and could therefore be considered as not only and environmental improvement, but a recreational improvement as well. This would especially be true if other recreational features (lock and whitewater features) are not advanced.

5.6.1 Types of Passage

Two approaches to providing fish passage at the dam were considered: a traditional fish ladder concept and a more natural rock rapids type feature.

While fish ladders can be an effective method to pass fish, they can be somewhat specific to species or life stages (for example adult salmonids in the Pacific Northwest) and feature relatively high-water velocities and the ability of fish to jump from compartment to compartment to make their way up the ladder. These salmonid species have evolved to pass natural barriers such as small waterfalls to reach spawning habitat and can withstand high stream velocities and make jumps between pools (or artificial compartments). While salmonids are present in Minnesota and the Rum River, they are not the dominant species. Figure 5-11 presents a schematic diagram of a typical fish ladder. Figure 5-12 is a photograph of an existing fish ladder at John Day Dam near Goldendale, Washington.

Many of the species found in Minnesota are found in sluggish streams and rivers that lack waterfalls, so jumping and bypassing high velocities are generally not required traits. The rock rapids approach would be designed to simulate a series of natural stream falls, with pool sections located upstream of riffle sections to provide a recovery area for fish as they exert energy going up the rapids. The stream depths and velocities going through the riffle section of the reach would be designed to promote passage of as many species and as many life stages of species as practicable. Over the past 30 years, 75 arched rock rapids have been implemented with success throughout the major drainages in Minnesota (MnDNR 2010). Figure 5-13 shows an existing rock rapids structure (Pine Lake Outlet near Gonvick, Minnesota). Figure 5-14 shows an existing rock rapids structure (Steam Plant rock arch rapids near Fergus Falls, Minnesota).

In addition to the physical means of passage being provided by the two approaches, the constructability and habitat benefits were taken into consideration. The fish ladder would likely be constructed out of concrete while the rock rapids would be constructed out of large boulders and streambed materials intended to replicate existing Rum River conditions. The natural materials would provide habitat for fish and other aquatic species within the pools, while the concrete ladder likely would not.

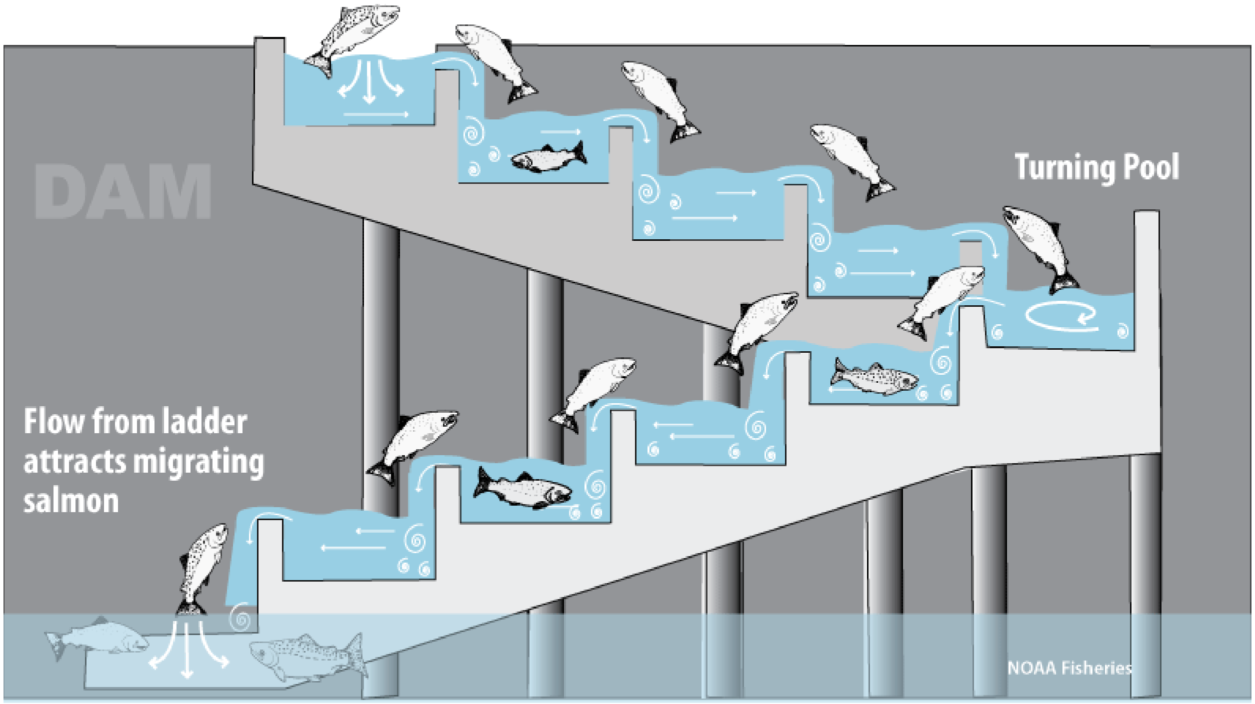


Figure 5-11. Fish ladder schematic

Figure 5-12. John Day Dam fish ladder near Goldendale, Washington

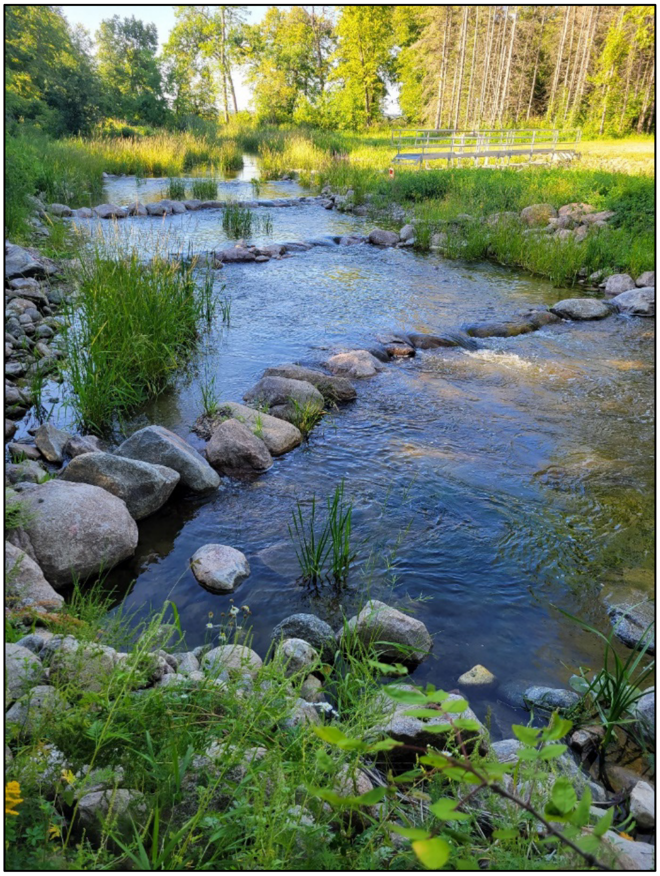


Figure 5-13. Rock arch rapids: Pine Lake outlet near Gonvick, Minnesota

Figure 5-14. Steam Plant rock arch rapids: Fergus Falls, Minnesota

5.6.2 Target Species

The Rum River typical aquatic wildlife includes many species of fish along the medium sized fresh & warm-water stream. Specifically, for the portion of the Rum River from the confluence of the Mississippi River to the Rum River Dam located just north of the Main Street bridge the fish population is average. The fish species present in this stretch of the river include walleye, smallmouth bass, bluegill, crappie, and northern pike (MnDNR 2024).

Restoring ecological connectivity in natural ecosystems involves the removal of human barriers that inhibit the natural movements of organisms that would otherwise occur without the barrier. In river ecosystems, this commonly applies to dams. For this reason, the goal of aquatic conservation is often to provide passage past a dam to advance restoration of the natural movements and seasonal migrations (e.g., to spawning habitat, or to deeper pools for overwintering) of native species existing below the barrier. Related to this, there are often interactions between native species essential for survival. A clear example in Minnesota includes native mussel species that have very specific requirements for the native fish species that serve as temporary hosts for their larvae. As a relevant example, the heel splitter mussel was once abundant in waters of the Mississippi River above St. Anthony Falls but, because of habitat loss, is now of conservation concern. Four native fishes serve as hosts of the glochidia (larval stage) of the heel splitter—yellow perch, black crappie, slimy sculpin, and spotfin shiner. Providing broad fish passage of all native species would likely support expansion of populations of heel splitter mussels in the Rum River. Lastly, it is likely that other popular game fish in the Rum River, including walleye, northern pike, and smallmouth bass, would have increased access to habitats necessary for supporting elevated productivity of these popular fishes.

5.6.3 Invasive-Species Considerations

A key invasive species concern in Minnesota is invasive Asian carp, primarily bighead, silver carp, and black carp, now present in the lower Mississippi pools including Pool 19. The risk of invasion into the Mississippi River above St. Anthony Falls presently appears very low because the locks at St. Anthony Falls are permanently closed. Unlike pools downstream, such as at Lock and Dams 2, 3, and 5, the lock chamber would be the only possible passage for any fish at St. Anthony Falls. Furthermore, the Coon Rapids Dam was modified in the 2010s to create a more effective barrier against invasive carp. This assessment has been corroborated via MnDNR, personal communication, and further consultation generally is anticipated on not only invasive species, but fish passage generally. One native fish that may move upstream past the Rum River Dam is channel catfish, which are expanding much farther north in the Mississippi River in Minnesota. However, this particular fish is native to Minnesota and is not believed to be an ecological risk, and unlikely to make significant changes to the existing aquatic community.

5.6.4 Fish Passage Concept

A conceptual layout and design for a rock rapids feature to provide fish passage was developed for the Rum River Dam. The design used the guidance provided by Luther Aadland in the document he authored for MnDNR referenced in Section 5.6.1. The rock arch rapids were designed to have a thalweg depth at the rock weirs of 2 feet, with pools behind the weirs being 3 to 4 feet deep. The slope of the feature would be between 2 and 3 percent, and the alignment would follow that of the recreation feature. The conceptual fish bypass channel would be approximately 12-feet-wide, with 2:1 (horizontal [H]:vertical [V]) channel slopes (see Figure 5-15). The boulders would be placed such that the weirs would provide a range of opening gaps between 6 inches up to 2 feet to accommodate a range of species and sizes. The fall at each weir would be limited to 0.6 foot. Using the conceptual cross section and slope of the rock rapids, a design flow of approximately 50 cfs would be required to produce the desired thalweg depth of 2 feet over the rock weirs.

The desired slope (upstream to downstream) of a rock rapids fish passage feature is similar to that of a recreational feature (discussed in the next section). Given this plus the potential construction efficiencies that could be potentially realized, the fish passage and recreation features were co-located immediately adjacent to one another. By doing so, basically a single structure can be constructed that takes advantage of a common riverside wall and cofferdam. This arrangement significantly improves constructability considerations and has potential to reduce overall construction cost. The location of the fish passage feature is shown on Figure 5-18.

HDR acknowledges that further agency consultation, analysis and design refinements of the fish passage feature are required in subsequent stages of design. Specific analysis/design considerations would include the following:

- Attracting fish to the entrances of the fish passage feature with consideration to water flowing through other dam features
- Detailed design of pools and riffles with consideration of water velocities and shear stresses
- Channel materials, e.g. concrete, natural rock, etc.
- Criteria for determining effectiveness of fish passage including range of flows, operating times/seasons for other dam features, etc.

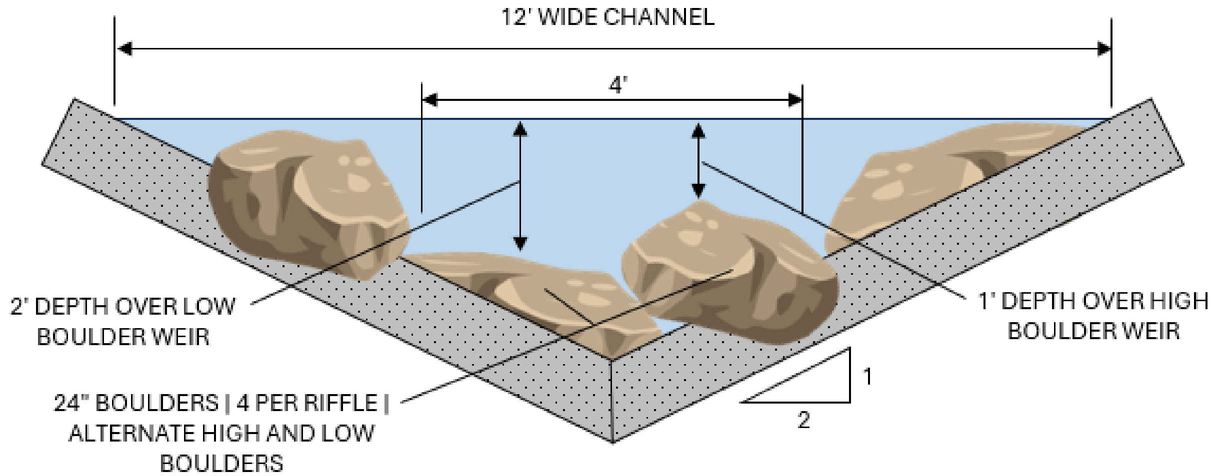


Figure 5-15. Conceptual rock arch rapids weir cross section

5.7 River Recreation

Recreational features such as whitewater parks come in a variety of shapes and sizes, ranging from instream grouted boulder arch structures to adjustable wave shapers, to large-scale pumped facilities that are off-river (closed-loop systems). Each project site is different and requires a customized solution based on site constraints and end-user objectives. An example of this site-specific approach to design is provided in Figure 5-16, a project for Duke Energy that involved modifying an existing dam to provide a safe bypass channel with recreational features and water releases down a dewatered branch of the Catawba River in South Carolina. The proposed project site in Anoka has been examined and analyses of hydrological data, physical site conditions, as-builts, and other available data, along with stakeholder input to inform an appropriate conceptual design for the Rum River Dam site.

Figure 5-16. Recreation features on the Catawba River in South Carolina

5.7.1 Rum River Dam Site Conditions

The feasibility of a surfing wave is typically determined by the available head, or drop, as well as the available flow. In combination these two factors provide the designer with the potential power available at the site to be used to create a surf wave. Preliminary analysis of the site shows that adequate flow and drop are available. In fact, the drop, which averages roughly 12 feet at the dam site, exceeds the typical maximum drop for a whitewater feature. Figure 5-17 provides a cross section of the drop across the Rum River Dam.

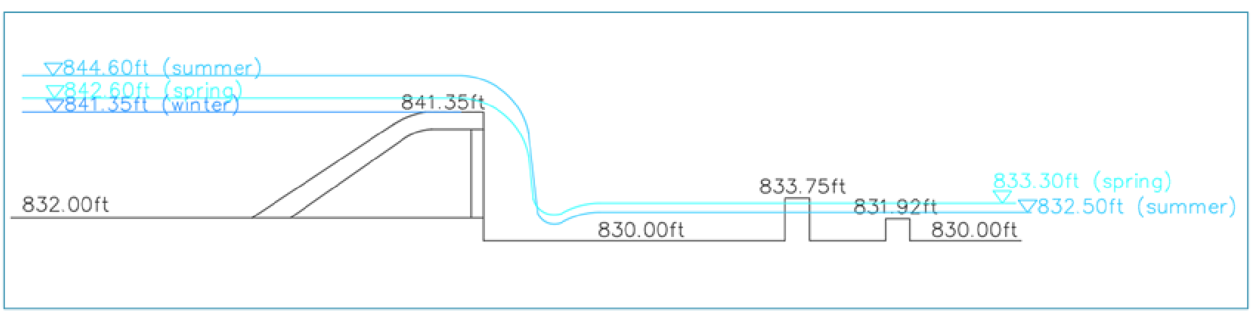


Figure 5-17. Rum River Dam spillway profile

Typical whitewater features for surfing require 2.5 to 3.0 feet of drop. The presence of more drop in this instance necessitates a longer run of rapids to better account for safety considerations and navigation down the river.

5.7.2 Rum River Dam Recreation Concept

The proposed layout and profile of a recreation channel are shown in Figure 5-18 and Figure 5-19 below, respectively. Note also the relative location of the fish passage feature (label outlined in red).

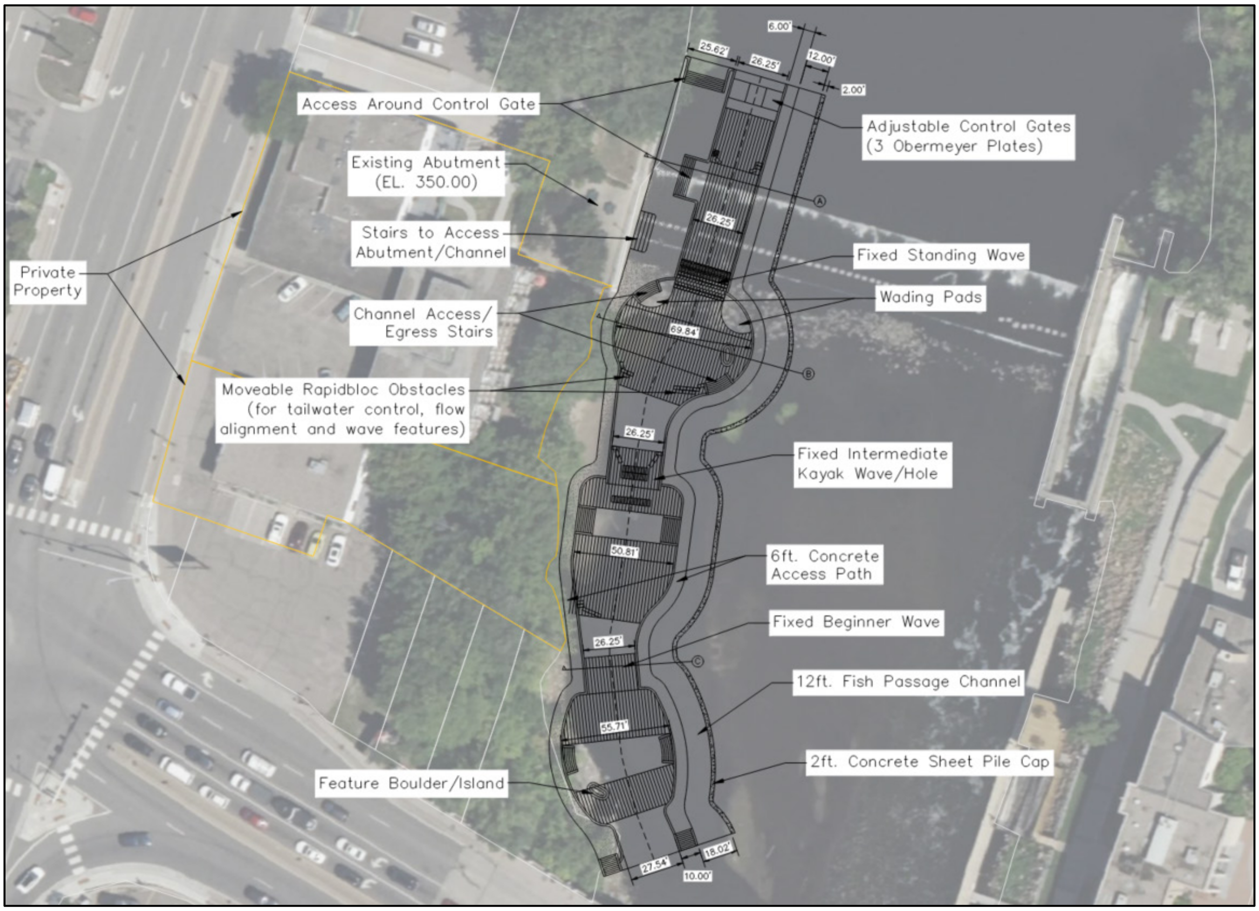


Figure 5-18. Plan view of conceptual recreation channel

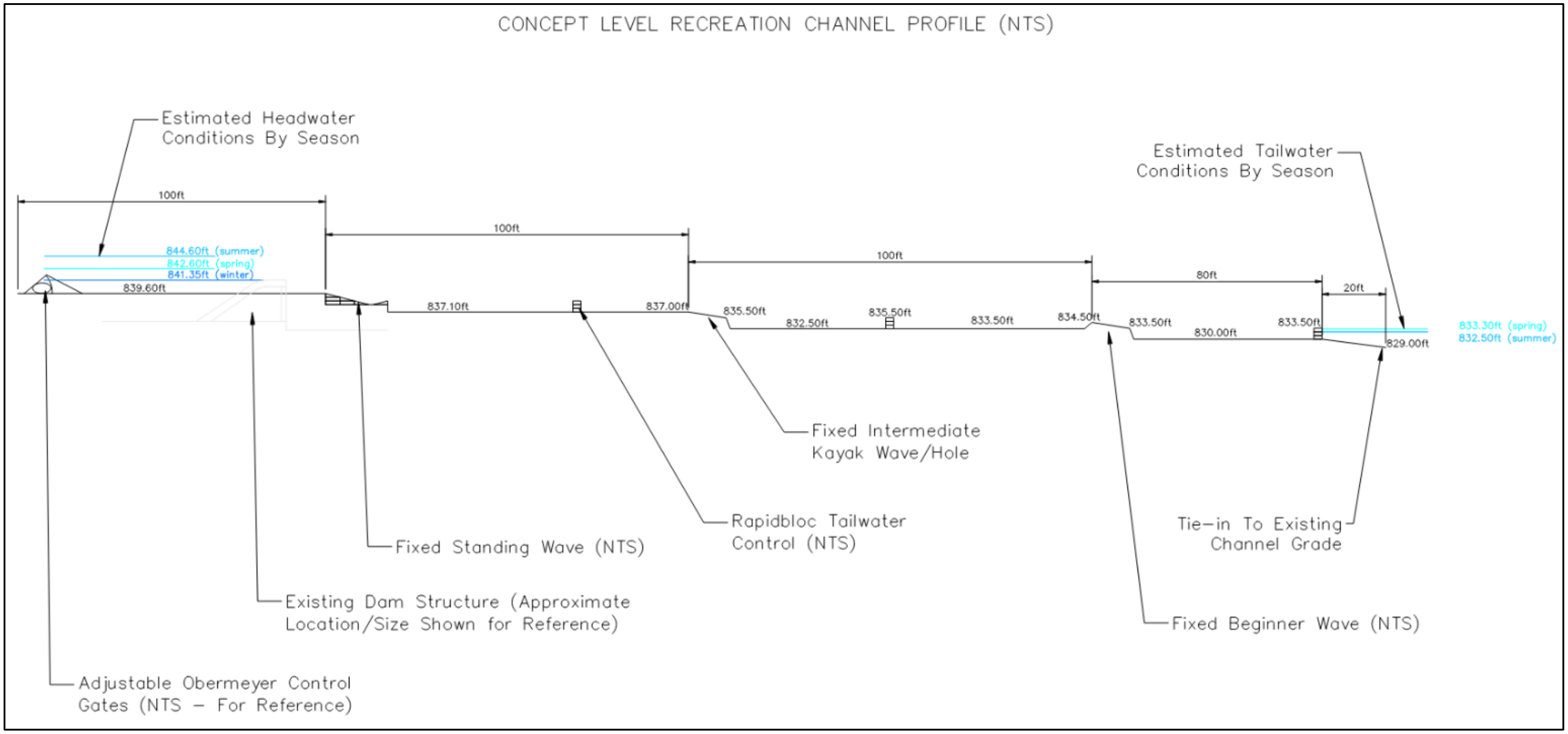


Figure 5-19. Profile of conceptual recreation channel

The proposed conceptual design envisions the surf wave as a part of a larger whitewater channel. Whitewater parks are a growing movement in the United States and around the world that have been shown to attract not just surfers, but kayakers and other watercraft enthusiasts who come to float, compete, train, and take part in river events and festivals. Including these additional whitewater features can broaden the attraction of the facility while using the excess available drop to create additional recreation and incorporating more features can also make better use of the range of available Rum River flows.

The site plan above (see Figure 5-18) assumes that access to the channel would primarily be from the east bank (river left) via a proposed pedestrian bridge that would cross the river. Watercraft would also have the option to approach from upstream and paddle into the channel. Pathways are included in the proposed design on the river right (west) bank along the entire length of the whitewater channel for users to float the rapids and walk back to the top, and for emergency access and egress. A pathway is also included in the design between the recreation channel and fish passage channel, which is intended for emergency egress.

The recreational and fish passage channels are intended to be separated from the adjacent river by a sheet pile, or king pile, wall[18]. This wall would serve the dual purpose of (1) providing temporary water control so that the recreational channel could be constructed in a dry environment and (2) form the permanent outer edge of the recreation feature. A driven or bored pile wall would provide structural benefits in combination with a narrow profile and easy installation in a wet environment, making this method ideal for both purposes without causing impacts to the floodplain. Figure 5-20 below shows a similar facility in South Bend, Indiana, that uses sheet pile as the primary wall structural element. Note in this figure that the sheet pile walls are capped with reinforced concrete.

[18] Future phases of design will consider addition measures to restrict public access into the fish passage channel such as signage and railings. Note that railing may have adverse impacts due to collection of debris and loss of spillway capacity.

Figure 5-20. South Bend, Indiana recreation feature

A typical channel section will be 26 feet wide with a water depth of approximately 3 feet. Wider pools below each of the feature drops are installed for recovery of gear and queuing to surf. The water depth is an important consideration, and a balance between sufficient depth to minimize the chance of paddlers hitting bottom when they flip over in a kayak, but shallow enough to allow a person to stand and walk to shore in the pools below drops if necessary. Access stairs have been included below each feature drop and at the entrance and exit of the channel to allow paddlers to choose which sections they feel comfortable running through. Figure 5-21 through Figure 5-23 show three characteristic cross sections along the proposed channel.

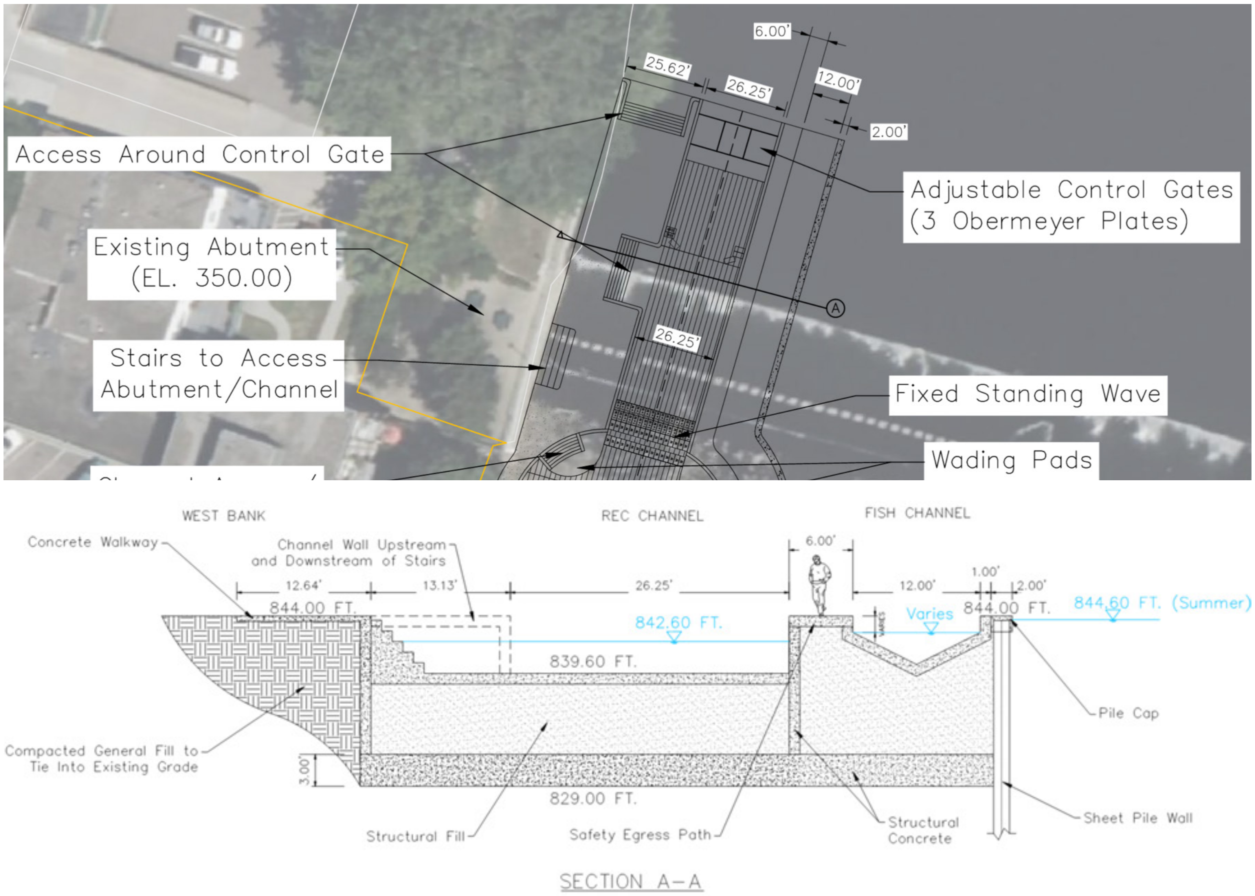


Figure 5-21. Upper channel plan and conceptual Section A-A (typical channel)

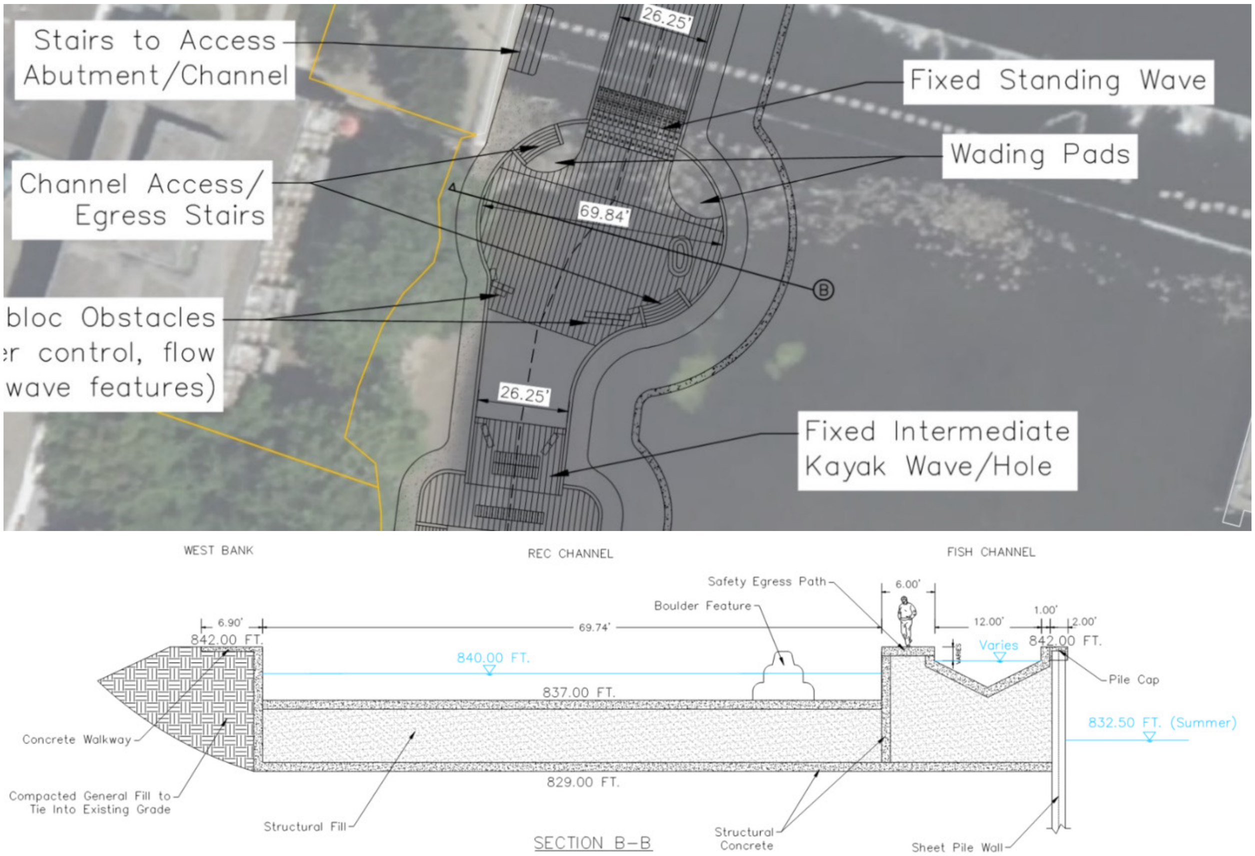


Figure 5-22. Mid-channel plan and conceptual Section B-B (pool)

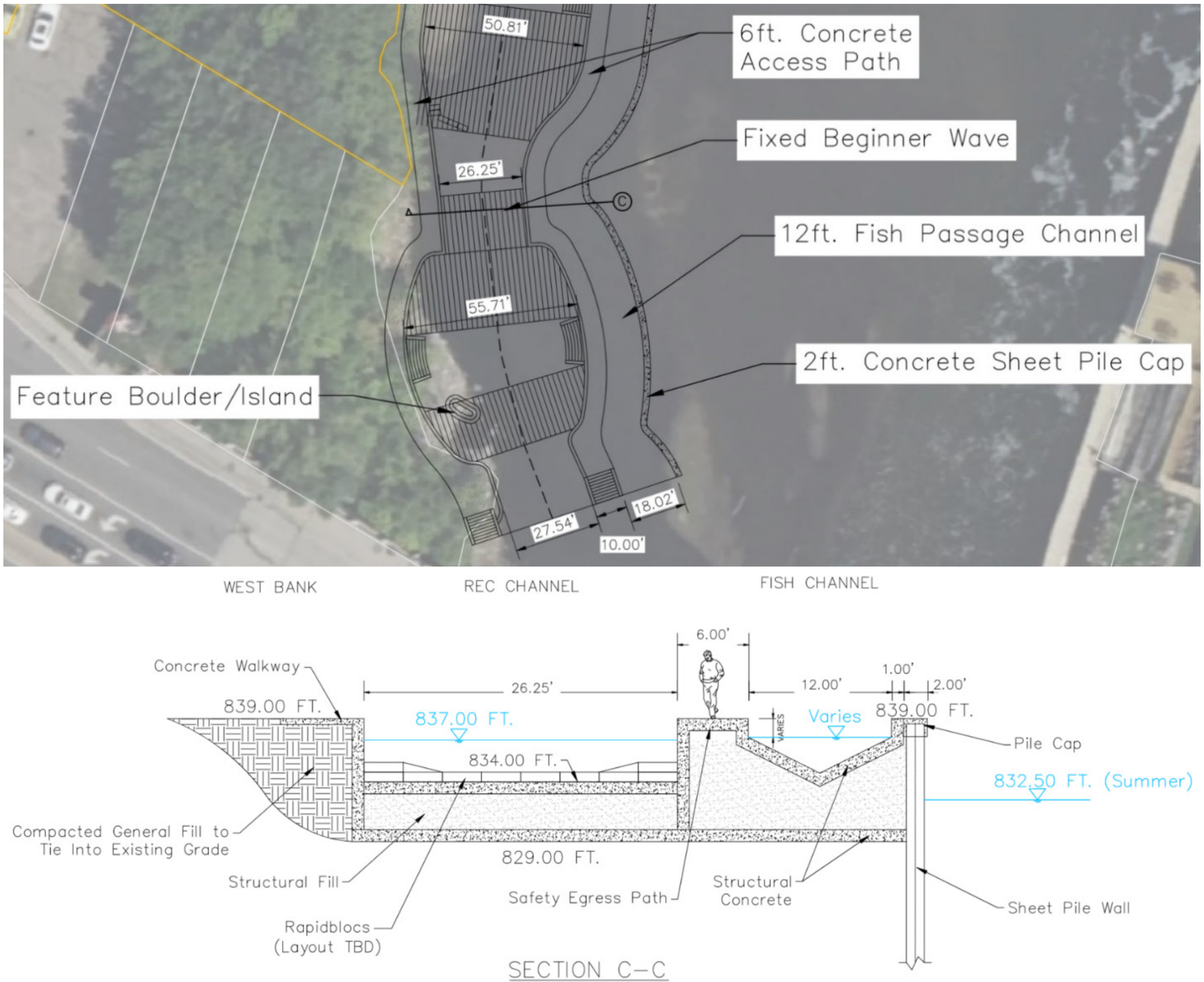


Figure 5-23. Lower channel plan and conceptual Section C-C (wave structure)

Several options are available to create the standing surf wave and rapids throughout the proposed whitewater channel including shaped concrete, adjustable pneumatic gates, or removable whitewater obstacles. In this case, a removable obstacle system called RapidBlocs could be used. Adjustable gates are expensive and need to be staffed for use and in case of emergency, while concrete features can be very effective but do not provide for feature flexibility or adjustment post-construction. Removable obstacles are simpler and more economical than adjustable gate systems and can be reconfigured to tune whitewater features, are removable for maintenance, or to increase flood conveyance during periods of high flows if removed preemptively. RapidBlocs can also be modified to suit specific events or training (i.e. swiftwater rescue training programs). Figure 5-24 shows RapidBlocs removable obstacle system placed in a dry channel.

Figure 5-24. RapidBlocs removable obstacle system in a concrete channel

Regardless of the option selected to create the standing surf wave, adjustable head gates will be required at the upstream channel entrance. These head gates will be necessary to ensure that an appropriate amount of water enters the recreation channel. When fully opened, these gates provide maximum flood capacity and when fully closed will provide a dry work environment to remove or reconfigure RapidBlocs from the channel. These gates also allow the water level in the channel to be lowered in the event of an emergency situation.

Calibre has worked closely with HDR engineers to coordinate the recreation channel with the other design components of this project including dam modifications and structural design, and fish passage channel. Figure 5-25 and Figure 5-26 show the anticipated structural components of the channel at the dam and head gate system for the channel entrance to control flow into the channel.

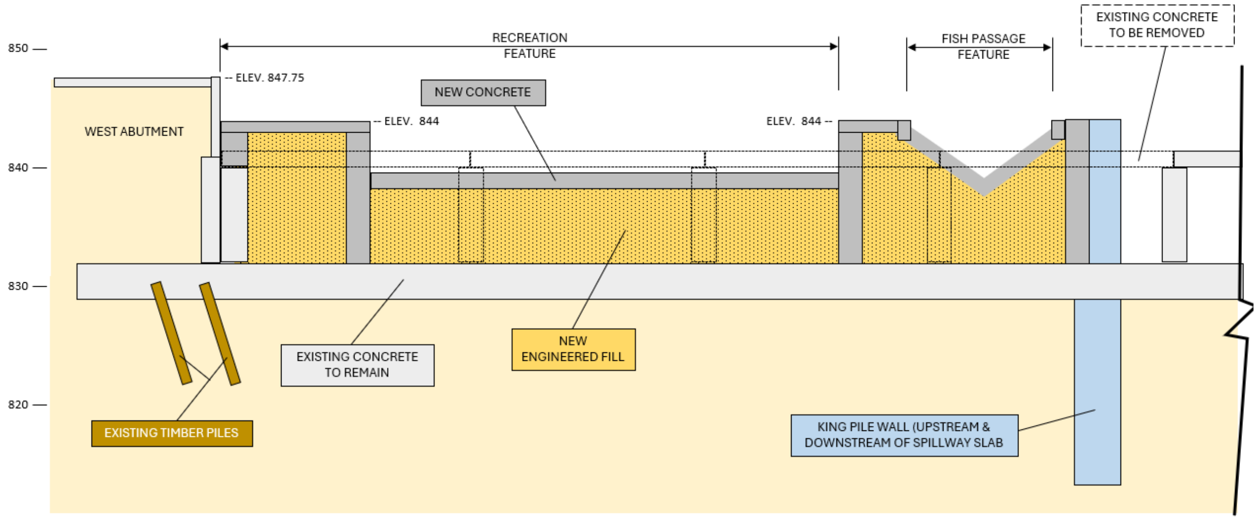


Figure 5-25. Cross section of recreation/fish feature at dam (looking upstream)

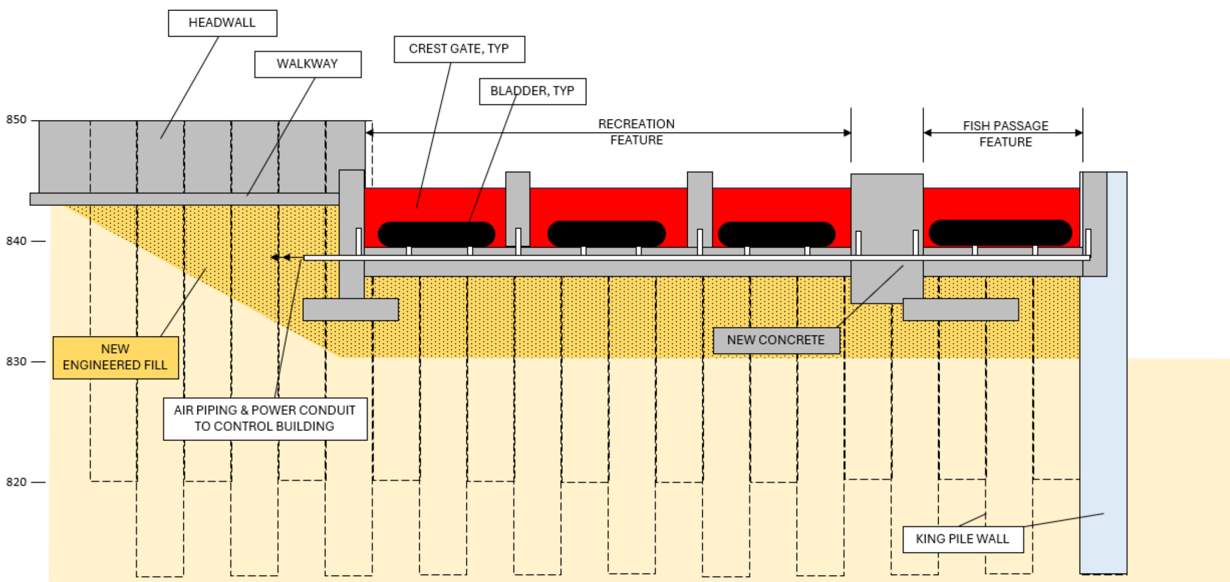


Figure 5-26. Cross section of recreation/fish feature at upstream channel entrance (looking upstream)

Figure 5-27 shows the 1992 Summer Olympics whitewater venue in Spain, which is a hybrid instream design with similar elements to the concept proposed for Anoka. This course consists of an artificial concrete recreation channel (far left), a hydropower canal (center), and the natural river channel (right).

Figure 5-27. La Seu d'Urgell 1992 Summer Olympics venue: artificial whitewater channel

5.7.3 Recreation Design Considerations

Evaluation of the site suggests that, while possible, there are several challenges to building the park in this area. These challenges include, but may not necessarily be limited to the following:

- **Floodplain and Floodway, requirements:** In the United States, particularly in a developed area such as downtown Anoka, strict regulations prevent construction of new features in a way that will impact the 100-year floodplain, and floodway. If hydraulic modeling of the proposed improvements results in a "no-rise" condition, meaning 0.0 feet increase (or a reduction) in regulatory Base Flood Elevations (1-percent Annual Chance Flood Level), then a "no-rise" permit may be pursued with the local Floodplain Administrator. In the event that a "no-rise" condition cannot be achieved (more than 0.0 feet increase in regulatory Base Flood Elevations), then a more intensive permitting process may be required. This process involves obtaining a Conditional Letter of Map Revision (CLOMR) before construction, and a Letter of Map Revision (LOMR), after construction. A CLOMR/LOMR is required to modify the existing flood insurance rate maps. At this site there will be three locations where achieving "no-rise" will be a challenge:
    - The first is at the dam crest, which sets the elevation of the water upstream of the dam. In this area care will have to be taken to ensure that the entrance and headgate to the channel, in combination with other features across the crest of

the dam, do not cause a rise. This will require that the entrance channel be recessed and designed with sufficient flow capacity to pass the river's flows without backing water up at the crest.

- The second will be at the location of the proposed pedestrian bridge. The bridge, and its piers may negatively impact the conveyance capacity of the channel, causing a rise in water surface elevations.
- The third will be at the downstream end of the channel as the river approaches the East Main Street bridge. At this location the river is narrowing and is confined by the bridge supports. Addition of fill, in the form of an extended channel, in this location could also cause a rise.

Given the strict requirements for no impact to regulatory flood elevations under local permitting authority, care will need to be taken to evaluate the proposed geometry in the channel at each stage of design to minimize impact to the regulatory flood elevations; and this notion will apply to not only the recreational aspects, but all aspects of the improvements when taken as whole.

- **Stream power:** As mentioned above, there is significant stream power in the river at this location as indicated by the slope of the river. Figure 5-28 shows the amount of gradient in the conceptual design for Anoka in comparison to other whitewater/surf canals around the world.

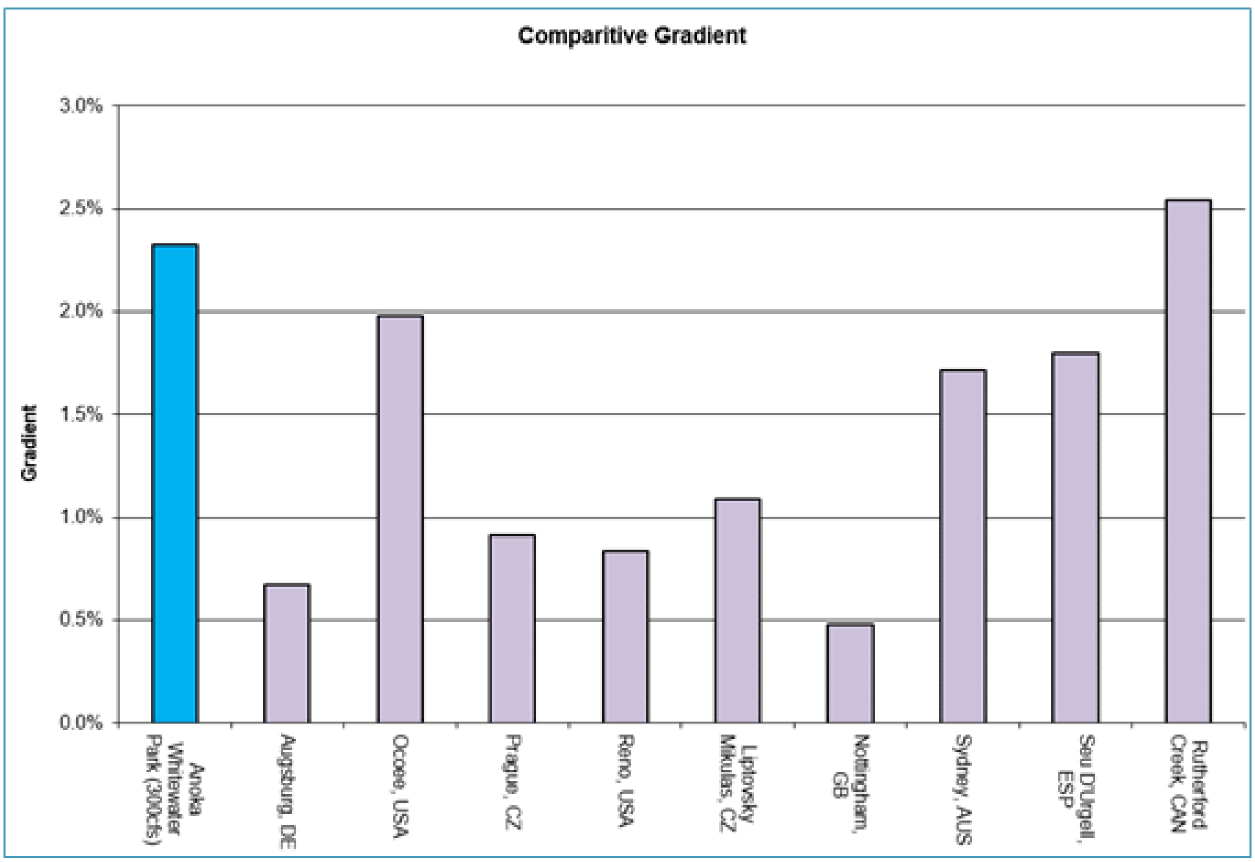


Figure 5-28. Anoka recreation channel gradient comparison

Channel design will need to be modeled at varying flow rates to ensure that the power is adequately dissipated, allowing for navigation, safety considerations and to prevent scour at the downstream bridge.

Access to the site will need to be addressed in two ways. As mentioned above, access across the proposed pedestrian bridge will need to be designed to attract and accommodate all likely users as well as emergency access and egress (see more in Section 5.7.9 below).

The second concern for access is how approaching boaters navigate the entrance to the channel. The design will need to account for additional users. The recreation area will need to be isolated from the motorized river traffic entering the lock system and protected from the spillway crest. With the proposed lock system anticipated to use the existing Tainter gate spillway, and recent dredging along the river left (east) bank for boat traffic, river recreation should be located along the river right (west) bank.

Other channels have used physical barriers that let in small boat traffic without allowing motorized traffic. The example from Holme-Pierrepont in the United Kingdom shows how the entrance to the National Watersports Centre is designed to prevent canal boats, which use the adjacent lock system, from entering the whitewater canal, is shown in Figure 5-29.

Figure 5-29. Holme-Pierrepont National Watersports Centre

5.7.4 Preliminary Analysis of Available Stream Power

To gain a better understanding of the whitewater recreation value in Anoka, a Power Surface Index (PSI) was determined for the proposed recreation channel. The PSI is a metric developed by the International Canoe Federation (ICF), the international governing body of paddle sports. The PSI provides a way to compare potential energy available at the project site to other existing whitewater parks. A PSI value was calculated for the Anoka Recreation Channel at optimal flow (300 cfs), reduced flow (200 cfs), and very low flow (100 cfs). The equation used to calculate PSI considers typical flows, channel width, channel slope, and surface roughness. This metric measures the available power normalized by the factors that cause diffusion of this power, namely roughness over the surface area of the river. The equations used to calculate PSI are shown below.

$$\boldsymbol{PSI} = \frac{(\boldsymbol{discharge})(\boldsymbol{drop})(\boldsymbol{10000})}{(\boldsymbol{length})(\boldsymbol{width})}$$ Equation 4 (for smooth concrete channels)

$$\boldsymbol{PSI} = \frac{(\boldsymbol{discharge})(\boldsymbol{drop})(\boldsymbol{10000})}{(\boldsymbol{2})(\boldsymbol{length})(\boldsymbol{width})}$$ Equation 5 (for natural waterways)

Figure 5-30 compares the PSI values for the proposed recreation channel in Anoka with other previously completed whitewater channels.

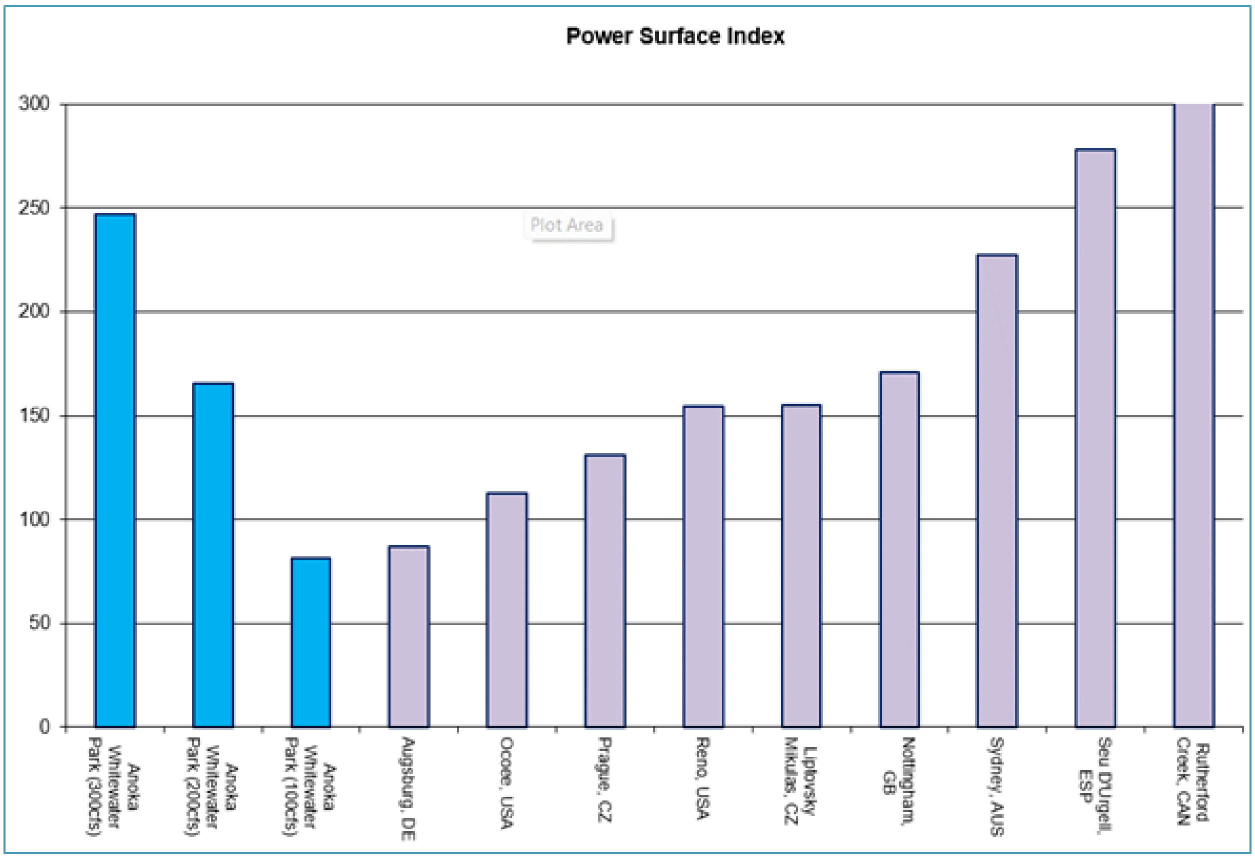


Figure 5-30. Power Surface Index comparison for the Anoka Whitewater Park

In addition to PSI, the Freestyle Surface Index (FSI) is another metric based on PSI, which can be useful in predicting recreation value. This index focuses on the individual whitewater features rather than the channel as a whole. This modified index was used to compare available energy at each whitewater structure in the channel normalized by roughness over the width of the river. This metric is similar to the PSI with the exception that the constant of 10,000 has been changed to 10 to put the numbers in a range more easily understood:

$$\boldsymbol{FSI} = \frac{(\boldsymbol{discharge})(\boldsymbol{drop})(\boldsymbol{10})}{(\boldsymbol{drop\ length})(\boldsymbol{width})}$$ Equation 6

Figure 5-31 provides a comparison between the proposed drop structures in the proposed recreation channel in Anoka, versus other similar whitewater parks.

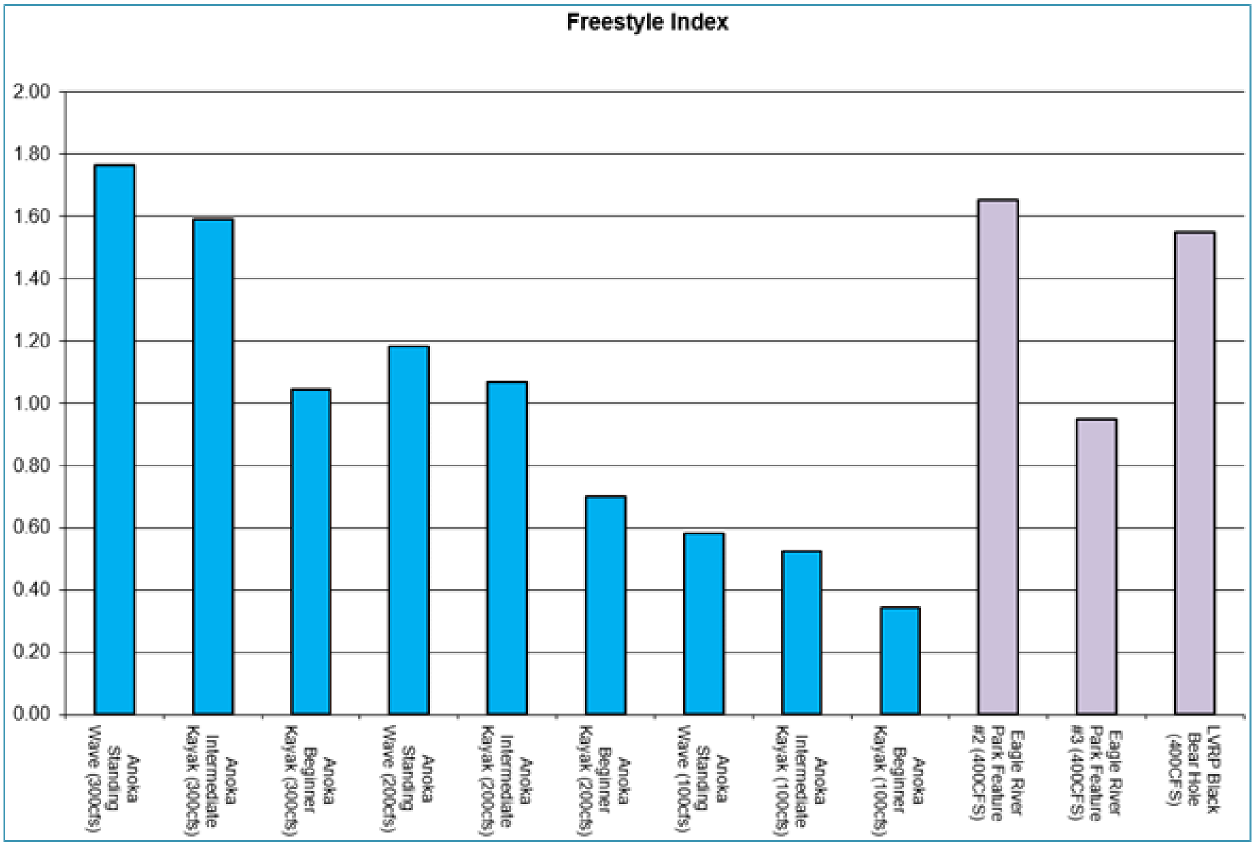


Figure 5-31. Comparison of the Freestyle Surface Index for the Anoka standing wave

These calculations suggest that the slope defined is appropriate, and that the power at each drop structure, as laid out in the conceptual design, is appropriate.

5.7.5 Surf Wave Logistics

Based on input received, the provided recreation channel concept assumes that a fixed, or static, standing wave is preferred to an adjustable standing wave.

The most common style of adjustable wave uses gates by Obermeyer patented technology to shape a wave using metal panels attached with a hinge point that is bolted down to a concrete pad on the upstream end of the panel. The downstream end of the panel is free to pivot, allowing the gate system to rise and fall in an “inch-worm” fashion as air is pumped into or removed from a rubber air bladder that sits under the panel. Obermeyer gates can be controlled as one continuous gate or operated independently. The gate system does require periodic inspections to check the condition of the gate panels and air bladders. Adjustable waves can be successful, but often the recreational benefit has not been shown to justify the additional costs (see Figure 5-32).

Figure 5-32. Adjustable surf wave in Idaho

A static surf wave can be created in a few ways. The more traditional approach is to carefully shape a concrete ramp with very specific geometry. The design for Anoka Dam involves embedding strut rail into the flat concrete channel bottom, and fixing RapidBloc obstacles to the strut in order to create a removable, modifiable ramp. When fast moving water flows over the ramp and interacts with the slow-moving pool downstream, it creates a hydraulic jump. This jump is a transition from supercritical flow to subcritical flow that releases energy and produces a standing wave feature (see Figure 5-33 and Figure 5-34).

Figure 5-33. Static surf feature shaped from RapidBlocs

Figure 5-34. Static surf wave in Prague

Surf waves in general can be finicky and are particularly sensitive to changes in flow rate. In this case, adjustable head gates are proposed to control a set flow rate into the recreation channel. This consistent flow rate allows the use of static wave technology downstream to produce the actual wave feature, with the goal being a consistent and reliable wave that will provide high quality recreation for visitors. The fixed wave will likely require some tuning after installation (using bolt-on RapidBloc elements designed into the channel). Once tuned the wave can reasonably be expected to perform with consistent flow.

5.7.6 Surfing Season

Observations provided by the City indicate that ice out is typically around late March, and flashboard install occurs from late April to mid-June, with flashboard removal typically in early November. Based on this information, the earliest the recreation channel is anticipated to be operational is the beginning of April, or whenever the upstream pool and channel are free of ice. The ability to fluctuate the top pool levels will aid in breaking up the ice and may lead to a longer season.

Peak season for these types of parks is summer. Other parks typically see more users during runoff events (post-storms) because of higher water, and during peak summer when potential visitors are out of school and able to travel. Warmer weather during the summer also aids in drawing users out to parks.

5.7.7 Water Requirements

The proposed channel was sized to appropriately accommodate the standing wave feature, which was identified to use a flow rate of approximately 300 cfs in an approximately 26-foot-wide, 3-foot-deep channel. The design of the headgates will need to consider flows in the channel for the summer season, accommodate flows during flood events, and provide recreation during periods of lower flow in the river. The use of adjustable headgates can aid in achieving these objectives.

5.7.8 Anticipated Usage

Based on usage at similar whitewater parks, such as the parks in Salida, Durango, or Eagle, Colorado, it is expected that the most significant feature, in terms of branding and marketing the park, will be the surf feature. Surf features can draw visitors from throughout the greater region and, because of the popularity of surfing, have a significant presence in local and social media.

However, similar parks also suggest that the usage throughout the whitewater channel could be significant and, in terms of number of visitors, may be the most used. Similar parks show that at lower flows tubers and inflatable traffic are prevalent as are hard boat paddlers (kayakers and canoers). The parks often develop a following of users who return to tube or kayak on a regular basis.

Events can also be significant to operations. Whitewater parks tend to host river festivals, competitions, and other paddling events. This can affect or influence the design of the channel and surrounding landscape to accommodate visitors in terms of parking, event space, access and viewing, and competition infrastructure. This site is particularly well suited to larger events because of the adjacent parking, park space, and amenities on the eastern bank.

Aside from recreation, the proposed whitewater channel is capable of hosting first responders and industry professionals for swiftwater rescue training and other educational programs. The removable obstacle (RapidBloc) system provides flexibility to adjust rapids within the channel to create a variety of swiftwater training scenarios in a controlled environment. Figure 5-35 shows a concrete channel with RapidBlocs in use at a swiftwater rescue training facility in upstate New York.

Initial installation of the block system for the entire channel, including testing and tuning, typically takes a week or less. When modifying features after initial installation, re-configuring the obstacle system can take anywhere from 10 minutes to move a few blocks, up to a couple days to reconfigure the entire channel. Once a satisfactory configuration of blocks is determined for the channel, it is worth considering mapping the configuration (or multiple configurations) and marking locations on the channel, to assist with accurate re-installation of blocks in future.

Figure 5-35. Swiftwater rescue training facility in Oriskany, New York

5.7.9 Safety

Any project that involves water and the public has an element of risk. However, many of the risks associated with natural rivers can be reduced during the design of purpose-built channels. Common dangers such as trees, undercut rocks, strainers, dangerous hydraulics, etc. are not included in design, making the water predictable and generally safer than a natural river. Additionally, the presence of a headgate that allows the City to turn the water off in the case of an unforeseen emergency greatly adds to the safety of the channel system.

Whitewater channels typically have warning signage, a portage pathway, designated access/egress points, and recommendations for personal protective equipment and other safety considerations, all of which are applicable for this site. Applicable safety notices should be determined near the end of final design, but likely will include:

- Channel closure during periods of high flow, and the City may choose to close the facility outside of daylight hours, or when sufficient water is not available to run the channel at design flow
- No leashes should be allowed on surfboards
- Helmets, life jackets, proper footwear, and other personal safety equipment is recommended
- No motorized traffic in the whitewater channel except in the event it is used for swiftwater rescue scenarios as part of an organized and approved training

Certain features described in this report could result in increased public safety risk because of increased proximity, access, exposure to moving water or other factors. It is recommended that the City be aware of all risks it will carry or be exposed to and develop risk reduction or mitigation strategies in coordination with appropriate internal and external stakeholders. Generally, kayakers and river surfers often do a great job of policing themselves on safety practices and can perform self-rescue more efficiently than emergency services. With that said, the City may consider adopting specific river-related ordinances (i.e. requiring personal flotation devices, etc.) if there is an expectation that river users will not adequately police themselves.

5.7.10 Potential Local and Regional Benefits

As a public resource, users typically are not charged directly to use instream whitewater venues. Instead, profits are realized through vendor operations (i.e., watercraft and gear rentals, raft trips, lessons) and secondary economic impacts (i.e., restaurants, shops, hotels), which are often driven by river-based events that bring river enthusiasts and spectators into the local community.

Several different economic impact studies have been done on whitewater venues, and they clearly show that spectators vastly outnumber actual river users at whitewater parks. One study showed that for every one person who actively recreates in a whitewater park, eight or more people visit just to watch, spend time near the river, or attend river festivals. Designing riverside space and access for non-paddlers will be equally important to design of the in-stream features.

As the design is progressed, it will be important to create connectivity between the recreation channel and riverside amenities to provide a functional space to host events and provide access for river users and spectators. A properly designed instream whitewater park will be capable of hosting surfing, freestyle, and other events. Similar venues have seen economic impacts as high as $9 million per year. These numbers are based on regular usage at the venue, as well as instructional programs, competitions, festivals, and other river-based events. Freestyle events like the Mountain Games in Vail, Colorado, have a documented yearly economic impact of $3.5 million.

For a region-specific detailed analysis of potential revenue generation as a result of a whitewater park, the City may wish to commission an economic impact analysis specific to the Rum River Dam site. In addition to creating economic impacts, these venues and events help to bring focus to the river as a city amenity and market the local community as an outdoor destination. Figure 5-36 illustrates how successful river-based events and competitions can be with a properly designed venue.

Figure 5-36. FibArk Festival in Salida, Colorado

5.8 Rum River Bridge

The goal of the Rum River Bridge is to provide maintenance access to remove debris from the dam and provide recreational access to the proposed river recreation area; create another river crossing for the expanding Anoka Riverwalk system; and provide overlooks for respite, fishing, and taking in the natural vistas and historic downtown views.

The initial bridge concepts assumed that the bridge would be supported directly on the dam buttresses and extend in a straight line from the east riverbank to the west riverbank. After consideration of boat vertical clearances at the proposed lock, it was determined that the bridge would need to be downstream of the proposed lock. A bridge alignment that followed the dam closely but skirted around the downstream side of the proposed lock, was developed.

The east side of the bridge splits into two bridges, one connecting to the existing Rum River Regional Trail that is part of the City's riverwalk (lower level) and one connecting to the City Hall plaza (upper level). The west side of the bridge has to provide adequate clearance for the proposed recreation channel users and then connects to the park on the west dam abutment and the proposed Riverwalk Trail extension.

5.8.1 Structure Type and Size

A curved steel girder bridge type was selected because of the numerous curves/bends in the bridge alignment, the desire to minimize the number of bridge piers in the river, the desire to minimize the girder depth/flood impact, and the placemaking impact in the historic downtown.

Concrete wall piers were selected to support the bridge, eliminating openings in the piers that could snag river debris. Bridge piers are assumed to be founded on deep pile foundations, as opposed to the existing dam buttresses. See Section 5.8.4 below regarding foundation design considerations.

Architectural treatments include girder cladding to soften the industrial feel of bare girders, decorative railings to complement the historic downtown character, Anoka "A" medallion with backlighting, and decorative LED lighting. In addition, the incorporation of painted or stained form-liner (patterned) concrete will be considered to align with the City's Riverwalk vision.

5.8.2 Alternative Bridge Configurations

A steel bridge design will require a robust paint system to protect the steel and regular maintenance to keep the coating system functional. Weathering steel was considered but is not well suited for a high-moisture environment.

A concrete bridge type was considered but ruled out because of the complexities of formwork support over the river, making a steel bridge type more cost-effective.

In future phases of design, bridge profile (including low-chord elevation) will be determined with consideration to more detailed hydrologic and hydraulic analyses and floodplain regulations stipulated by FEMA and/or other regulatory agencies.

5.8.3 Bridge Loading

The out-to-out width of the bridge is 12-feet 6-inches with a 10-foot 0-inch clear distance between the concrete parapets. The design of the bridge will follow the current editions of the *Load and Resistance Factor Design (LRFD) Guide Specifications for the Design of Pedestrian Bridges*, American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications, and the MnDOT *Bridge Design Manual*.

The range of loadings evaluated for the bridge are as follows:

- **Pedestrian loading:** 90 pounds per square foot (psf) uniform loading
- **Maintenance vehicle loading:** With the 10-foot 0-inch clear deck width a H-5 design vehicle is required. At the owner's direction an H-10 vehicle will be evaluated for the purpose of debris removal equipment.
- **Water and ice loads** resulting from Rum River hydraulics
- **Wind load** on structure

5.8.4 Piers Founded on Dam

The design team examined the possibility of landing the bridge piers on the existing dam. However, based on initial estimates of bridge pier reactions and an examination of the bearing capacity of the existing structure, this option was determined to be impractical and abandoned in favor of founding the bridge piers independently on the riverbed.

Based on the current understanding of the existing soil below the spillway, the presumptive load-bearing pressure is low (1,500 psf to 2,000 psf). This being the case, the existing structure likely does not have sufficient reserve bearing capacity to support the additional loads from a bridge pier considering the in-situ weight of the spillway concrete and the normal water column. Under these conditions, the existing structure would have to be capable of distributing the concentrated bridge pier reactions over an unreasonable area to mobilize sufficient soil resistance, but it is unlikely that the existing slab has adequate strength and stiffness to accomplish this without a significant retrofit. In addition, the bridge reactions by themselves (which are on the order of 300 kips in some cases) would drastically increase localized bearing pressures at the spillway which may result in unfavorable or damaging levels of deformation and differential settlement.

The recommendation to support the bridge piers on the riverbed, rather than on the existing structure, would be subject to change if subsequent geotechnical studies and analysis (e.g., field exploration and laboratory testing of soil samples) justify the use of substantially higher allowable bearing pressures for design, or if the bridge configuration is revised to include more piers, creating shorter bridge spans and smaller reactions.

5.8.5 Piers Founded on Riverbed

The foundation type for these piers will be traditional pile-supported footings. Applicable pile types could include cast-in-place (CIP) concrete, steel H-pile, or pipe piles. Pile recommendations will be determined at later phases of design and based upon additional geotechnical information obtained in the river. Construction of the pile-supported footings will require the use of a cofferdam and seal method. In this method, a mass of unreinforced concrete is poured underwater inside a sheet piling of a cofferdam. Water is removed from inside the cofferdam allowing the cutting of piles, placement of footing reinforcement, and pouring of the footing cap in a dry environment.

5.9 Safety Boom

A safety boom is recommended to reduce the potential for boaters, kayakers, etc. from approaching the spillway. The boom would be anchored to the riverside lock wall, the riverside recreation/fish passage feature wall, and the riverbed. In subsequent phases of design, performance specifications for the boom would be determined, e.g., anchorage requirements, debris passage, strength, removability, etc. An example installation (from Worthington Waterway Barriers) is shown on Figure 5-37.

Figure 5-37. Example safety boom (Worthington Waterway Barriers)

5.10 Proposed Overall Configuration

Figure 5-38 through Figure 5-40 show the overall project configuration with the selected alternatives, and proposed bridge, included. The lock and whitewater channel can be seen on river left and river right looking downstream, respectively. Note that the figures show the bridge aligned over the dam which, as discussed in Section 5.8, may not be the final alignment.

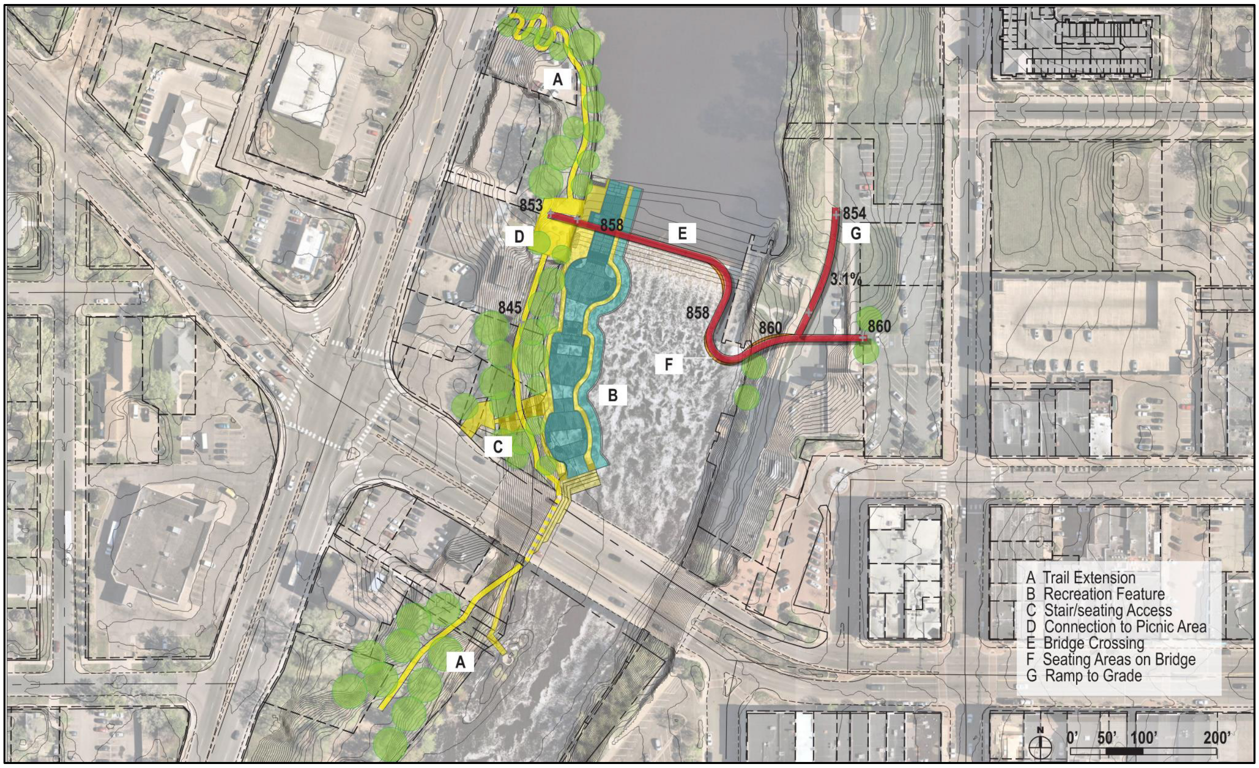


Figure 5-38. Proposed site plan

The overall site plan configuration highlights the project's primary components. New trail connections and public realm improvements (items A, C, D, and F) shown in yellow provide access to the river crossing, recreation feature, and additional improvements along the right (west) side of the river. The impact of the project reaches beyond the immediate improvements with the recreation feature, trail access, and additional river crossing. Additional access for river usage with kayaks, canoes, tubes, and pontoons through the lock improvements are all key benefits of the project.

The downstream view shows the trail extension along the right (west) riverbank, allowing access to the recreation feature, as well as to the pedestrian bridge crossing just above the dam. A primary goal is to improve full access on both sides of the river to maximize river usage and to continue to promote the numerous programmed activities and events in Anoka's historic downtown area. Energy efficient and dark sky compliant LED lighting improvements on the pedestrian bridge can create a safe and inviting environment into the evening hours.

Figure 5-39. Proposed configuration looking downstream

Figure 5-40. Proposed configuration looking upstream

The upstream view highlights additional components of the recreation feature, the right (west) riverbank trail connection that integrates with the existing bridge abutments, the stair access and seating areas leading up to Main Street, the pedestrian bridge crossing, and the lock improvements allowing for a more functional boat access up and down the Rum River. All improvements will continue to support and promote safe pedestrian and bicycle access along the river and create a connected loop vital for successful programming and events in the downtown area.

5.11 Hydropower

During the PMT presentation to the Anoka City Council, hydropower was not selected as a viable alternative based on its economic feasibility under conditions at the time of this report. However, significant analysis was performed leading up to the presentation to arrive at the economic feasibility of hydropower at the Rum River Dam. This section details that analysis.

5.11.1 Maximum Installed Capacity

The first step in the evaluation of hydropower at the Rum River Dam site is to determine the maximum capacity (measured in kilowatts) that the site's hydrologic and hydraulic conditions would support without considering other prospective facilities (e.g., recreation feature) water demand. This exercise is generic in nature and does not require selection of unit technology.

The analysis is based on the summer and winter flow duration curves and the following assumptions:

- Summer (May through October) pool elevation = 845.00 feet mean sea level (msl)
- Winter (November through April) pool elevation = 842.00 feet msl
- Minimum spillway flow = 100 cfs
- Minimum turbine flow = 20 percent × maximum turbine flow
- Minimum gross head = 50 percent × maximum gross head
- Turbine efficiency = 85 percent

Results (shown on Figure 5-41) show that annual energy increases significantly with installed capacities up to approximately 400 to 600 kW. Beyond that point, annual energy flattens, representing diminishing returns on installed capacity. In other words, the river cannot adequately support installed capacities beyond about 600 kW.

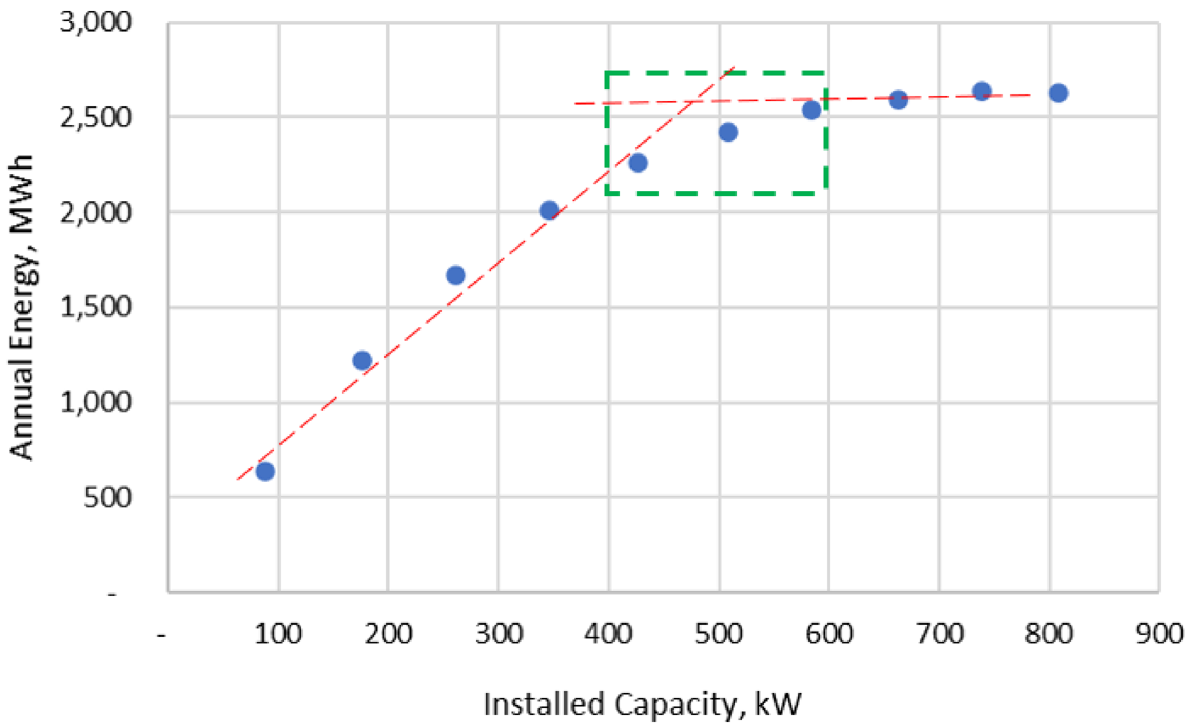


Figure 5-41. Preliminary capacity vs. annual energy

A summary of previous reports' hydropower recommendations is provided in Table 5-2.

Table 5-2. Hydropower cost summary

Study	Capacity (kW)	Annual energy (MWh)	Capital cost		
			Study year ($MM)	2024 [a] ($MM)	2024 ($/kW)
SAFHL 1981	650	2,830	$1.7	$6.5	$10,100
SAFHL 1982	565	2,320	$2.0	$6.8	$12,100
	552	2,440	$2.1	$7.2	$13,000
	603	2,570	$2.1	$7.2	$11,900
Stanley 2002	550	2290	$3.2	$7.1	$12,800

[a] Costs escalated to 4th quarter 2024 based on USACE construction cost index (USACE 2024).

A comparison of the preceding cost estimates can be made by applying published cost data. The following equation is from an Oak Ridge National Laboratory (ORNL) study (ORNL 2012) and represents costs for single-regulated axial flow turbines electromechanical equipment only.

$$C_{EM} = 18{,}872\ H^{-0.546}\ P^{0.761} \text{ (Equation 7)}$$

Where:

- C_{EM} = cost for electromechanical equipment, $2010
- H = turbine net head, meters
- P = plant capacity, kW

The above equation yields an electromechanical cost of $1.9 million in 2010 dollars. Escalating to 2024 dollars increases this cost to $3.1 million. The ORNL (2012) report also indicates that powerhouse construction accounts for 54 to 68 percent of the construction costs for developments at non-powered dam sites. Therefore, assuming an allocation of 50 percent for the powerhouse cost, the total cost using the ORNL method would be approximately:

$C_{TOTAL} = 2\ C_{EM} = \$6.2$ million.

This aligns with the escalated cost presented in Table 5-2 reasonably well.

A 600 kW project would generate approximately 2,420 MWh per year. Applying an estimated value of energy of $40/MWh[19] results in annual revenues of approximately $96,800. Assuming a $6 million capital cost and applying simplified economics results in a simple payback period as follows:

Payback period = $6,000,000 ÷ $96,800 ~ 62 years

The above high-level payback period calculation excludes O&M- and FERC-related costs. On Its own (i.e., absent generation incentives or capital funding assistance), it appears that development of a full-capacity hydropower facility at the Rum River Dam is not economically viable.

5.11.2 Reduced Capacity Installation

As an alternative to the 600 kW facility, HDR evaluated a smaller installation that would have lesser capital costs and higher plant factor[20]. For this exercise, an "off-the-shelf" modular turbine was selected, such as the StreamDiver unit offered by Voith Hydro. Figure 5-42 shows information from Voith on the unit.

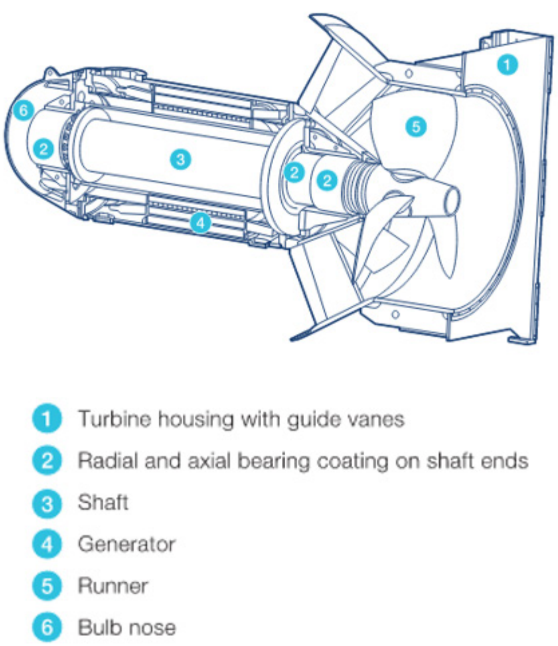


Figure 5-42. Voith Hydro StreamDiver unit

---

[19] Value provided by Anoka Municipal Utility, noting that this rate is variable, i.e., can change over time.

[20] Plant factor is a measure of the facility's predicted energy generation divided by its theoretical maximum generation (e.g., running 100 percent of the time at rated capacity).

The compact design of a modular unit would facilitate installation in a space within the Tainter gate bay and adjacent to the navigation lock as shown on Figure 5-43. The unit would be removable (e.g., for maintenance) by an overhead traveling crane. Pool level control would be provided by a new crest gate mounted on a new concrete bulkhead that would house the turbine and draft tube.

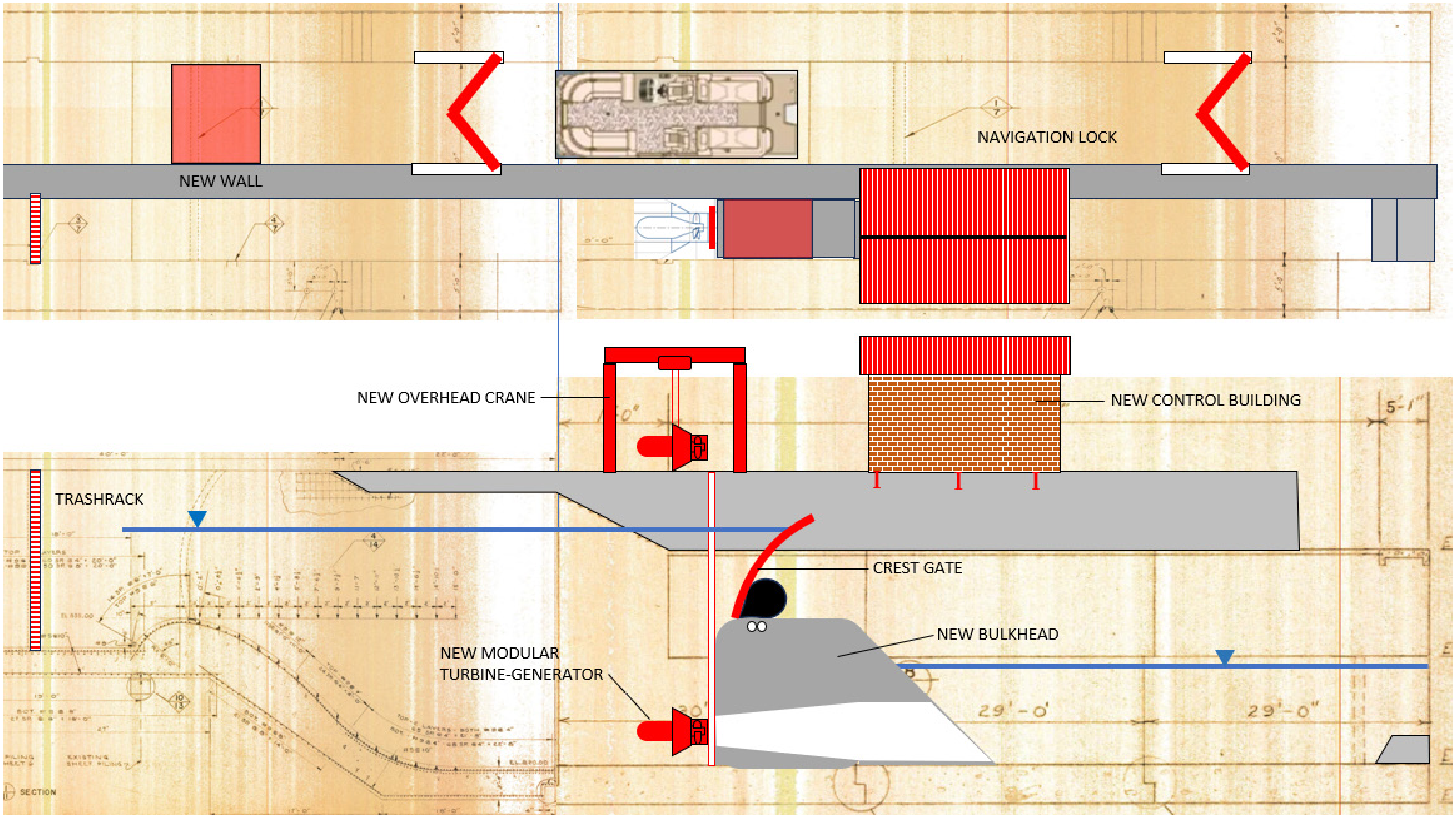


Figure 5-43. Conceptual modular turbine-generator configuration

It is anticipated that a 60 kW modular unit could be configured within the Tainter gate bay and leave approximately 10 to 11 feet of width for a lock chamber.

Voith provided a budgetary quote of $750,000 to supply the StreamDiver unit. Assuming civil costs total $250,000 brings the total capital cost to $1 million.

As shown in Table 5-2, a 60 kW project would generate approximately 420 MWh per year. Applying an estimated value of energy of $40/MWh results in annual revenues of approximately $17,000. A simplified payback period is then calculated as follows:

Payback period = $1,000,000 / $17,000 ~ 59 years

The above high-level payback period calculation excludes O&M- and FERC-related costs. As with the larger (600 kW) installation, the smaller (60 kW) installation does not appear to be economically feasible (again absent generation incentives or capital funding assistance).

5.11.3 FERC Considerations

FERC regulates non-federal[21], jurisdictional hydropower facilities in the United States.

Unless a project has a valid pre-1920 federal permit, non-federal hydroelectric projects are subject to FERC's jurisdiction if any of the following conditions apply:

1. The project is located on navigable waters of the United States
2. The project occupies public lands or reservations of the United States
3. The project uses surplus water or waterpower from a federal dam
4. The project is located on a body of water over which Congress has Commerce Clause jurisdiction, project construction occurred on or after August 26, 1935, and the project affects the interests of interstate or foreign commerce

Because item 1 above would apply to a hydropower development at the Rum River Dam, it would be FERC jurisdictional.

FERC authorization to construct a hydropower facility comes in two forms: a "license" or an "exemption." Both licenses and exemptions begin with an approximate 5-year-long process leading to and including a National Environmental Policy Act (NEPA) process with FERC as the lead agency. Following issuance of a license or exemption order by FERC, the two authorizations differ. Licenses are typically granted for 30 to 40-year terms and licensees are required to relicense their projects at the end of each term, including new NEPA processes. As the term suggests, exempted projects are exempt from relicensing so long as conditions of the exemption are met.

In both the FERC license and exemption processes, applicants are required to conform with, monitor, and report on dam-safety features associated with their project(s). "Dam safety" encompasses many common hydropower project features including embankment dams, concrete gravity dams, piers, abutments, walls, spillways, spillway gates, aprons, powerhouses, and river scour/sedimentation. For a new hydropower project at an existing dam, the license or exemption applicant must prove to FERC that the project

[21] Examples of federal hydropower owners includes USACE, U.S. Bureau of Reclamation, and the Tennessee Valley Authority.

satisfies FERC's dam-safety guidelines. Despite the fact that the Rum River Dam has had no significant dam-safety issues since its original construction, the following factors may need to be revisited through field investigations and engineering analyses:

- Structural stability of spillway and Tainter gate bay
- Structural adequacy of spillway apron and Tainter gate
- Inflow design flood for project
- Discharge capacity of spillway and Tainter gate
- Design of Tainter gate stilling basin

5.11.4 Conclusions

The following conclusions are drawn from the preceding hydropower discussion:

- From a hydrologic standpoint, the maximum installed capacity that the Rum River Dam could support is approximately 600 kW. Based on anticipated energy generation and capital cost, a 600 kW installation is not economically viable without being subsidized by capital funding assistance or energy production incentives.
- A smaller (e.g., 60 kW) installation is not economically viable without being subsidized by capital funding assistance or energy production incentives.
- Hydropower development would require an approximate 5-year licensing or exemption process through FERC.
- Hydropower development may lead to additional capital expenditures associated with dam safety and ongoing dam-safety monitoring and reporting.

Based on the above and discussions with City staff, it was agreed that hydropower development does not warrant further consideration.

6 Alternative Renewable Energy Sources

The evaluation of hydropower potential at Rum River Dam is discussed in the previous section. Because hydropower development was deemed unviable, HDR performed high-level evaluations of other renewable energy sources, which are presented in the following sections.

6.1 Solar

This section describes solar power, including utility background, a solar system description, the solar evaluation approach, and results.

6.1.1 Utility Background

Anoka Municipal Utility (AMU) provides electrical service to Anoka and surrounding areas. AMU is a member of the Minnesota Municipal Power Agency (MMPA).

For solar systems, AMU offers a net-metering connection for installations under 40 kilowatts alternating current (kWAC). This arrangement allows solar energy to offset a customer's electricity bill by crediting excess generation back to the electrical grid. Systems that generate more than 40 kWAC require a Power Purchase Agreement (PPA) with MMPA. The City is primarily seeking solar solutions that will generate less than 40 kWAC, avoiding the need for a PPA.

6.1.2 Solar System Description

A photovoltaic (PV) system generates power by converting solar irradiance into electrical energy. PV systems consist of the following major components: (1) panels (i.e., modules), (2) racking, and (3) inverters. These components are described below.

6.1.2.1 Solar PV Panels

Solar PV panels (i.e., modules) convert solar-radiated energy into direct-current (DC) electricity at an efficiency of approximately 20 percent. Typical panels are approximately 3.2-feet-wide and 6.5-feet-tall, and weigh 50 to 60 pounds. Each panel contains 72 individual PV cells wired together. The chemistry of most commercial-scale PV panels is crystalline silicon, and each panel has a positive (+) and negative (-) wire lead. An example of a PV panel is presented in Figure 6-1.

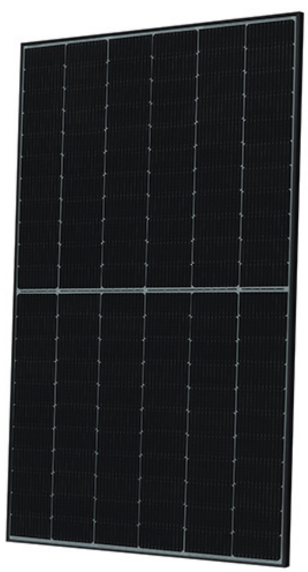


Figure 6-1. Example solar PV panel

6.1.2.2 Racking

This section describes solar system racking, including rooftop, parking garage, and canopy.

Rooftop

Solar PV rooftop systems use steel or aluminum racks to support PV modules and anchor them to the rooftop. Racking depends on the roof type. Flat roof racking systems are held in place on the roof with concrete block ballasts and anchored mechanical attachments. PV racking on standing-seam roofs can be accomplished with mechanical attachments that clip the panel frames to the roof seams as seen in Figure 6-2.

Figure 6-2. Example rooftop (standing-seam) racking

Parking Garage

Systems installed on a parking garage typically consist of a steel superstructure that provides an elevated support for PV panels approximately 10 feet above the final parking level. The structure consists of steel I-beam supports and cross members. Panels are mounted on the structure in east/west south-facing rows at a mild tilt angle. Ancillary benefits include vehicle weather protection and additional lighting for wayfinding and security. Figure 6-3 shows the system mounted on the parking garage at the Minneapolis-Saint Paul (MSP) Airport.

Figure 6-3. Example parking garage racking

Canopy

A solar PV canopy consists of PV panels mounted on top of a steel and/or aluminum racking structure that is in turn supported on steel columns and reinforced concrete foundations. While typically popular for use as covered parking or "carports," PV canopies can also be used for walkways or other general storage areas. Canopy height and width can vary to accommodate the intended use. An example canopy is shown in Figure 6-4.

Figure 6-4. Example canopy racking

6.1.2.3 Inverter

Inverters use power electronics to convert the DC output of the PV panels into usable alternating-current (AC) electricity.

Rooftop and ground-mounted commercial-scale PV systems (100 kW to 2 megawatts [MW]) use string inverters. String inverters are modular with unit ratings that range from 20 kW to 150 kW. The output voltage is 480 volts alternating current (VAC), suitable for a direct connection into a building electrical service without a transformer. A string inverter is 2.5 by 2.5 by 1.5 feet and weighs approximately 150 pounds. Inverters can be wall-mounted in an electrical room or the building exterior, or they can be directly mounted on the roof. The inverter has a disconnect switch that allows the solar PV system to be shut down. The inverter can be monitored and controlled locally or remotely. An example inverter is shown in Figure 6-5.

Figure 6-5. Example inverter

6.1.3 Solar Evaluation Approach

HDR visited Anoka City Hall on June 6, 2024. The site visit resulted in identification of the following four potential solar implementation sites, which are shown on Figure 6-6:

- Anoka City Hall rooftop
- Public Safety Building rooftop
- North Central Business District (NCBD) parking ramp rooftop
- Maintenance walkway canopy

This study presents an overall, high-level comparison of these four sites and an initial reconnaissance-level indication of their feasibility.

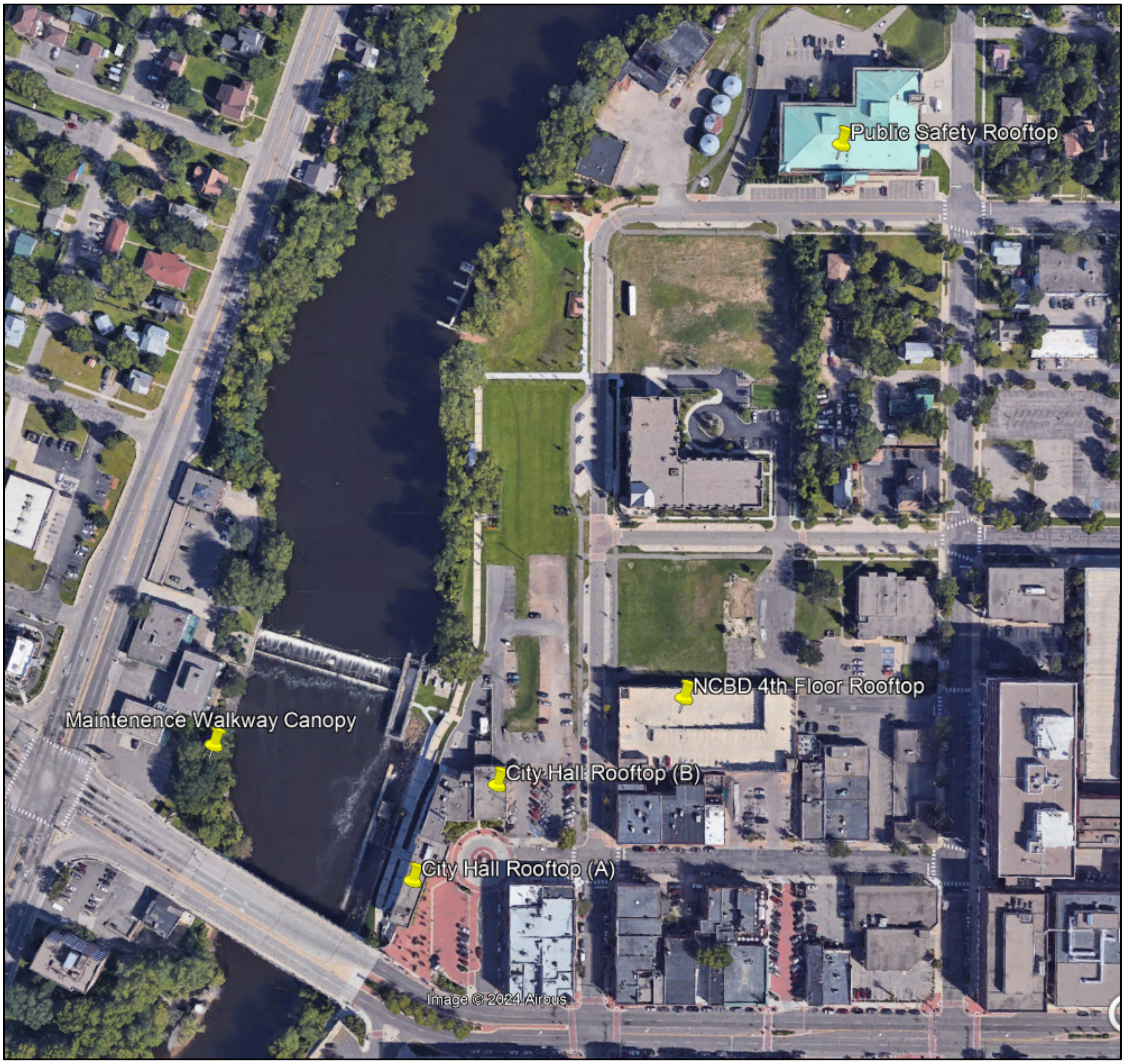


Figure 6-6. Map of prospective sites

6.1.3.1 Annual Energy Generation Methodology

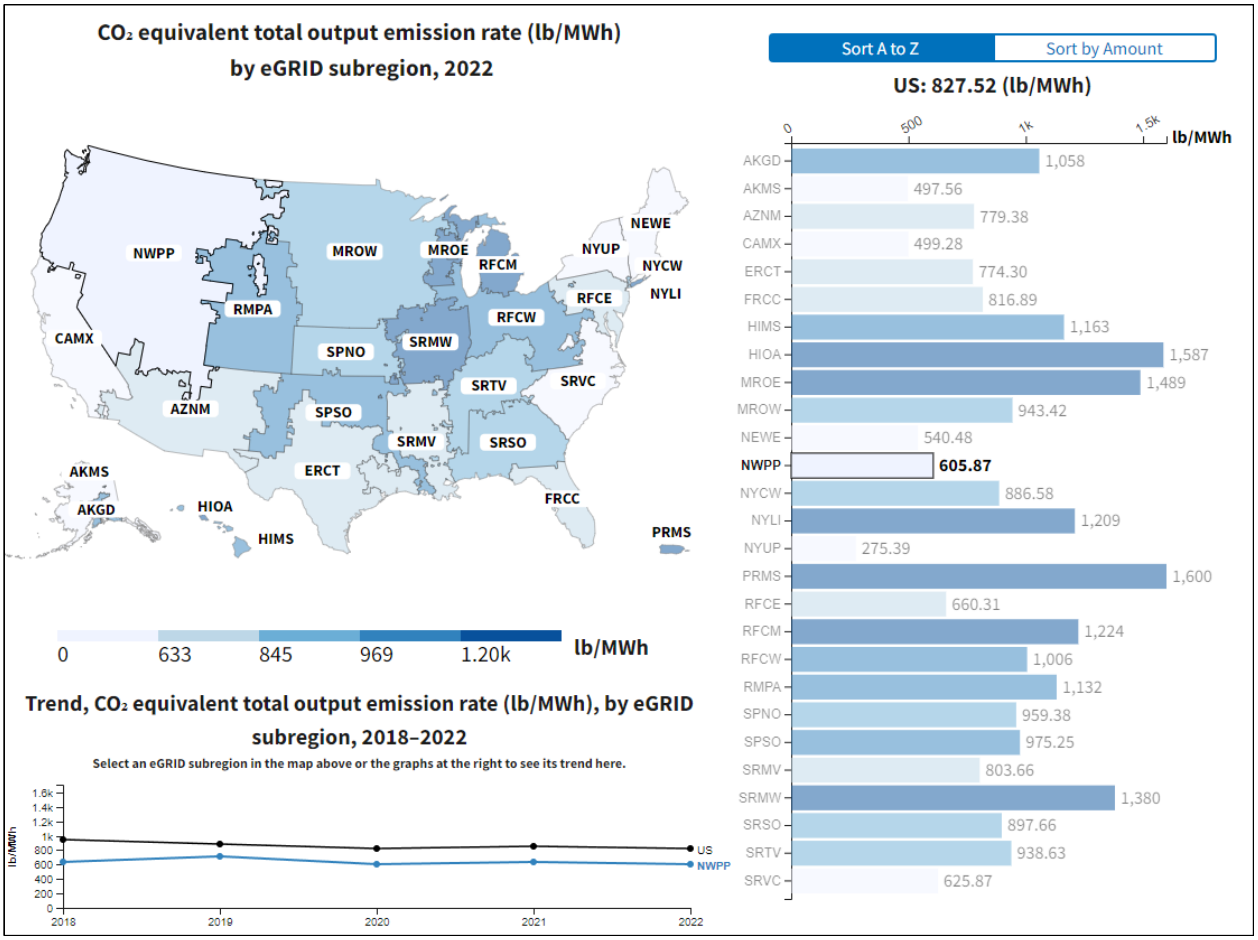
The estimated annual energy output from each PV system was determined using PVSyst software. PVSyst is an industry-standard energy modeling software that uses site-specific weather data to calculate a PV system's energy production.

A model was developed for each site based on the parameters of the concept designs. Model inputs include typical meteorological conditions, equipment selection/quantity, and loss assumptions. The models include the impact from shading where appropriate.

Model results are preliminary and should be used only to inform early planning activities, and not as the basis for future activities including for example contract terms.

Carbon Footprint

The annual PV energy output from each system can be used in conjunction with greenhouse gas (GHG) emission rates to quantify potential GHG emission reductions. Figure 6-7 shows carbon dioxide equivalent (CO_2e) emission rates in pounds per megawatt-hour (lb/MWh) of electricity generated across subregions of the U.S. power grid. The emission rate in the Midwest Reliability Organization West (MROW) region is 936.49 lb/MWh CO_2e.



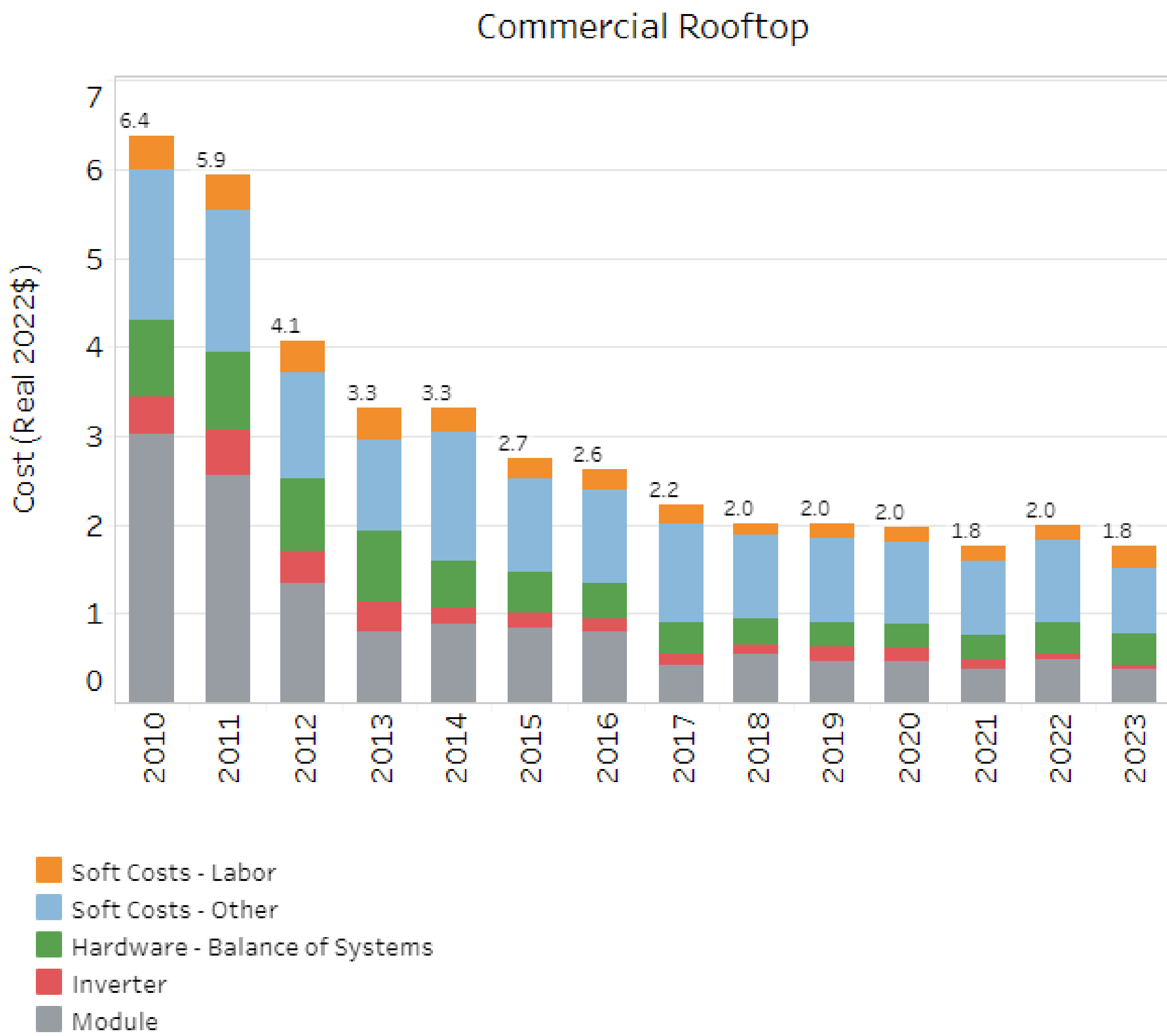
Source: EPA 2024.

Figure 6-7. CO_2e total output emission rate

6.1.3.2 Budgetary Cost Opinions

PV system cost estimates were developed for each system from industry benchmarks and biased with recent vendor quotes. The National Renewable Energy Laboratory (NREL) provides quarterly cost benchmarks for PV systems across a range of sizes and locations.

Terrasmart Inc. provided a quote for the NCBD parking ramp for the superstructure. Terrasmart concluded that the cost of design, materials, and installation is $2.92 per watt direct current (WDC). This cost is for the structure only, and not the electrical equipment. Winter costing benchmarks for 2023/2024 are presented in Figure 6-8.



Source: NREL 2022/2023.

Figure 6-8. PV cost benchmarks: winter 2023/2024

System costs have come down substantially since 2010, but pricing has been volatile in the past 5 years because of changing policies and other manufacturer market forces. Consequently, cost estimates are considered high-level and should be validated by a solar contractor during detailed design.

In general, rooftop systems are the most cost-effective type for new installations as they can leverage the structural foundation of another facility and minimize racking costs. Canopy systems are advantageous when no other suitable rooftop- or ground-mounted space is available, but the added cost of structural steel can be prohibitive.

The following summarizes PV system unit pricing:

- **NCBD parking ramp:** $4.50/Wdc
- **Rooftop:** $1.80/Wdc
- **Canopy:** $4.10/Wdc

6.1.4 Results

This section presents results of the solar evaluation for the NCBD parking ramp, Anoka City Hall rooftop, Public Safety Building, and maintenance walkway canopy.

6.1.4.1 NCBD Parking Ramp

The NCBD parking ramp is located east of City Hall and the Rum River Dam, across 2nd Avenue. The City has plans to construct a future fourth floor to the parking ramp. This fourth floor could be made ready for a rooftop solar installation. The building has a footprint of approximately 42,300 square feet (ft^2), making it the largest area of the four proposed sites for solar implementation. Figure 6-9 shows the NCBD Ramp and Figure 6-10 shows a proposed system layout. A summary of the system is presented in Table 6-1.

Table 6-1. NCBD parking ramp system data

System type	Rooftop: parking garage
System size	378 kWdc, 300 kWAC
Annual energy	558 MWh
GHG avoided	552,561 lb

Figure 6-9. NCBD parking ramp

Figure 6-10. Potential system configuration on NCBD parking ramp

Design Considerations

The following are design considerations for the NCBD parking ramp:

- A parking garage type racking system would allow for an approximately 300 kWAC PV system installed on a steel superstructure above the new fourth level.
- Implementing rooftop solar during new roof construction is advantageous, as the structure can be designed to support the additional load, eliminating the need for retrofitting and avoiding warranty complications.
- The system will provide added weather protection for vehicles on the top level but also presents the possibility of enhancing security lighting and installing electric-vehicle charging stations.
- The garage's electrical load is relatively small and unlikely to consume all the energy produced by the system. Therefore, the excess generation credit would have to be allocated virtually to other City utility services within the region.

System Performance and Cost

The following are system performance and cost notes for the NCBD parking ramp:

- As indicated in Section 5.11, the value of energy is estimated at $40 per mega-hour (MWh). Applying this value to the 558 MWh results in annual revenue of approximately $22,000.
- The approximate cost of this system is as follows:

  Cost = $4.50 per watt × 378,000 watts = $1.7 million

- The resulting simplified payback period is as follows:

  Payback period = $1,700,000 / $22,000 ~ 77 years

- Note that PV systems typically have a design life of 25 to 30 years, though systems will continue to generate energy with degradation.
- A garage superstructure is much more costly compared to a typical standing-seam roof-mounted system. These costs impact the overall payback of the system.
- The analysis does not include financial incentives. The projects may be eligible for direct payment credits as currently defined under the Inflation Reduction Act (IRA) as it exists at the time of this report, as much as 40 percent of material costs provided that domestic content and other requirements are met. Note, this and other financial incentives may be affected by prevailing or future legislation, policy or other considerations and should be closely examined at the time of detailed consideration.

6.1.4.2 Anoka City Hall Rooftop

The City Hall building is located east of the Rum River Dam. The southernmost section (A) and northernmost section (B) of this rooftop are suitable to place PV modules. Section A of the rooftop has approximately 500 ft^2 of buildable area. Much of this rooftop has various heating, ventilation, and air conditioning (HVAC) equipment, limiting space for solar. Section B has approximately 900 ft^2 of buildable space. The racking for these PV modules would use a ballast system.

This location is served by a 300-kilovolt-ampere (kVA) pad-mounted transformer at 208-volt (V) three phase, with a backup 300 kW diesel generator. Figure 6-11 presents system location alternatives on the City Hall roof and Figure 6-12 presents potential system configurations for the City Hall roof. Table 6-2 presents system information for the City Hall rooftop installation.

Table 6-2. City Hall system data

System type	Rooftop
System size	28 kWdc, 23 kWAC
Annual energy	42,311 kWh
GHG avoided	4,572 lb

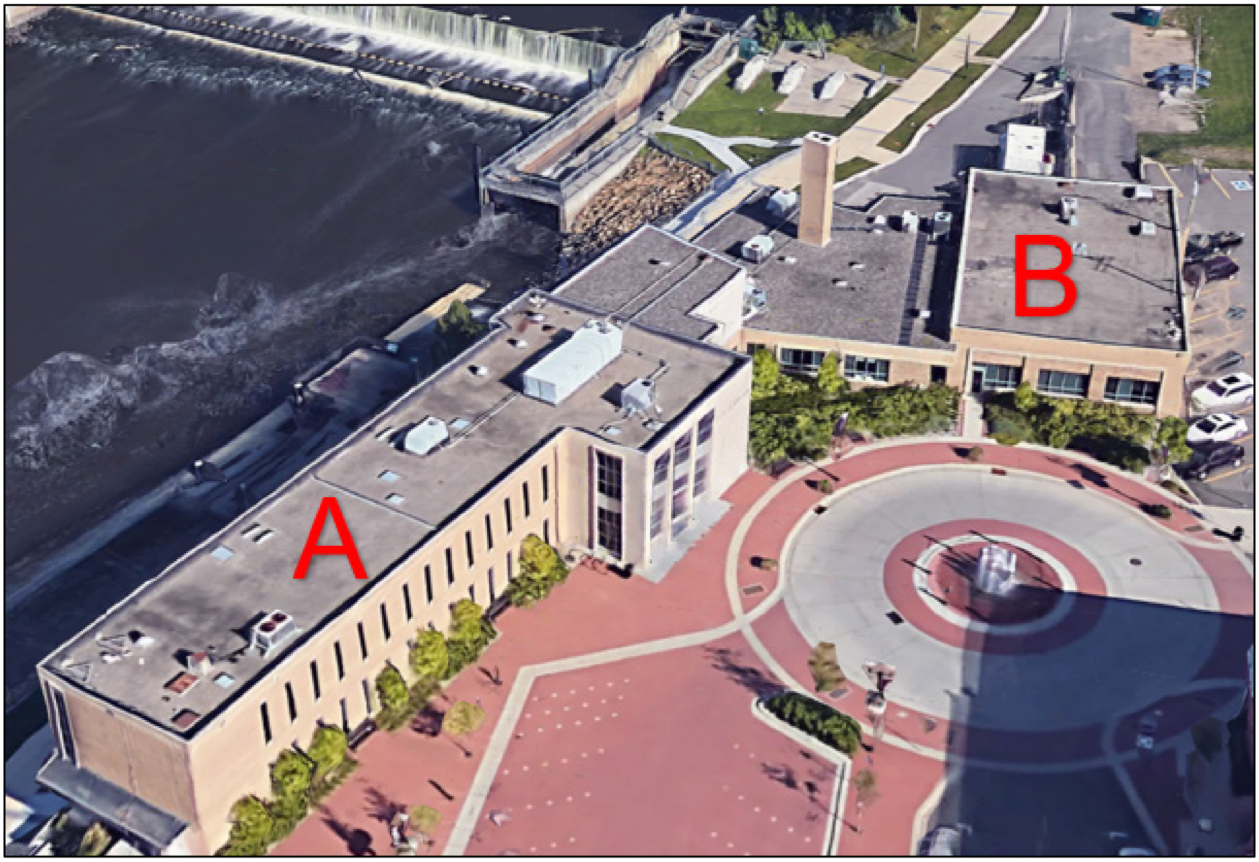


Figure 6-11. City Hall rooftop installation alternatives

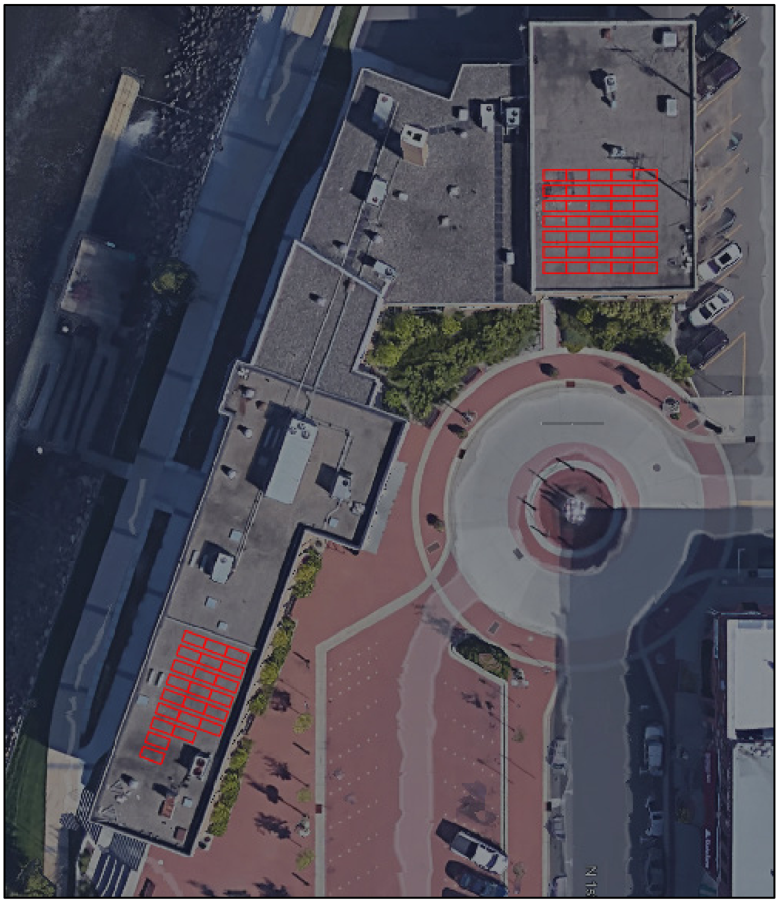


Figure 6-12. Potential City Hall rooftop installation configuration

Design Considerations

The following are design considerations for the Anoka City Hall rooftop:

- A roof assessment is recommended to validate the condition and load-bearing capacity of the building.
- Coordinate installation with roof warranty. The roof of the southern section (A) is 6 months old.
- The PV system is ballasted with concrete blocks; no mechanical attachments are on the roof.
- The PV system would interconnect to the building's main service point. All generation is likely to be consumed within the facility with no export to the grid.

System Performance and Cost

The following are system performance and cost notes for the Anoka City Hall rooftop:

- Applying an energy value of $40/MWh to the annual generation of 42.3 MWh results in annual revenue of approximately $1,700. The approximate cost of this system is as follows:

  Cost = $1.8 per watt × 28,000 watts = $51,000

- The resulting simplified payback period is as follows:

  Payback period = $51,000 / $1,700 ~ 30 years

- Note that PV systems typically have a design life of 25 to 30 years, though systems will continue to generate energy with degradation.
- The analysis does not include financial incentives. The projects may be eligible for direct payment credits as currently defined under the IRA as it exists at the time of this report, as much as 40 percent of material costs provided that domestic content and other requirements are met. Note, this and other financial incentives may be affected by prevailing or future legislation, policy or other considerations and should be closely examined at the time of detailed consideration.

6.1.4.3 Public Safety Building

The Public Safety Building is located north of City Hall on Harrison Street. Buildable sections of this rooftop include the south and west-facing sections. These sections provide approximately 3,000 ft^2 of buildable area. The PV modules will be mounted to the rooftop with module clips.

This location is served by a 300 kVA pad-mounted transformer at 208 V three phase. The south-facing roof would be viable for east/west rows of solar modules. Figure 6-13 shows the Public Safety Building and Figure 6-14 shows the layout of the system for the Public Safety Building roof installation. Table 6-3 presents data for the Public Safety Building system.

Table 6-3. Public Safety Building system data

System type	Rooftop
System size	166 kWdc, 140 kWAC
Annual energy	208.24 MWh
GHG avoided	195,015 lb

Figure 6-13. Public Safety Building

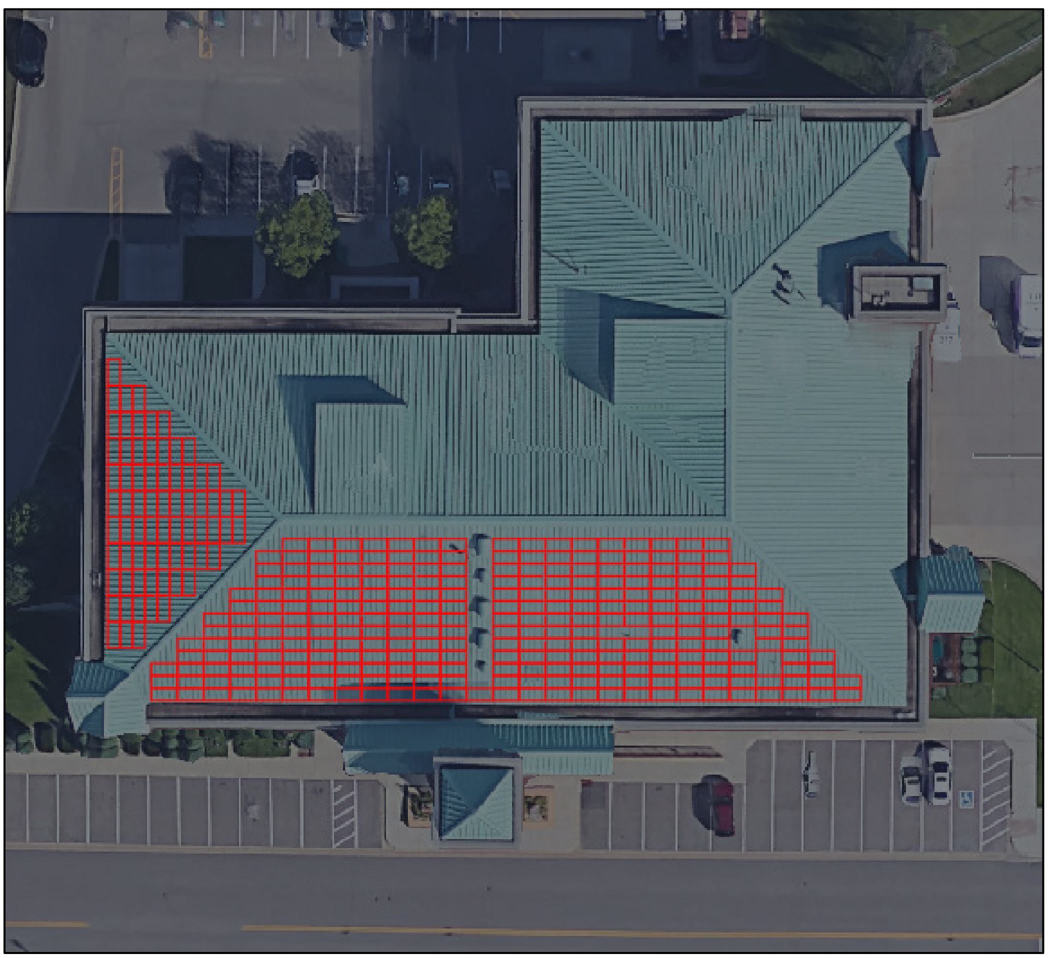


Figure 6-14. Public Safety Building system configuration

Design Considerations

The following are design considerations for the Public Safety Building:

- Sloped roof systems are more challenging and costly to maintain.
- The system may negatively impact the visual aspects of the facility.
- The tower above the entrance will significantly shade some of the PV modules on the southern section of the roof.
- The PV system would interconnect to the building's main service point. All generation is likely to be consumed within the facility with no export to the grid.

System Performance and Cost

The following are system performance and cost notes for the Public Safety Building:

- Applying an energy value of $40/MWh to the annual generation of 208 MWh results in annual revenue of approximately $8,300. The approximate cost of this system is as follows:
- The approximate cost of this system is as follows:

  Cost = $1.80 per watt × 166,000 watts = $300,000

- The resulting simplified payback period is as follows:

  Payback period = $300,000 / $8,300 ~ 36 years

- Note that PV systems typically have a design life of 25 to 30 years, though systems will continue to generate energy with degradation.
- The analysis does not include financial incentives. The projects may be eligible for direct payment credits as currently defined under the IRA as it exists at the time of this report, as much as 40 percent of material costs provided that domestic content and other requirements are met. Note, this and other financial incentives may be affected by prevailing or future legislation, policy or other considerations and should be closely examined at the time of detailed consideration.

6.1.4.4 Bridge Canopy

The river-crossing bridge (described in Section 5.8) could be provided with a canopy that could be used for mounting solar modules. This location may be able to connect to the City Hall service point. The location of the proposed bridge is shown in Figure 6-15. Note that this alignment assumes that the bridge can be founded on the dam. Table 6-4 presents data for the bridge canopy system.

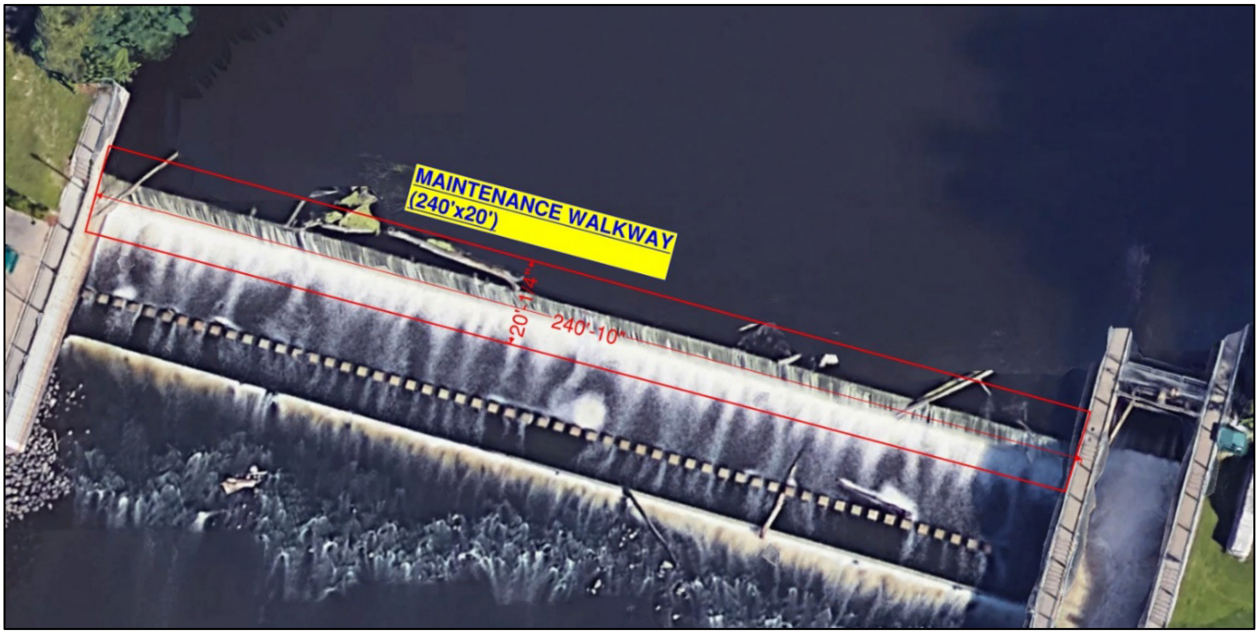


Figure 6-15. Bridge canopy

Table 6-4. Bridge canopy system data

System type	Canopy
System size	101.9 kWdc, 85 kWAC
Annual energy	156.4 MWh
GHG avoided	146,435 lb

Design Considerations

The following are design considerations for the bridge canopy:

- This project would be tied to the overall dam construction project works, which could allow for more efficient design and construction.
- Maintenance on such a system will be more challenging.
- The system is more costly than rooftop systems because of the added structural complexity.
- The point of interconnection is uncertain, but could potentially be tied into the City Hall electric service where all generation is likely to be consumed on site with no grid export.

System Performance and Cost

The following are system performance and cost notes for the bridge canopy:

- Applying an energy value of $40/MWh to the annual generation of 156 MWh results in annual revenue of approximately $6,200. The approximate cost of this system is as follows:
- The approximate cost of this system is as follows:

  Cost = $4.10 per watt × 101,900 watts = $420,000

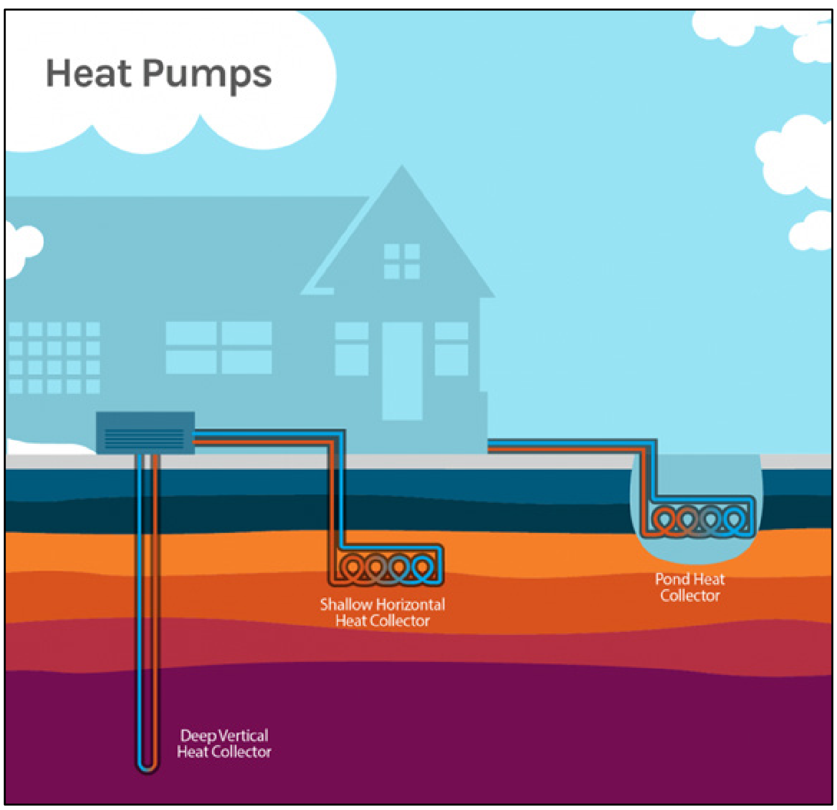
- The resulting simplified payback period is as follows:

  Payback period = $420,000 / $6,200 ~ 68 years

- Note that PV systems typically have a design life of 25 to 30 years, though systems will continue to generate energy with degradation.
- The analysis does not include financial incentives. The projects may be eligible for direct payment credits as currently defined under the IRA as it exists at the time of this report, as much as 40 percent of material costs provided that domestic content and other requirements are met. Note, this and other financial incentives may be affected by prevailing or future legislation, policy or other considerations and should be closely examined at the time of detailed consideration.

6.2 Heat Exchanger Using Rum River Water

This section discusses the reconnaissance-level feasibility of using a river water heat exchanger to heat and cool Anoka City Hall. Currently, fuel-fired equipment is used for heating and direct expansion refrigerant-based equipment is used for cooling. The existing mechanical systems that heat and cool the building could be replaced with heat pumps that would use river water as a heat exchanger. Figure 6-16 provides an example of heat pumps that use deep vertical wells, shallow horizontal loop field, and water located collector for heat exchangers.



Source: Office of Energy Efficiency & Renewable Energy 2024.

Figure 6-16. Heat pump application

The heat pumps inside the building transfer heat between the liquid circulated in the distribution system in the building to the water or ground heat exchanger outside.

A heat pump absorbs heat energy from a heat sink. Outside air is utilized as the heat sink for air-source heat pumps and ground or surface water is used as the heat sink for water-source heat pumps. Heat pumps can transfer heat even in cold temperatures to the indoor environment. In cooling operation, a heat pump absorbs heat from the indoor environment via air or water and releases it through the heat sink. An example of a heat pump is an air conditioning unit where heat is absorbed from the indoor air coil and released through the outdoor condensing unit. Heat pumps use refrigerant as a heat transfer medium to move heat from the heat source to a heat sink.

For this project, the concept is to use heat exchangers installed in the river to serve as the heat sink. Heat would be extracted from the water during the heating season and rejected to the river during the cooling season. The heat extraction or rejection takes place via heat transfer between the heat exchanger and the river water.

6.2.1 Heat Exchanger and System Sizing

System sizing is based on existing heating and cooling demands. In heating-dominated climates the heat exchanger loop is sized based on the heating demands. HDR used existing building drawings and existing boiler sizing to determine the approximate heating demand. The existing boilers have a combined heat output of 2,140,000 British thermal units per hour (Btuh). The existing boilers are natural gas fired with fuel oil backup.

The existing cooling system capacity is not known, but the heating capacity will drive equipment selection. The preliminary size needed for the building is 250 tons. A mechanical concept design would need to be completed that includes a building enveloped heat requirement calculation to determine the required size of the equipment. A 250-ton system will have a 750 gpm (approximately 2 cfs) flow that circulates from the heat exchangers to the heat pumps. The flow rate would be controlled by variable-speed pumps to allow for energy savings when the full flow rate is not needed. Fluid would be circulated from the heat pumps to the river water heat exchanger.

The size of the river water heat exchanger and heat pump is impacted by the temperature of the river water. The heat pumps and associated heat exchanger need to be sized to accommodate the approximate river water temperature range of 32 to 76 degrees Fahrenheit (°F).

Two alternatives for the river water heat exchanger include the use of installing high-density polyethylene (HDPE) piping coiled connected to collection headers or installing a plate heat exchanger submerged in the river water. Figure 6-17 shows an example of the latter.

Source: Thermco Energy Systems 2024.

Figure 6-17. Example plate and frame heat exchanger

Assuming a maximum water velocity of 5 feet per second and the design flow of 750 gpm from above, the pressure-side supply pipe diameter would be on the order of 8 inches. Pumps could be located within a wet well/vault located upstream of the new lock chamber. An approximately 18-inch-diameter gravity line could extend from the lock filling intake structure to the wet well. Should the City decide to pursue the heat exchanger concept at some point in the future, it would be advisable to install a portion of the gravity supply piping during construction of the overall dam improvements.

In lieu of a river water exchanger, the ground could be used as a heat exchanger by using horizontal bore holes or a vertical field of piping. The advantage to using the ground as a heat exchanger is that there is less difference in ground temperatures during the year.

The following notes reflect preliminary discussions with MnDNR:

- Since 2015, MnDNR is no longer allowed to issue a permit for any new once-through geothermal systems that use groundwater. However, surface water appropriated for a once-through system is still allowed if the water is being returned to its source. If the appropriation is more than 10,000 gallons per day or 1 million gallons per year, then an MnDNR water use permit is required.
- A closed-loop system installed in or on the bed of a public water body would require a public waters permit from MnDNR. For these types of systems, MnDNR strongly encourages landowners to install these systems in an upland area, rather than below or on the bed of a public water body. If it is installed permanently on or below the bed and repairs/maintenance are required, that would require drawing down the water level to do work (a complicating factor). The public waters rule (Minnesota Administrative Rules Part 6115.6211, Subpart 6b) also encourages that these systems be installed outside of public waters by requiring that a government agency accept responsibility for the installation.

Although not specifically discussed with the DNR, the heat exchange system would also need to be evaluated from the standpoint of impacts to river water temperature.

6.2.2 Building Modifications Required and Additional Considerations

The existing building would require extensive modifications to accommodate the use of water source heat pumps to heat and cool the building. Further design and analysis will be required to properly size and select the equipment.

Heat pumps use electricity as the power source for operation and there will be an increase in the electrical demand for the building. The building's electrical equipment and electrical service would need to be reviewed to determine if there is adequate capacity.

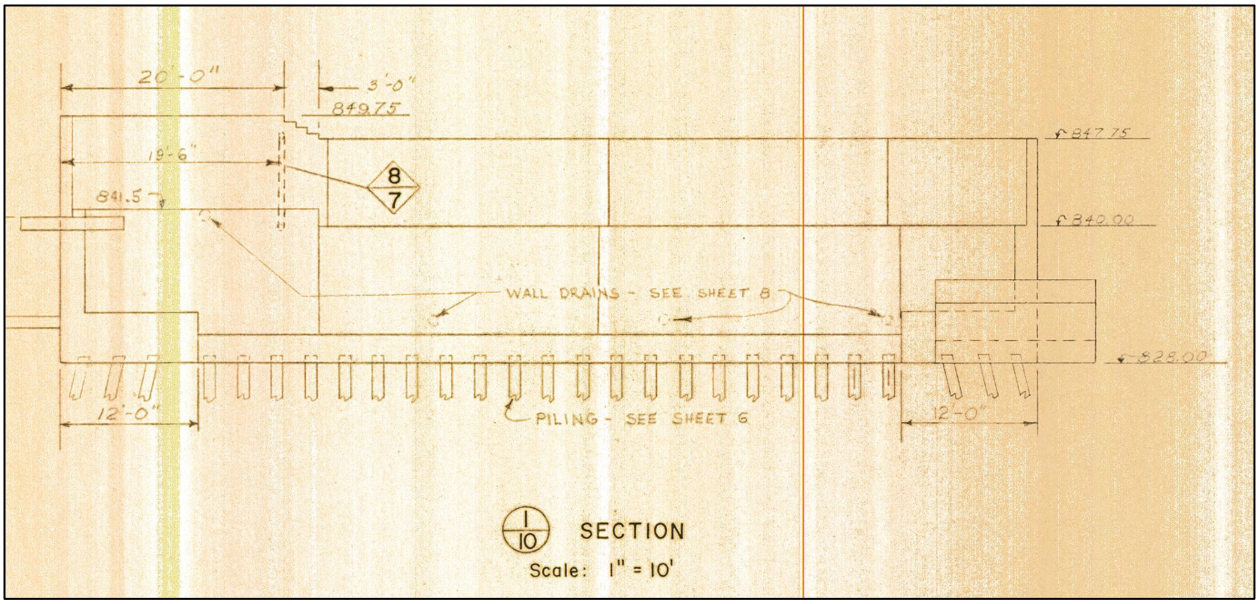
6.2.3 Conclusions

The concept of a Rum River heat exchanger could possibly be a viable renewable energy resource for the City/City Hall, but much more study is needed given that development of OPCCs, energy savings, economics or other applicable evaluations was beyond the scope of this study. Further examination of the heat exchanger concept may prove beneficial as existing City Hall mechanical systems age and planning for their replacement begins.

7 Construction Considerations

7.1 Right Abutment Piles

Of note to prospective construction activities on the western side of the dam, the right abutment is founded on timber pilings that are battered riverward at a 1H:3V slope. Any proposed modifications below existing grade, adjacent to the west bank retaining wall, will need to accommodate these existing piles (see Figure 7-1). Aboveground modifications, or additional load, will also need to be analyzed during detailed design.



Source: Barr 1968a.

Figure 7-1. Right (west) abutment

7.2 Construction Materials

This section describes construction materials likely or anticipated to be used on the project, that have site proximity advantages including concrete and cofferdam fill. Other materials are assumed to be less bound by the proximity of the material source, to project location are not discussed.

7.2.1 Concrete

Several cement batch plants are located in the Anoka area. Two examples are Cemstone (approximately 10 miles southwest of the project) and Moline (approximately 5 miles northeast of the project. It is anticipated that concrete for the project would be sourced from one of, if not both locations.

7.2.2 Cofferdam Fill

The City maintains a stockpile of earthen materials near Sunny Acres Park, which is located approximately 2.5 road-miles from the dam (see Figure 7-2). It is anticipated that this stockpiled material would be suitable for construction of temporary earthen cofferdams but analysis of the material is required as design advances.

Figure 7-2. Soil stockpile location

7.3 Care of Water

This section describes care of water to be applied during the project.

7.3.1 Conceptual Design

Based on what is known at the time of this report, it is anticipated that construction of dam improvements could conceivably take place over two seasons with the assumption that no work would be performed between January and May and no delays[22]. Under this assumption approximately half of the dam improvements could be constructed during each season. Cofferdams would be used to divert Rum River flows around the work area

[22] Note that MnDNR permits for past Rum River projects undertaken by the City included conditions to not perform activities affecting the riverbed between March 15 and June 15 unless work during this time is essential and written approval is obtained from the Area Fisheries Manager.

to functioning discharge facilities. Drawdown of the upstream pool during construction would be of benefit but is not necessarily required.

The recreation/fish passage feature extends upstream and downstream from the existing spillway. The upstream riverside walls of the structure are envisioned to be formed by a “king pile” wall. For the upstream west side of the dam improvements, preliminary engineering indicates that a “king pile” wall (or similar) is required to resist water loads and provide a dry work area for construction. King pile walls feature a combination of pipe and Z-type sheet piles, as shown on Figure 7-3. The pipe (or king) piles provide the majority of the structural resistance. Between the king piles are a pair of Z-shaped sheet piles that bridge the gap between the king piles. King piles are driven relatively deep and the sheet piles shallower, i.e., to the depth required for seepage control only. Conceptual designs for the two pile types are as follows:

- **King pile:** 48-inch diameter, 0.75-inch-thick, 60 kilopounds per square inch
- **Sheet pile:** NZ 26 (17.3 inches deep, 27.6 inches long, 0.5 inch thick)

Figure 7-3. Example king pile wall

Because of reduced water loads, preliminary engineering indicates that the downstream west-side cofferdam can be formed by NZ 26 sheet pile alone.

The majority of the west-side cofferdam will remain to serve as a portion of the recreation/fish passage feature permanent wall. The balance of the wall will be formed by reinforced concrete as shown on Figure 7-4.

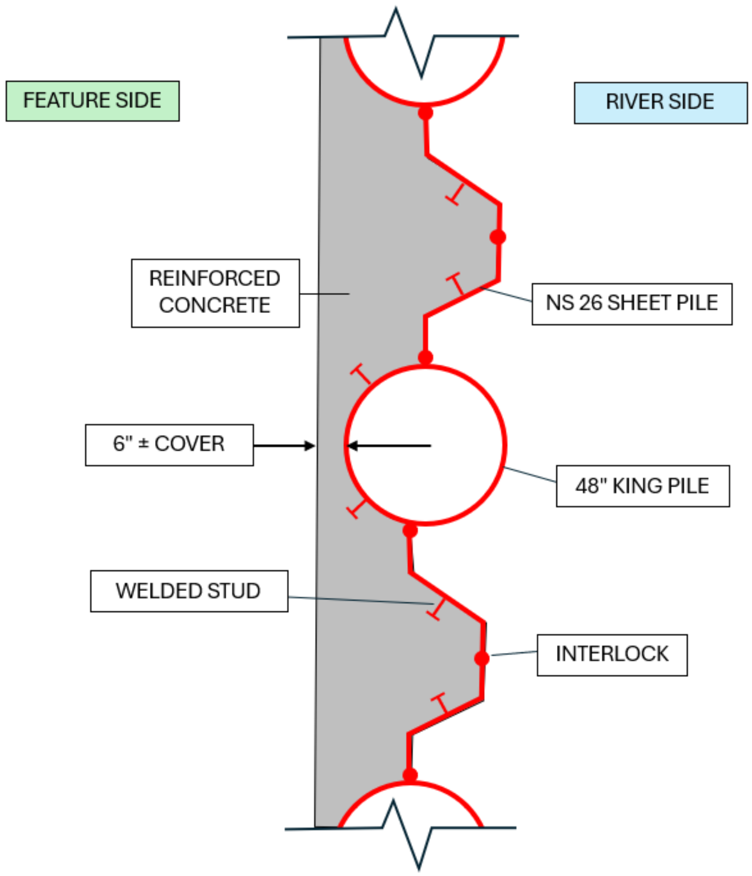


Figure 7-4. Cofferdam/permanent wall concept plan

Remnants of the original timber crib dam and associated timber falsework likely exists in the pool where the cofferdam would be placed (see Figure 7-5), and care should be taken with respect to the contractor and associated provisions for unforeseen conditions, unknown underground structures or other factors should they be encountered.

It is anticipated that the design of all temporary cofferdams would be the responsibility of the construction contractor according to performance specifications developed.

Source: Anoka County Historical Society 2024.

Figure 7-5. Photograph of original dam construction

7.4 Construction Sequencing

7.4.1 Single General Construction Contract

Although construction sequencing and means & methods would be left to the construction contractor, the following generalized sequence was prepared as an example of how the project could be constructed and to support the OPCC. See Figure 7-6 through Figure 7-8.

- Phase 1:
  1. King pile and sheet pile walls
  2. Temporary earthen cofferdam plug
  3. Removal of sediment from spillway upstream slab
  4. Recreation/fish passage features including crest gates
  5. Construction of gate control building
  6. Inspection and refurbishment of existing concrete, drain systems, and piezometers
  7. Spillway lighting
- Phase 2:
  1. Extension of king pile and sheet pile walls

2. Cutting Phase 1 king pile and sheet pile walls to finished elevation
3. Removal of sediment from spillway upstream slab
4. Construction of elongated pier
5. Modification of west Tainter gate wall to serve as crest gate pier
6. Installation of spillway crest gates
7. Installation of portion of lock filling system
8. Inspection and refurbishment of existing concrete, drain systems, and piezometers
9. Spillway lighting

- Phase 3:
  1. Extension of king pile and sheet pile walls to eastern shore
  2. Installation of balance of lock filling system
  3. Conversion of Tainter gate bay to lock including new concrete; interior filling system; crest gate; and miter gate foundation, structure, and gates
  4. Construction of gate/lock control building
  5. Cutting remaining king pile and sheet pile walls to finished elevations

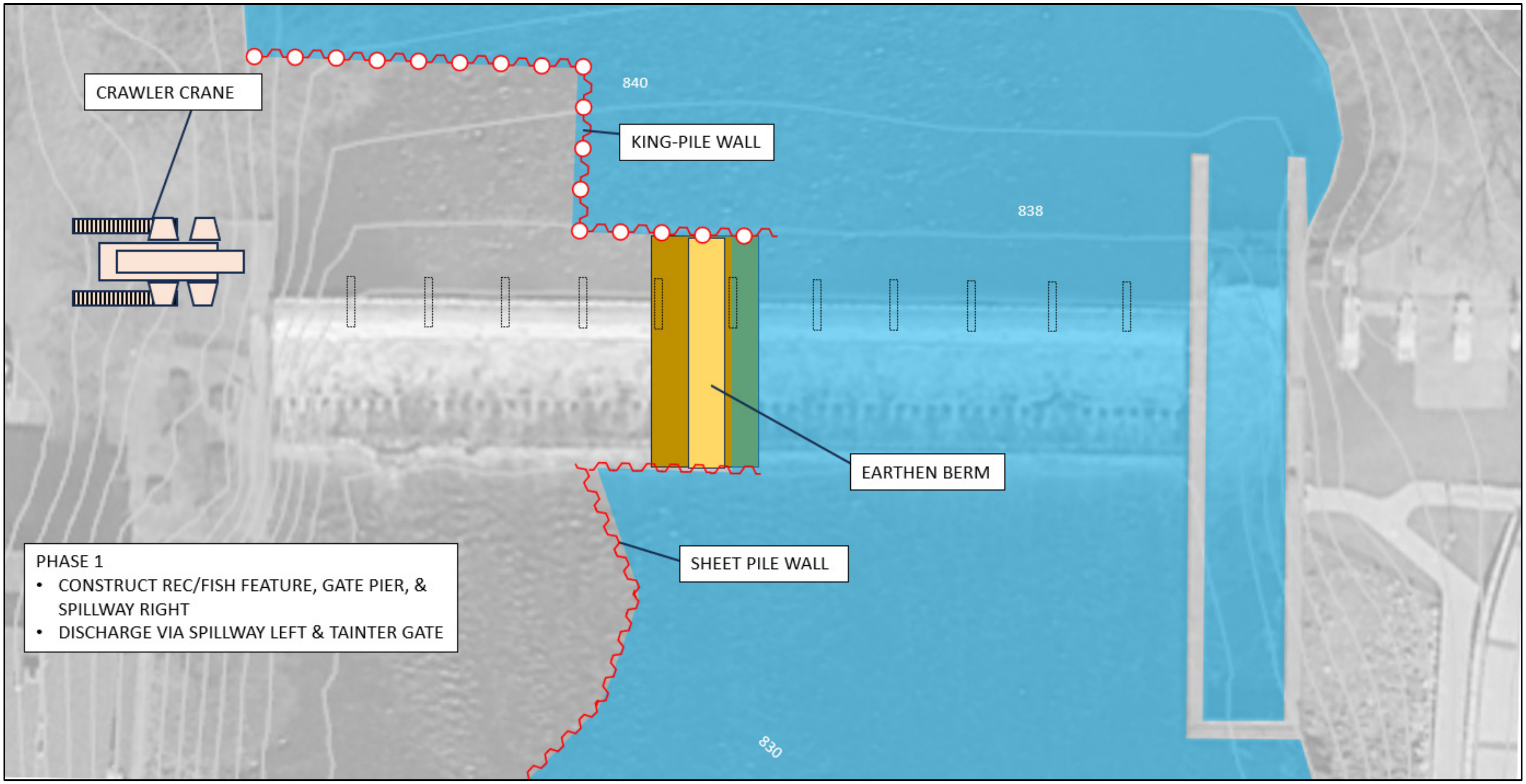


Figure 7-6. Phase 1 cofferdam concept

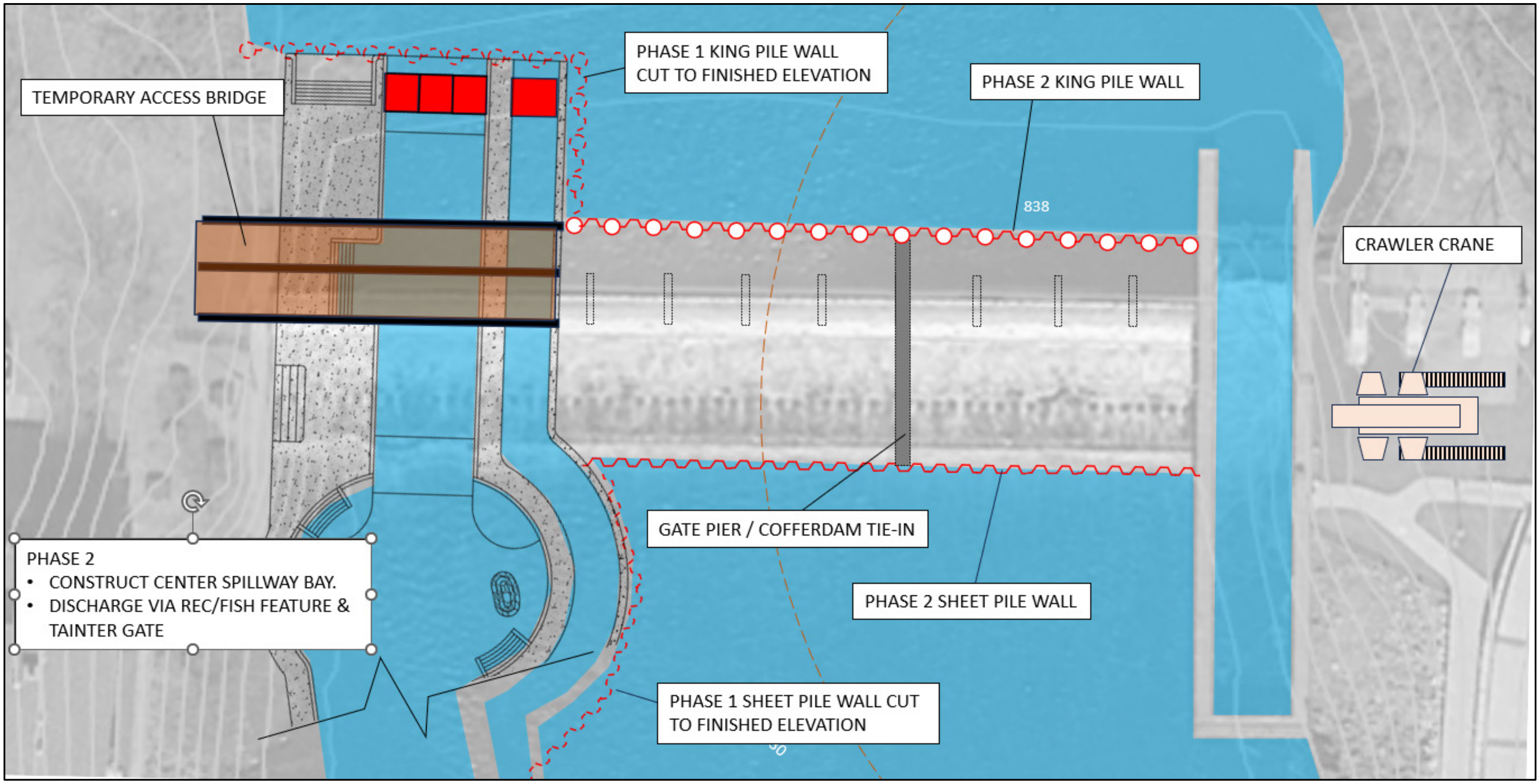


Figure 7-7. Phase 2 cofferdam concept

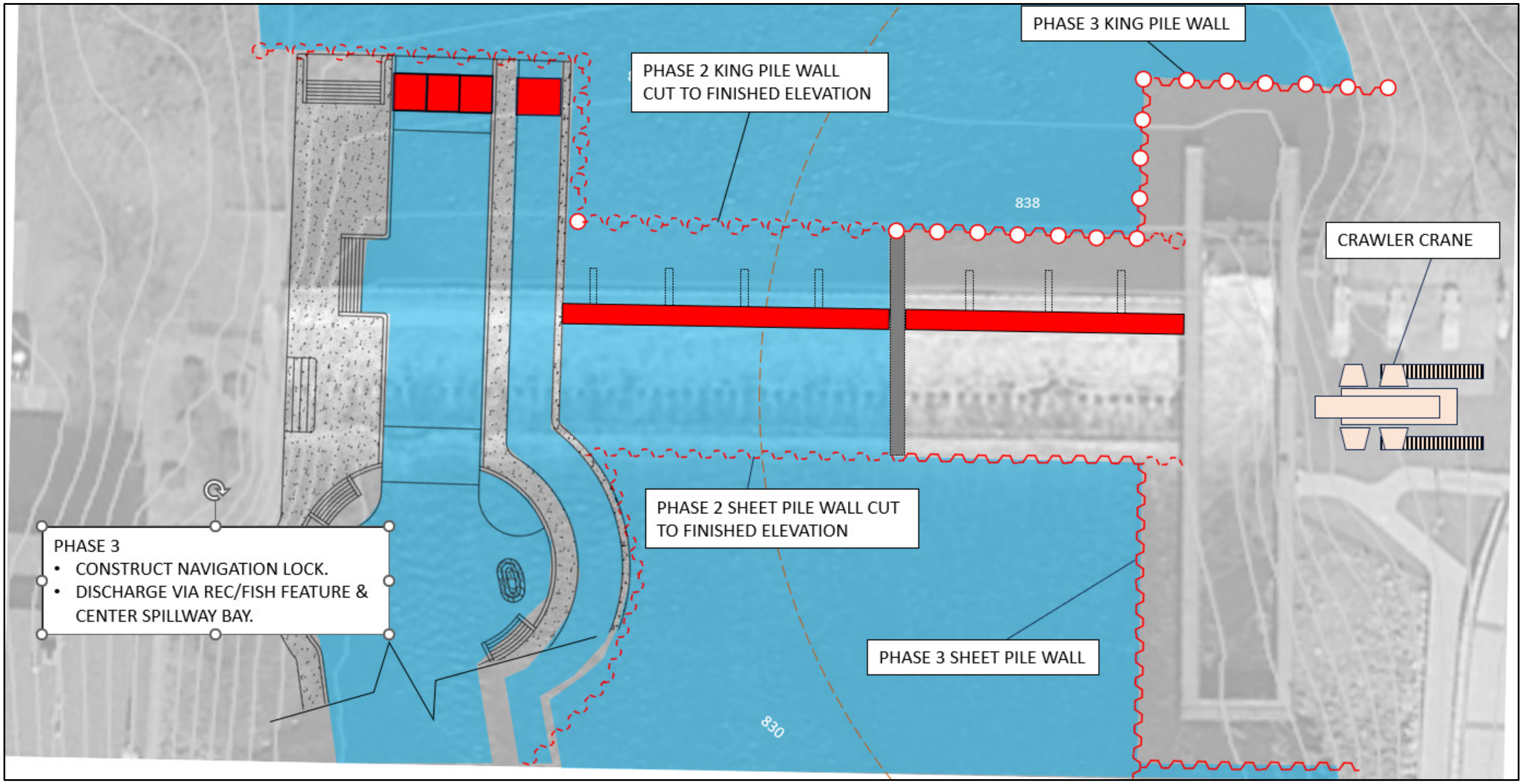


Figure 7-8. Phase 3 cofferdam concept

7.4.2 Multiple General Construction Contracts

An alternative to constructing all features in a single general construction contract would be to construct features as separate projects and thus spread costs over several years. Although this is possible, it would likely result in significant cost increases[23]. Reasons for this may include:

- Cost escalation and price volatility over time.
- Increased administrative, engineering, and permitting costs.
- Multiple contractor mobilizations.
- Multiple installation of temporary works, e.g., cofferdams.
- Certain new dam features may require reconstruction/replacement as new features are added. For example:
  - Project A: Overflow Spillway. Install new crest gates to replace flashboards.
  - Project B: Navigation lock. Maintaining spillway capacity requires reconstruction of portion of overflow spillway with new (higher) crest gate system.
  - Project C: Recreation and Fish Passage Features. Requires reconstruction of portion of overflow spillway and partial replacement crest gate system. Maintaining spillway capacity requires reconstruction (lowering) of separate portion of overflow spillway and partial replacement of crest gate system.

Advanced planning and design refinements could reduce the above-described cost risks but would likely increase initial construction costs. Revisiting the previous example:

- Project A': Overflow spillway. Construct walls to accommodate future recreation feature and fish passage. Reconstruct (lower) portion of overflow spillway to accommodate current and potential future loss of spillway capacity. As part of overflow spillway reconstruction, install portion of lock filling system infrastructure. At this point, spillway capacity would be designed to exceed present-day capacity.
- Project B': Navigation Lock. Reconstruct Tainter gate interior to serve as lock. Utilize Project A infrastructure to complete lock filling system. At this point, spillway capacity would be designed to exceed present-day capacity.
- Project C'. Recreation and Fish Passage Features. Construct recreation and fish passage features utilizing Project A walls as portion of required cofferdam. Replace portions of crest gate system impacted by new features. At this point, spillway capacity would be designed to match present-day capacity.

Figure 7-9 illustrates the dam as it may appear upon completion of the initial phase of construction, i.e., Project A'.

[23] The exception to this is the Rum River bridge if it is designed with minimal impact to the dam.

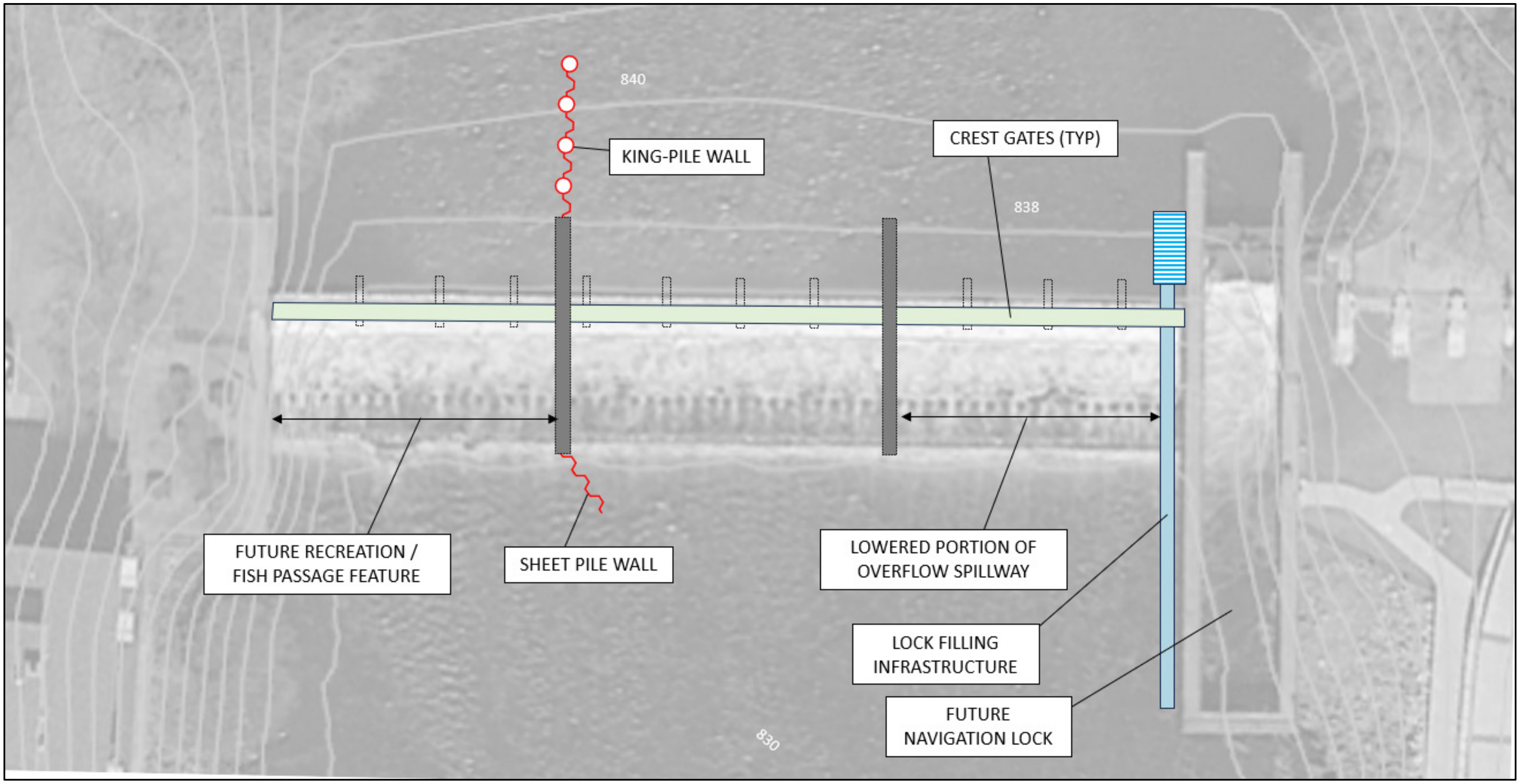


Figure 7-9. Initial stage dam improvements concept for multiple general constructon contract approach

7.5 Staging and Laydown

The primary staging and laydown area is anticipated to be located in the parking area immediately north of City Hall. This area would be used through both phases/seasons of construction. Of note here is the prospective restaurant development that would occupy a portion of the current available area. Staging area limitations and enhanced traffic control measures would be required should the restaurant development be advanced prior to, or in parallel with dam improvements.

The Phase 2 supplemental staging and laydown area is anticipated to be located within the City-owned parcel west and north of the west abutment.

7.6 Access

Access to the east (Phase 3) side of the dam would be directly from the primary staging and laydown area discussed earlier. Although the City of Anoka controls some lands that would be used to access the west side of the dam, access here is anticipated to be more challenging given the proximity of commercial properties.

8 Opinion of Probable Construction Cost

This section presents an opinion of probable construction cost (OPCC) for the project, including estimate methodology/type, assumptions/exclusions, escalation, and limitations.

The OPCC represents the full project as described in Section 5 (i.e., dam safety measures, crest gates, navigation lock, recreation feature, and fish passage). The OPCC also assumes that these features are constructed together rather than sequenced/staged over several separate construction contracts. Refer to Section 10 for a discussion on staged construction.

8.1 Estimate Methodology/Type

The OPCC is based on crew development and projection rates, quotes, and unit costs. The crew costs are based upon national average union wage rates, with a judgment adjustment as necessary.

Based on AACE guidance and review of the conceptual design documents, a Class 4 estimate, with an accuracy range of +50 percent to -30 percent, was developed.

Listed below are the basis definition of an AACE Class 4 cost opinion.

- **Level of Project Definition:** Between 1 percent and 15 percent complete
- **End Usage:** Concept/Alternatives, Feasibility Study
- **Methodology:** Timberline Model Estimating, Parametric Models, Selective Deterministic, Equipment Budgets
- **Definition of Estimate:** Class 4 estimates are generally prepared based on limited information, and subsequently have wide accuracy ranges. They are typically used for alternatives or concept screening, determination of feasibility, concept evaluation,

and preliminary budget approval. Typically, engineering is from 1 percent to 15 percent complete and would comprise at a minimum the following: capacity, block schematics, indicated layout of structures and piping, sized process flow diagrams (PFDs) for main process systems, preliminary motor and instrument lists, and preliminary engineered process and utility equipment lists. Estimates may be limited to compare alternatives and not indicative of project cost.

8.1.1 Results

The costs shown in Table 8-1 are presented in 2024 dollars and include direct construction costs, contractor indirect costs, continency and owner procurement costs.

Table 8-1. AACE Class 4 Cost opinion summary

Description	Cost	
Access	$ 205,000	
Sediment Removal	$ 387,000	
Care of Water	$ 1,734,000	
Crest Gates	$ 414,000	
Recreation Vessel Lock	$ 1,480,000	
River Surfing Feature	$ 3,653,000	
Control Buildings	$ 369,000	
Construction Allowances	$ 2,580,000	
Direct Construction Costs		**$ 10,822,000**
Contractors Field Overhead @ 10%	$ 1,083,000	
Contractors General Conditions @ 5%	$ 542,000	
Contractors Bonds and Insurances @ 6.85%	$ 742,000	
Taxes @ 4.45%	$ 482,000	
Contractor Fee @ 20%	$ 2,165,000	
Total Construction Cost		**$ 15,836,000**
Construction Risk Contingency @ 10%	$ 1,083,000	
Estimate and Design Contingency @ 15%	$ 1,624,000	
Total Construction Cost + Contingency		**$ 18,543,000**
Owner Procured Rapid Blocks	$ 203,000	
Owner Procured Lock Gates	$ 1,600,000	
Owner Procured Crest Gate Systems	$ 1,144,000	
Pedestrian Bridge Cost	$ 7,300,000	
Trails and Urban Design Elements	$ 2,200,000	
Total Construction Cost + Contingency + Owner Procured Items		**$ 30,990,000**
Non-Construction Cost Allowance	$ 6,000,000	
Total Project Cost		**$36,990,000**
AACE Class 4 Accuracy Rance (-30% to +50%)		
Low Range **$25,900,000**	**High Range** **$ 55,480,000**	

8.1.2 Cost Basis

This estimate uses the following data for all pricing included. The direct costs and indirect cost percentages are based on experience, market conditions at the time of this report, and historical data.

8.1.2.1 Direct Cost Methodology

The factors considered in the direct cost and contingency estimation include the following:

- A combination of HDR Constructors database pricing, similar project costs, and historical data were used to establish direct costs.
- Labor rates include all burden and fringes.
- All labor is done on normal 8-hour days, 5 days per week, Monday through Friday.
- All labor is performed during a seasonal 6-month window from approximately June to December.

8.1.2.2 Indirect Cost and Contingency Methodology

The factors considered in the indirect cost and contingency estimation include the following:

- Contractor's field overhead (10 percent)
- Setup and removal of all temporary facilities, including contractor field office
- Equipment necessary for self-performed scopes of work
- General contractor bonds and insurance

Field general conditions include but are not limited to the following:

- Site office facilities adequate for staff required to manage the project site
- Field office staff vehicles and equipment
- Stormwater Pollution Prevention Plan (SWPPP) and minor maintenance of SWPPP measures
- Project consumables
- Temporary utilities
- Temporary facilities
- Contractor's general conditions (5 percent)

Field overhead includes but is not limited to the following:

- Field project staff and standard burden
- Procurement
- Project controls/scheduling
- Quality assurance/quality control manager
- Safety manager
- Corporate overhead
- Contractor's bonds and insurance (6.85 percent)
- Taxes (4.45 percent)
- Contractor's fee (20 percent)
- Construction risk contingency (10 percent)

- Estimate and design contingency (15 percent)
- Non-construction cost allowances include permitting, land and right-of-way acquisition (initial placeholder allowance only), site characterization, design, construction services, etc.

8.2 Assumptions/Exclusions

The assumptions used for the OPCC, and costs excluded from the OPCC, are listed in the following sections.

8.2.1 Assumptions

The following are assumptions used during development of the OPCC:

- Seasonal demobilization is considered part of the contractor's field overhead, and it is anticipated that no care of water diversion components will remain in the river over the winter.
- The location provides for sufficient laydown and staging areas.
- Facilities can be shut down by the owner as necessary to facilitate new construction.
- Any/all environmental impact studies and associated permitting will be completed by others prior to mobilization.
- Water for construction activities is available on site at no cost to the contractor.
- Bridge costs assume a 750-feet-long by 13-feet-wide bridge, and applying $500/SF with a 50-percent contingency to account for visual quality and lighting.
- Urban design elements include 1,200 LF of trails at 10-feet-wide at $100/SF with $250,000 for seat steps and a 50-percent contingency to account for visual quality and lighting.

8.2.2 Exclusions

The following are exclusions to the OPCC:

- All permits, regulatory fees, environmental fees, environmental requirements and acquisitions
- Interest during construction
- Any off-site storage facilities
- Non-construction cost allowances
- Asbestos, lead, and zebra mussel abatement
- Site security measures
- Handling/disposal of any hazardous materials, including sediment
- Extended warranty costs

- Costs associated with endangered-species mitigation or other environmental mitigation measures
- Subsurface/underwater anomalies
- Rock excavation
- Modifications to the existing dock system
- Recovered costs from scrap/recycling

8.3 Escalation

Escalation has not been evaluated at this time but can be added once a more accurate funding/ construction schedule is available. At that time, costs would be escalated to the midpoint of construction at a rate of 4.5 percent or as desired by the City.

8.4 Limitations

In addition to limitations described earlier in this report, the OPCC is based on information available to the engineer at the time of the writing of this report and the engineer's experience and qualifications. Because the engineer has no control over the cost of labor, materials, or equipment; services furnished by others; the contractor's methods of determining prices; or competitive bidding or market conditions, the engineer does not guarantee that proposals, bids, or actual project or construction costs will not vary from the OPCCs that the engineer prepares.

9 Regulatory and Permitting Considerations

This section presents regulatory and permitting considerations, including federal, state, and local permits and approvals.

9.1 Federal Permits and Approvals

Based on what is known at the time of this report, the following discussion outlines the anticipated permits and approvals that could be required at the federal level. The primary permit would be required by USACE; however, the issuance of that permit will require that additional regulatory processes be addressed.

9.1.1 United States Army Corps of Engineers (USACE)

At the direction of the City, the (recreational) navigation feature of the project was discussed with the USACE. The USACE indicated that it has no navigation authority upstream of the (former) barge terminal on the Mississippi River (just upstream of Upper St. Anthony Falls) and it was not involved with the original construction of the Rum River Dam. Therefore, USACE would have no navigation authority over a lock constructed as part of the dam project.

However, the project would require a Clean Water Act (CWA) Section 404 permit and Rivers and Harbors Act Section 10 permit. The issuance of a Section 404/10 permit by USACE requires the agency to also comply with NEPA, Section 7 of the Endangered

Species Act (ESA), and Section 106 of the National Historic Preservation Act of 1966 (NHPA).

A cursory review of the available regional general permits and nationwide permits suggests that an individual permit may be required for the project. If an individual permit is required, USACE will need to prepare a CWA Section 404(b)(1) alternatives analysis, environmental assessment (EA), or environmental impact statement (EIS) under NEPA, and a Public Interest Determination.

NEPA. Section 102 of NEPA requires all federal agencies to consider the environmental impacts of “major Federal actions significantly affecting the quality of the human environment.” An understanding of the potential impacts is intended to inform the federal decision-making process. Regulations for implementing NEPA for USACE projects, permits, and approvals are located at Code of Federal Regulations (CFR) Title 40 Parts 1500–1508 and 33 CFR 230.

Three NEPA pathways could apply to a project. First, an action could be categorically excluded (CatEx) from NEPA. In order for a CatEx to apply the project would need to meet specified conditions. An EIS is required for all major federal actions that could significantly affect the human environment. An EA is used when there is no applicable CatEx and it is unclear if the action would result in significant impacts. The result of an EA is either a Finding of No Significant Impact (FONSI) or a mitigated FONSI if mitigation is proposed to lessen an impact below significance, or the issuance of a Notice of Intent to prepare an EIS. The expected timelines for the preparation of a CatEx, EA, and EIS are 3 months, 12 months, and 24 months, respectively.

ESA: Section 7(a)(2) of the ESA requires federal agencies to ensure that its actions, including the issuance of permits, do not jeopardize the existence of threatened or endangered species or result in the destruction or adverse modification of designated critical habitat. When issuing CWA permits, USACE must consider the effects to listed species and designated critical habitat. If the proposed project would result in effects, USACE must consult with USFWS. If the project will not have impacts on listed species or designated critical habitat, USACE can make a “No Effect” determination meeting its responsibility under the ESA. No ESA-listed species are currently located in the area of the project; however, there are one proposed endangered bat species, one experimental, non-essential listed bird species, and one butterfly that is a candidate for listing. There is no designated critical habitat. It is likely that USACE could make a No Effect Determination.

NHPA: Section 106 of the NHPA, as amended (United States Code [USC] Title 54 Section 300101 et seq.) requires federal agencies to consider effects on historic properties from projects they carry out, fund, permit, or license. Acquiring federal permits is a federal undertaking and requires compliance with Section 106 of the NHPA. As the responsible federal agency, USACE will be obligated to consult with the SHPO, tribes, and other interested parties to complete the Section 106 process prior to issuance of permits.

9.1.2 Federal Emergency Management Agency (FEMA)

Per FEMA's FIS (FEMA 2015), the FIS:

> …revises and updates information on the existence and severity of flood hazards in Anoka County… and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood-risk data for various areas of the community that will be used to establish actuarial flood insurance rates and to assist the community in its efforts to promote sound floodplain management. Minimum floodplain management requirements for participation in the National Flood Insurance Program (NFIP) are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

As discussed in Section 3, this study assumes that the overall spillway capacity of the dam cannot be reduced. Notwithstanding this criterion, modification of the dam and the individual nature and totality of all improvements may require revision of the floodplain mapping via the LOMR process or other FEMA related needs, studies or processes. Per FEMA (2022):

> The map revision process revises the effective FIRM when there is an existing, proposed, or modified dam or detention basin along a flooding source…The information required to support a map revision request is summarized, but not limited to, the items below.
>
> 1. Submit completed applicable MT-2 Forms and detailed information about the dams/ basins, to include the MT-2 Form 3, Riverine Structures Form. As usual, indicate the reason for the revision request involving a dam/basin, including if the dam/basin is existing or part of the project associated with the MT-2 case. For each dam/basin, indicate what the primary purpose of the facility is.
>
> 2. Indicate the agency or organization that designed the dam/basin.
>
>   i. Indicate the name of the agency or organization responsible for permitting the dam, along with the appropriate permit or identification number for the dam.
>
>   ii. Provide related "as-built" or "proposed" drawings, specifications, and supporting design information for a local dam or a private dam.
>
> 3. Indicate if the dam/basin is regulated by the state dam safety program.
>
> 4. If the dam/basin is not regulated by the state dam safety program, submit all federal, state, and/or local regulatory and permitting information pertinent to the structure.

5. Indicate if the hydrologic analysis is revised as a result of the dam/basin and complete Form 2, Riverine Hydrology & Hydraulics Form. Any storage upstream of the dam/basin considered in the hydrologic analysis to reduce the peak base flood discharge should be dedicated to flood storage as part of the flow regulation plan or designated as floodway on the FIRM in accordance with the Floodway Analysis and Mapping, accessible through the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage. If the outflow of the dam is regulated, submit an explanation of the flow regulation plan. Provide this documentation as part of the O&M information required per Item 9, below. Provide documentation showing that the dam/ basin was designed using the critical storm duration that would yield the maximum reservoir stage or maximum volume of runoff during the design storm. Provide the regulatory BFE for the reservoir behind the dam/basin.

6. If the dam/basin has been included in previous H&H analyses completed by FEMA, indicate if any changes are being proposed.

7. In locations where sediment transport will affect the BFEs, the effects of sediment transport should be considered in the design of the dam/basin, and Section F of Form 3 should be submitted. Provide justification if sediment transport analysis is not considered for the dam/basin design.

8. Indicate if the BFEs change as a result of the dam/basin. If impacted, list the stillwater elevations behind the dam/basin in the table provided.

9. Include a copy of the formal O&M Plan and EAP if required by the regulator for the dam/ basin. For CLOMR submittals, draft versions of the plans are acceptable and need to be submitted if the plans are required by the regulator."

9.2 State Permits and Approvals

Based on what is known at the time of this report, the following discussion outlines the anticipated permits and approvals that could be required at the state level. The primary permit would be required by MnDNR; however, the issuance of that permit will require that additional regulatory processes be addressed.

9.2.1 Minnesota Department of Natural Resources (MnDNR)

The alteration of a dam and implementation of associated improvements will require a dam-safety permit issued by MnDNR. Alteration is defined as "any activity that will change or diminish the course, current, or cross-section of public waters" (Minnesota Administrative Rules Part 6115.0170 Subpart 2). Minnesota Administrative Rules Part 6115.0320 Subpart 5 defines dams that require a safety permit with several exceptions:

- **Public Waters Permit:** MnDNR regulates activities in public waters. As part of the application process for a permit to alter a dam, the applicant would submit a Public Waters Work Application on the MnDNR Permitting and Reporting System (MPARS). The applicant can use the information entered into MPARS to substitute for completing parts of the *Joint Application Form for Activities Affecting Water Resources in Minnesota* described above.
- **Minnesota Environmental Policy Act (MEPA):** For projects that "will change or diminish the course, current, or cross-section of one acre or more of any public water" a mandatory Environmental Assessment Worksheet (EAW) is required (Minnesota Administrative Rules Part 4410.4300 Subpart 27). In preparing the EAW, either MnDNR or the local governmental unit is the responsible governmental unit (RGU). If it is determined that the project would "eliminate a public water or public water wetland" then a mandatory EIS would be required (Minnesota Administrative Rules Part 4410.4400 Subpart 20). As part of the environmental review process, the RGU is required to review natural-heritage information and cultural-resources information.
- **Wetland Conservation Act (WCA):** The WCA regulates impact to wetlands that are not public waters. Because the Rum River is a public water, the WCA would not apply. Any necessary permits would be obtained through the public water permitting program described above.

The MnDNR was provided with a draft version of this report for preliminary review and comment. Appendix F includes a listing of these comments and responses from the design team.

9.2.2 Minnesota Pollution Control Agency (MPCA)

For USACE to issue the CWA Section 404 permit, the applicant must also acquire a CWA 401 Water Quality Certification . Section 401 of the CWA is intended to ensure that a federal permit is not issued that will violate state water quality standards. MPCA is the entity that issues these certifications.

The Section 401 Water Quality Certification process uses a joint state and federal application form. USACE coordinates with MPCA on application submittals. If a Section 404 individual permit it required from USACE, MPCA will request a copy of the joint application from the applicant. The applicant must also include a completed Antidegradation Assessment Form with the application.

Prior to submitting a request, there is a requirement for a 30-day pre-filing meeting with MPCA. Once the MPCA has a complete request, it must make its decision in a "Reasonable Period of Time," which USACE typically sets at 120 days. MPCA can request an extension; however, a decision is required within one year or MPCA waives its 401 authority over the project. USACE cannot issue a 404 permit until a certification is received or waived. MPCA cannot issue 401 certification prior to the conclusion of environmental review. The MPCA can waive its authority, certify the project, or deny a certification. Certification of a project will typically include measures to ensure water quality standards are met.

Section 402 of the CWA established the National Pollutant Discharge Elimination System (NPDES) allowing permits for the discharge of pollutants into navigable waters. MPCA issues this permit for construction-related stormwater runoff. MCPA has combined the NPDES program with the State Disposal System (SDS) permit program and issues a combined NPDES/SDS construction stormwater permit. Permit applications require the inclusion of a SWPPP. Additional permitting may also be required if the project results in dredging the river and dredge material storage.

9.3 Local Permits and Approvals

Based on what is known at the time of this report, the following discussion outlines the anticipated permits and approvals that could be required at the local level. Additional permits and approvals may be required once the project is better defined and initially designed.

9.3.1 Lower Rum River Watershed Management Organization

The LRRWMO issues permits for any project affecting the course, current, cross section, or quality of surface-water features. Specifically, a Grading, Stormwater Management, and Erosion/Sediment Control permit may be required.

9.3.2 Anoka County

Construction activities may require local county permits. For example, the use of any oversized loads transported on Anoka County roads would require a transportation permit.

9.3.3 City of Anoka

For the placement of fill, City Code section 78-473 will requires a conditional use permit (CUP). The City of Anoka will have to issue itself a CUP which would require planning commission approval, public hearing and City Council approval.

10 Development Schedule

Section 7.4 of this report discusses two basic approaches to the project. One assumes that all proposed dam features are incorporated in a single general construction contract. The other assumes that dam features are constructed over a longer period of time via multiple general construction contracts.

A high-level initial development schedule is presented on Figure 10-1. This represents the single construction contract approach. A more detailed schedule will be prepared in later phases of design. The schedule assumes the following:

- Early consultation with regulatory agencies to determine what, if any, field studies may be required to support the various permitting processes.
- The two procurement contracts (crest gates and miter gates) would be executed by the City and later assigned to the general contractor. Limited notices to proceed (LNTPs) would be issued to the original equipment manufacturers (OEMs) for design

activities to support overall project design. These LNTPs would be issued in advance of receipt of required construction permits.

- The City would execute a single general construction contract. This would be a conventional design-bid-build contract as opposed to engineer-procure-construct or other alternative delivery type contract.
- Construction will take approximately 2 years to allow for winter downtime.

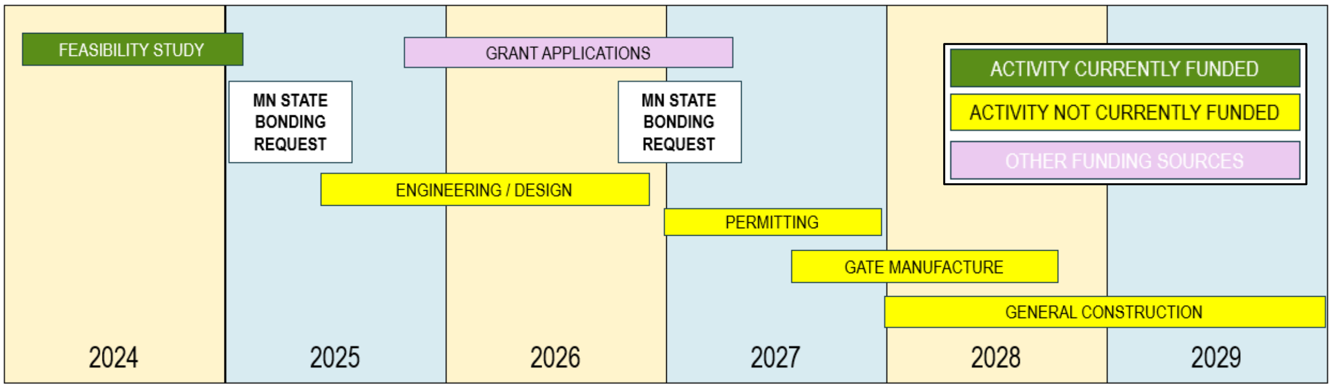


Figure 10-1. Preliminary development schedule

11 Funding Opportunities

This section presents funding opportunities for the project as generally understood at the time of this report (others may exist, others may surface, and others may cease to exist), including federal government programs and grants, environmental and recreational funding opportunities, bond financing and state support, and a summary. Note, these and other funding opportunities may be affected by prevailing or future legislation, policy or other considerations and should be closely examined at the time of detailed consideration.

11.1 Federal Government Programs and Grants

The Rum River Dam project incorporates critical infrastructure enhancements including spillway gate replacement, vessel passage, fish passage, and whitewater recreation. To finance these elements, the following federal programs and grants align well with the project's diverse scope and should be considered:

- **FEMA Hazard Mitigation Assistance (HMA) and Building Resilient Infrastructure and Communities (BRIC) programs:** FEMA's HMA and BRIC programs are highly relevant for projects aimed at disaster mitigation and flood control. For example, the installation of spillway gates to mitigate flood risks and manage water levels aligns well with FEMA's objectives. The Flood Mitigation Assistance (FMA) program is particularly suitable if the project is designed to reduce long-term flood risks to structures insured under the NFIP. In fiscal year 2023, FEMA allocated $800 million to the FMA program. Additionally, if the dam upgrades enhance resilience against flooding or other natural hazards, the BRIC program could also provide support. BRIC funding for 2023 totaled $2.3 billion, focusing on large-scale infrastructure projects that mitigate disaster risks and improve community resilience.

- **U.S. Environmental Protection Agency's (EPA's) water infrastructure programs:** EPA's Water Infrastructure Finance and Innovation Act (WIFIA) provides long-term, low-cost financing for water management infrastructure projects. This funding could be used for upgrades to the Rum River Dam, including spillway gate replacements and water flow management improvements. The WIFIA program has supported similar projects, such as the San Francisco Public Utilities Commission's dam upgrades, highlighting its potential for financing significant infrastructure improvements.
- The **Energy Infrastructure Reinvestment (EIR) category of the Title 17 Clean Energy Financing Program,** created by the IRA (as it exists at the time of this report), offers funding opportunities for projects that repurpose, retool, or replace energy infrastructure, including facilities that have ceased operations or need upgrades to reduce emissions. This program could be relevant to the City of Anoka's Rum River Dam project by potentially funding clean energy improvements or replacements related to the dam's infrastructure, especially if the project aims to reduce air pollutants, use legacy energy sites, or repurpose the existing infrastructure for environmental and community benefits. This aligns with efforts to enhance the dam's operational efficiency and support sustainability goals in the region.
- The **Boating Infrastructure Grant Program (BIG)**, provides funds for tie-up facilities and support facilities for transient vessels greater than 26 feet in length for stays of up to 15 days. The recreational vessel passage system could be considered a support facility, to the city's existing dock system. The design vehicle for the project satisfies the grant requirements, and the program aligns with goals of the city to strengthen transient boater ties, increase the economic benefit of transient boaters in downtown Anoka, and provide safe harbor for transient boaters.
- The **Corps Water Infrastructure Financing Program,** created by the U.S. Army Corps of Engineers focuses on providing loans for safety projects to maintain, upgrade, and repair non-Federal dams. The program provides below-market interest rates, spreading the repayment of initial investment costs across the useful life of the asset. Project Initiation, design, and construction are all eligible costs.

11.2 Environmental and Recreational Funding Opportunities

The ecological focus of the Rum River Dam project, specifically its fish passage and recreational features, opens additional avenues for environmental and recreational funding:

- The **Lessard-Sams Outdoor Heritage Council (LSOHC)** is a potential funding source for the fish passage component of this project. The City Council, through the Outdoor Heritage Fund (OHF), supports projects focused on the restoration, protection, and enhancement of habitats for fish, game, and wildlife. With the Anoka Conservation District strongly backing the fish passage, the project is well-positioned for an OHF application. A nature-based aesthetic design would likely increase the project's chance of securing funding, as it aligns with OHF's priorities for ecological restoration. Though grant applications are never guaranteed funding, Anoka County has successfully ushered two phases of funding for Rum River Enhancement through the OHF process with potential for more. OHFs are allocated by the State Legislature following a recommendation by the LSOHC. Applications are due in the summer of each year.

- The whitewater recreation element qualifies the project for funding through the **Recreational Trails Program (RTP)** and the **Land and Water Conservation Fund (LWCF)**, both of which support outdoor recreation development. These programs could help finance construction of the whitewater recreation channel, promoting regional tourism and water-based activities such as kayaking.
- The **Interagency Fish Passage Program**, funded through the Bipartisan Infrastructure Law, has various grant programs that are applicable to upgrades that also vary in grant size. The program focuses on removing barriers to fish migration and restoring aquatic habitats; grants from this initiative could support the fish passage component of the Rum River Dam improvements. By applying, the City may be able to secure funding for environmental restoration, aligning with the project's goals for both ecosystem recovery and community recreation.
- The Minnesota Pollution Control Agency (MPCA) offers **Local Climate Action Grants** to support planning and implementation projects that help local jurisdictions adapt to extreme weather events and reduce their contributions to climate change. Eligible projects include climate resilience planning, infrastructure upgrades, and community programs aimed at reducing greenhouse gas emissions. The grants focus on enabling local governments to address climate challenges proactively. Local Climate Action Grants are a cost-effective way for communities to finance initiatives that align with state climate goals, fostering sustainable and adaptive practices at the local level.
- **Geothermal Planning Grants** provide financial assistance to assess the technical and economic feasibility of installing geothermal energy systems. Available statewide, these grants help eligible applicants, such as local governments and institutions, explore renewable energy solutions that reduce reliance on traditional energy sources. Grant funds can be used for feasibility studies, energy modeling, and site assessments. By supporting the early planning stages, Geothermal Planning Grants enable communities to transition to clean, efficient energy systems while promoting long-term cost savings and sustainability.

11.3 Bond Financing and State Support

Additionally, tax-exempt revenue and general obligation bonds present options for financing.

- The Minnesota **Clean Water State Revolving Fund (CWSRF)** could be a valuable funding option for the Rum River Dam project, especially if components of the upgrade contribute to improving water quality or stormwater management. By enhancing fish passage, restoring natural water flow, or reducing pollutants in the water, the project could align with the CWSRF's mission to protect and restore water resources. Additionally, the CWSRF offers low-interest loans with favorable repayment terms, making it a cost-effective way for the City to finance portions of the project that focus on environmental benefits, such as improved water quality and ecosystem health.

- The **Minnesota State Bonding Program** could be a valuable funding option for the Rum River Dam project, particularly for components that ensure public safety, environmental protection, and infrastructure resilience. State bonding works by issuing bonds to fund public infrastructure projects, with allocations determined by the state legislature through bonding bills typically passed every two years. Projects are evaluated based on statewide significance and their alignment with public interests, such as safety, environmental stewardship, and economic development. Eligible projects like dam repairs, flood mitigation, and ecological enhancements—such as fish passage and improved water flow—can receive substantial financial support, often ranging from several hundred thousand dollars to multi-million-dollar appropriations, depending on the project's scope and urgency. Since state bonding provides funding through direct appropriations rather than loans, it offers a cost-effective way for the City to finance critical upgrades and align with state priorities for sustainable water management.
- The **Outdoor Recreation Grant** is a DNR grant program provides matching funds, for local parks, and outdoor recreation areas, Minnesota Statutes 85.019, subd. 2. The pedestrian bridge, and river recreation have been identified as a project element that could fit under these funds.
- **The Outdoor Heritage Fund,** and **Environment and Natural Resources Trust Fund** are both funding sources that could be used to fund a portion of the proposed fish ladder. The programs use an application process that opens up in the spring, for two fiscal years ahead, i.e., application in calendar year 2025, for funding in state fiscal year 2027.
- The **Outdoor Recreational Opportunities for Underserved Communities Account,** within the **Natural Resources Fund** may also be an opportunity for project funding. Funds may be applied to projects and activities that connect diverse and underserved Minnesotans through expanding cultural environmental experiences, exploration of their environment, and outdoor recreational activities. The river recreation element of this project has been identified as potentially viable for these funds.
- The **DNR Water Recreation Account,** is another source of state funding for public water access, and boating facilities on public waters. These funds have not been used for recreational navigation in the form of a lock in the past, but the recreational navigation portion of the project may technically be an applicable project, despite the type of project being different than typical projects funded from this source.

Table 11-1 below further details potential funding sources for the project recognizing that other opportunities may exist and does not represent success or outcome of any funding the City may elect to pursue. Details are based on publicly available information when the list was compiled.

HDR prepared a Project information handout/ flyer for use by the City to inform Minnesota State legislators and to with funding solicitations, i.e. Federal and State grant applications. The flyer is included in Appendix G.

Table 11-1. Summary of potential funding sources at the time of this report

Program	Description	Grant Award	Potential projects	Matching requirements	Applications Due	Funding cycle	Eligible Activities
Dam Safety Grants | Minnesota DNR	The Dam Safety Grant Program funds the repair, reconstruction, or removal of dams, focusing on safety and ecological restoration. Priority is given to projects on the DNR's high-need list, submitted biennially to the legislature. These grants enhance safety, mitigate flood risks, and support environmental sustainability, ensuring long-term functionality and protection for Minnesota's water infrastructure.	Amounts range from $25,000 to $1,000,000	Grants to local units of government may be made for dam repair, reconstruction, or removal.	50% for repairs and up to 100% for removals.	Application is ongoing and no specific guideline. Entities should contact their area hydrologist of State Dam Safety Engineer	Annual	Construction
LCCMR	Provides funding for projects that protect, conserve, preserve, and enhance Minnesota's natural resources.	Varies; determined by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).	Natural resource protection and enhancement projects, including research, habitat restoration, and environmental education.	No specific match requirement, but matching funds can strengthen proposals.	Request for proposals typically issued in January; proposals due in March.	Annual; subject to legislative appropriation.	Planning Environmental Final Design Construction
Public Water Access Sites - Partnership Funding | Minnesota DNR	The Water Recreation Account funds the development, maintenance, and rehabilitation of public water access and boating facilities. These projects enhance safe recreational navigation and access to Minnesota's waterways. While traditionally used for conventional boating projects, this funding source also supports innovative initiatives that promote sustainable recreational use and protect natural water resources for future generations.	Depends on project size	Public water access, boating facilities, lake and river improvements, boat and water safety.	Depends per project	Need to contact nancy.stewart@state.mn.us	Annual	Planning Environmental Final Design Construction
Clean Water Revolving Fund / Public Facilities Authority	The Minnesota CWSRF offers low-interest loans for wastewater treatment upgrades, nonpoint source pollution control, and other water-related projects. By supporting the construction and improvement of water infrastructure, the program enhances Minnesota's water quality. Municipalities and organizations benefit from an affordable financing mechanism to implement projects that protect public health, preserve water resources, and ensure environmental sustainability.	Depends on project size, ranking, and availability	Wastewater, pollution control, green infrastructure, stormwater management	Non-federal match at least 20% of the total project cost.	Project Priority List (March 26)/ Intended Use plan (June 6)/Loan Application (December 6)	Annual	Planning Environmental Final Design Construction O&M
Outdoor Recreation Grant Program | Minnesota DNR	The Outdoor Recreation Grant Program provides matching funds for acquiring, developing, and redeveloping local parks and recreation areas. Funded projects often include pedestrian bridges, park enhancements, and river recreation improvements. These initiatives aim to expand recreational access, preserve green spaces, and foster vibrant communities by improving outdoor opportunities for residents and visitors.	$350,000	Park acquisition, development/redevelopment, internal park trails, picnic shelters, playgrounds, athletic facilities, boat accesses, fishing piers, swimming beaches, campgrounds	50% local match	March 31, 2025	Annual	Planning Environmental Final Design Construction
Boating Infrastructure | U.S. Fish & Wildlife Service	Provides grants to states for the construction, renovation, and maintenance of boating facilities. Divided into Tier I (up to $200,000 per state) and Tier II (competitive grants up to $1.5 million per project).	Tier I: $200,000 per state; Tier II: $1.5 million per project	Dock construction and renovation, mooring buoys, restrooms, utilities, navigational aids, waste disposal facilities, and other amenities improving transient boater access.	25% match of total project cost (minimum).	Varies, would need to reach out to MN DNR	Annual funding cycle, with applications typically due mid-year.	Planning Environmental Final Design Construction
LSOHC	The LSOHC provides annual recommendations for funding habitat restoration, wetland and prairie enhancement, and forest protection projects. The council ensures alignment with Minnesota's Constitution and state laws while addressing conservation goals, such as preventing forest fragmentation and encouraging prairie restoration. The program emphasizes habitat improvement for fish, game, and wildlife, fostering sustainable environmental stewardship and long-term ecological benefits.	No maximum	Projects that directly relate to the restoration, protection, and enhancement of wetlands, prairies, forests, and habitat for fish, game, and wildlife, and that prevent forest fragmentation, encourage forest consolidation, and expand restored native prairie	No requirement, but 10% match usually expected	Typically around April/May, but hasn't been confirmed for 2025	Annual	Environmental Final Design Construction
Community-Based Habitat Restoration | NOAA Fisheries	The NOAA Habitat Restoration Program funds projects to restore coastal habitats affected by hydropower infrastructure. Key goals include removing barriers to fish migration, enhancing fish passage, and improving habitat connectivity. Projects may involve dam removal, ecosystem restoration, and fish ladder installation. These efforts aim to rebuild biodiversity, support sustainable ecosystems, and address the ecological impacts of waterpower operations on coastal environments.	$100,000 to $15 million	Dam removals, fish passage improvements, barrier removal and habitat reconnection, ecosystem restoration, hydropower mitigation	Non-federal match of 50%	April 16, 2025	Varies per grant program	Planning Environmental Final Design Construction O&M
Minnesota's Capital Budget / Minnesota Management and Budget (MMB)	Minnesota State Bonding provides direct funding for statewide projects, including dam repairs, flood mitigation, and fish passage improvements. Bonding funds are allocated through legislative bills and can range from thousands to millions of dollars. This funding mechanism allows municipalities to finance critical water infrastructure upgrades while ensuring safety, sustainability, and public benefit. The program is a cost-effective way to address urgent infrastructure needs.	Depends on project size	Public safety, environmental protection, and infrastructure resilience	Typically range from 10% to 50% or more of the total project cost.	Historically even numbered years through the legislative session	Bi-Annual to align with the states budget cycle (even years).	Environmental Final Design Construction

Program	Description	Grant Award	Potential projects	Matching requirements	Applications Due	Funding cycle	Eligible Activities
Land and Water Conservation Fund (U.S. National Park Service)	The Land and Water Conservation Fund supports acquiring land and developing recreational facilities to enhance parks, forests, and outdoor spaces. In Minnesota, the program has funded over $81 million in projects, improving trails, parks, and public access to nature. LWCF prioritizes resource preservation, public access, and sustainable outdoor recreation, ensuring benefits for both current and future generations.	Range from $250,000 to maximum $5 million	Boat ramps and launch areas, recreational trail, canoe/kayak access, and habitat restoration and green infrastructure	50% of total project cost	March 31, 2025	Annual	Planning Environmental Final Design Construction
CWIF Program Eligibility	The CWIFP offers long-term, low-cost credit for water resource projects, focusing on dam safety and infrastructure resilience. This program helps municipalities address critical water infrastructure needs, ensuring safe, reliable systems that protect public health. By supporting cost-effective upgrades, CWIFP contributes to sustainable community development and long-term environmental benefits.	$20 million minimum	Dam safety and structural improvements, fish passage improvements, hydropower generation, climate resilience and flood mitigation	49% of project costs	Historically late fall/early winter. 2025 has not been specified.	Rolling application	Planning Environmental Final Design Construction O&M
Federal Recreational Trail Program | Minnesota DNR	The Minnesota Recreational Trail Users Association annually prioritizes funding categories prior to the solicitation process. Projects that involve urban youth corps workers such as the Conservation Corps Minnesota & Iowa opens in a new browser tab (CCMI) will be given special consideration.	$2,500 to $200,000	All projects must be sponsored by a unit of government, preferably in cooperation with a local trail organization.	25% cash or in-kind match	February 28, 2025	Varies	Planning Environmental Final Design Construction
Water Infrastructure Finance and Innovation Act (WIFIA) | US EPA	The WIFIA program provides low-interest loans for innovative water infrastructure projects. Eligible projects focus on improving water quality, enhancing resilience, and ensuring sustainability. By providing flexible and affordable financing options, WIFIA supports municipalities in addressing critical water needs and implementing solutions that promote long-term water security for their communities.	Loans can cover up to 49% of a project's eligible costs. Loans typically range from $20 million to $1 billion, depending on the size and scope of the project.	Water supply, wastewater treatment, stormwater management, recycling and reuse, infrastructure upgrades	Requires a minimum non-federal match of 51% of the total project cost. This match can include both cash contributions and in-kind services.	Must submit LOI on a rolling basis, no fixed annual deadline	Annual	Planning Environmental Final Design Construction
Building Resilient Infrastructure and Communities | FEMA.gov	BRIC provides funding for projects that reduce risks from natural disasters, such as floods, hurricanes, and wildfires. The program emphasizes community resilience, disaster preparedness, and climate adaptation. By supporting mitigation efforts, BRIC helps reduce damages, protect public safety, and enhance sustainable development in vulnerable areas facing climate-related and geological hazards.	Varies on project type	Broadband, dams, road and bridge improvement, earthquake retrofit, drought aquifers	Up to 75%	April 18, 2025	Annual	Planning Environmental Final Design Construction O&M
Closed: Local climate action grants | Minnesota Pollution Control Agency	Local Climate Action Grants, offered by the MPCA, support climate resilience and adaptation projects in local communities. These grants fund infrastructure upgrades, planning efforts, and programs to reduce greenhouse gas emissions and address extreme weather impacts. By enabling jurisdictions to align with Minnesota's climate goals, the program fosters sustainable development, mitigates environmental risks, and enhances public health and safety through innovative solutions.	Depends on project size. Total funding goes around $3 million.	Climate resilience planning, infrastructure upgrades, green infrastructure	Planning Grants: Local jurisdictions with populations under 20,000 must provide a 5% match (in-kind or cash). Jurisdictions with populations over 20,000 need to provide a 50% cash-only match. Implementation Grants: The match for planning grants applies similarly, with the 5% or 50% cash match depending on population size	Expected January 2026	Annual	Planning Environmental Final Design Construction O&M

12 Recommended Next Steps

Should the decision be made to advance the design of Rum River Dam improvements, it is recommended that the following activities be considered:

- **Tailwater rating and overall hydraulic modeling:** Design and construction of the dam improvements warrant verification of the tailwater rating curve, refined tailwater analyses, and feature specific hydraulic modeling
  - Verification of the tailwater rating curve can be achieved through a tailwater measurement program that would involve periodic recording of tailwater elevations and river flows. USGS may be willing to participate in this exercise.
  - Refined tailwater analysis can be achieved through more robust hydraulic modeling of the dam and downstream channel to capture interactions between the new features (whitewater channel, fish passage, lock, temporary cofferdam, etc.). It is recommended that advanced hydraulic modeling (two-dimensional or three-dimensional) be calibrated against tailwater measurements and then used to model project impacts.
  - Lastly, overall hydraulic modeling of each component and the composite system of the Rum River Dam improvements could prove beneficial in supporting and may prove necessary for detailed design efforts.
- **Dam and topographic survey:** Although quality light detection and ranging (LiDAR) data exist for the dam area, advancement of design and construction drawing development will require a more accurate baseline survey. The survey would include the following:
  - Precise dimensions and elevations of key dam elements
  - Confirm or establish applicable vertical datum
  - Upstream and downstream bathymetry
  - Topography of lands adjacent to the dam
  - Location and dimensions of existing structures and utilities
  - Property boundaries and easements
- **Detailed Hydrologic Investigation:** As the hydrologic analysis included in this study is based off of FEMA data from 2015, a detailed hydrologic analysis is recommended. Increased confidence in the site hydrology will improve the design. This study would likely be an extended period of recording flow data at the dam at a sub-daily interval. Automated devices are available to record this data.
- **Geotechnical investigation:** Advancement of dam improvements design will require completion of a geotechnical investigation program following by development of a Geotechnical Interpretive Report (GIR). The investigation program will likely consist of a series of borings, piezometers, and geophysical surveys followed by laboratory testing and preparation of a Geotechnical Data Report (GDR). The GDR will include boring logs, test pit logs, piezometer construction logs, field and laboratory test data/plots, results of geophysical surveys, and photographs of recovered core

samples. It is recommended that a preliminary budget of $150,000 be allotted for the geotechnical investigation.

- **Sediment Analyses:** Collection and laboratory testing of river sediment samples and sediment transport analyses.
- **Regulatory outreach and Stakeholder outreach strategy:** Facilitate a meeting with regulators to solicit initial thoughts and concerns with the project. Assemble a prospective list of environmental field studies that may be required and execute studies as needed. Also, it may prove beneficial to develop a strategic communications plan to facilitate effective stakeholder engagement as the process unfolds.
- **Preliminary Design for Project Phasing:** Based on the Senate Capital Investment Meeting held in October 2024, preliminary plans should consider a phased construction approach, i.e., based on available funding and to allow for cost management over time.

13 References

This section presents references used in development of this report.

13.1 References Cited in This Study

Anoka (City of Anoka)

2023 “Notification to Manage Dredged Material Without a Permit (for Rum River between Rum River Dam and Madison Street),” October 2.

Anoka County Historical Society

2024 MN Collections - Minnesota's Local History Database : Member Institution : Anoka County Historical Society [malhm_anoka]

Barr (Barr Engineering Co.)

1963 “Reconnaissance Report No. 2 to the City of Anoka, Minnesota – Effects of Abandonment of the Rum River Dam,” February 5.

1968a “Construction Plans – Rum River Dam.”

1968b “Specifications for the Construction of the Rum River Dam,” December.

1972 “Operations and Maintenance – Rum River Dam,” published March 16, revised July 28.

2023 “2023 Dam Inspection Report – Rum River Dam,” November.

Braun (Braun Intertec Corporation)

2008 “Results of Sediment Sample Collection and Testing – Rum River Recreation Channel” (prepared for Hakanson Anderson Associates, Inc.), March 10.

BTS (Bettenburg, Townsend and Stolte Architects and Engineers)

1954 “City Hall – Anoka, Minnesota” (construction drawings).

EPA (U.S. Environmental Protection Agency)

2024 Data Explorer. https://www.epa.gov/egrid/data-explorer.

FEMA (Federal Emergency Management Agency)

2015 "Flood Insurance Study – Anoka County, Minnesota and Incorporated Areas (Volumes 1 and 2)," December 16.

2022 "Guidance for Flood Risk Analysis and Mapping - Dams/Reservoirs and Non-Dam Features," November.

FERC (Federal Energy Regulatory Commission)

2024 "Engineering Guidelines for the Evaluation of Hydropower Projects."

Fischer, P.A.

1993 "Rum River Dam – Preliminary Assessment – Small Recreational Craft Navigation Lock," July.

HA (Hakanson Anderson)

1999 "Flood Elevation Data – Mississippi River at Rum River," May 25

2012 "2012 Sanitary Sewer Lining Project – City of Anoka" (construction plans), April 14.

2019 "Bridge Elevation Exhibits for City of Anoka," June 10.

Kimley-Horn

2016 Construction Plans for Grading, Bituminous Pavement, Curb and Gutter, ADA Improvements, Utility Improvements and Landscaping – City Hall North Parking Lot, 2016.

Legend (Legend Technical Services, Inc.)

2023 "Letter to Haugo Geo Technical Services, LLC re Analytical Services (related to Rum River sediment sampling)," September 13.

MCD (Minnesota Conservation Department: Division of Waters, Soils and Minerals)

1969 "Permit to Change the Course, Current, or Cross Section of Rum River, Anoka County," March 18.

MnDNR (Minnesota Department of Natural Resources: Division of Ecological Resources Stream Habitat Program)

2010 "Reconnecting Rivers: Natural Channel Design in Dam Removals and Fish Passage (Volumes 1 and 2)," January.

2024 Web site: https://www.dnr.state.mn.us/areas/fisheries/eastmetro/rivers/rum.html

MnDOT (Minnesota Department of Transportation)

2001 Construction Plans for Reconstruction, Widening, Retaining Walls, Signing, Lighting, and Traffic Signals – T.H. 169 From Bridge No. 4380 to T.H. 10 in Anoka, January.

Mossler, J.H.

1992 Sedimentary rocks of Dresbachian age (Late Cambrian), Hollandale embayment, southeastern Minnesota: Minnesota Geological Survey Report of Investigations 40, 71 p

MPCA (Minnesota Pollution Control Agency)

2007 "Managing Dredged Material in the State of Minnesota," last updated 2024.

NREL (National Renewable Energy Laboratory)

2022/2023 Solar Installed System Cost Analysis.

Office of Energy Efficiency & Renewable Energy

2024 Geothermal Heat Pumps. https://www.energy.gov/eere/geothermal/geothermal-heat-pumps

ORNL (Oak Ridge National Laboratory)

2012 "ORNL/TM-2012-501 – Small Hydropower Cost Reference Model," October.

Q.Cells

2024Q.PEAK DUO XL-G10.2 (datasheet).

Runkel, A.C., McKay, R.M., and Palmer, A.R.

1998 Origin of a classic cratonic sheet sandstone: Stratigraphy across the Sauk II-Sauk III boundary in the upper Mississippi valley: Geological Society of America Bulletin, v. 110, pp. 188–210.

S-5!

2024 Solar Mounting Brackets and Systems.

SAFHL (University of Minnesota – St. Anthony Falls Hydraulic Laboratory)

1982 "Hydropower Feasibility at the Rum River Dam in Anoka, Minnesota," August.

Setterholm, D.R.

2013 C-27 Geologic Atlas of Anoka County, Minnesota [Part A], Minnesota Geological Survey, Scale 1:100,000

Soil Engineering Services

1966 66-125 Soil Borings, Rum River Dam, Anoka, Minnesota, Prepared for Mr. Robert B. Johnson, PE, City Engineer, City Hall, Anoka, Minnesota, August 31.

1968a 66-125 Additional Soil Borings, Rum River Dam, Anoka, Minnesota, Prepared for Mr. Robert B. Johnson, PE, City Engineer, City Hall, Anoka, Minnesota, June 25.

1968b 66-125 Additional Soil Borings, Rum River Dam, Anoka, Minnesota, Prepared for Mr. Robert B. Johnson, PE, City Engineer, City Hall, Anoka, Minnesota, August 14.

Soil Exploration Company

1962 "Soil Borings - Proposed Dam Repair – City of Anoka," April 2.

Stanley (Stanley Consultants)

1996 "Evaluation Report – Rum River Dam," October.

1997 "Port of Anoka Dock Access and Mooring System (construction plans)," December 18.

2002 "Rum River Dam Hydroelectric Project Reconnaissance Study (Draft)," December.

Stantec

2016 Construction Plan for Grading, Aggregate Base, Concrete Pavement, Lighting, Landscaping, Signing and Related Appurtenances – Rum River Regional Trail from Main Street to Anoka Metro Regional Treatment Center, May.

State of Minnesota

2024 Minnesota Administrative Rules.

Thermco Energy Systems

2024 Geothermal Copper Heat Exchanger https://thermcoenergysystems.com/product_copper_lake_pond_river_heat_exchanger.html

USACE (United States Army Corps of Engineers)

2005 "EM 1110-2-2100 – Stability Analysis of Concrete Structures," December 1.

2024 "National Inventory of Dams" https://nid.sec.usace.army.mil/#/.

USGS (United States Geological Survey)

2024a "National Water Information System - Minnesota water conditions - USGS Water Data for the Nation

2024b "StreamStats" (StreamStats | U.S. Geological Survey (usgs.gov)).

13.2 Additional References

Barr (Barr Engineering Co.)

1962 "Reconnaissance Report to Anoka, Minnesota – Restoration of Rum River Dam," July 10.

1967a "Preliminary Design – Rum River Dam," January.

1967b "Preliminary Design – Rum River Channel Improvement," July.

Marohn, K.

2024 "Go with the flow: Minnesota towns see success replacing aging dams with rock rapids." Minnesota Public Radio, July 3.

MnDNR (Minnesota Department of Natural Resources)

2023 "Dam Inspection Report – MN00549, Anoka, MN," May 23.

SAFHL (University of Minnesota: St. Anthony Falls Hydraulic Laboratory)

1981 "Brief Analysis of Hydropower Potential at the Rum River Dam MN00549 in Anoka, MN," March 17.

Appendix A

Project Background

Appendix A1

1968 Construction Drawings

CONSTRUCTION PLANS

RUM RIVER DAM

ANOKA, MINNESOTA

MAYOR DONALD K. ELVIG

CITY COMMISSIONERS

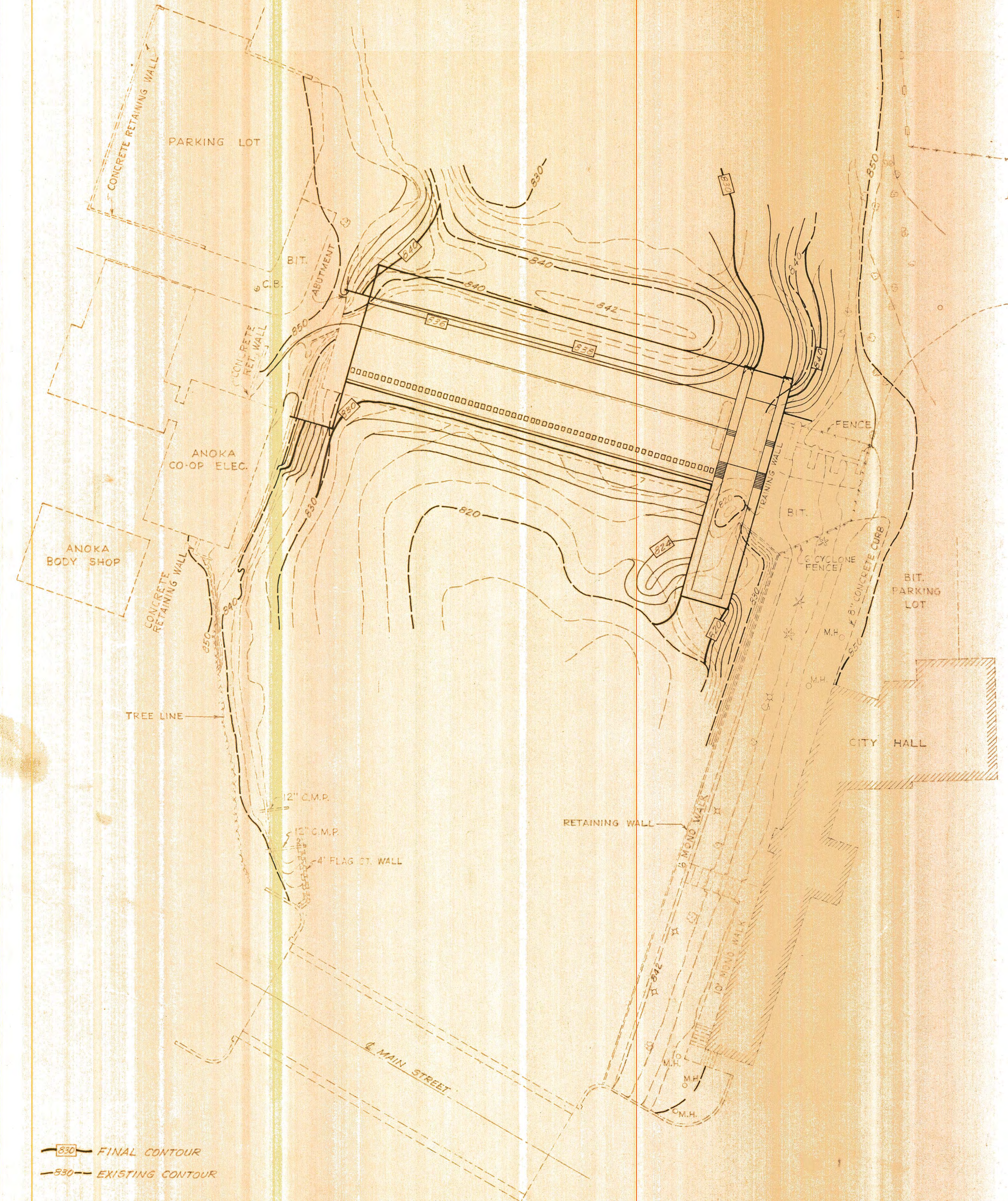
MRS. MARSHALL WAY THOMAS E. WILBERG

LEON DEHEN JERRY E. JACOB

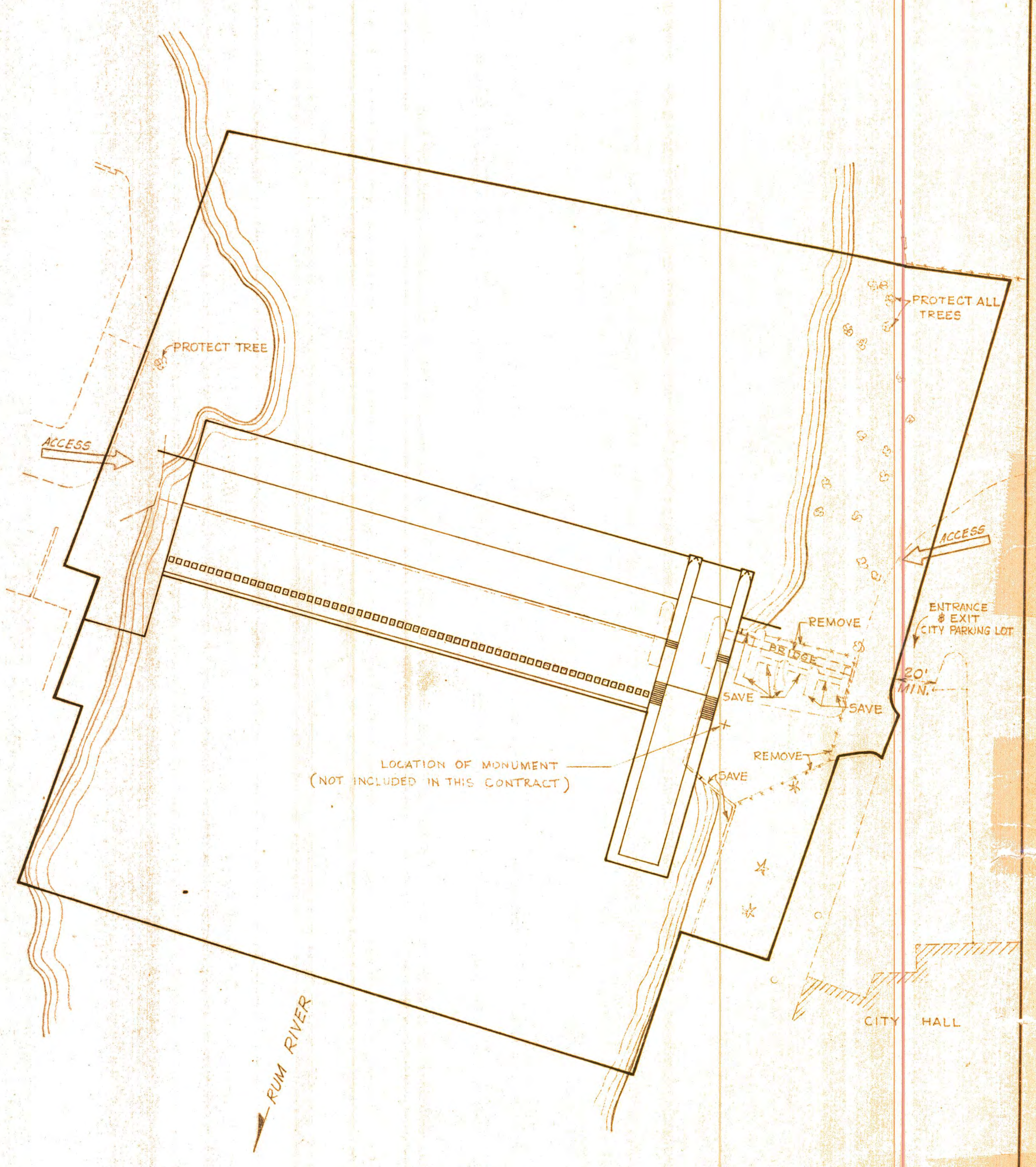
CITY MANAGER S. C. GESKO, JR.

CITY ENGINEER ROBERT B. JOHNSON

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
1968



LOCATION AND GRADING PLAN



CONSTRUCTION LIMITS

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

Douglas W. Barr

DATE 12-9-68

REG. NO. 3615

REVISIONS

SCALE: 1" = 40'

DWN. BY: J. M.

DATE: 11-8-68

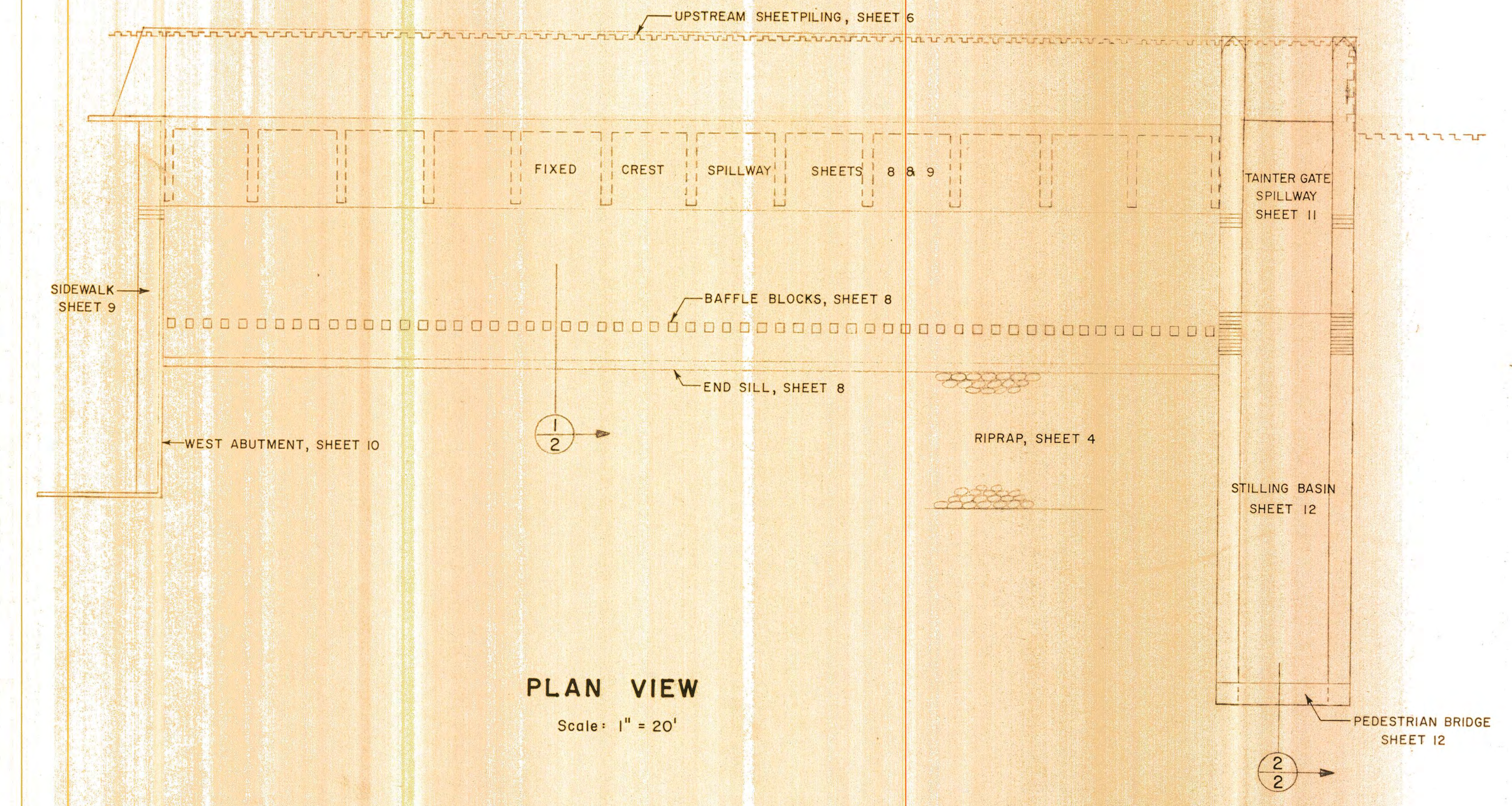
DWG. NO.: 23/2-40042

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

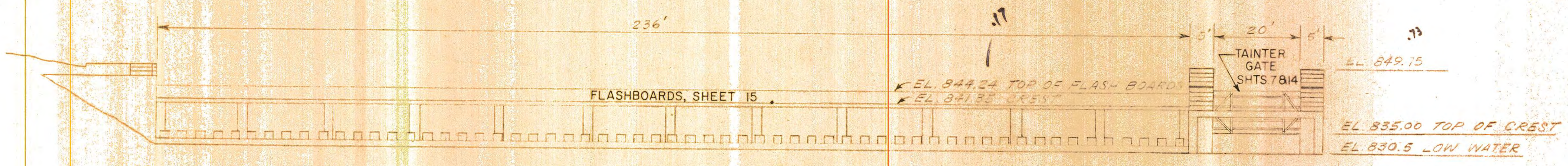
RUM RIVER DAM
LOCATION PLAN

SHEET N[illegible] 1



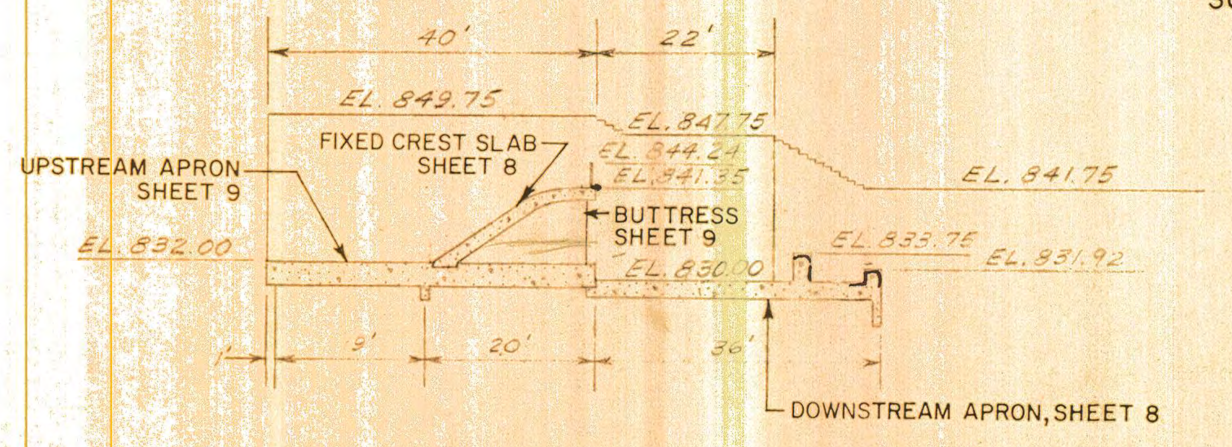
PLAN VIEW

Scale: 1" = 20'



DOWNSTREAM ELEVATION

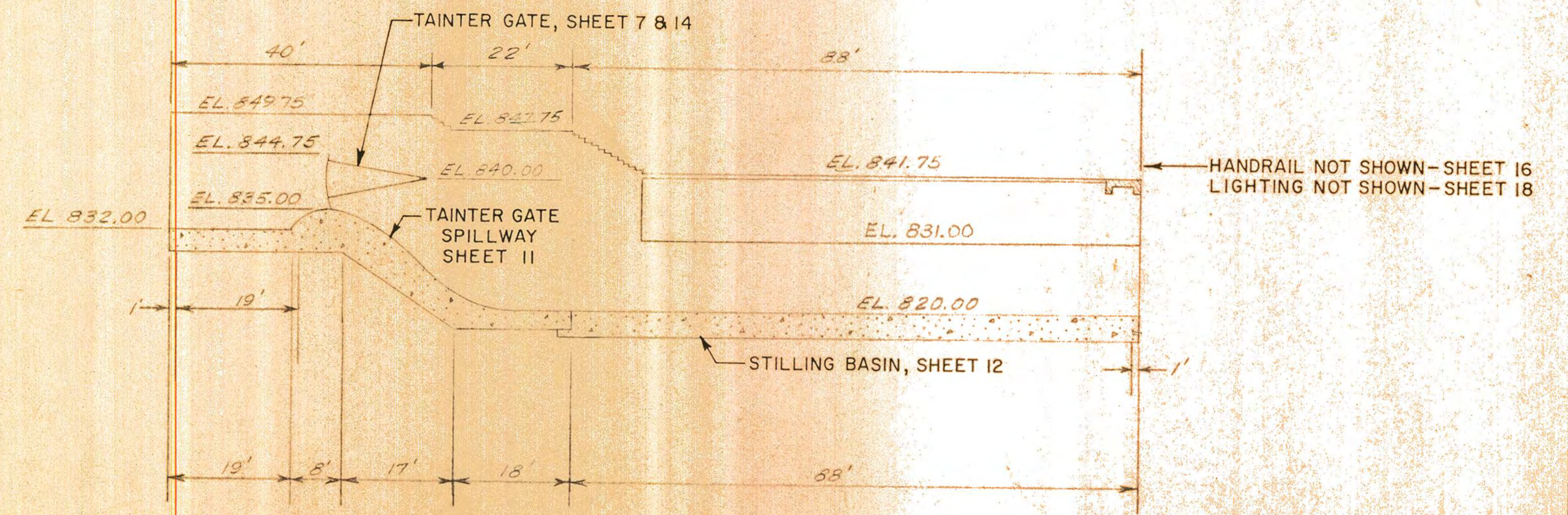
Scale: 1" = 20'



1/2 SECTION

FIXED CREST SPILLWAY

Scale: 1" = 20'



2/2 SECTION

Scale: 1" = 20'

TAINTER GATE SPILLWAY

INDEX

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

Douglas W. Barr

DATE 12-9-68

REG. NO. 3615

REVISIONS

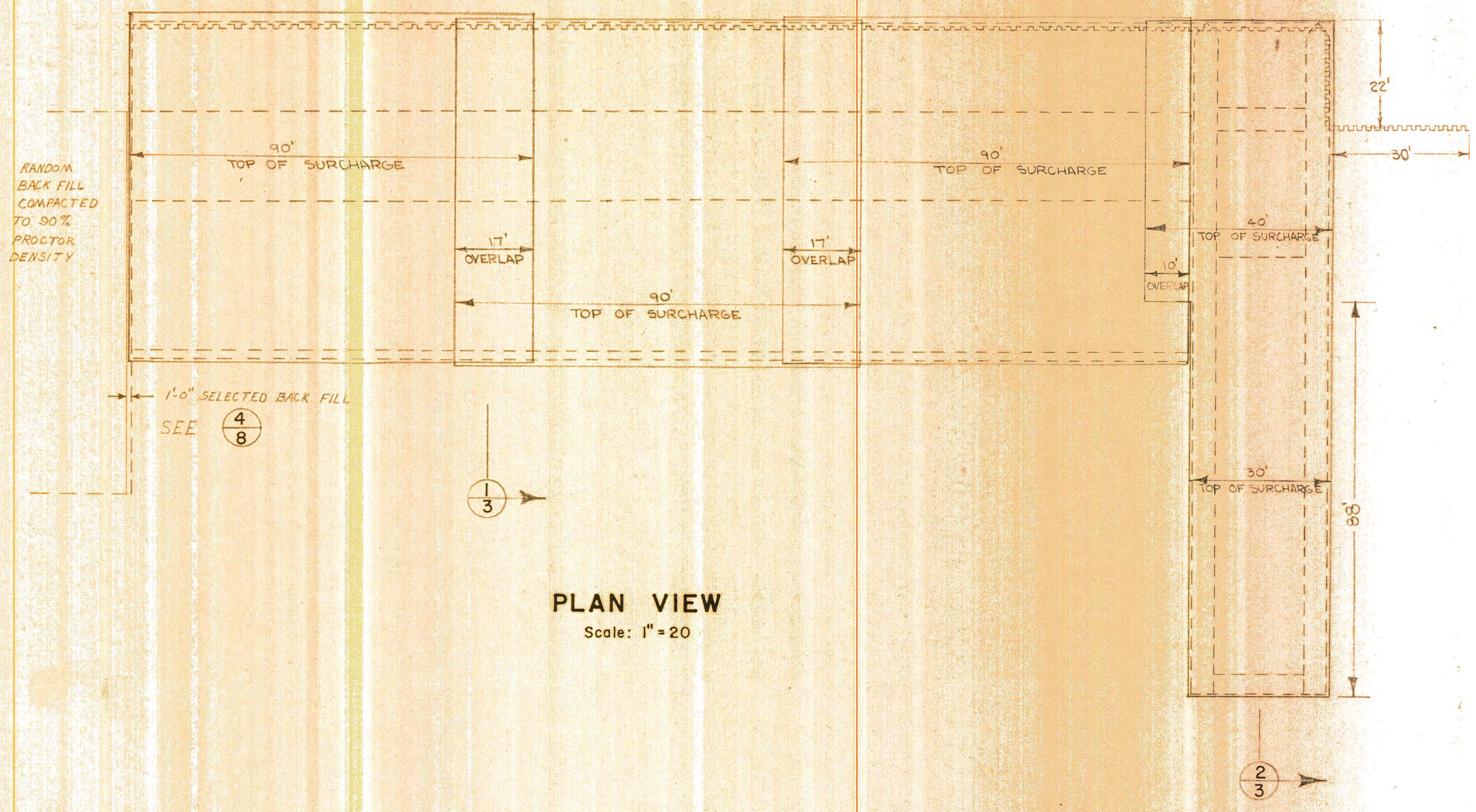
SCALE:	1" = 20'
DWN. BY:	A.C.B.
DATE:	10-29-68
DWG. NO.:	23/2-40043

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

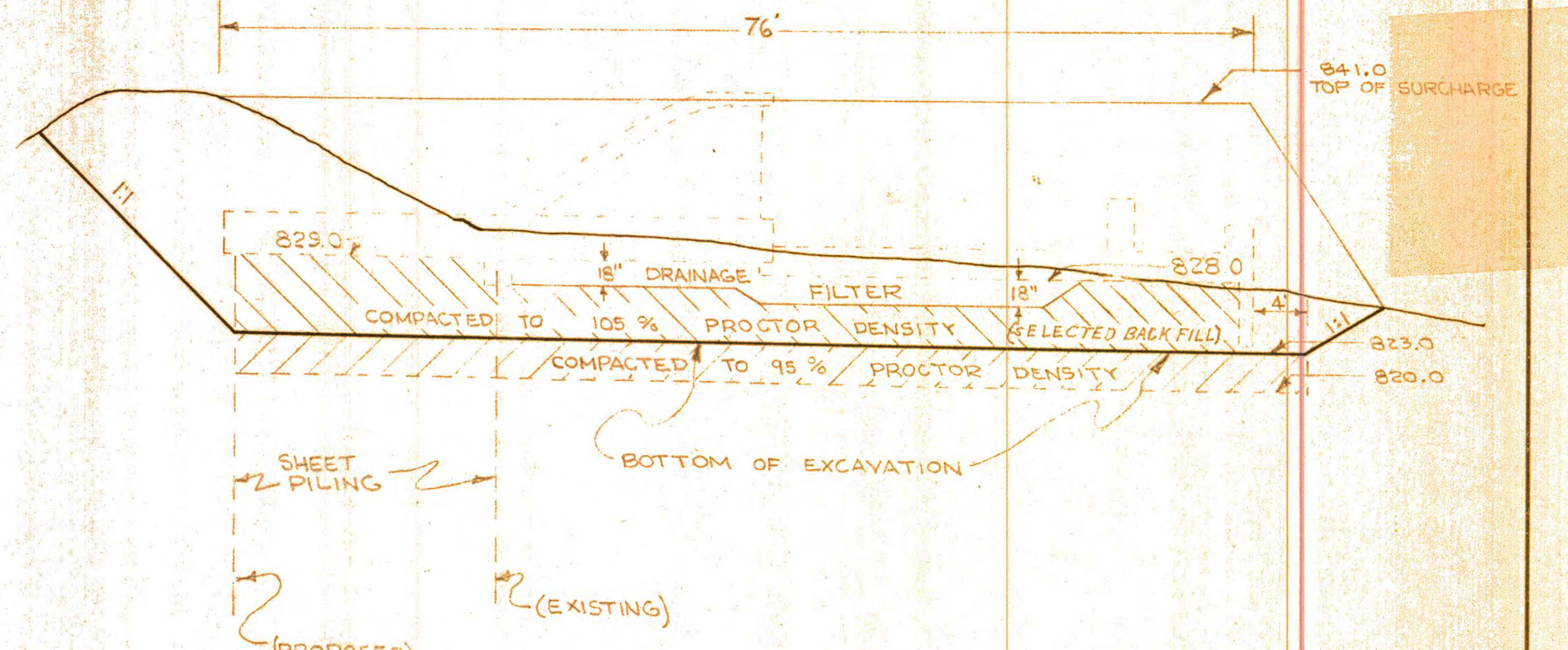
RUM RIVER DAM
INDEX SHEET

SHEET NO. 2 OF 19 SHEETS



PLAN VIEW

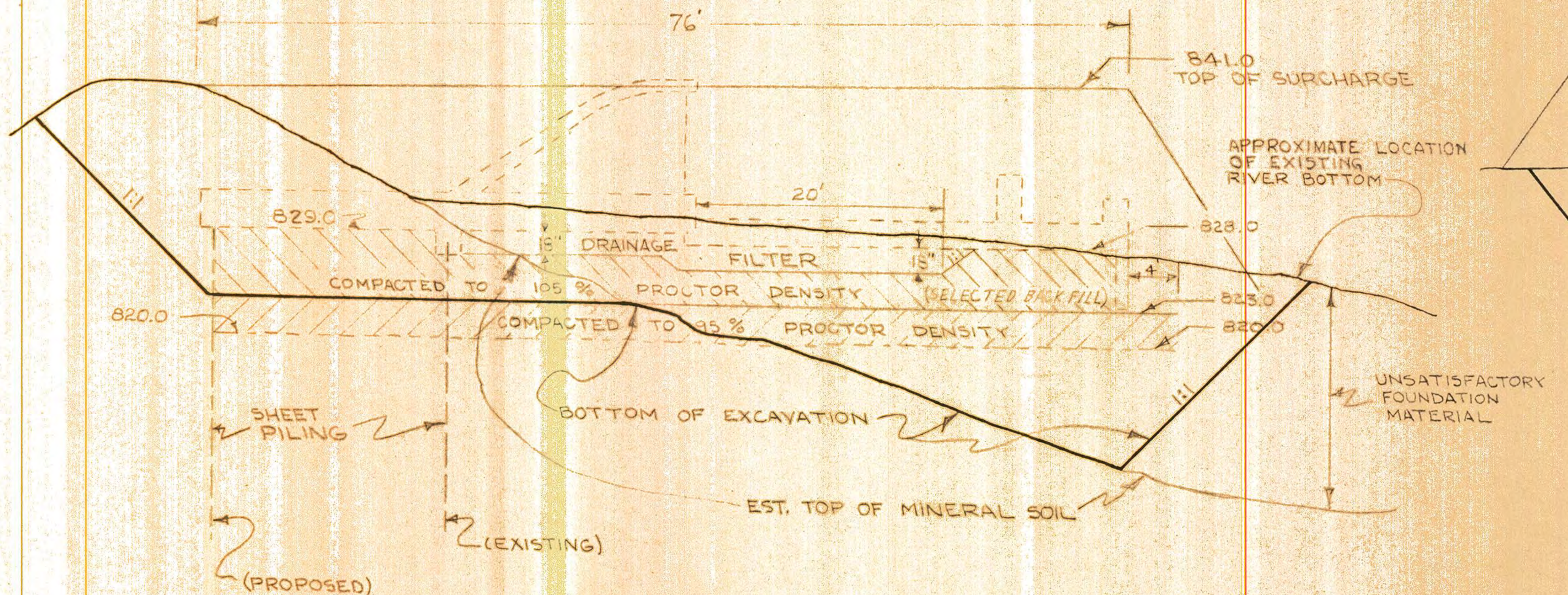
Scale: 1" = 20



NOTE: THIS SECTION TYPICAL WHERE RIVER BOTTOM IS MINERAL SOIL.

1/3 SECTION

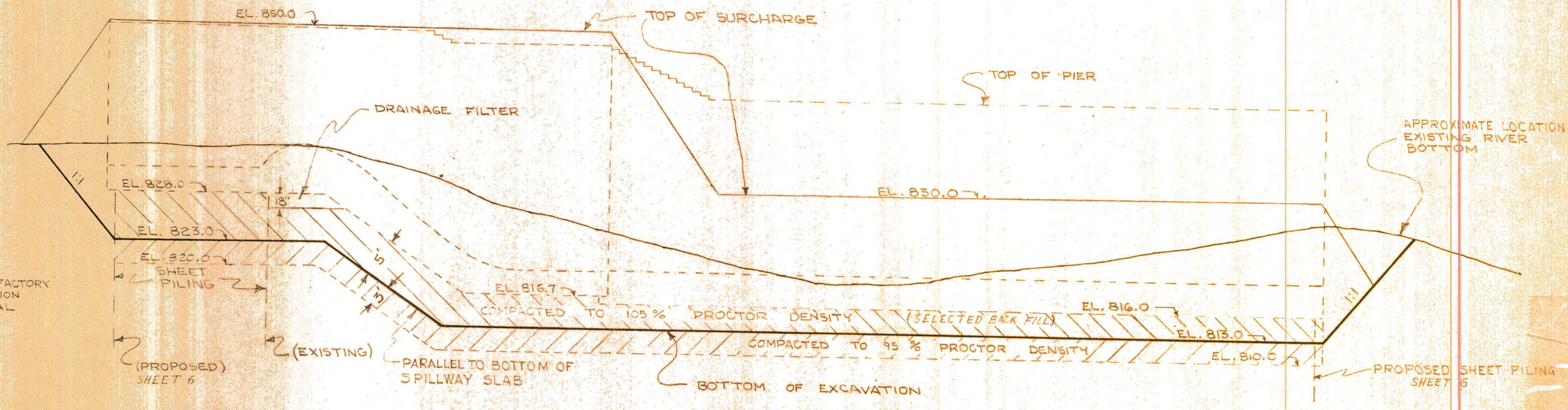
Scale: 1" = 10'



NOTE: THIS SECTION TYPICAL WHERE OLD SCOUR HOLE HAS FILLED WITH UNSATISFACTORY FOUNDATION MATERIAL.

1/3 SECTION

Scale: 1" = 10'



2/3 SECTION

Scale: 1" = 10'

NOTE: THIS SECTION TYPICAL WHERE BOTTOM OF SUBCUT IS MINERAL SOIL. IF THE BOTTOM OF THE SUBCUT IS UNSATISFACTORY MATERIAL, THE MATERIAL SHALL BE REMOVED AS SHOWN IN SECTION 1/3

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

SCALE: AS SHOWN

DWN. BY: T.H.G.

DATE: 11-21-68

DWG. NO.: 23/2-4D044

CITY OF ANOKA

ANOKA, MINNESOTA

BARR ENGINEERING CO.

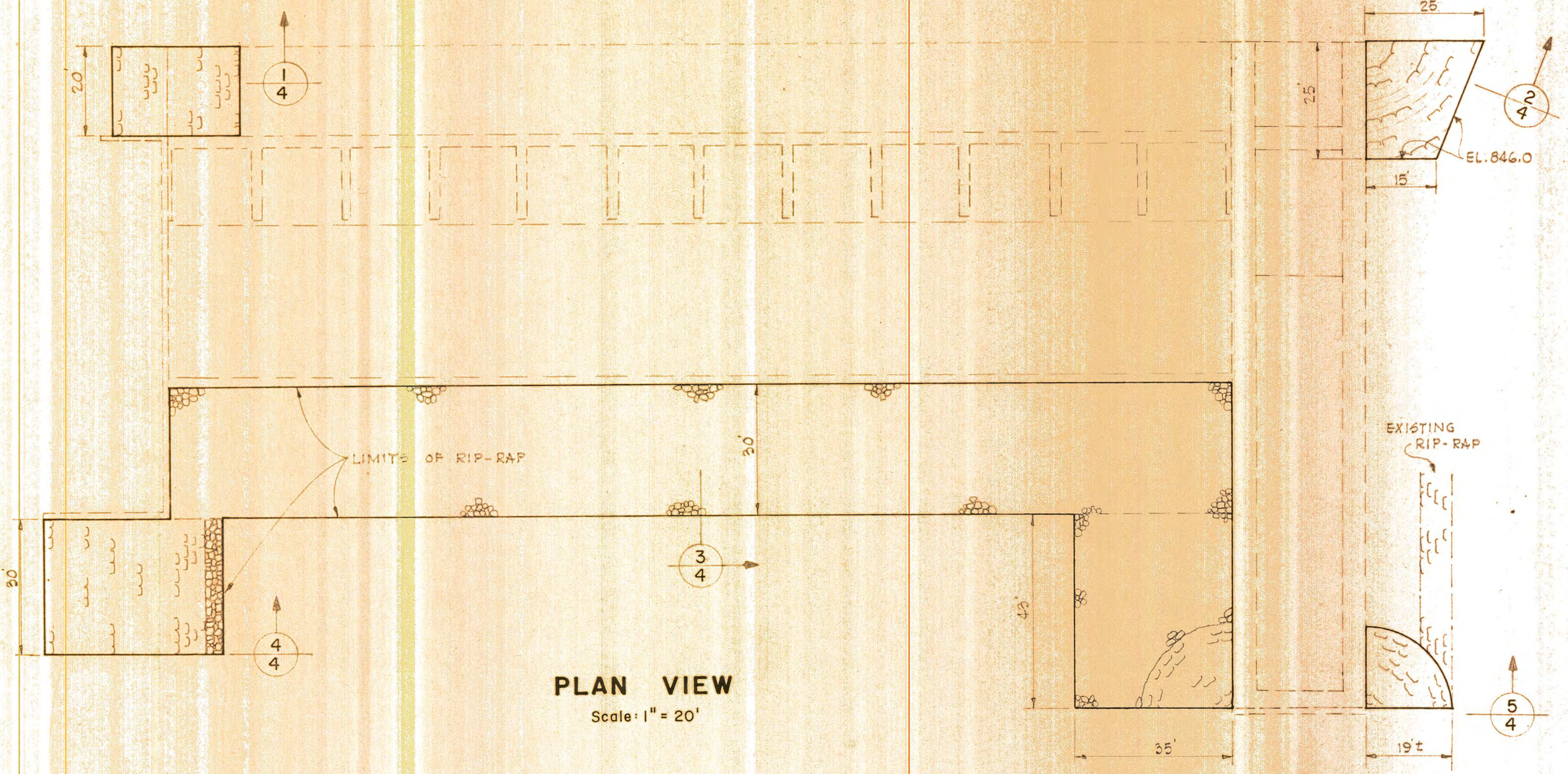
CONSULTING HYDRAULIC ENGINEERS

MINNEAPOLIS, MINNESOTA

RUM RIVER DAM

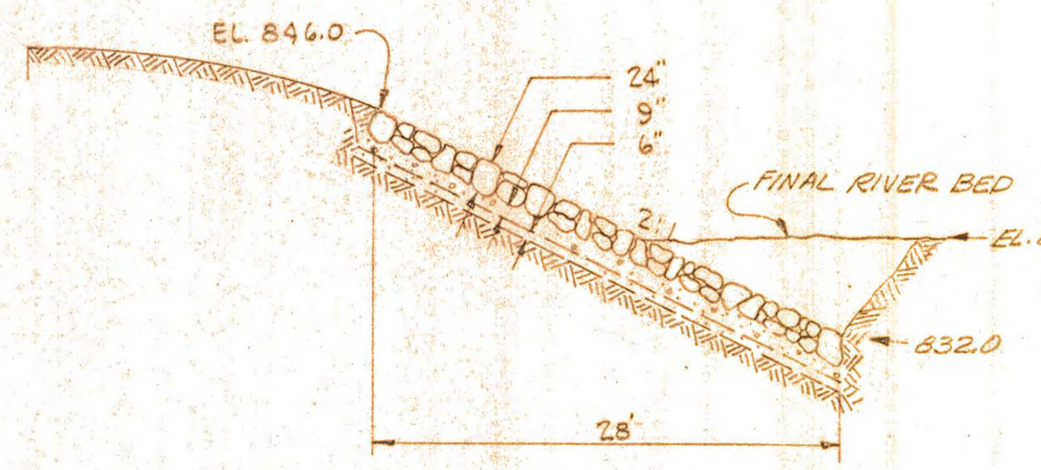
FOUNDATION PREPARATION

SHEET NO. 3 OF 19 SHEETS



PLAN VIEW

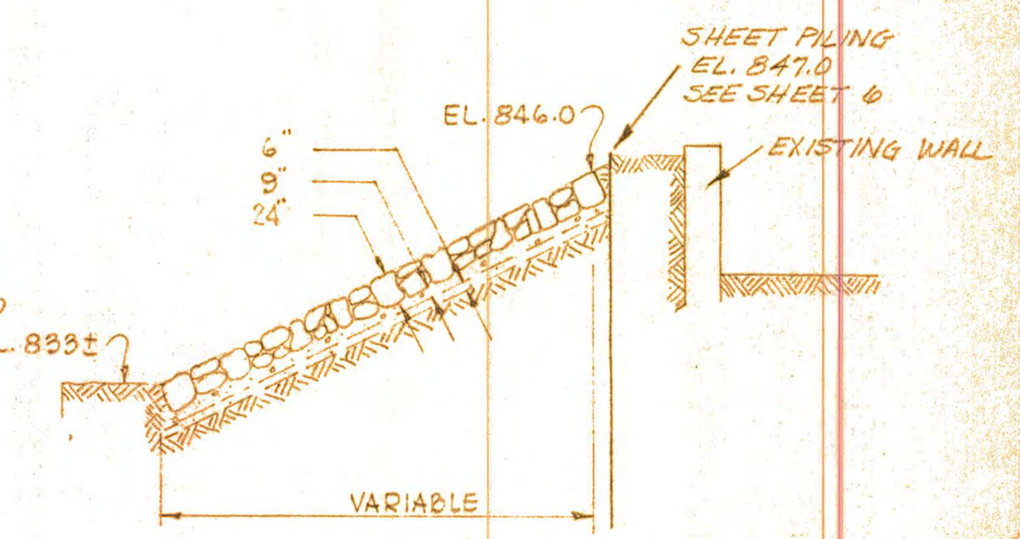
Scale: 1" = 20'



1/4 SECTION

RIP-RAP ON WEST BANK UPSTREAM OF DAM

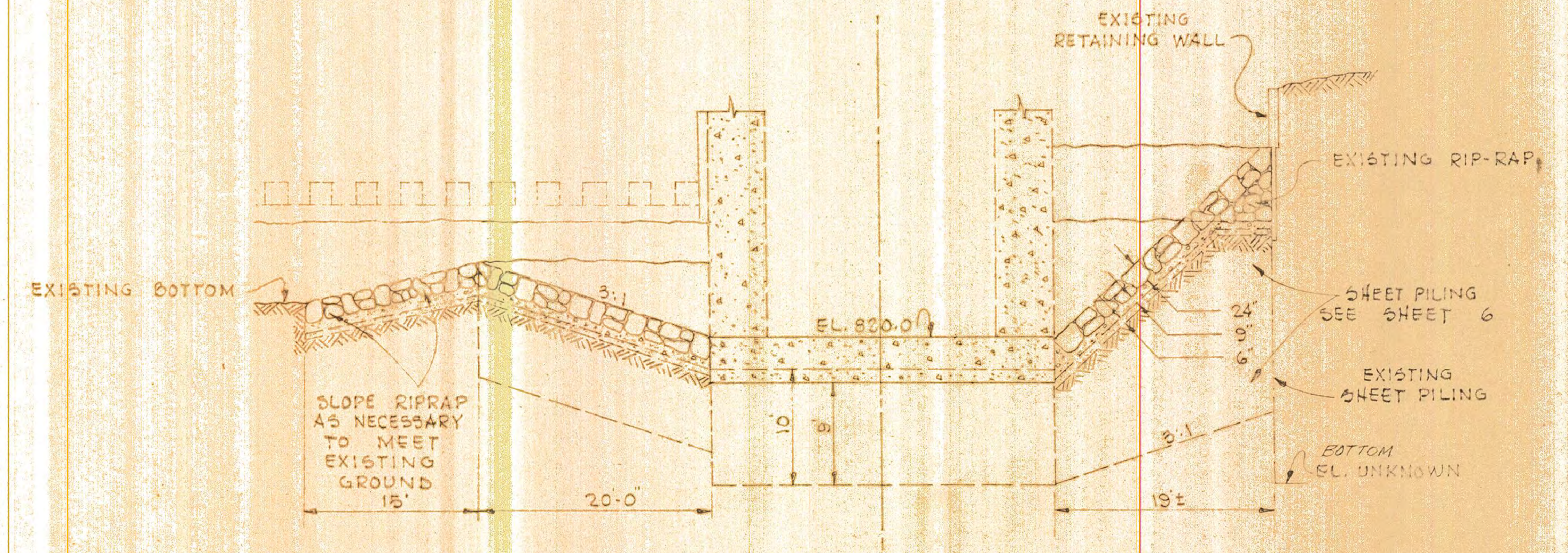
Scale 1" = 10'



2/4 SECTION

RIP-RAP ON EAST BANK UPSTREAM OF DAM

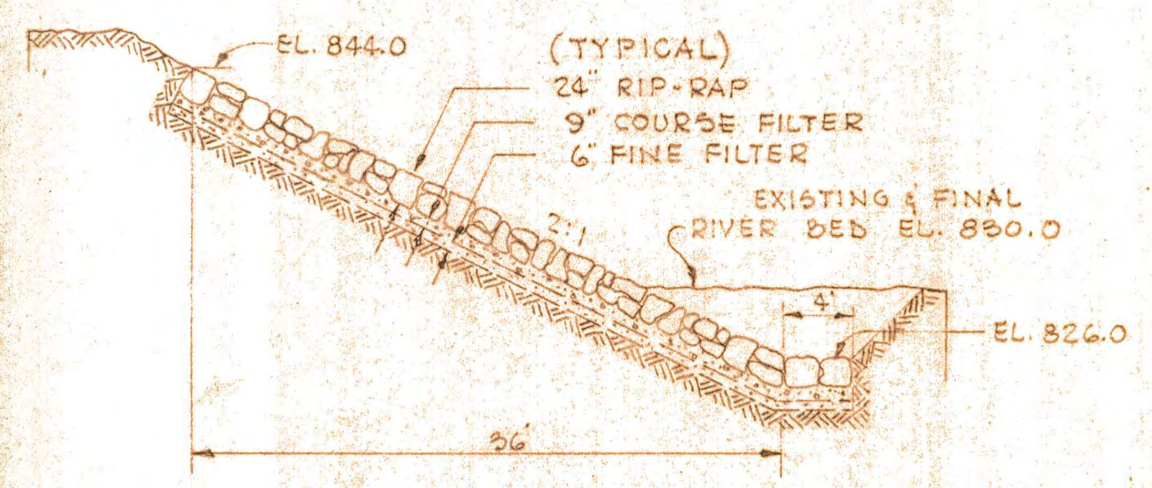
Scale 1" = 10'



5/4 SECTION

RIP-RAP AROUND TAINTER GATE SPILLWAY

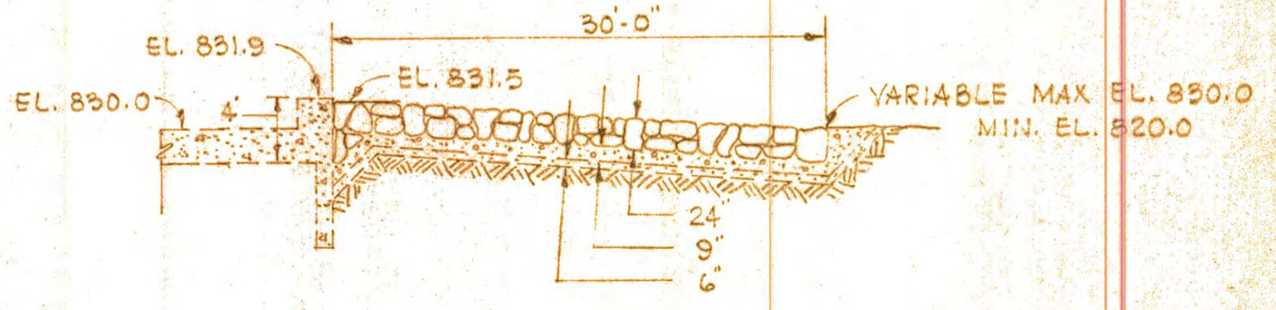
Scale 1" = 10'



4/4 SECTION

RIP-RAP ON WEST BANK DOWNSTREAM OF DAM

Scale 1" = 10'



3/4 SECTION

RIP-RAP DOWNSTREAM OF FIXED CREST SPILLWAY

Scale 1" = 10'

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE ______

REG. NO. ______

REVISIONS

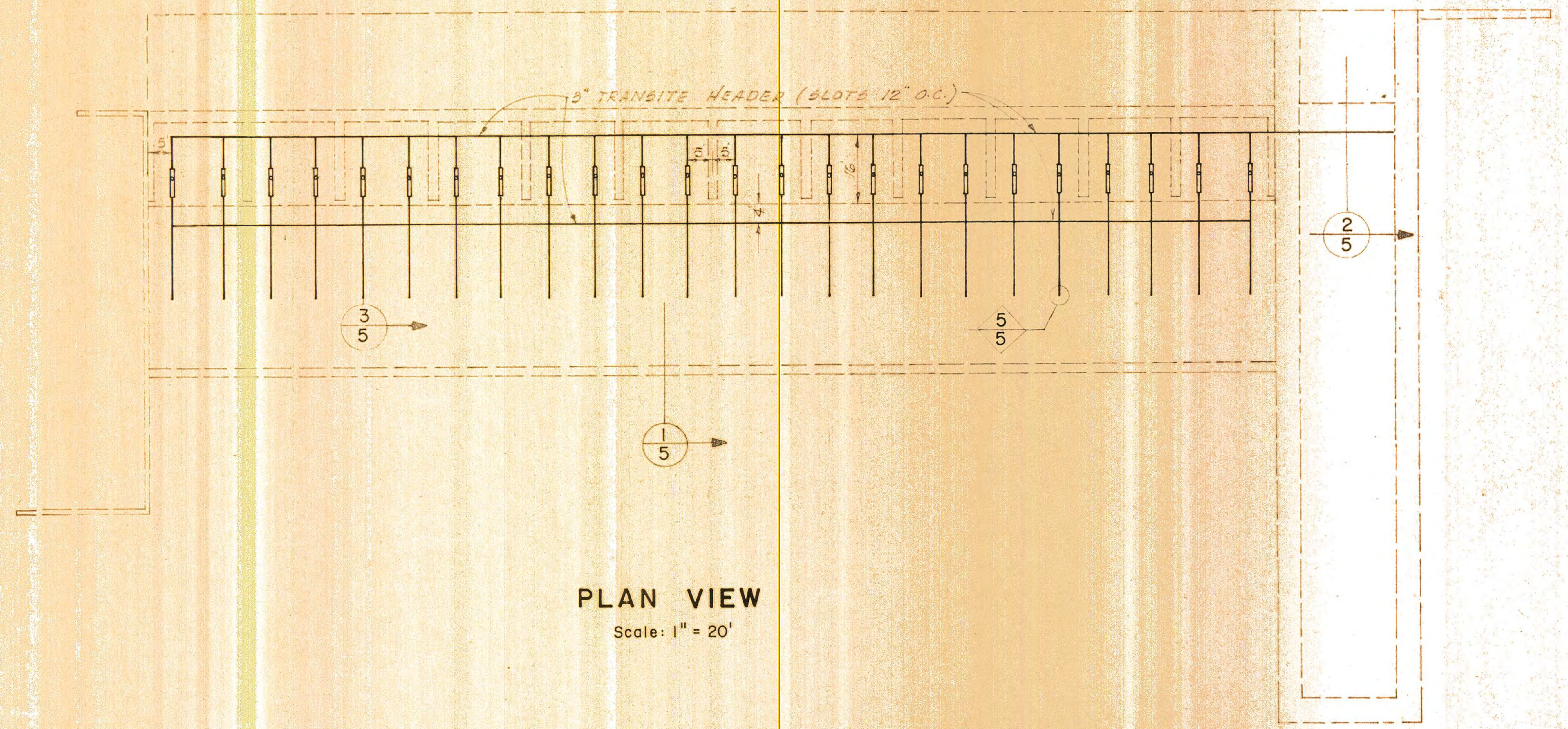
SCALE: AS SHOWN
DWN. BY: R.W.M.
DATE: 11-25-68
DWG. NO.: 23/2-40045

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

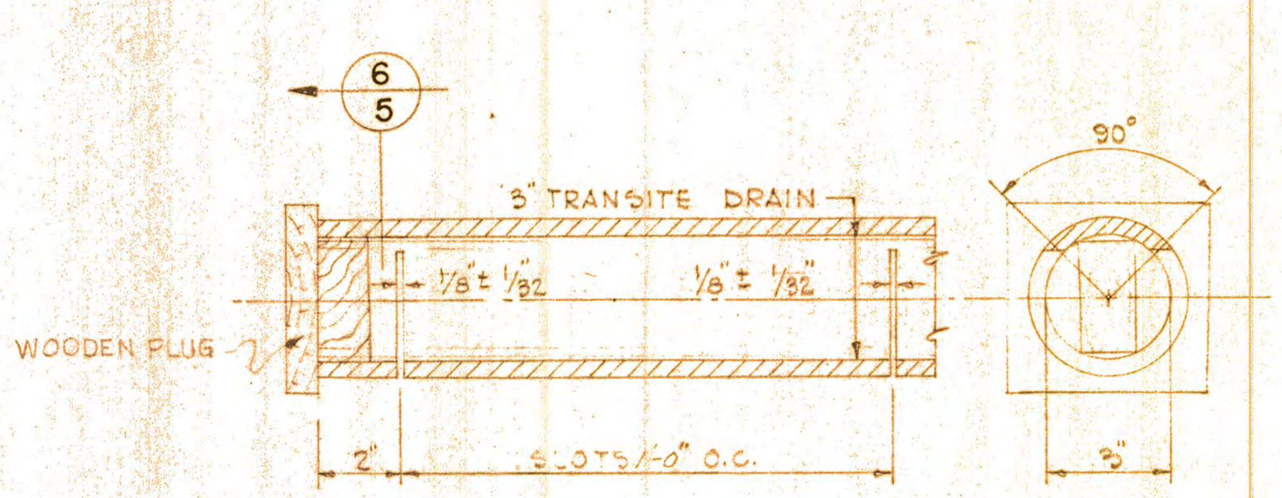
RUM RIVER DAM
RIP-RAP DETAILS

SHEET NO. 4 OF 19 SHEETS



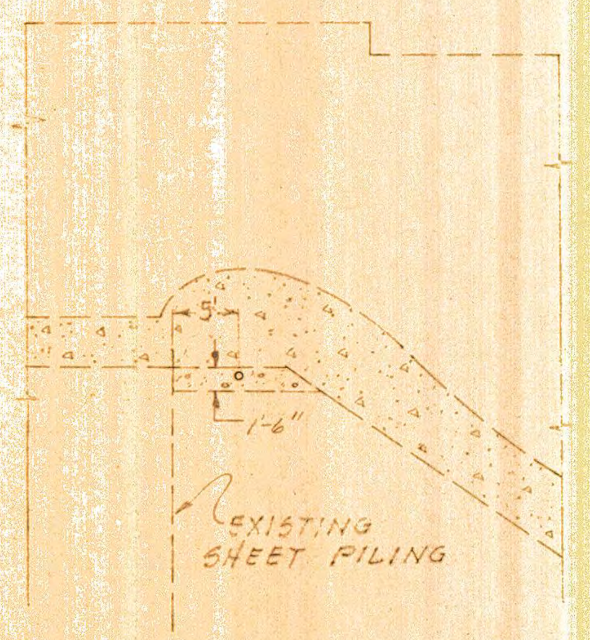
PLAN VIEW

Scale: 1" = 20'



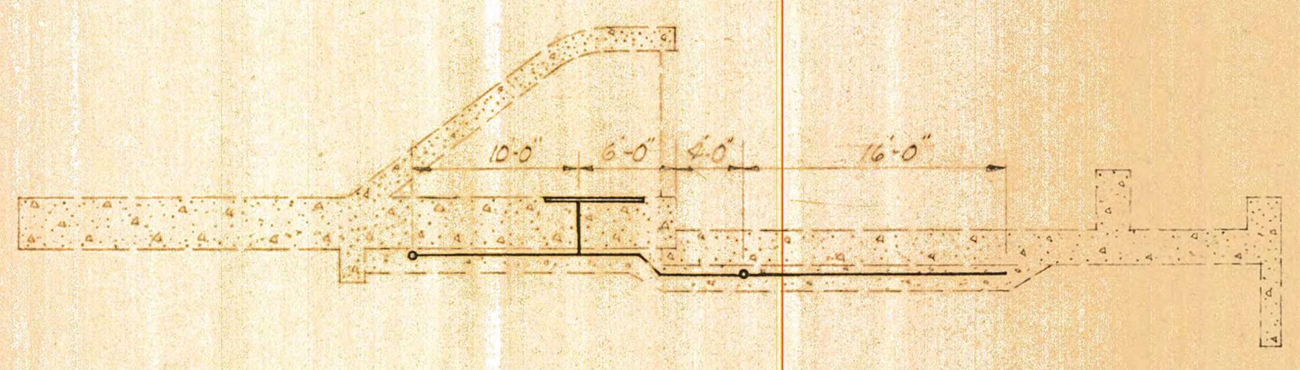
5/5 DETAIL 6/5

Scale: 1" = 4"



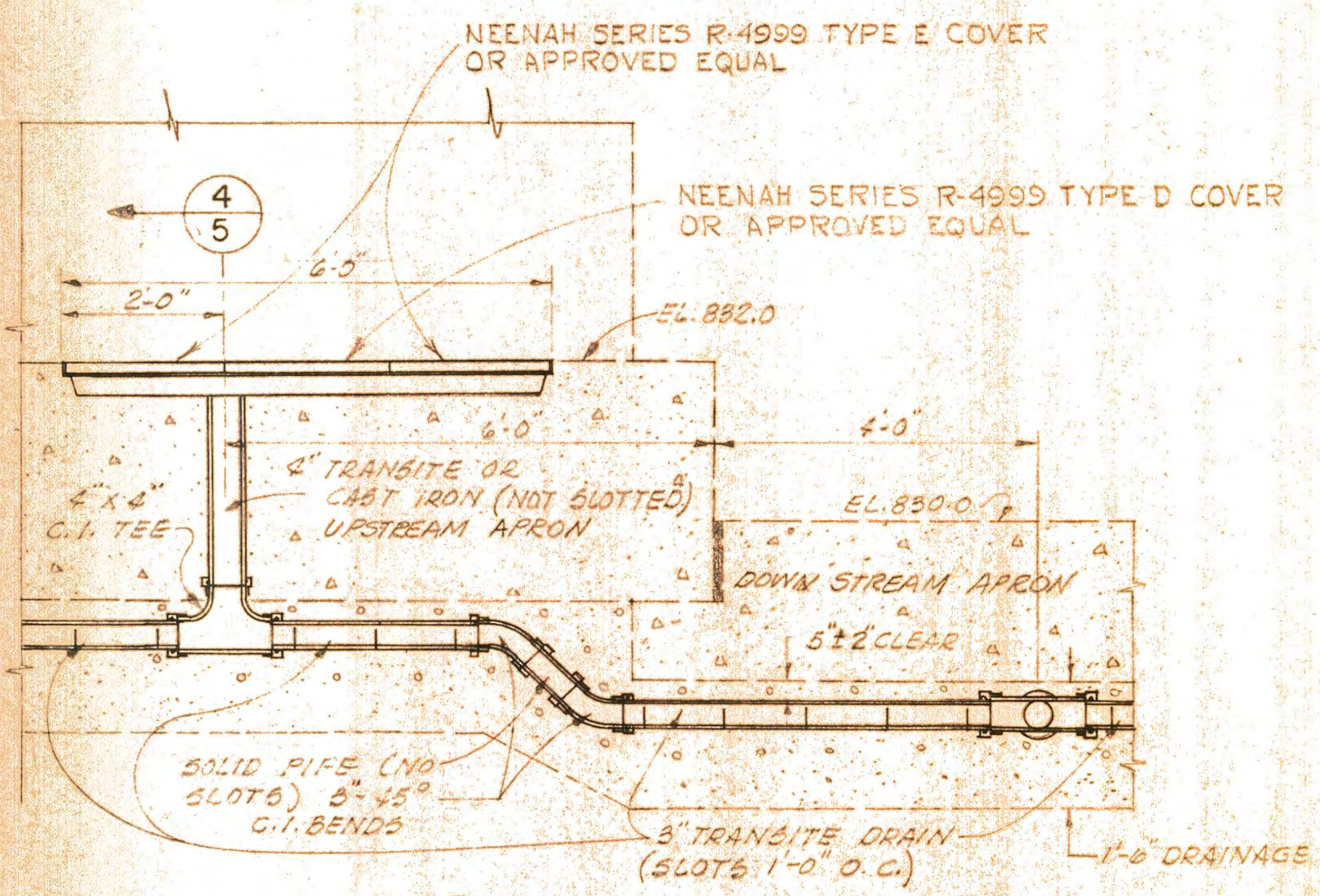
2/5 SECTION

Scale: 1" = 10'



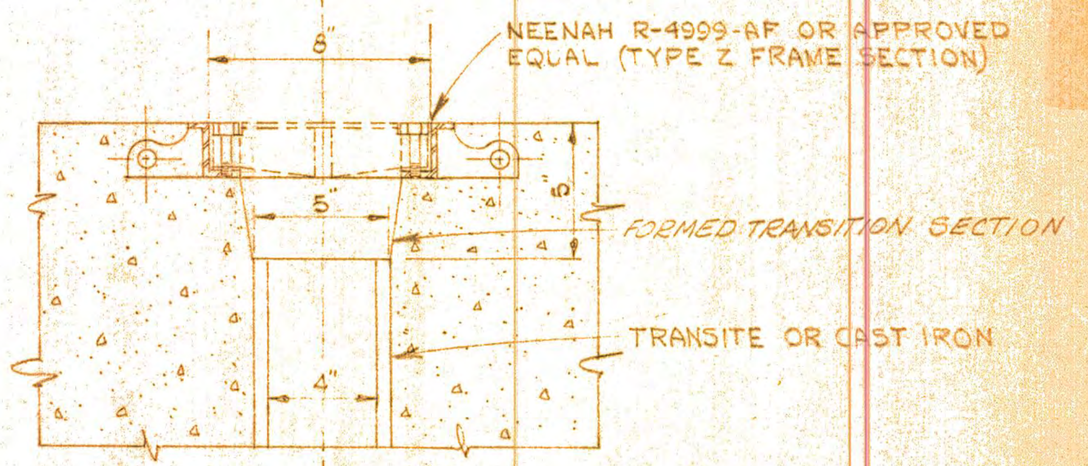
1/5 SECTION

Scale 1" = 10'



3/5 SECTION

Scale: 1" = 2'



4/5 SECTION

Scale: 1" = 6"

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

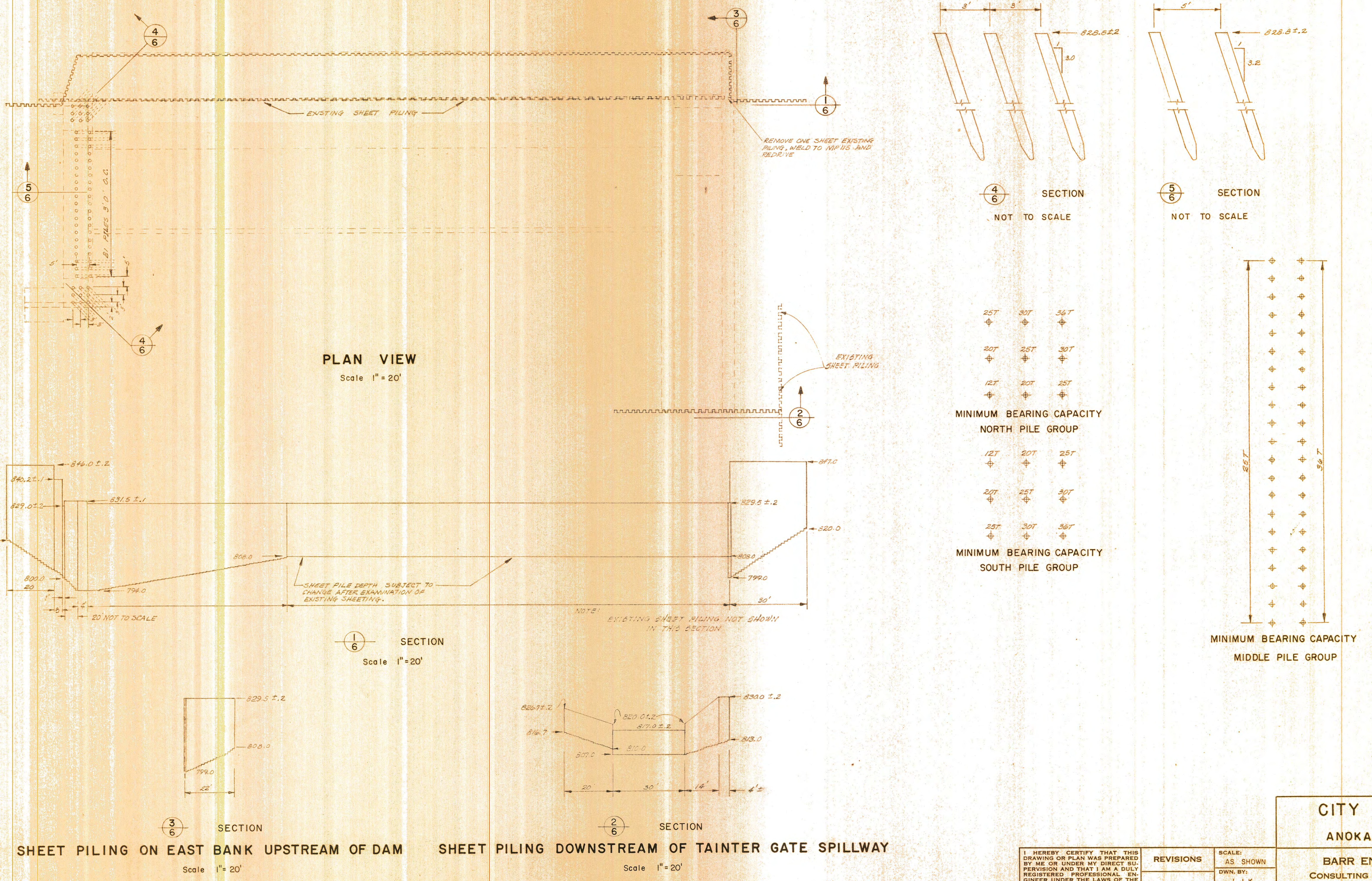
SCALE: AS SHOWN
DWN. BY: R.W.M.
DATE: 11-4-68
DWG. NO.: 23/2-40046

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
FOUNDATION DRAINAGE

SHEET NO. 5 OF 19 SHEETS



I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

SCALE: AS SHOWN
DWN. BY: L.J.K
DATE: 12-2-68
DWG. NO.: 23/2-4D047

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
SHEET PILING

SHEET NO. 6 OF 19 SHEETS

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

SCALE: AS SHOWN
DWN. BY: T.H.G.
DATE: 11-15-68
DWG. NO.: 23/2-4D048

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
MISCELLANEOUS DETAILS

SHEET NO. 7 OF 19 SHEETS

NOTES:
1. 3" COVER UNLESS OTHERWISE NOTED.
2. EXPOSED CORNERS SHALL HAVE 1" CHAMFER.

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

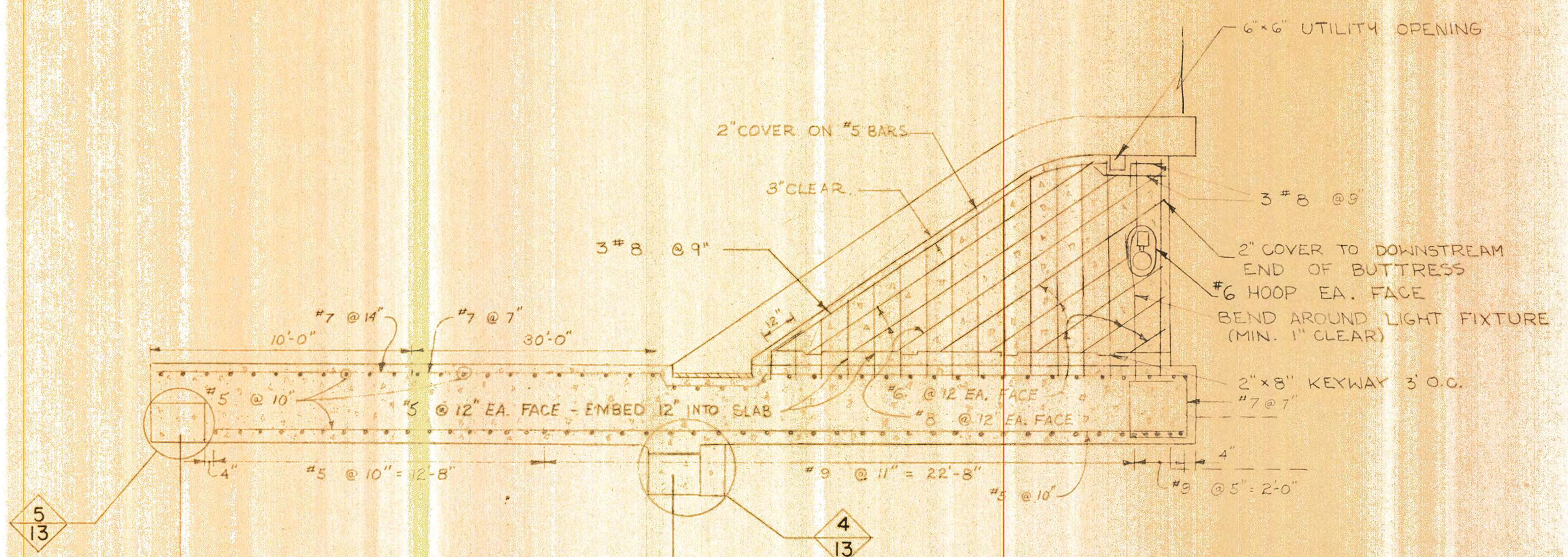
SCALE: AS SHOWN
DWN. BY: A. C. B.
DATE: 11-5-68
DWG. NO.: 23/2-40049

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
FIXED CREST SPILLWAY

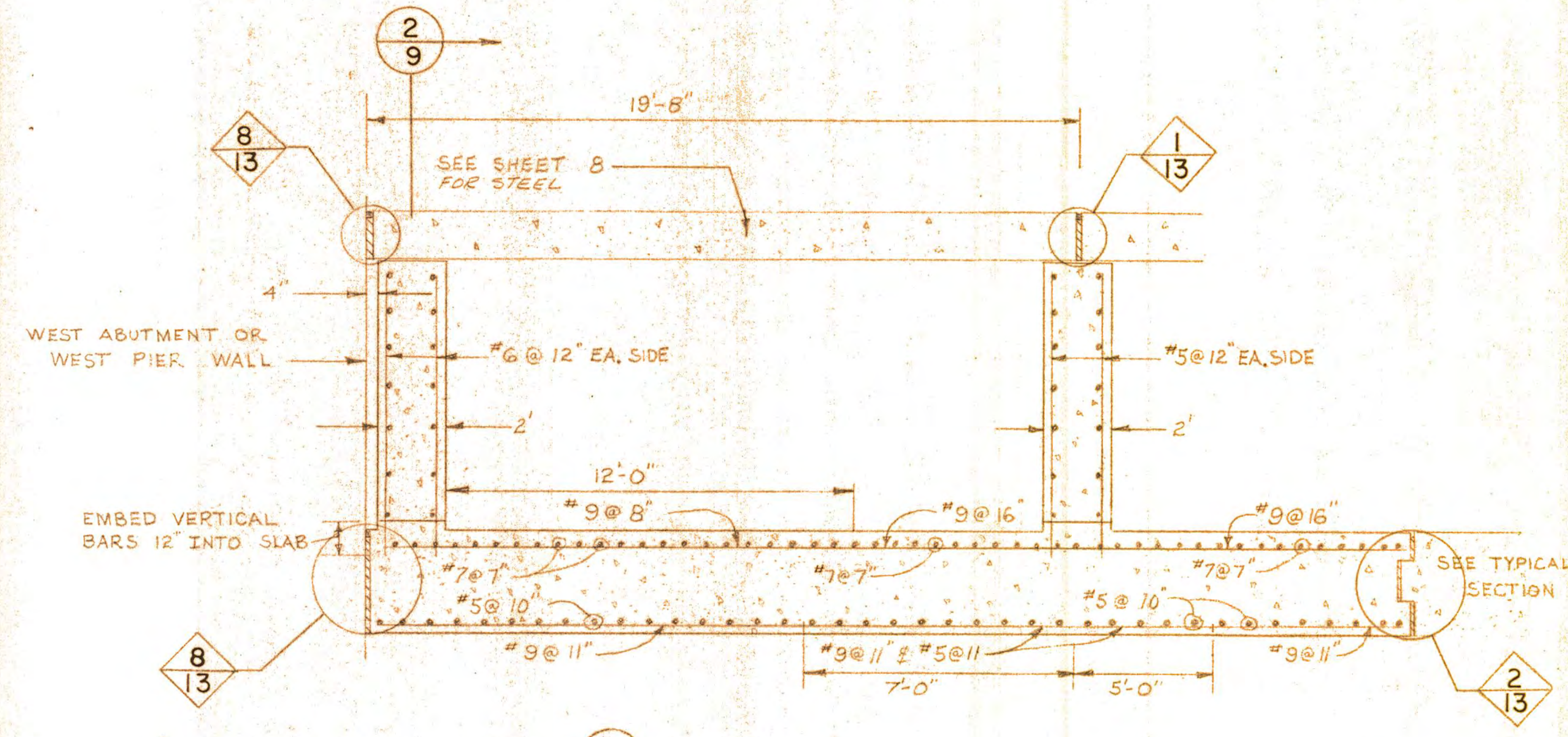
SHEET NO. 8 OF 19 SHEETS



1/9 SECTION

TYPICAL SECTION THROUGH BUTTRESS AND UPSTREAM APRON

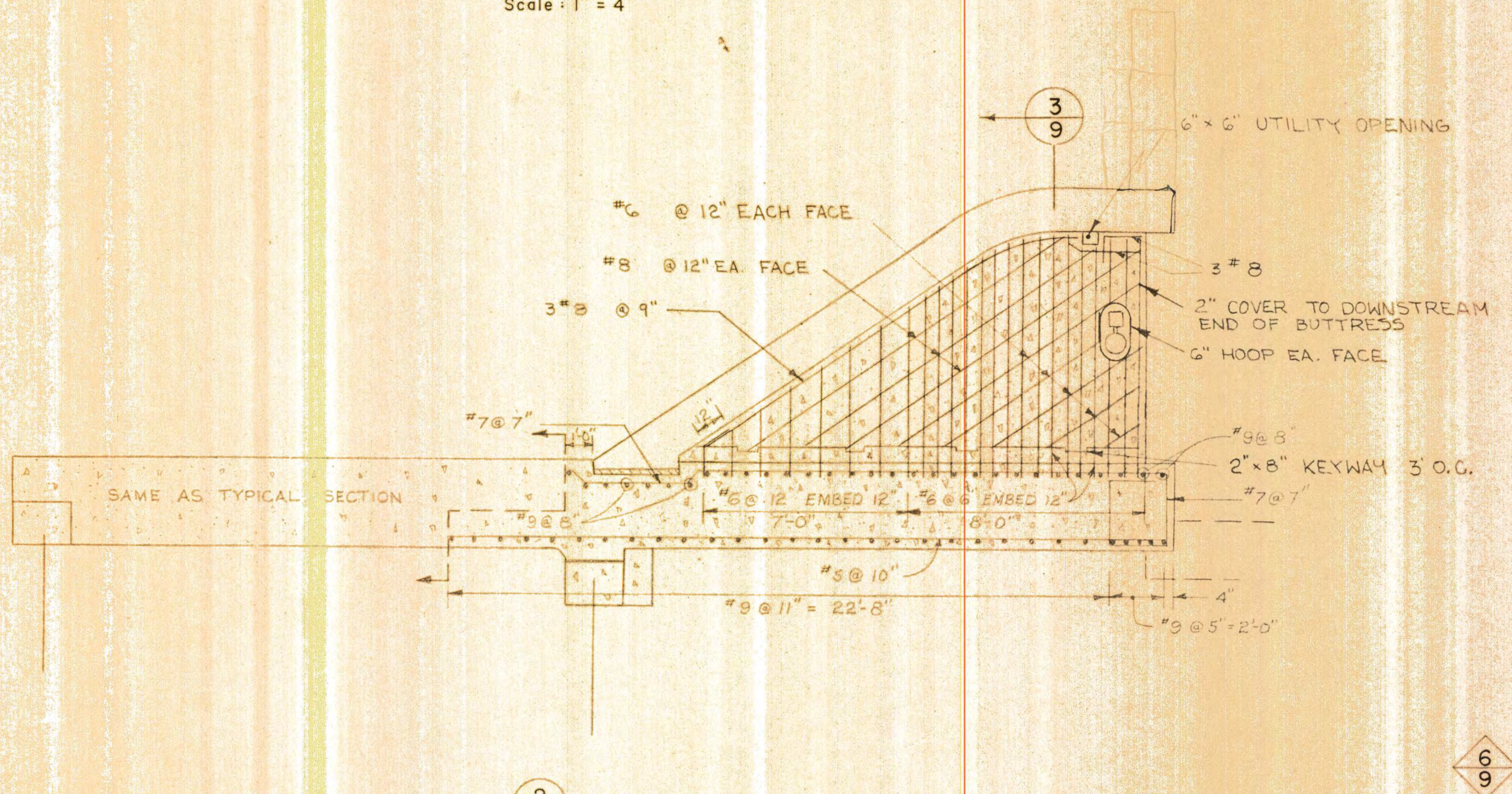
Scale : 1" = 4'



3/9 SECTION

END BAYS

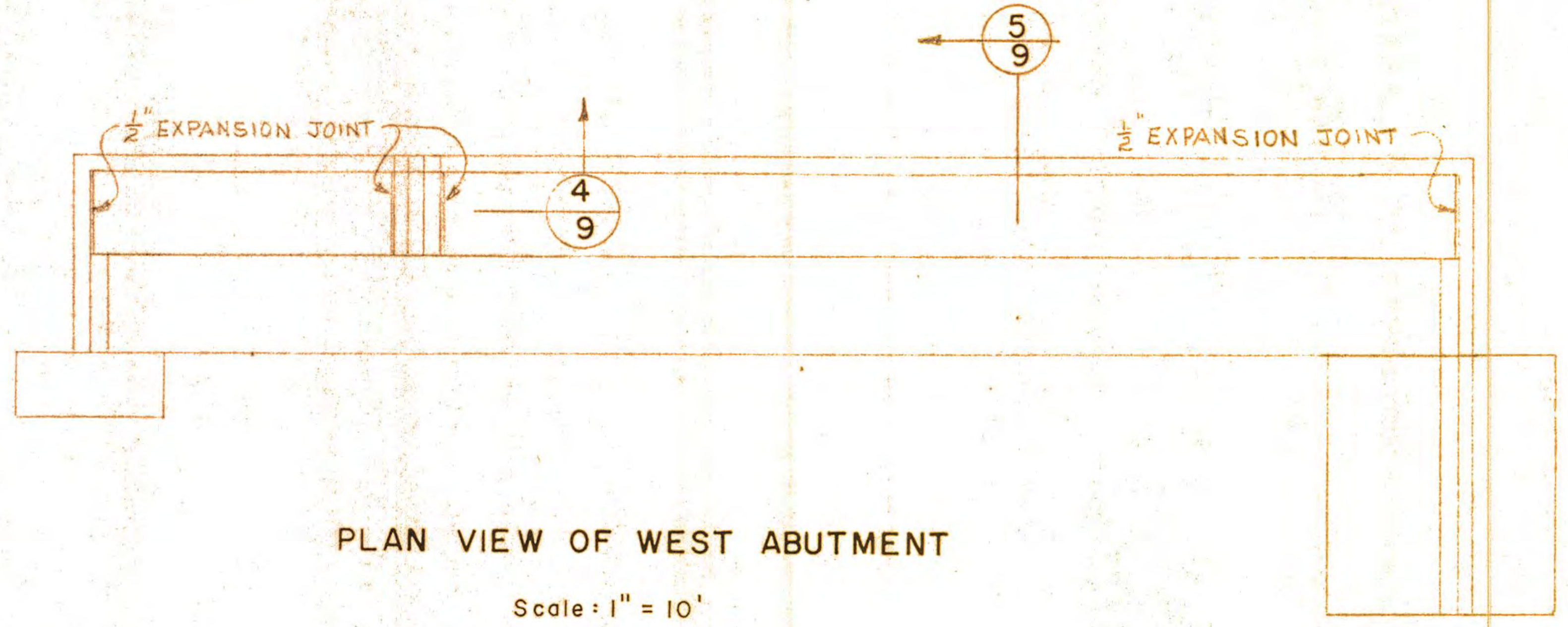
Scale : 1" = 4'



2/9 SECTION

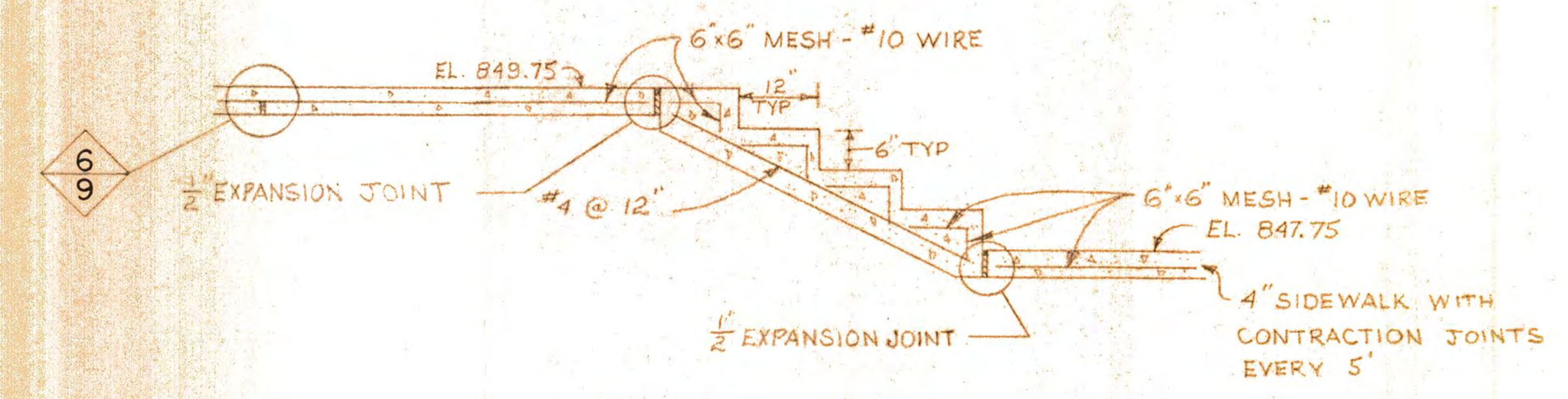
END BUTTRESSES

Scale : 1" = 4'



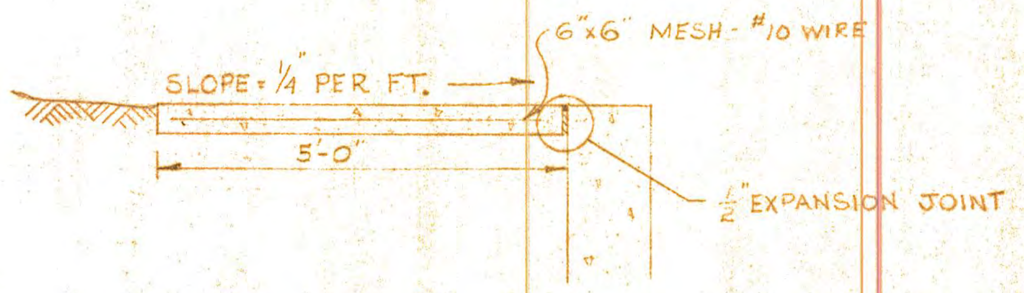
PLAN VIEW OF WEST ABUTMENT

Scale : 1" = 10'



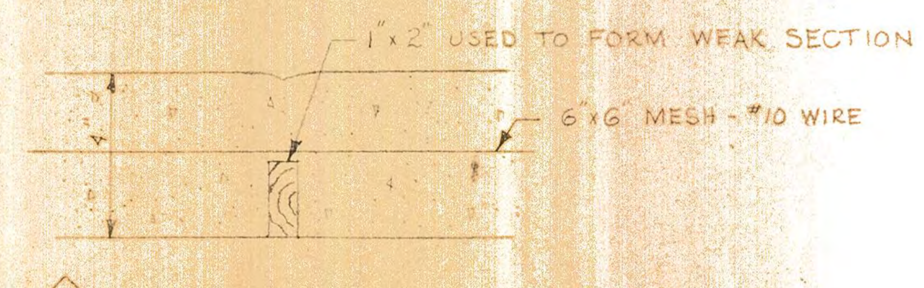
4/9 SECTION

Scale : 1" = 2'



5/9 SECTION

Scale : 1" = 2'



6/9 DETAIL

CONTRACTION JOINT

NOTE:
1) 3" COVER UNLESS OTHERWISE NOTED
2) ALL EXPOSED CORNERS SHALL HAVE 1" CHAMFER

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

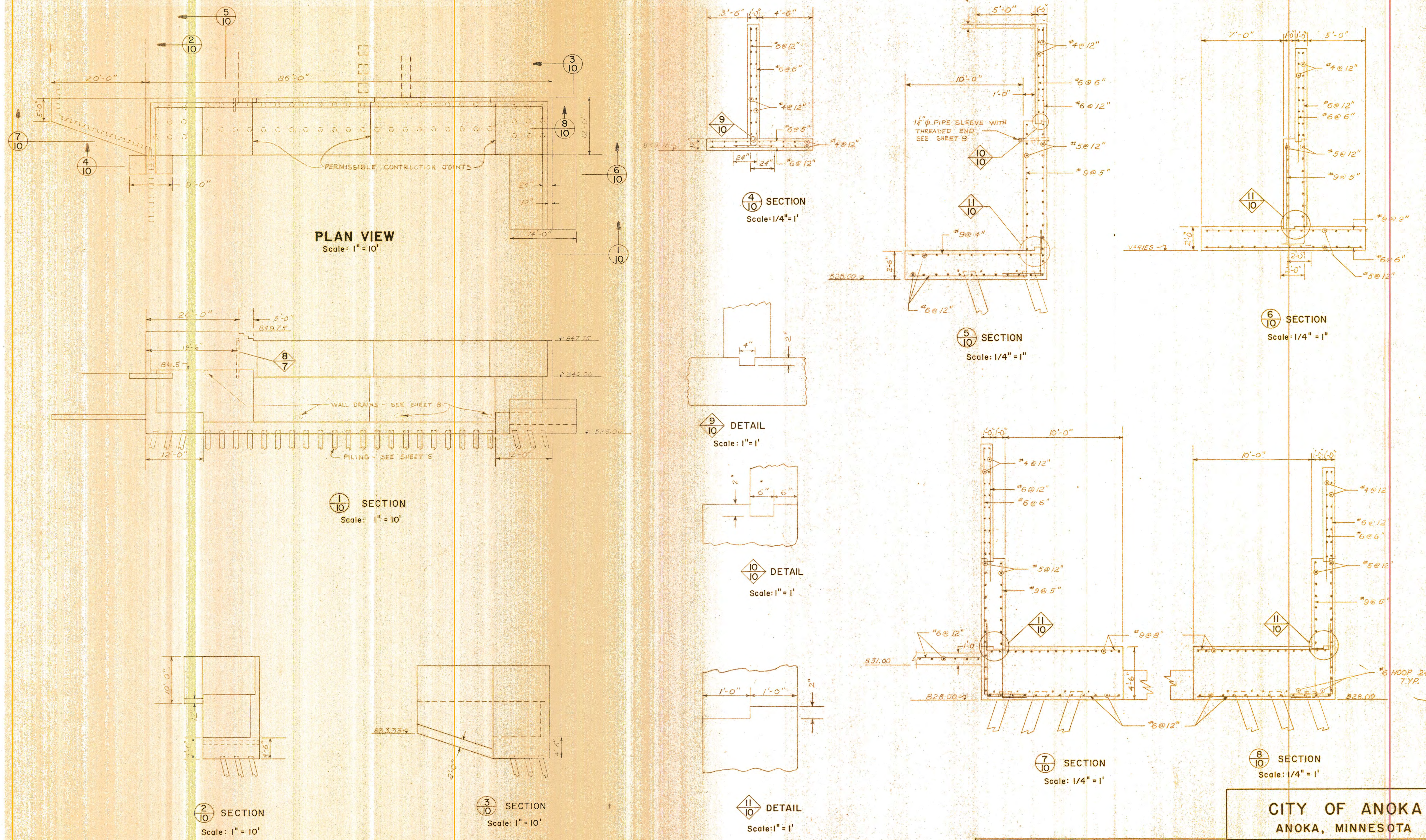
SCALE: AS SHOWN
DWN. BY: A. G.
DATE: 12-6-68
DWG. NO.: 23/2-4D050

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
MISCELLANEOUS STRUCTURAL DETAILS

SHEET NO. 9 OF 19 SHEETS



NOTES 1.) 3" COVER UNLESS OTHERWISE NOTED
2.) ALL EXPOSED CORNERS SHALL HAVE 1" CHAMFER
3.) LOCATION OF WATERSTOPS SHOWN ON SHEET 13

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE ______

REG. NO. ______

REVISIONS

SCALE: AS SHOWN
DWN. BY: A.J.R.
DATE: 12-2-68
DWG. NO.: 23/2-4D051

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
WEST ABUTMENT

SHEET NO. 10 OF 19 SHEETS

NOTES:
1. 3" COVER UNLESS OTHERWISE NOTED
2. ALL EXPOSED CORNERS SHALL HAVE 1" CHAMFER
3. ALL LONGITUDINAL STEEL SHALL BE #5@10"

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE
REG. NO.

REVISIONS

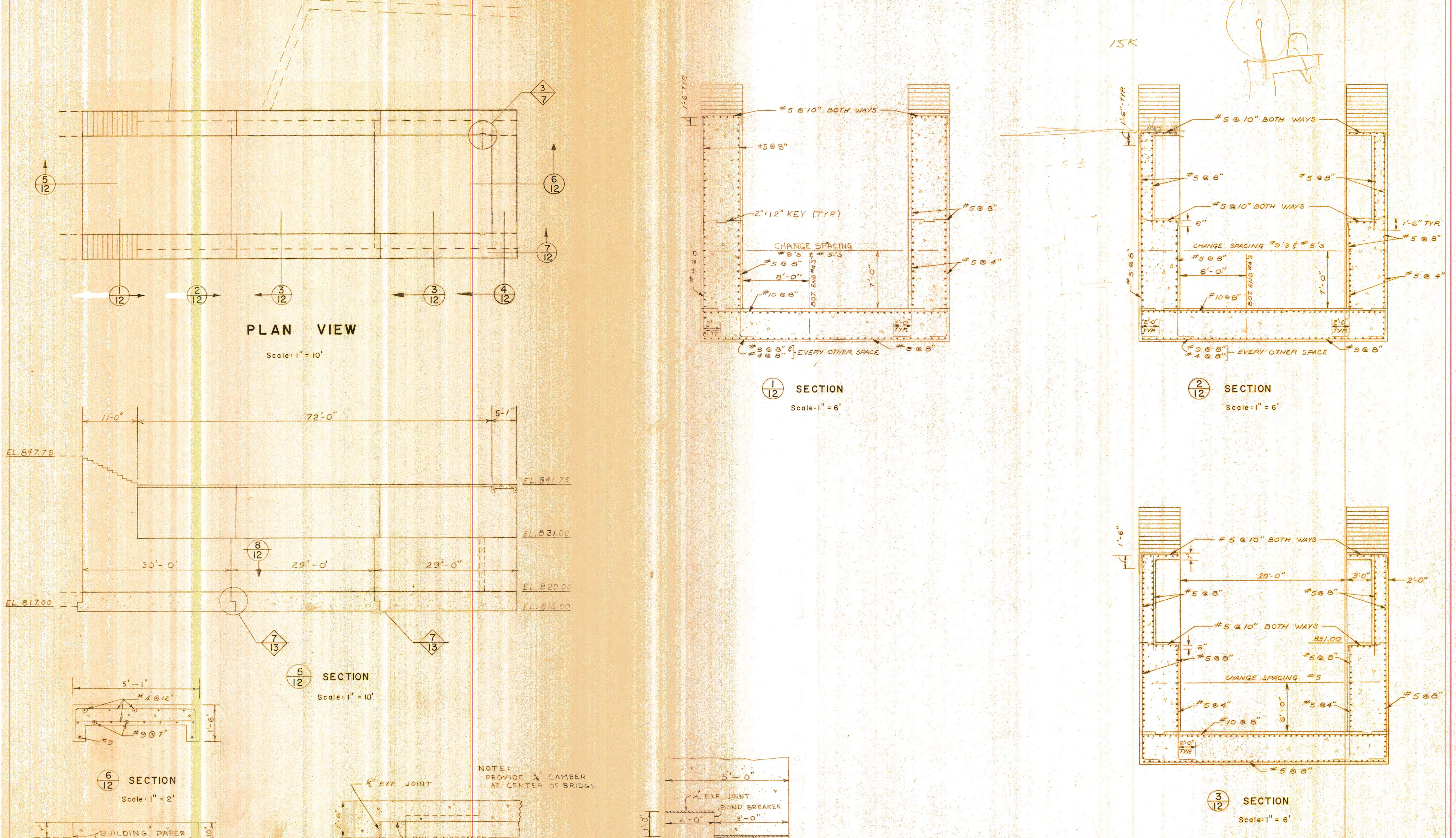
SCALE: 1" = 4'-0"
DWN. BY: A.K.
DATE: 11-15-68
DWG. NO.: 23/2-40052

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
TAINTER GATE SPILLWAY

SHEET NO. 11 OF 19 SHEETS



NOTE:
1.) ALL LONGITUDINAL STEEL #5 @ 10"
2.) 3" COVER, UNLESS OTHERWISE NOTED
3.) ALL EXPOSED CORNERS SHALL HAVE 1" CHAMFER

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

SCALE: AS SHOWN
DWN. BY: M.D.L.
DATE: 11-12-68
DWG. NO.: 23/2-40053

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
STILLING BASIN

SHEET NO. 12 OF 19 SHEETS

PLAN VIEW
Scale 1" = 20'
PLAN VIEW
(FIXED CREST SLAB)
Scale : 1" = 20'
ELEVATION WEST ABUTMENT
Scale : 1" = 10'
ELEVATION WEST PIER
Scale : 1" = 10'
1/2" PREMOLDED JOINT FILLER
1" CAULK
6" WATERSTOP TYPE 4 OR EQUAL
9" WATERSTOP TYPE 7C OR EQUAL
2" STYROFOAM
SHEET PILING
DETAIL
SHEET PILING CONNECTION TO WEST ABUTMENT
Scale : 1" = 2'
DETAIL
DOWNSTREAM CUTOFF FOR SPILLWAY
Scale : 1" = 2'
1" CAULK
1/2" PREMOLDED JOINT FILLER
6" WATERSTOP TYPE 4 OR EQUAL
BUILDING PAPER
DETAIL
TOP OF BUTTRESS
Scale 1" = 1'
BOND BREAKER
1/2 SLAB THICKNESS
HARDBOARD
DETAIL
FIXED CREST APRON
Scale 1" = 1'
BUILDING PAPER
1" CAULK
EXPANSION JOINT
2" STYROFOAM
9" WATERSTOP TYPE 7C OR EQUAL
DETAIL
BOTTOM FIXED CREST SLAB
Scale 1" = 1'
FORMED SIDE
BURN HOLE IN SHEETING FOR REINFORCING
IF EXISTING SHEETING DOES NOT FALL IN THIS RANGE ENGINEER WILL CHANGE AS REQ'D
BOND BREAKER (1/2" MAXIMUM)
EXISTING SHEET PILING
DETAIL
DOWNSTREAM CUTOFF (FIXED CREST)
Scale 1" = 1'
DETAIL
UPSTREAM CUTOFF
Scale 1" = 1'
DETAIL
CONNECTION UPSTREAM APRON TO DOWNSTREAM APRON
Scale : 1" = 2'
DETAIL
SPILLWAY & STILLING BASIN
Scale : 1" = 2'
VARIABLE
DETAIL
WALL TO SLAB CONNECTION
No Scale
NOTE:
MIN. COMPRESSIVE STRENGTH OF STYROFOAM = 5 PSI
I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.
DATE
REG. NO.
REVISIONS
SCALE: As Shown
DWN. BY: L.K.
DATE: 11-29-68
DWG. NO.: 23/2-4D054
CITY OF ANOKA
ANOKA, MINNESOTA
BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA
RUM RIVER DAM
WATERSTOPS
SHEET NO. 13 OF 19 SHEETS

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE________

REG. NO.________

REVISIONS

SCALE: AS SHOWN

DWN. BY: T.H.G.

DATE: 11-21-68

DWG. NO.: 23/2-4D055

CITY OF ANOKA

ANOKA, MINNESOTA

BARR ENGINEERING CO.

CONSULTING HYDRAULIC ENGINEERS

MINNEAPOLIS, MINNESOTA

RUM RIVER DAM

TAINTER GATE

SHEET NO. 14 OF 19 SHEETS


236'
5'
20'
EL. 844.2± TOP OF FLASH BOARDS
ELEVATION
Scale: 1" = 20'
1/15 SECTION
Scale: 1" = 10'
6'-4"
2/15 DETAIL
TRIP CABLE TUBE
Scale: 1" = 4'
6" TOP CASTING (NEENAH R-6013 OR EQUAL) W/ LOCKING DEVICE
5C6.7 EMBEDDED IN PIER FOR FLASHBOARD SUPPORT. ALSO REQ'D FOR WEST ABUTMENT
1 1/2" DIA. FLEXIBLE PLASTIC CONDUIT (INCIDENTAL TO CONSTRUCTION OF PIER)
R-2'-0"
3/15 DETAIL
ANCHOR EYE (24 REQD.)
Scale: 1" = 4'
1 1/2" DIA.
CROSBY TYPE U BOLT CLIPS
3/8" WIRE ROPE
ANCHOR EYE
THIMBLE (MIN. 1 1/2" I.D.)
CROSBY TYPE U BOLT CLIP (OVERSIZE)
ATTACHMENT WITH WEAK LINK WIRE
WRAP WIRE AROUND THIMBLE THREE TIMES THEN TIE
4/15 DETAIL
TIE BACK CABLE (24 REQD.)
Scale: 1" = 4"
1/4 CHAMFER
4"x4"x1/2" ℞
3/8" ℞
SEE DETAIL FOR CABLE CONN.
(3-4"x12" TIMBERS)
4 WF 13
ROUND BOTH EDGES BOTH ENDS
2"x6"x1/2"
2" DIA. x 7/8" WASHER TAPPED FOR STUD BOLT
3 1/2"x4"x3/4" ℞
5/8" x 1/2" ROD
#4's (12" LONG)
1" CHAMFER
6 3"x3"x1/4"x5" LG. GALVANIZE EXPOSED FACE & WELD TOGETHER
3/8"x1"x1/4" STRAP
3/8" STUD BOLT x 3/4" Lg.
1 1/2" ROD x 8" LG.
2"x 1/8" WASHER (INSIDE DIA. 1 9/16")
1 1/2" ROD x 2" LG.
2"x2"x3/8" ℞
1"x1"x1/4" ℞
3/4"x1" BAR TAPERED TO 1/2" AS SHOWN
2"x1"x1/2" ℞
1/8" CHAMFER
5"x2 1/2"x1/2" ℞
FIELD WELD OPTIONAL
5/15 DETAIL
VERTICAL FLASHBOARD SUPPORT
Scale: 1" = 4"
1/4" PLATE
#4's
5C6.7
GALVANIZE EXPOSED SURFACE
6/15 DETAIL (2 REQD.)
Scale 1" = 4"
1/16" RADIUS
1/8" RADIUS
2" DIA.
DETAIL
TRIP CABLE ENDS (2 REQ'D)
Scale: 1" = 1"
I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.
DATE
REG. NO.
REVISIONS
SCALE: AS SHOWN
DWN. BY: A.C.B.
DATE: 11-6-68
DWG. NO.: 23/2-40054
CITY OF ANOKA
ANOKA, MINNESOTA
BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA
RUM RIVER DAM
FLASH BOARDS
SHEET NO. 15 OF 19 SHEETS

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

SCALE: AS SHOWN
DWN. BY: T.H.G.
DATE: 11-30-68
DWG. NO.: 23/2-40057

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
HANDRAIL

SHEET NO. 16 OF 19 SHEETS

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE________

REG. NO.________

REVISIONS

SCALE: AS SHOWN

DWN. BY: A.K.

DATE: 11-29-68

DWG. NO.: 23/2-4D058

CITY OF ANOKA

ANOKA, MINNESOTA

BARR ENGINEERING CO.

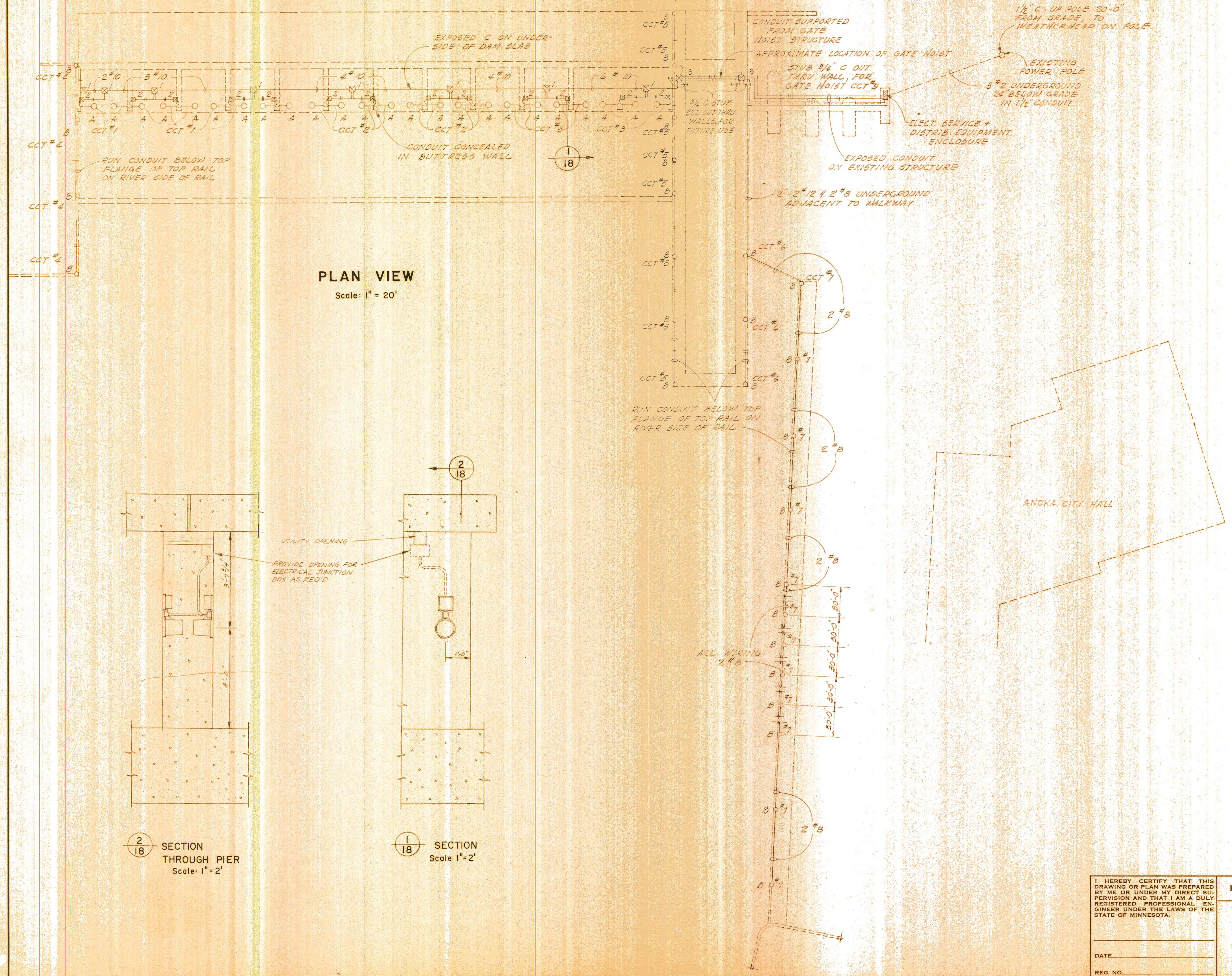
CONSULTING HYDRAULIC ENGINEERS

MINNEAPOLIS, MINNESOTA

RUM RIVER DAM

ARCHITECTURAL TREATMENT

SHEET NO. 17 OF 19 SHEETS



PLAN VIEW
Scale: 1" = 20'

2/18 SECTION THROUGH PIER
Scale: 1" = 2'

1/18 SECTION
Scale 1" = 2'

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE

REG. NO.

REVISIONS

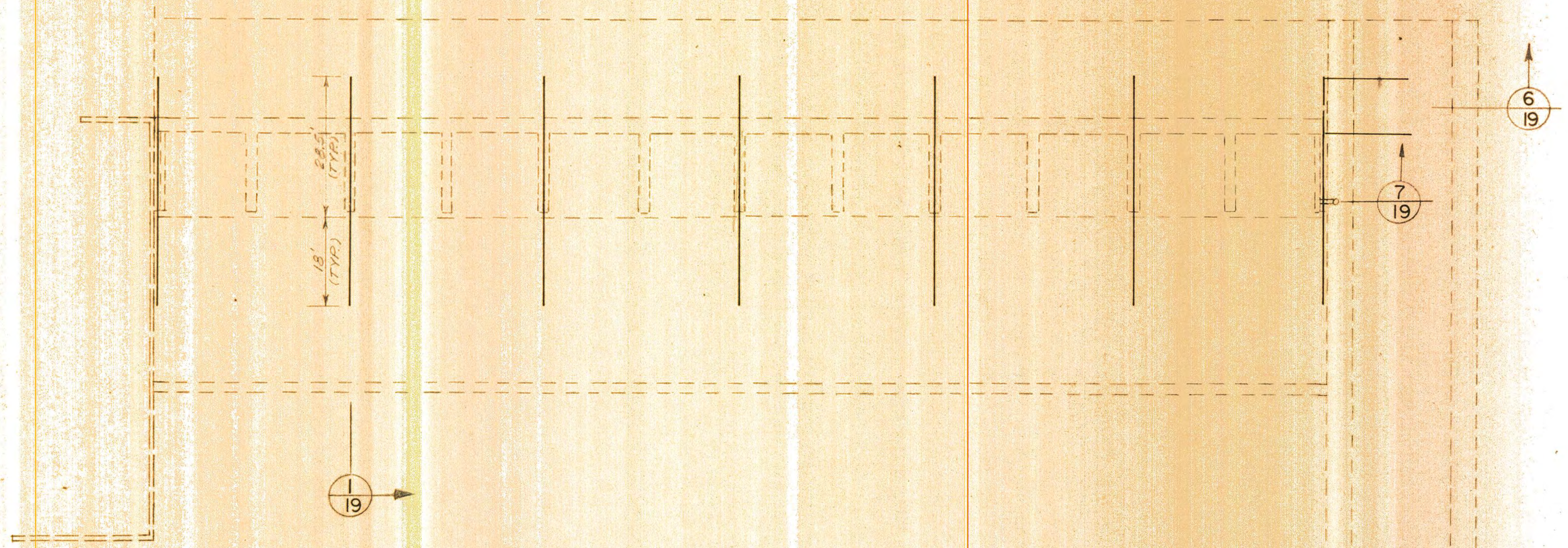
SCALE:	1" = 20'
DWN. BY:	R.W.M.
DATE:	11-29-68
DWG. NO.:	23/2-40059

CITY OF ANOKA
ANOKA, MINNESOTA

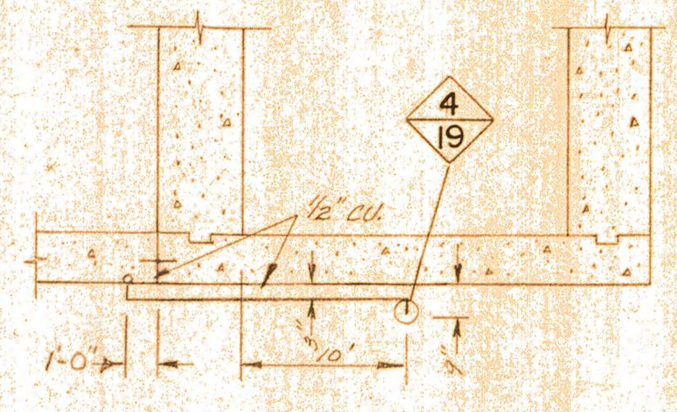
BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
ELECTRICAL CONSTRUCTION

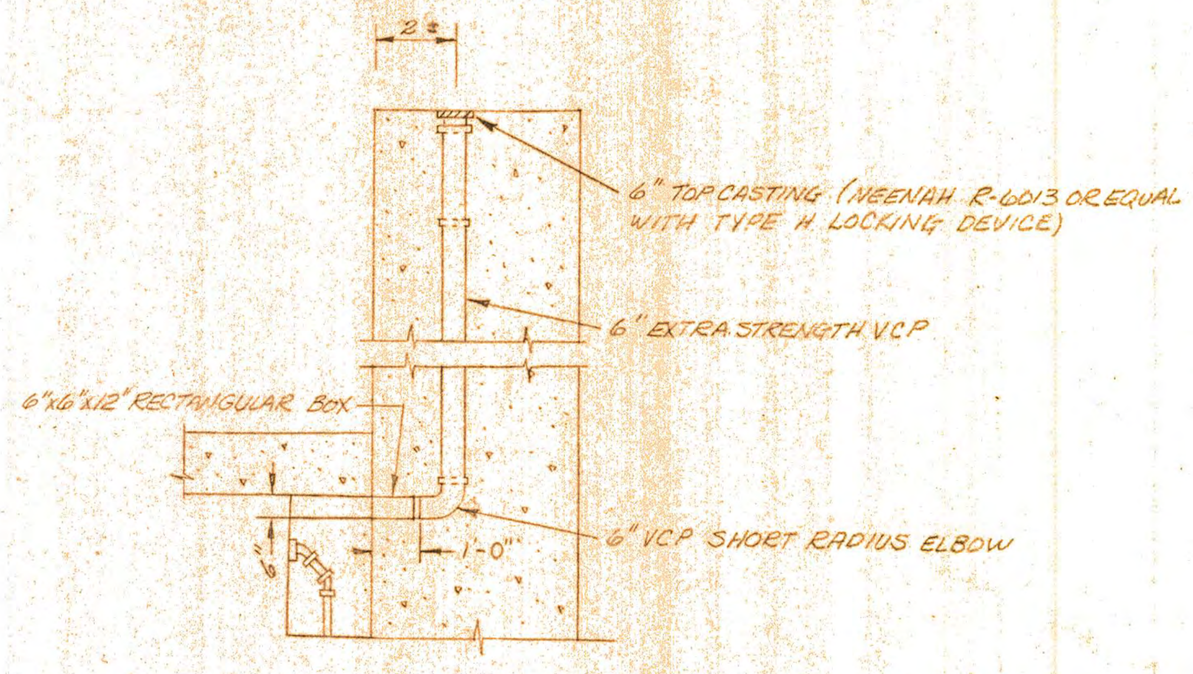
SHEET NO. 18 OF 19 SHEETS



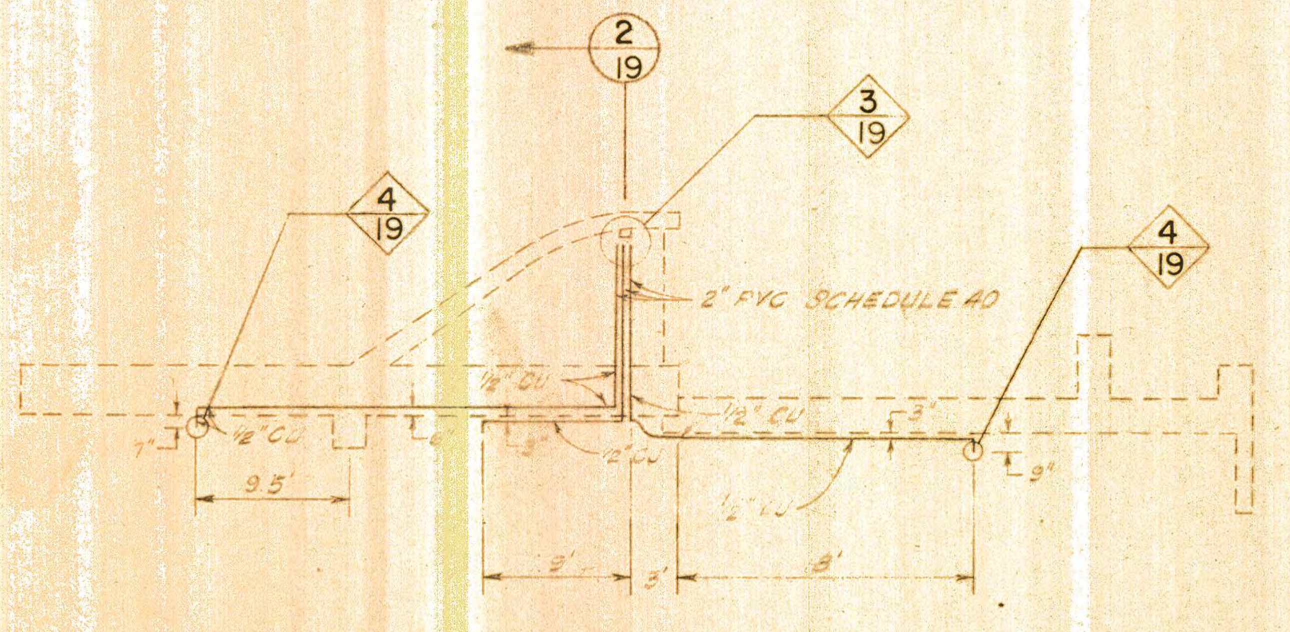
PLAN VIEW
Scale: 1" = 20'



6/19 SECTION THROUGH GATE SPILLWAY
Scale 1" = 10'

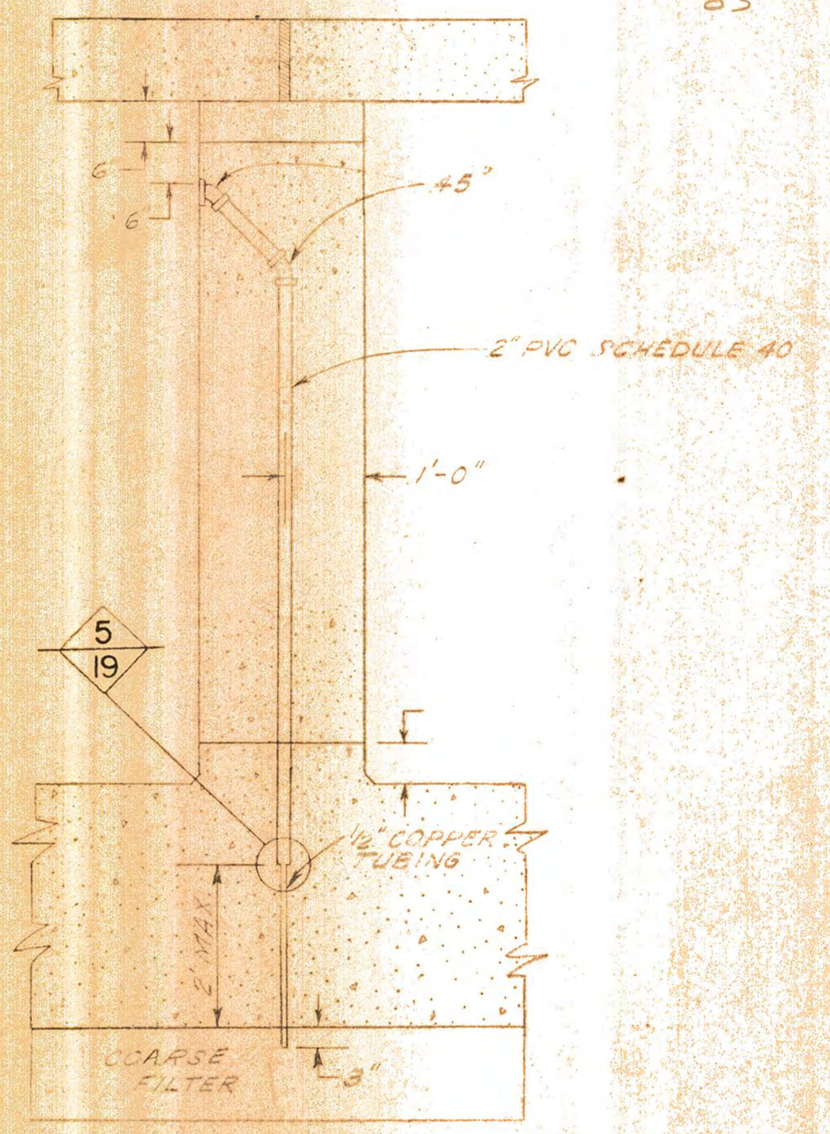


7/19 SECTION THROUGH PIER
Scale 1" = 4'

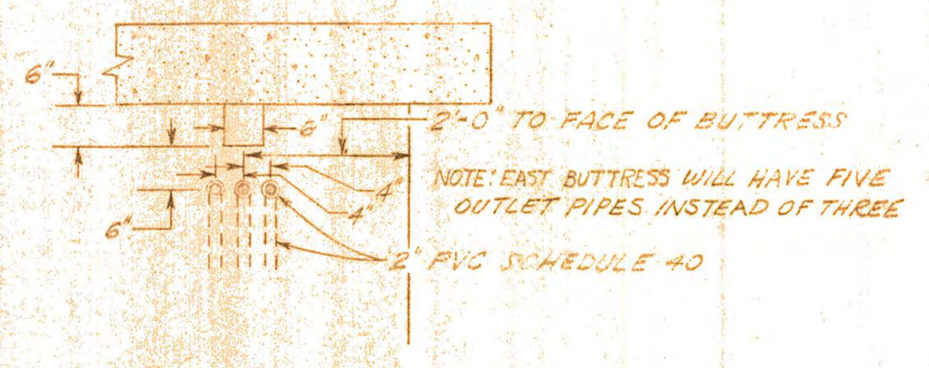


NOTE: ALL COPPER PIPE SHALL BE SOFT SEAMLESS TUBING CONFORMING ASTM SPECIFICATIONS B-88-53 TYPE K

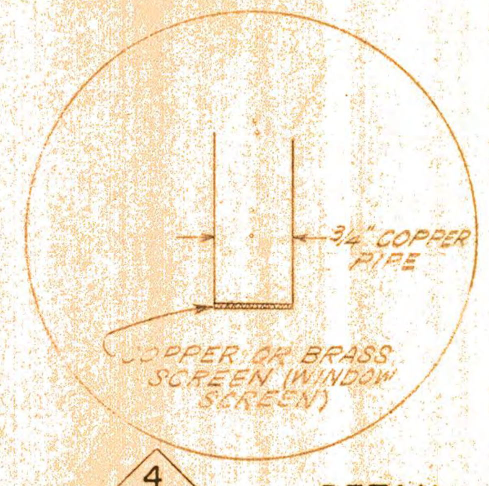
1/19 SECTION
Scale: 1" = 10'



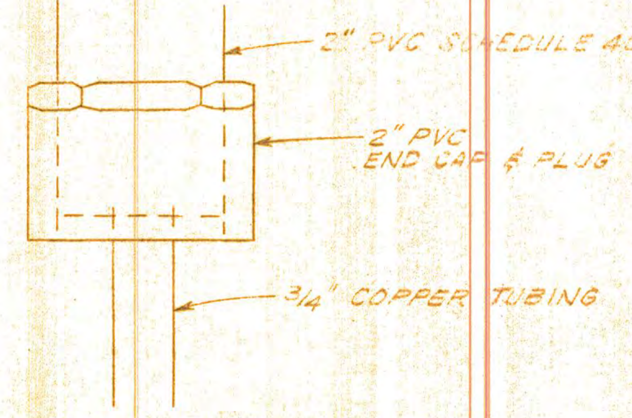
2/19 SECTION
Scale: 1" = 2'



3/19 SECTION
BUTTRESS OUTLET
Scale 1" = 2'

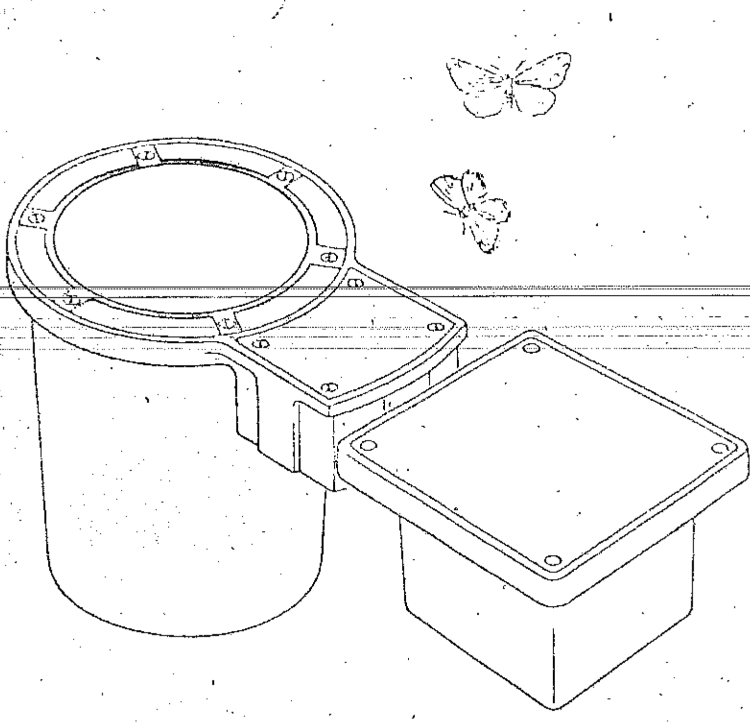


4/19 DETAIL
Scale: None



5/19 DETAIL
PVC TO COPPER TRANSITION
Scale 1/2" = 1"

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA. DATE ____ REG. NO. ____	REVISIONS	SCALE: AS SHOWN DWN. BY: A.C.B DATE: 11-14-68 DWG. NO.: 23/2-40060	CITY OF ANOKA ANOKA, MINNESOTA BARR ENGINEERING CO. CONSULTING HYDRAULIC ENGINEERS MINNEAPOLIS, MINNESOTA RUM RIVER DAM PIEZOMETER SYSTEM SHEET NO. 19 OF 19 SHEETS



Intense, controlled, adjustable up lighting... all cast construction for recessed mounting.

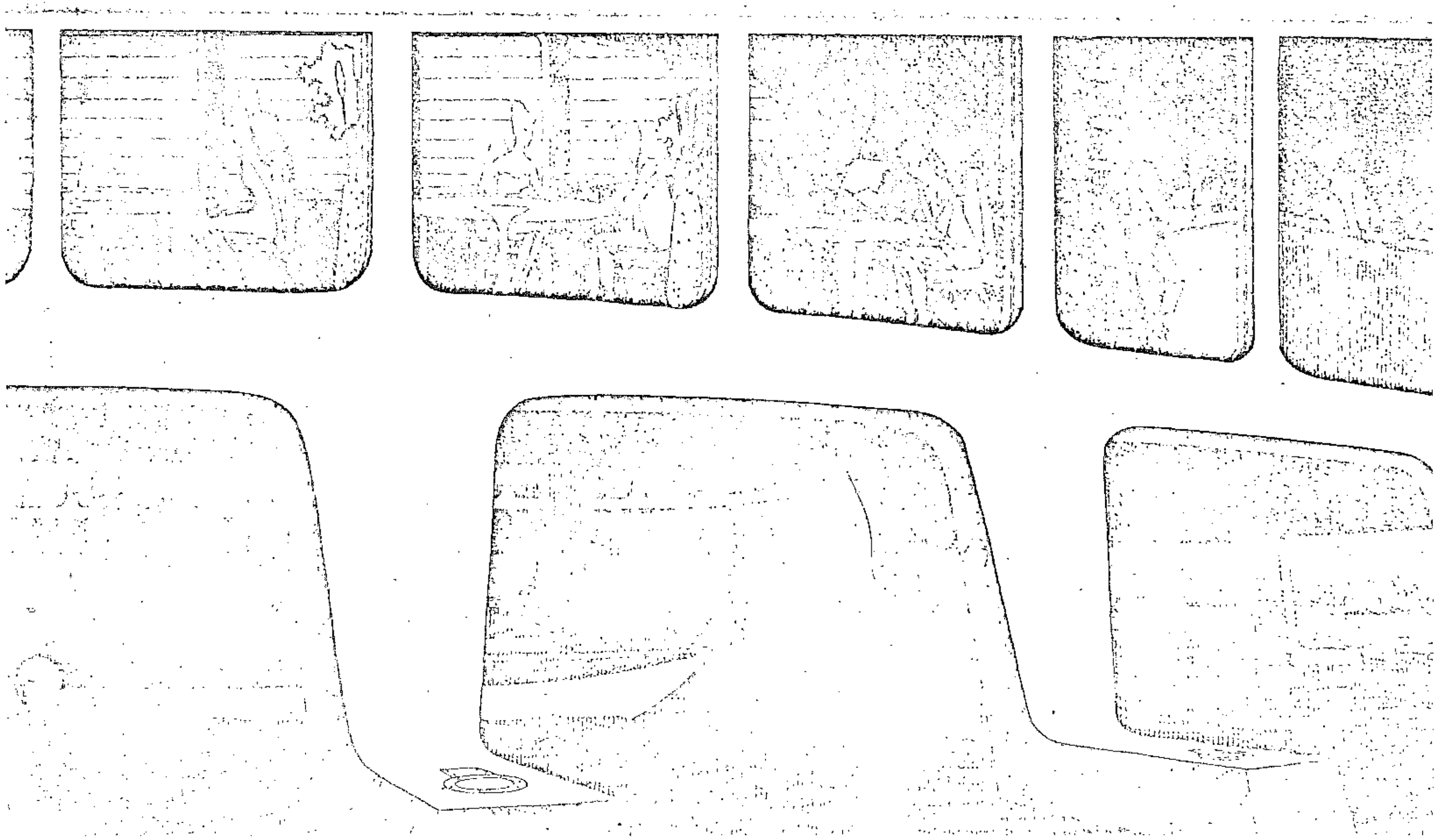
For accenting and spotlighting building facades, columns, trees or signs, the unit is flush mounted in ground, concrete or other surface materials providing an unobtrusive light source. The recessed housing is fully contained with integrally cast and pre-wired junction box. Lamp rotation is 360°; angular adjustment is 20°, enabling these units to be used ideally for effect lighting of monuments, public buildings, exterior displays, flag poles, mosaics, textured walls and trees.

Mercury vapor illumination is especially effective on light green foliage or wherever a tint of blue white color is desirable.

Flat or convex impact resistant tempered lens is gasketed for weathertight installation.

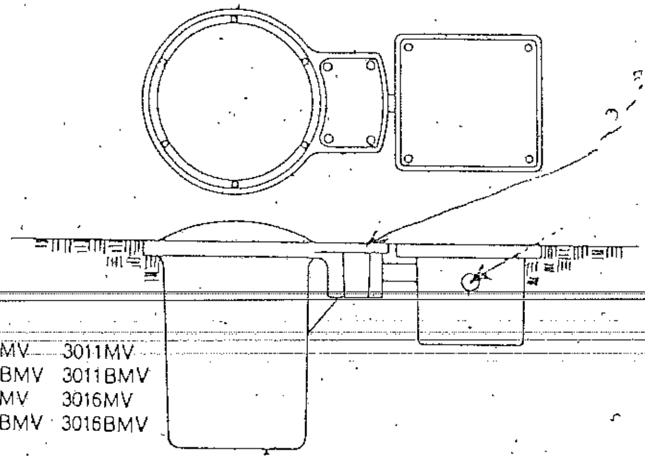
APPLICATIONS

Museums	*Churches*
Civic Centers	*Monuments*
Multi-story Structures	*Shopping Centers*
Malls & Parks	*Industrial Parks*



C4

3000 SERIES
Weather-resistant All Aluminum or Bronze Construction



Catalog No.	Description	Dimension: Depth	Dimension: Diameter	Dimension: Overall width with J-Box & Transformer	Wattage & Lamp
3010MV	Convex lens, cast aluminum	10¼″	9½″	20″	H4JM or H4GS 100W/MV PAR38
3010BMV	Convex lens, cast bronze	10¼″	9½″	20″	H4JM or H4GS 100W/MV PAR38
3011MV	Flat lens, cast aluminum	10¼″	9½″	20″	H4JM or H4GS 100W/MV PAR38
3011BMV	Flat lens, cast bronze	10¼″	9½″	20″	H4JM or H4GS 100W/MV PAR38
3015MV	Convex lens, cast aluminum	10¼″	9½″	20″	175W/MV R40 medium base only
3015BMV	Convex lens, cast bronze	10¼″	9½″	20″	175W/MV R40 medium base only
3016MV	Flat lens, cast aluminum	10¼″	9½″	20″	175W/MV R40 medium base only
3016BMV	Flat lens, cast bronze	10¼″	9½″	20″	175W/MV R40 medium base only

Catalog numbers are for complete units.

ENGINEERING SPECIFICATIONS

CONSTRUCTION — For flush mounting in ground, concrete or other surface materials. All cast aluminum or bronze construction with integral pre-wired J-box. Transformer box is standard with one ½″ N.P.T. in side. Additional tapings available on request. A water-tight isolation seal is provided between the J-box and housing to prevent entry of condensation from the conduit system. All cast bronze construction is recommended for use in areas where soil has high alkaline content or where corrosive elements are present.

LENS — Available with clear tempered convex lens or ⅜″ thick clear tempered impact resistant flat lens.

ADJUSTABILITY — 360° horizontal rotation. 20° angular tilt from vertical in two directions. Swivel is all cast construction with positive lock.

GASKETING — Lens & J-box access plates are fully gasketed for water-tight seal using silicone and neoprene gaskets.

WIRING — Pre-wired hi-temp wire.

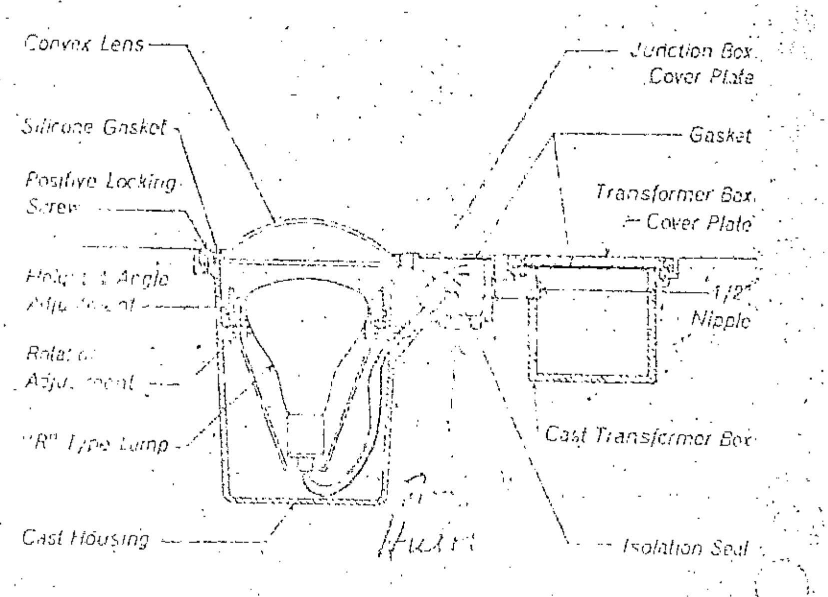
SOCKET — Units for "R" type lamps are supplied with medium base socket. Units for PAR lamps are supplied [illegible] medium PAR connector.

RELAMPING — Requires [illegible] of [illegible] flat head screws.

FINISH — Cast aluminum [illegible] protective epoxy exterior finish; interior [illegible] flat black. Bronze units are [illegible]

MERCURY VAPOR TRANSFORMER — Transformer housing for flush mounting with 120 volt [illegible] coil [illegible] power factor transformer is supplied as standard with [illegible] mercury vapor units. Transformer housing has cast top [illegible] water-tight seal with neoprene gasket. Construction [illegible] furnished in same material as lamp housing — cast [illegible]. Transformer housing is attached to lamp housing [illegible]. NOTE: If voltage or transformers other than standard [illegible] please contact your agent or factory for price quotation.

CAUTION — Due to the high temperature of lens, care should be exercised in the installation of units in walk over areas near swimming pools, playgrounds or parks where the possibility of contact with bare feet exists.



Appendix A2

1969 Construction Permit

W-76-50
Rev. 67

Minnesota Conservation Department
DIVISION OF WATERS, SOILS AND MINERALS
Centennial Building, St. Paul, Minnesota 55101

March 18, 1969

City of Anoka
c/o S.C. Gesko, Jr.
City Manager
2015 First Avenue North
Anoka, Minnesota 55303

Re: P.A.68-1566

Dear Sir:

Enclosed is a copy of the permit authorizing you to change the course, current or cross section of the Rum River, Anoka County.

Attached is notice to the public of the authority under which this work is being done. This card is to be securely posted in a conspicuous spot at the site of operations before any work is started.

It is your responsibility to notify this office and the local game warden before you undertake any work authorized by the permit in addition to complying with all of the provisions thereof.

Yours very truly,

Eugene R. Gere

Director, Division of Waters,
Soils and Minerals

Enc: Permit
Public Notice

W 70-50
Rev. 67

Minnesota Conservation Department
DIVISION OF WATERS, SOILS AND MINERALS
Centennial Office Building, St. Paul, Minnesota

Director	No. 68-1566
Sub-Owner	
Regulation	
Data	
Graphics	

P.A. 68-1566

IN THE MATTER OF THE APPLICATION OF **the City of Anoka, c/o S.C. Gesko, Jr. City Manager**

for a PERMIT TO CHANGE THE COURSE, CURRENT, OR CROSS SECTION of **Rum River**

Anoka County.

PERMIT

Pursuant to Minnesota Statutes, Chapter 105, and on the basis of statements and information contained in the permit application, letters, maps, and plans submitted by the applicant, and other supporting data, all of which are made a part hereof by reference, PERMISSION IS HEREBY GRANTED to **the City of Anoka, c/o S.C.Gesko,Jr. City Manager** whose address for the purpose of notices and other communications pertaining to this permit is **2015-1st AveN, Anoka, 55303** which address is subject to change by written notice from the permittee.

To:

Reconstruct and maintain an existing dam at its present location. The new dam is to have the same crest elevations and a discharge capacity (including emergency spillway) which at least equals that of the old dam. Construction shall be in accordance with the plans submitted on December 10, 1968.

PROPERTY DESCRIBED as: **Lot 2 and part of Lot 6, Auditor's Subdivision No. 119, being part of Government Lots 4 & 5, Section 1, Township 31 north, Range 25 west, Rum River, Anoka** COUNTY

for the purpose of **navigational improvement, water level control and aesthetics.**

This permit is granted subject to the following GENERAL and SPECIAL PROVISIONS:

GENERAL PROVISIONS

1. This permit is permissive only and shall not release the permittee from any liability or obligation imposed by Minnesota Statutes, Federal Law or local ordinances relating thereto and shall remain in force subject to all conditions and limitations now or hereafter imposed by law.
2. This permit is not assignable except with the written consent of the Commissioner of Conversation.
3. The Director of the Division of Waters, Soils and Minerals shall be notified at least five days in advance of the commencement of the work authorized hereunder and shall be notified of its completion within five days thereafter. The notice of permit issued by the Commissioner shall be kept securely posted in a conspicuous place at the site of operations.
4. No change shall be made, without written permission previously obtained from the Commissioner of Conservation, in the hydraulic dimensions, capacity or location of any items of work authorized hereunder.
5. The permittee shall grant access to the site at all reasonable times during and after construction to authorized representatives of the Commissioner of Conservation for inspection of the work authorized hereunder.
6. This Permit may be terminated by the Commissioner of Conservation, without notice, at any time he deems it necessary for the conservation of the water resources of the state, or in the interest of public health and welfare, or for violation of any of the provisions of this permit, unless otherwise provided in the Special Provisions.

SPECIAL PROVISIONS

I. Construction work authorized under this permit shall be completed on or before **December 30, 1969**. Upon written request to the Commissioner by the Permittee, stating the reason therefore, an extension of time may be obtained.

II. The excavation of soil authorized herein shall not be construed to include the removal of organic matter **--------DOES NOT APPLY--------** unless the area from which such organic matter is removed is impervious or is sealed by the application of bentonite after excavation.

III. In all cases where the doing by the permittee of anything authorized by this permit shall involve the taking, using, or damaging of any property, rights or interests of any other person or persons, or of any publicly owned lands or improvements thereon or interests therein, the permittee, before proceeding therewith, shall obtain the written consent of all persons, agencies, or authorities concerned, and shall acquire all property, rights and interests necessary therefor.

IV. This permit is permissive only. No liability shall be imposed upon or incurred by the State of Minnesota or any of its officers, agents or employees, officially or personally, on account of the granting hereof or on account of any damage to any person or property resulting from any act or omission of the permittee or any of its agents, employees, or contractors relating to any matter hereunder. This permit shall not be construed as estopping or limiting any legal claims or right of action of any person other than the state against the permittee, its agents, employees, or contractors, for any damage or injury resulting from any such act or omission, or as estopping or limiting any legal claim or right of action of the state against the permittee, its agents, employees, or contractors for violation of or failure to comply with the provisions of the permit or applicable provisions of law.

V. No material excavated by authority of this permit nor material from any other source, except as specified herein, shall be placed on any portion of the bed of said waters which lies below **the normal high water level**. It shall be the duty of the permittee to determine correctly all pertinent elevations at the site of the work for the purpose of complying with the conditions of this permit.

VI. Any extension of the surface of said waters resulting from work authorized by this permit shall become public waters and left open and unobstructed for use by the public.

(over)

SPECIAL PROVISIONS
VII DOES NOT APPLY.

VII. Receipt is hereby acknowledged of $ XXXXXXXXXXXX as payment for XXXXXXXXXXXX cubic yards of sand, gravel or rock and XXXXXXXXXXXX cubic yards of muck and silt, the estimated amount of material to be removed hereunder computed at the rate of ten cents per cubic yard for sand and gravel and two cents per cubic yard for muck and silt.

Permittee agrees by acceptance of this permit as shown by commencement of work authorized hereunder to pay, by certified check, bank or postal money order, made payable to the State Treasurer and delivered to the Director, Division of Waters, Soils and Minerals, Department of Conservation, Centennial Office Building, St. Paul, Minnesota 55101, for any material removed from the bed of public waters in excess of that so estimated, at the above rate within thirty days after completion of the work authorized hereunder.

VIII. The permittee shall assume responsibility for custody, operation and maintenance of said dam; and assignment of such responsibility may be authorized only through written approval of the Commissioner of Conservation.

IX. The permittee shall submit, to the Director of the Division of Waters, Soils and Minerals, records of any future maintenance work, other than of a minor nature, as soon after such work is completed as is practicable.

~~APPROVED~~

XXXXXXXXXXXXXXXXXXXX

~~BY~~

XXXXXXXXXXXXX

DATED AT ST. PAUL, MINNESOTA, THIS 18th DAY OF MARCH 1969

STATE OF MINNESOTA
DEPARTMENT OF CONSERVATION

BY: Eugene R. Gere

Director, Division of Waters, Soils and Minerals

Appendix A3

1972 Operations and Maintenance Manual

- REVISED -
Rec'd 7/28/72

OPERATION AND MAINTENANCE

RUM RIVER DAM

ANOKA, MINNESOTA

Barr Engineering Co.
6800 France Avenue South
Minneapolis, Minnesota

MEMORANDUM

City of Anoka

Re: RUM RIVER DAM OPERATION

Date: DECEMBER 12, 1977

To: Robert Johnson, City Engineer

From: Jerry Dulgar, City Manager

I have discussed the potential liability of the City as owners and operators of a Dam with the City Attorney. His opinion is that our potential liability is no greater when we have the gates open a minimal amount to control the river level, than they are when the gates are closed.

Therefore, I want you to leave the dam accessible to the people, unless the gates are wide open, or for a drawdown for repairs or something of that nature, or during an extremely high water period such as spring runoff.

Jerry Dulgar

OPERATION AND MAINTENANCE

RUM RIVER DAM

ANOKA, MINNESOTA

BARR ENGINEERING CO.

6800 France Avenue South
Minneapolis, Minnesota

T A B L E   O F   C O N T E N T S

A P P E N D I X

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Douglas W. Barr

Date May 16 1972 Reg. No. 3615

OPERATION AND MAINTENANCE

RUM RIVER DAM

ANOKA, MINNESOTA

General

The purpose of this manual is to provide general information and advive relating to the operation and maintenance of the Anoka Dam. It is intended to be used with the as-built drawings and construction specifications prepared by Barr Engineering Co., Minneapolis, Minnesota. Much of the information included in this manual was prepared during the preliminary and final design of the Anoka Dam.

Flashboard and Tainter Gate Operation

The manner of operation of the gates and flashboards will have a bearing on the pool levels during flood. The tainter gate must be opened and the flashboards removed if undesirably high flood levels are to be avoided.

If the boards are not removed prior to the spring flood, it can be expected that the flashboards will be lost on the average of once every three years. If the flashboards are not removed they will fail automatically at a stage of 848.5, due to a weak link connection. The boards will be lost downstream and it will be necessary to replace the flashboards with new materials. In addition, there may be occasional losses due to ice pressure during the winter. The loss of the flashboards due to floods can be minimized by removing them about two weeks prior to expected floods based on predicted flood discharges. Removal of flashboards according to the following procedure is recommended:

1. When the pool is below elevation 845.0, the tainter gate should be closed.

2. When the pool is at elevation 845.0, the tainter gate should be opened as necessary to hold the pool level at approximately elevation 845.0.

3. When the discharge exceeds about 2,800 cubic feet per second, the pool level will rise above elevation 845.0, even though the gate is wide open. When the pool level reaches elevation 847.0 and is still rising, the flashboards should be manually tripped. If they have not been removed they will automatically drop at approximately 848.5.

4. When the flashboards have been removed and the gate is wide open, there is no way to further increase the discharge capacity, and the river will rise as necessary to pass the flood flow. As the flood recedes, the gate should be left open until the pool reaches elevation 845.0. Thereafter, the gate should be gradually closed to hold the pool at about elevation 845.0.

5. By the time the flow recedes to about 5,700 cubic feet per second, the gate will be completely closed. The pool level will then continue to fall as the flow recedes, reaching elevation 842.5 at a flow of 1,000 cubic feet per second. At that point, the tainter gate can again be opened completely to permit reinstallation of the flashboards without water flowing over the dam.

6. When the flashboards are in place, the gate can be closed and normal operations resumed according to paragraphs 1 and 2 on the preceding page.

Flashboard Replacement

When the flashboards are replaced, it is important that they be replaced with the material and in the manner as specified in the as-built plans and specifications. It is also important that the weak link wire be replaced with a wire that has been tested to fail between 900-1100 pounds tensile strength. The replacement of this weak link wire should be completed in accordance with the diagram included in the appendix or the as-built plans. Also, the trip rope should be replaced in the manner as shown on the as-built plans.

Tainter Gate Maintenance

There are several miscellaneous maintenance items which should be checked on an annual basis including:

1. The level of the 50 percent glycol solution in the gate heater should be checked in the fall before the heater is operated. Every three years the solution should be drained and replaced with a fresh solution. A drain is located under the fixed crest slab through the west pier of the tainter gate structure.

   The temperature setting for the gate heater thermostat can be adjusted if it appears that the gate heaters are not operating satisfactorily. In any case the thermostat should not be set above 42° F. without an investigation of the effects of the stresses caused by this temperature on the structure.

2. The gate pinion should be greased with a heavy duty axle grease.

3. The condition of the gate seals should be checked and noted.

4. There are several operational aspects of the gate hoist that should be checked over carefully. These are included in the manufacturer's maintenance manual.

5. Instructions for lubrication of the gate hoist are listed on the lubrication plate which is located on the gate hoist.

Structural Stability

The dam is an Amberson type structure with stilling basin on foundation slabs with the fixed crest portion 236 feet long. The tainter gate spillway is 20 feet wide and is an ogee type spillway with an 88 foot stilling basin. The west abutment is on pile footings and serves mainly for erosion control along the bank and downstream of the dam. The west abutment and tainter gate spillway both allow public access and use of the facilities.

There are two rows of steel sheeting under the dam, both serving as seepage cutoffs. The front row is new sheeting and a second row 19 feet downstream of the new sheeting was part of the old structure. To monitor the effectiveness of these seepage cutoffs a piezometric system was installed under the foundation slabs. Three tubes are located in every other buttress wall under the fixed crest slab as shown on Sheet 19 of the as-built plans. Piezometric readings should be taken at least once each year. The readings should be taken when there is maximum differential head or when the tailwater is low, elevation 832, or lower and the headwater at the top of the flashboards.

The readings should be recorded and compared to previous readings. The readings are taken by measuring from the edge of the piezometric tube to the water level in the tube then subtracting the value from 839.5 to determine the piezometric level. Piezometric levels in the upstream tube would be approximately elevation 838. Piezometric levels in the other two tubes would be approximately elevation 832. If piezometric levels are higher than these, an investigation should be conducted to determine the cause.

During construction it was noted that two of the steel sheet piling had torn interlocks at approximately elevation 818. The location is shown on Sheet 20 of the as-built plans. The damage occurred during driving possibly because of buried obstructions. It was decided that a polyvinyl sheet would be installed upstream of the dam at elevation 832.5 to provide additional seepage cutoff. The piezometric levels in the tubes downstream at this location could be slightly higher than the others and should be monitored more frequently.

Any future work in the area of this polyvinyl sheet should be done carefully to avoid puncturing or destroying the sheet.

Downstream Scour

After severe floods, the downstream pool should be checked to determine if any serious scour occurred. Sections should be taken after floods of 10,000 cfs or greater or at least every three years and compared with the latest previous soundings. If it appears that serious scour has occurred or that the existing riprap has been significantly disturbed, steps should be taken to replace the riprap or to otherwise remedy the problem. Contours drawn from soundings taken after final construction are shown on Sheet 1 of the as-built plans.

Inspections

A comprehensive inspection of the dam should be conducted every ten years. That inspection should include all of the following items:

1. Analysis of the record of piezometer readings.
2. Inspection of all concrete surfaces for deterioration or wear.
3. Underwater inspection of tainter gate spillway, stilling basin, upstream and downstream sheet piling.

4. Inspection of all painted surfaces including tainter gate and handrails.

5. A report of the condition of the structure and recommended maintenance.

A P P E N D I X

Flood Frequency

The Anoka Dam is located on the Rum River less than a mile from its confluence with the Mississippi River. The nearest U.S. Geological Survey gage is located at St. Francis upstream of Anoka.

The discharge of the Rum River has been gaged near St. Francis for a period of about thirty-two years. Utilizing the record of measured flows, adjusted for intervening drainage area, a discharge frequency curve for Anoka was prepared. The curve indicates the probable flood discharge which could be expected for various recurrence intervals. For instance, the curve indicates that a flood flow of 16,000 cubic feet per second can be expected to occur on the average of once in 150 years. The greatest flood in the period of record was 11,400 cubic feet per second. It occurred in 1965.

The dam is designed to handle all flood flows up to 16,000 cubic feet per second. Because of the tailwater conditions prevailing, the critical discharge for various parts of the dam are frequently at relatively low flood flows. Because the tailwater rises rather rapidly at high discharges, it is probable that flood flows even greater than 16,000 cubic feet per second can be passed without damage to the dam.

Hydraulics

Since the new dam essentially replaces the old wood structure hydraulically, the headwater and tailwater curves for the new structure are similar to those of the old structure. Four headwater curves and one tailwater curve are enclosed. The headwater curves show levels for discharges with flashboards inplace and for the fixed crest dam without flashboards. Both are also shown with the tainter gate open and with the tainter gate closed. Also shown on these headwater curves are stages for St. Francis. Since St. Francis has the nearest gage, flood warning information from the Environmental Sciences Service Administration is usually given in terms of expected stage at St. Francis. Using that information, expected stages at Anoka can be obtained from the headwater curves.

The enclosed tailwater curve shows the elevation of the water surface just downstream of the dam for various flows of the Rum River. This curve represents the existing tailwater condition which was not changed by construction of the new dam. The curve was computed on the assumption that the Mississippi River could be at a relatively low level at the time that the flood occurs in the Rum River. This is a conservative assumption because a higher level in the Mississippi would cause a similarly higher tailwater level in the Rum River at the downstream side of the dam. The higher tailwater, in turn, would reduce the stress on the dam.

MANUFACTURERS AND SUPPLIERS

Globe Lite on Steel Standard

Sterner Lighting
Winsted, Minnesota 55395

Buttress Lighting

Kim Lighting and Manufacturing Co., Inc.
1467 Lidcombe Ave.
El Monte, California

Gate Hoist

Murry Machinery, Inc.
P. O. Box 1167
Wausau, Wisconsin 54401

Tainter Gate

Maxson Corp.
500 Como Ave.
P. O. Box 3585
St. Paul, Minnesota 55103

Tainter Gate Seals

Rubber Specialties Inc. (supplier)
8117 Pleasant Ave. So.
Minneapolis, Minnesota

Huntington Rubber Mills (manufacturer)
Box 570
Portland, Oregon 97207

Paint on Handrails and Gate

Michel Sales Co. (supplier)
1400 Selby Ave.
St. Paul, Minnesota 55104

Koppers Co., Inc. (manufacturer)
612 Chatham Center
Pittsburg, Pennsylvania 15219

Gages

Standard Signs Inc.
3190 East 65th Street
Cleveland, Ohio 44127

MANUFACTURERS AND SUPPLIERS

Plaque

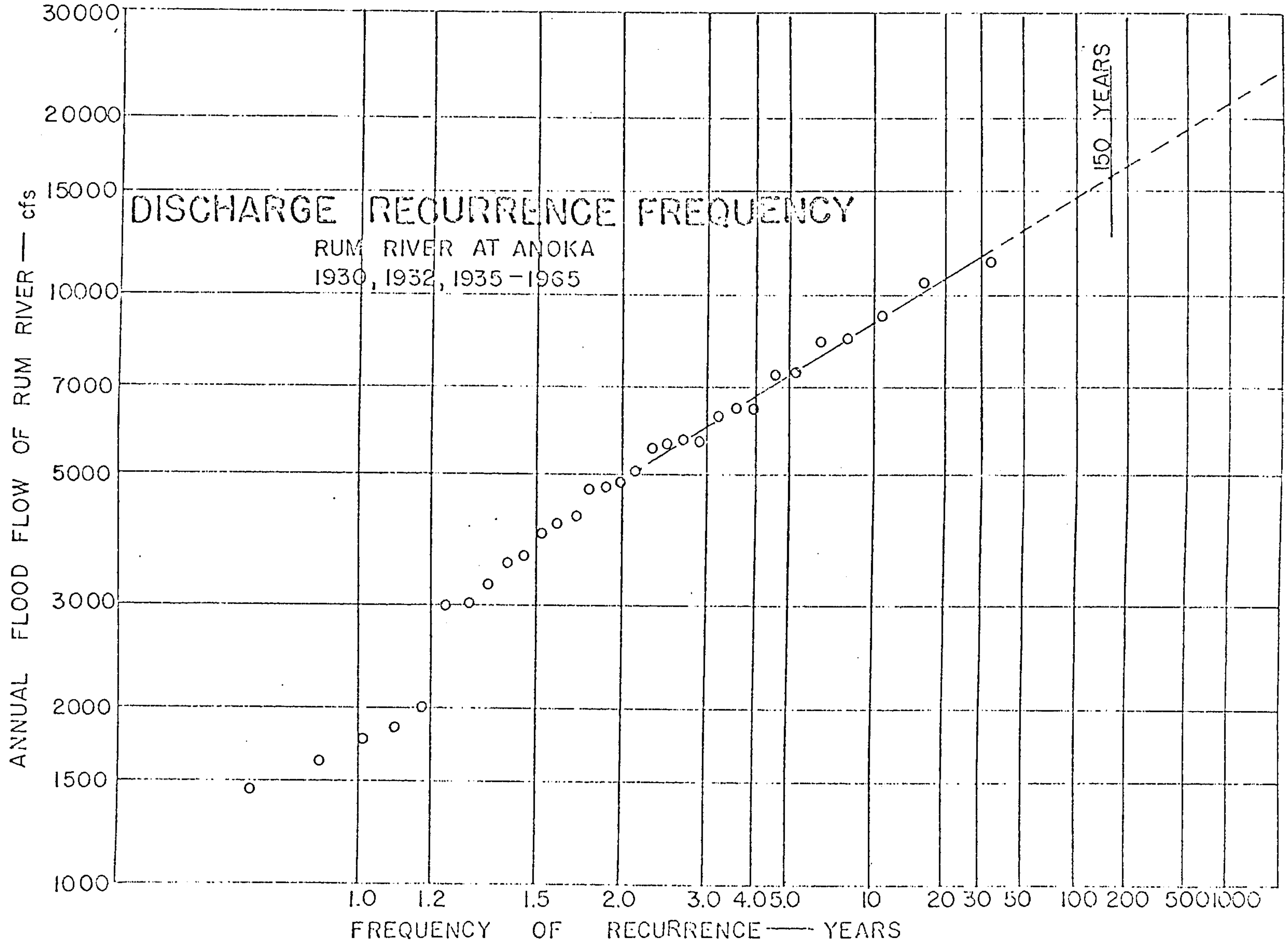
Wonderly Division of Concord
Industries Inc.
1243 Egan Industrial Blvd.
St. Paul, Minnesota 55118

Handrails

Standard Iron and Wire
2930 North 2nd St.
Minneapolis, Minn.

Foundation Drain Covers and Frames

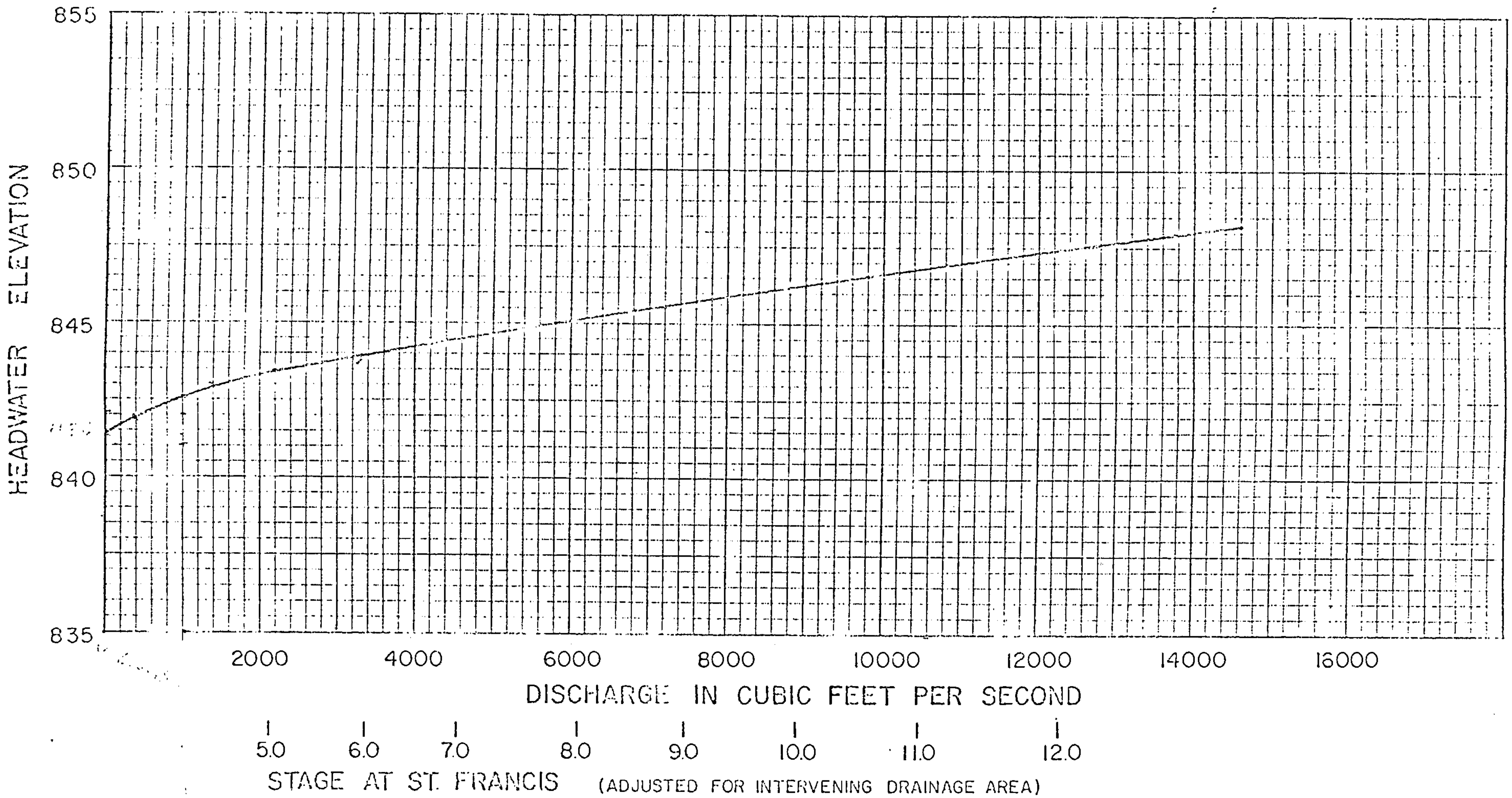
Neenah Foundry Company
Box 729
Neenah, Wisconsin 54956



DISCHARGE RECURRENCE FREQUENCY
RUM RIVER AT ANOKA
1930, 1932, 1935 - 1965
ANNUAL FLOOD FLOW OF RUM RIVER — cfs
30000
20000
15000
10000
7000
5000
3000
2000
1500
1000
150 YEARS
1.0
1.2
1.5
2.0
3.0
4.0
5.0
10
20
30
50
100
200
500
1000
FREQUENCY OF RECURRENCE — YEARS

ANOKA DAM

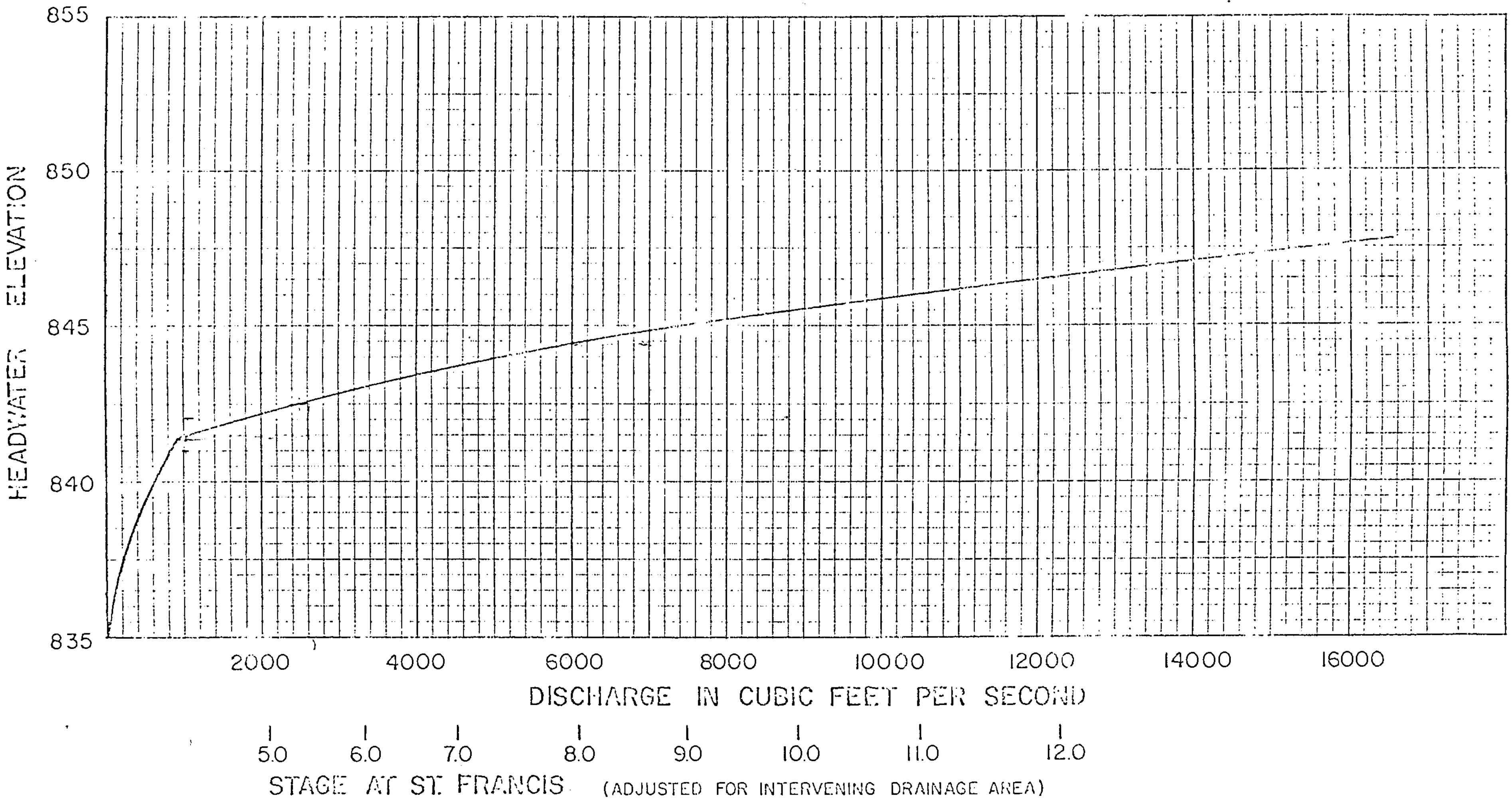
STAGE DISCHARGE FIXED CREST



BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS

ANOKA DAM

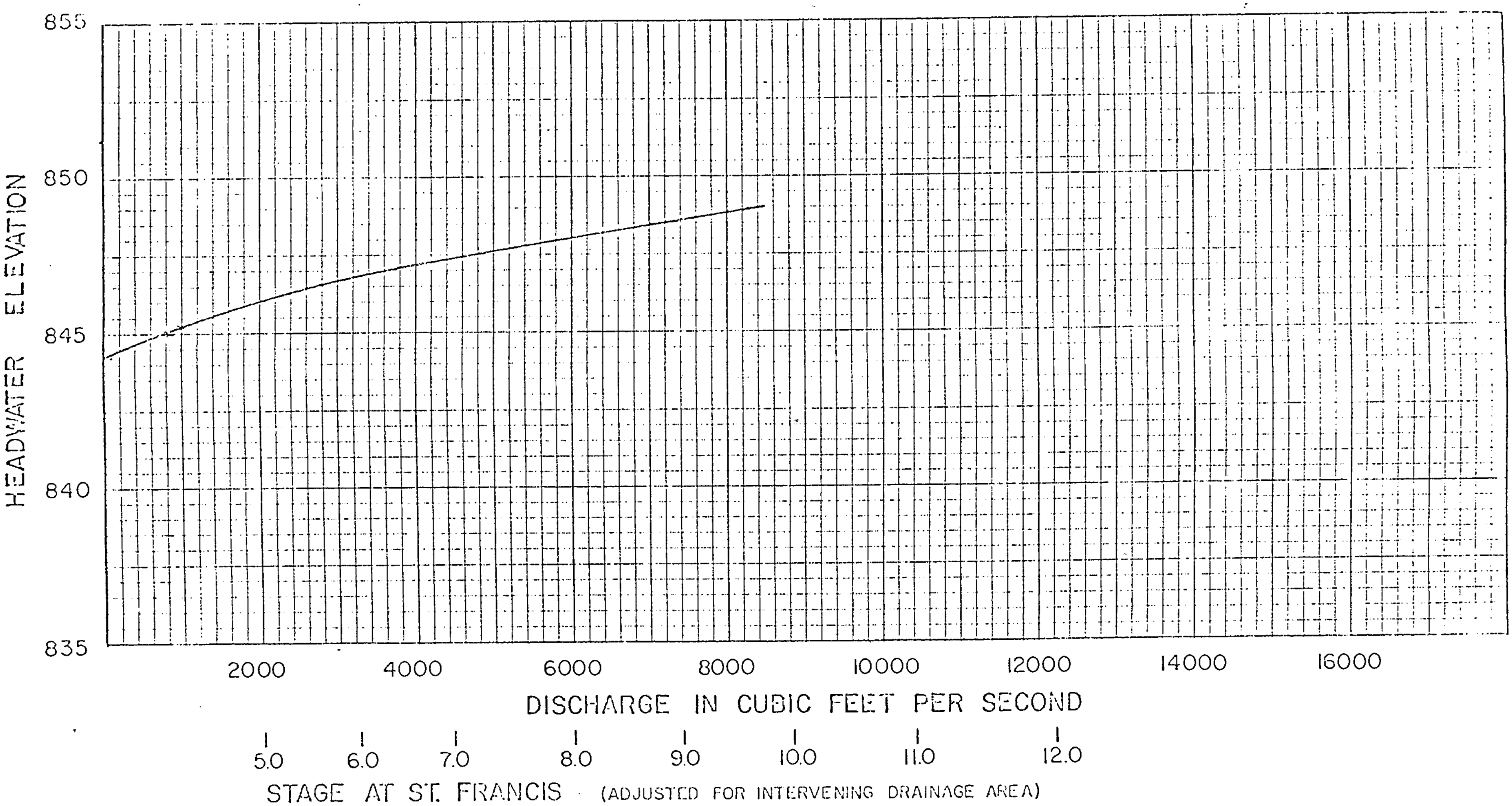
STAGE DISCHARGE FIXED CREST AND TAINTER GATE



BARR ENG ERING CO.
CONSULTING HYDRAULIC

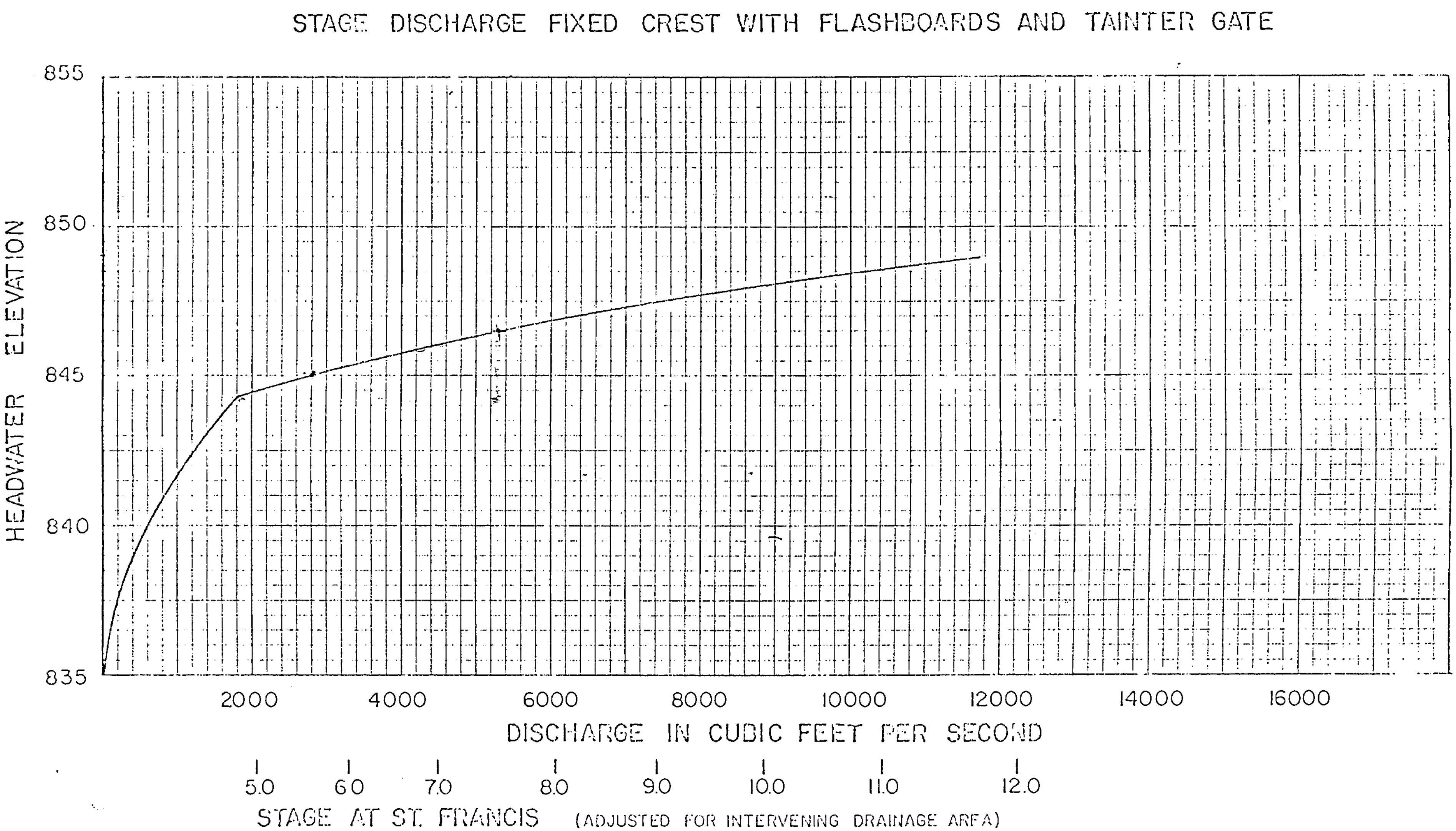
ANOKA DAM

STAGE DISCHARGE FIXED CREST WITH FLASHBOARDS INPLACE



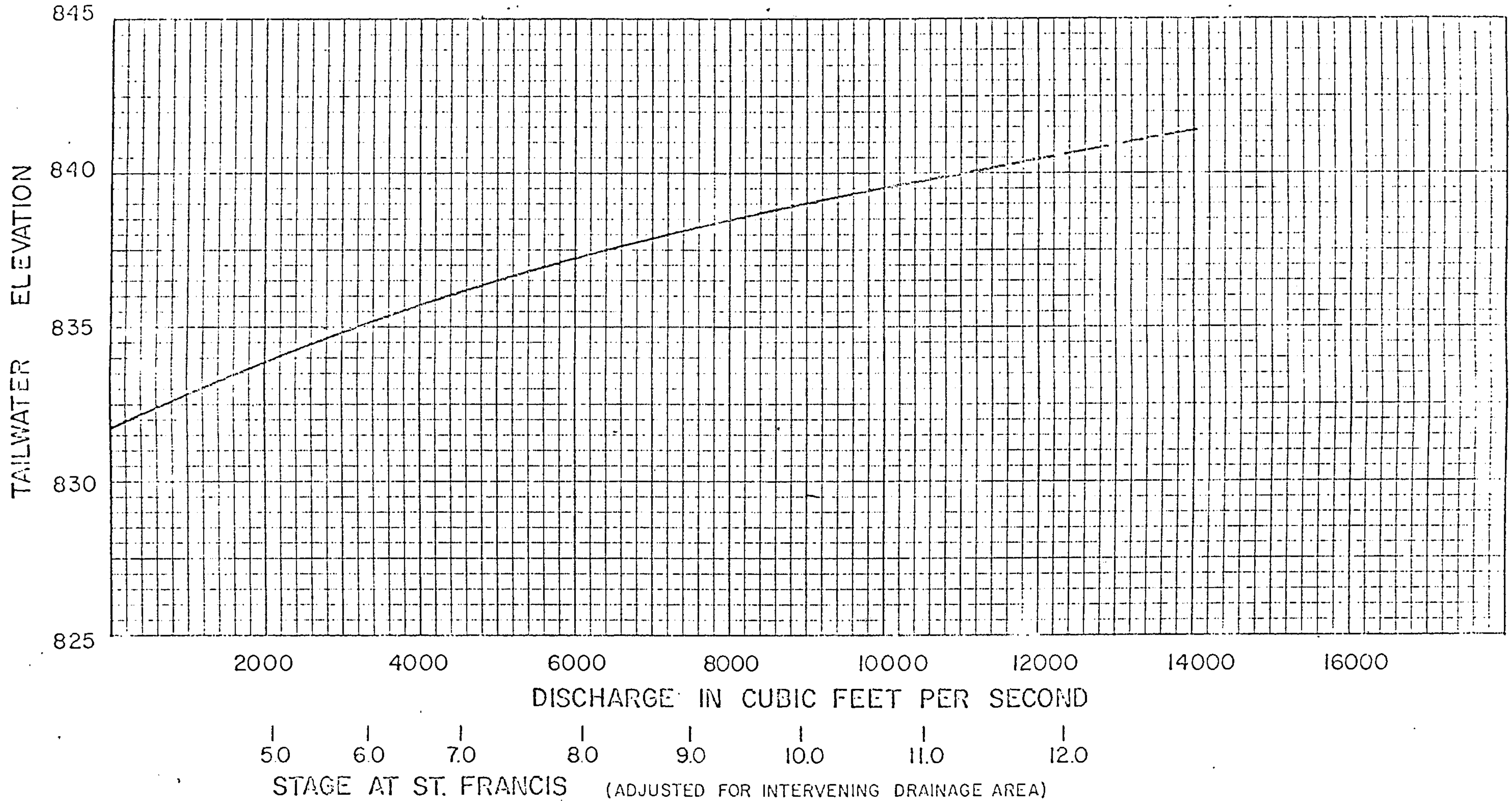
BARR ENGINEERING CO.

ANOKA DAM

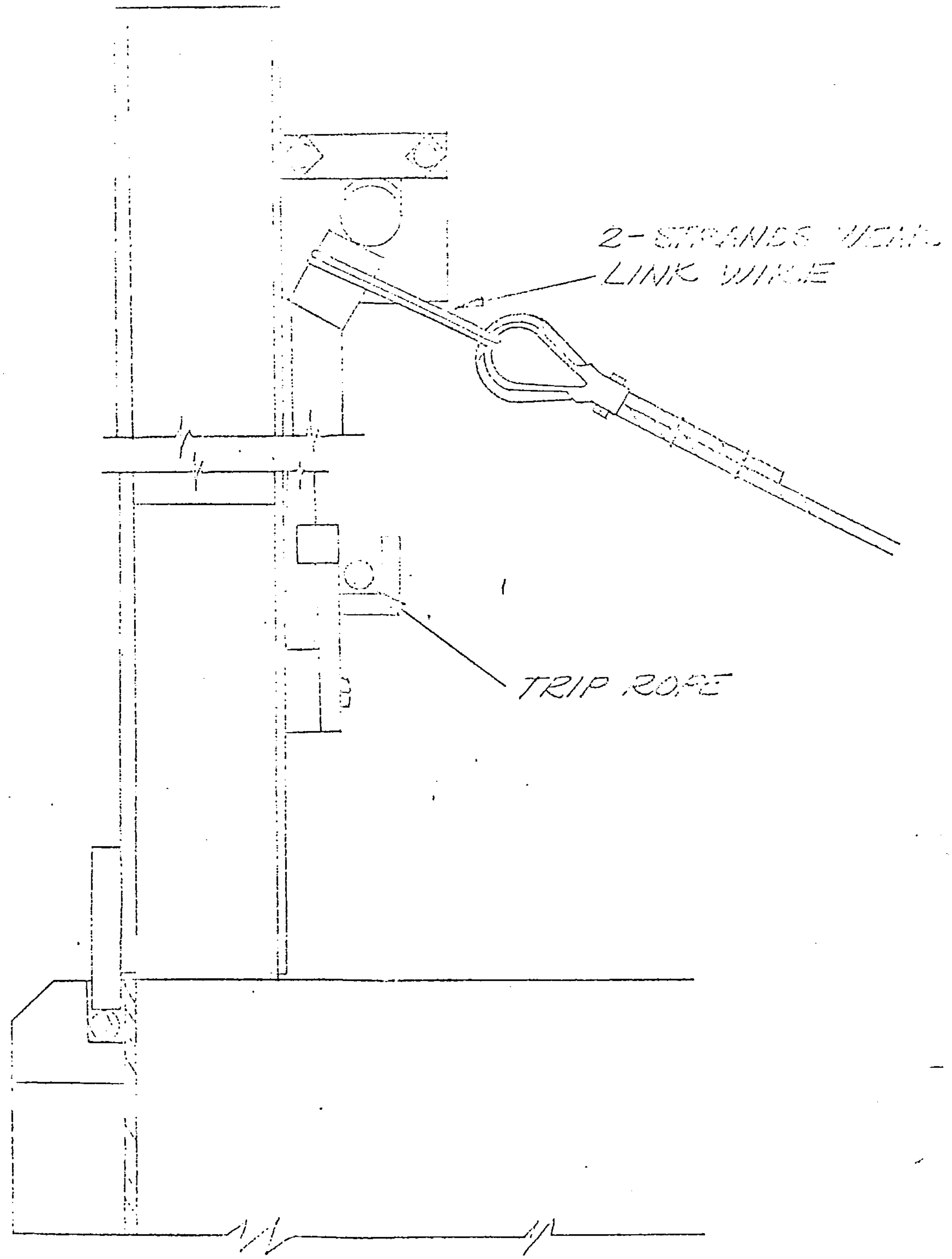


BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS

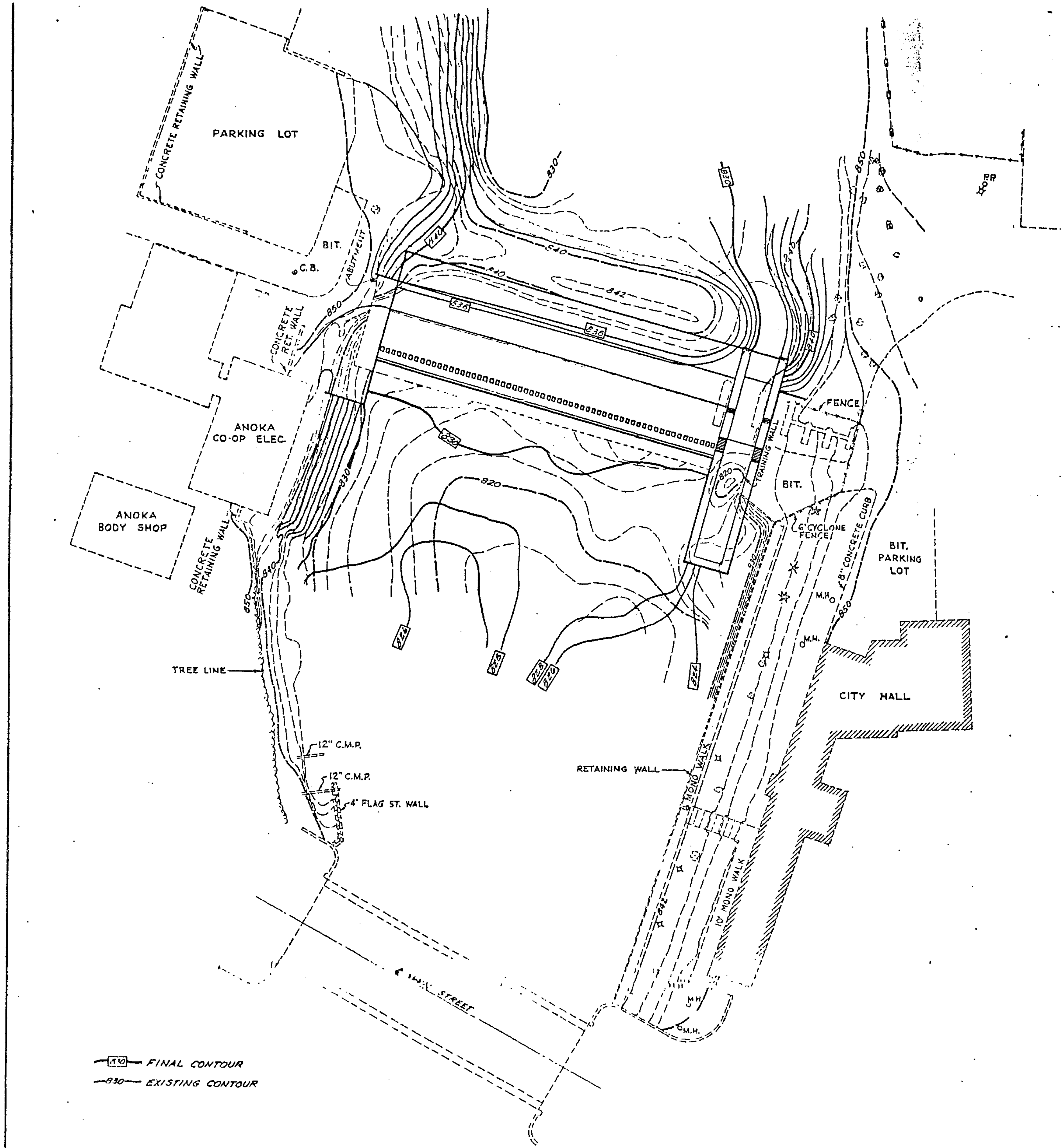
ANOKA DAM
TAILWATER LEVEL



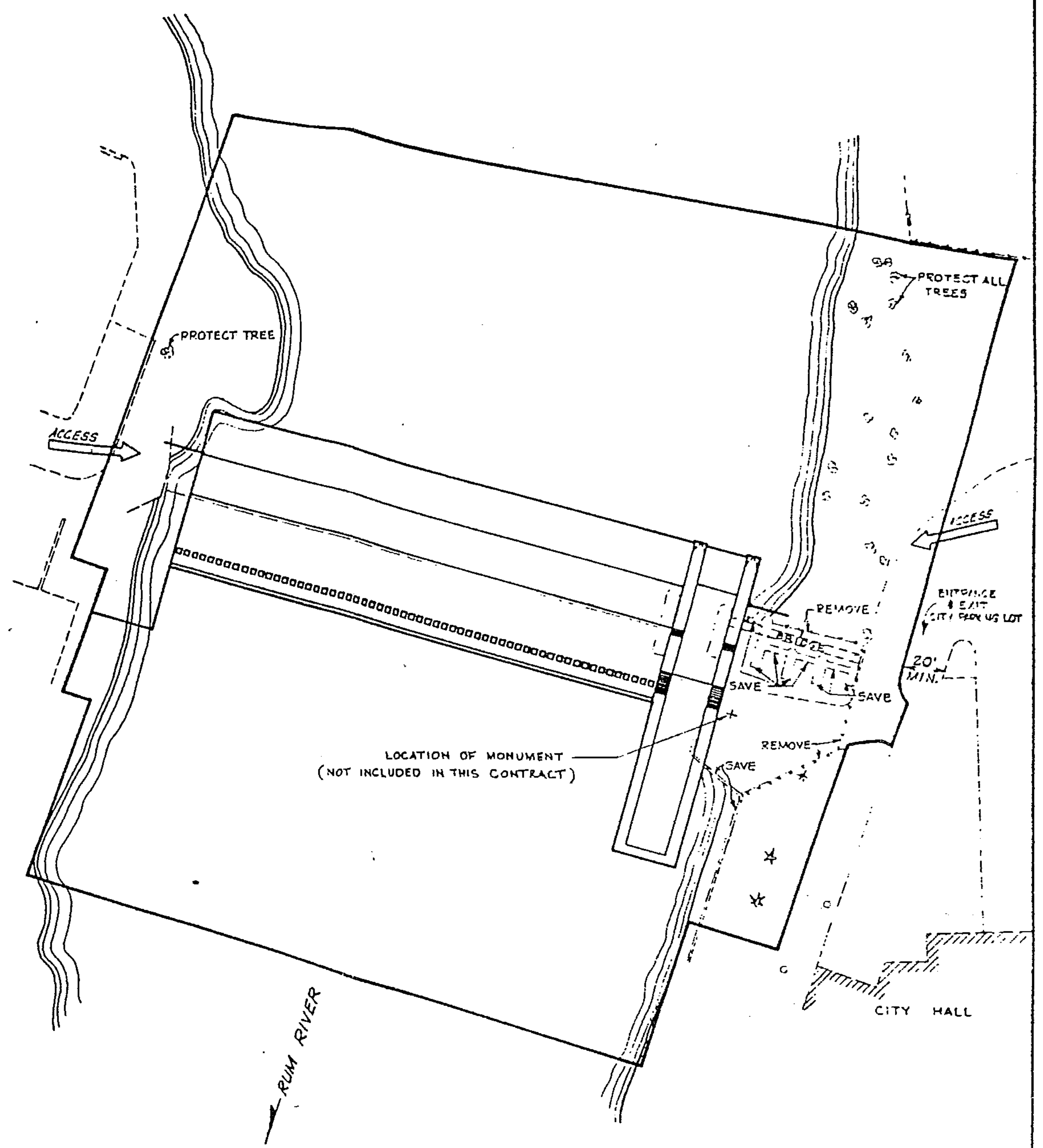
BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS



FLASH BOARD TRIP MECHANISM



LOCATION AND GRADING PLAN



CONSTRUCTION LIMITS

I HEREBY CERTIFY THAT THIS DRAWING OR PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

Douglas W. Barr

DATE 12-9-68

REG. NO. 3615

REVISIONS: AS BUILT 10/30/70

SCALE: 1" = 40'

DWN. BY: J. M.

DATE: 11-8-68

DWG. NO.: 23/2-40042

CITY OF ANOKA
ANOKA, MINNESOTA

BARR ENGINEERING CO.
CONSULTING HYDRAULIC ENGINEERS
MINNEAPOLIS, MINNESOTA

RUM RIVER DAM
LOCATION PLAN

SHEET NO. 1 OF 19 SHEETS

Appendix B

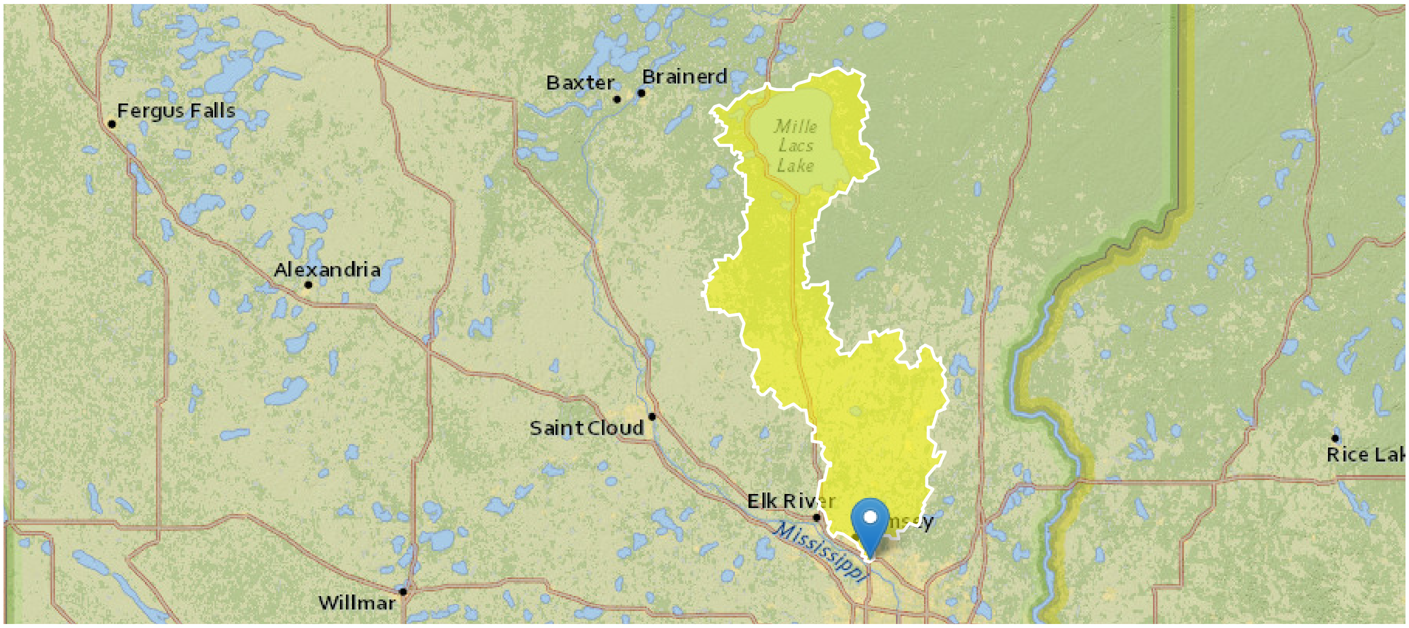
Hydraulics and Hydrology

Appendix B1

USGS StreamStats Report

Rum River Dam - StreamStats Report

Region ID: MN
Workspace ID: MN20240312130223159000
Clicked Point (Latitude, Longitude): 45.19952, -93.39088
Time: 2024-03-12 08:02:45 -0500



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
BSLDEM10M	Mean basin slope computed from 10 m DEM	1.88	percent
CSL10_85	Change in elevation divided by length between points 10 and 85 percent of distance along main channel to basin divide - main channel method not known	2.83	feet per mi
DRNAREA	Area that drains to a point on a stream	1573.22	square miles
GENRO	Generalized mean annual runoff in Minnesota 1951-85	7.11	inches
LAKEAREA	Percentage of Lakes and Ponds	14.4	percent
LAT_OUT	Latitude of Basin Outlet	45.199527	degrees
LC06CROP	Percentage of area of cultivated crops from NLCD 2006 class 82	34.5	percent
LC06FOREST	Percentage of forest from NLCD 2006 classes 41-43	24.3	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	0.0649	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	1.26	percent
LFPLENGTH	Length of longest flow path	186.79	miles
LOGDA	Logarithm base 10 of drainage area	3.2	Log base 10

Parameter Code	Parameter Description	Value	Unit
LONG_OUT	Longitude of Basin Outlet	-93.390877	degrees
PFLATLOW	Flat lands lower than median elevation from Wolock 2003 unpublished data	31.8	percent
PMPE	Precipitation minus potential evaporation from Wolock 2003 unpublished data	136	millimeters
SOILA	Percentage of area of Hydrologic Soil Type A	16.4	percent
SSURGOC	Percentage of area of Hydrologic Soil Type C from SSURGO	29.8	percent
SSURGOM	Percentage of organic matter in soils from SSURGO	7.92	percent
STORNWI	Percentage of strorage (combined water bodies and wetlands) from the Nationa Wetlands Inventory	38.3	percent

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Minnesota Peakflow B 2023 5079]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1573.22	square miles	0.23087298	1393.716374
LAKEAREA	Percent Lakes and Ponds	14.4	percent	0	18.18143582
SOILA	Percent Hydrologic Soil Type A	16.4	percent	0	54.49756
LONG_OUT	Longitude of Basin Outlet	-93.390877	decimal degrees	-96.1197813	-91.6585024

Peak-Flow Statistics Disclaimers [Minnesota Peakflow B 2023 5079]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [Minnesota Peakflow B 2023 5079]

Statistic	Value	Unit
66.7-percent AEP flood	1850	ft^3/s
50-percent AEP flood	2200	ft^3/s
20-percent AEP flood	3050	ft^3/s
10-percent AEP flood	3600	ft^3/s
4-percent AEP flood	4290	ft^3/s
2-percent AEP flood	4830	ft^3/s
1-percent AEP flood	5340	ft^3/s
0.2-percent AEP flood	6590	ft^3/s

Peak-Flow Statistics Citations

Christopher A. Sanocki and Sara B. Levin2023, Techniques for Estimating the Magnitude and Frequency of Peak Flows on Small Streams in Minnesota, excluding the Rainy River Basin, Based on Data through Water Year 2019, U.S. Geological Survey Scientific Investigations Report 2023-5079, 15 p. (https://doi.org/10.3133/sir20235079)

Flow-Duration Statistics

Flow-Duration Statistics Parameters [Flow duration Region BC 2015 5170]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1573.22	square miles	2.98	2960
STORNWI	Percentage of Storage from NWI	38.3	percent	2.44	48
SSURGOC	SSURGO Percent Hydrologic Soil Type C	29.8	percent	2.61	100

Flow-Duration Statistics Flow Report [Flow duration Region BC 2015 5170]

Statistic	Value	Unit
0.01 Percent Duration	13300	ft^3/s
0.1 Percent Duration	9570	ft^3/s
2 Percent Duration	4490	ft^3/s
5 Percent Duration	3110	ft^3/s
10 Percent Duration	2000	ft^3/s
25 Percent Duration	986	ft^3/s
50 Percent Duration	427	ft^3/s
75 Percent Duration	220	ft^3/s
90 Percent Duration	138	ft^3/s
95 Percent Duration	103	ft^3/s
99 Percent Duration	55.2	ft^3/s
99.9 Percent Duration	27.2	ft^3/s
99.99 Percent Duration	20.8	ft^3/s

Flow-Duration Statistics Citations

Ziegeweid, J.R., Lorenz, D.L., Sanocki, C.A., and Czuba, C.R.,2015, Methods for estimating flow-duration curve and low-flow frequency statistics for ungaged locations on small streams in Minnesota: U.S. Geological Survey Scientific Investigations Report 2015–5170, 23 p. (http://dx.doi.org/10.3133/sir20155170)

Maximum Probable Flood Statistics

Maximum Probable Flood Statistics Parameters [Crippen Bue Region 6]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1573.22	square miles	0.1	10000

Maximum Probable Flood Statistics Flow Report [Crippen Bue Region 6]

Statistic	Value	Unit
Maximum Flood Crippen Bue Regional	505000	ft^3/s

Maximum Probable Flood Statistics Citations

Crippen, J.R. and Bue, Conrad D.1977, Maximum Floodflows in the Conterminous United States, Geological Survey Water-Supply Paper 1887, 52p. (https://pubs.usgs.gov/wsp/1887/report.pdf)

Application Version: 4.19.4
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

Appendix B2

Water Allocation Model (sample)

User Operational Period Controls (Periods are Inclusive)

Fish Passage	On	Off	Minimum Aesthetic Spill	On	Off	Lock	On	Off	Recreation	On	Off	Hydropower	On	Off
Month	1	12	Month	1	12	Month	5	10	Month	5	10	Month	1	12
Day of Week	1	7	Day of Week	1	7	D.O.W.	5	7	D.O.W.	5	7	D.O.W.	1	7
Time of Day	0:00	23:59	Time of Day	0:00	23:59	T.O.D.	8:00	20:00	T.O.D.	8:00	20:00	T.O.D.	0:00	23:59
Cutoff River Q	3,000	cfs	Cutoff River Q	3,000	cfs	Cutoff River Q	3,000	cfs	Cutoff River Q	3,000	cfs	Cutoff River Q	7,500	cfs
Target Flow	75.0	cfs	Spill	100.0	cfs	Lock Fill Rate/Hr	21.7	cfs	Target Flow	300	cfs			
Min Flow	25.0	cfs				Lockages/Hr	4	OK	Min Flow	100	cfs			
0	< Loop Days		0	< Loop Days		1	< Loop Days		1	< Loop Days		0	< Loop Days	
0	< Loop Months		0	< Loop Months		0	< Loop Months		0	< Loop Months		0	< Loop Months	

FYI: Day of Week Excel Codes

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7

FYI: Feature Codes for Control Panel

FISH SPILL LOCK REC HYDRO

USER INPUTS

User Lock Controls

Depth (ft)	Length (ft)	Width (ft)	Volume (ft3)	Seconds	Q (cfs)
13	75	20	19,500	900	21.7

User Hydropower Controls

Min Q (cfs)	Max Q (cfs)	Efficiency (%)	Headloss (%)	Headwater Elevation
140	700	85%	5%	845

User Priority Controls

On (1) / Off (0)	1	1	1	1	1
Priority	1	2	3	4	5
	REC	FISH	LOCK	SPILL	HYDRO

User Chart Controls

X Axis		Y Axis	
Start Date	5/1/2012	Low Flow	0.0
End Date	11/1/2012	High Flow	1000.0

Update Chart (May take a minute)

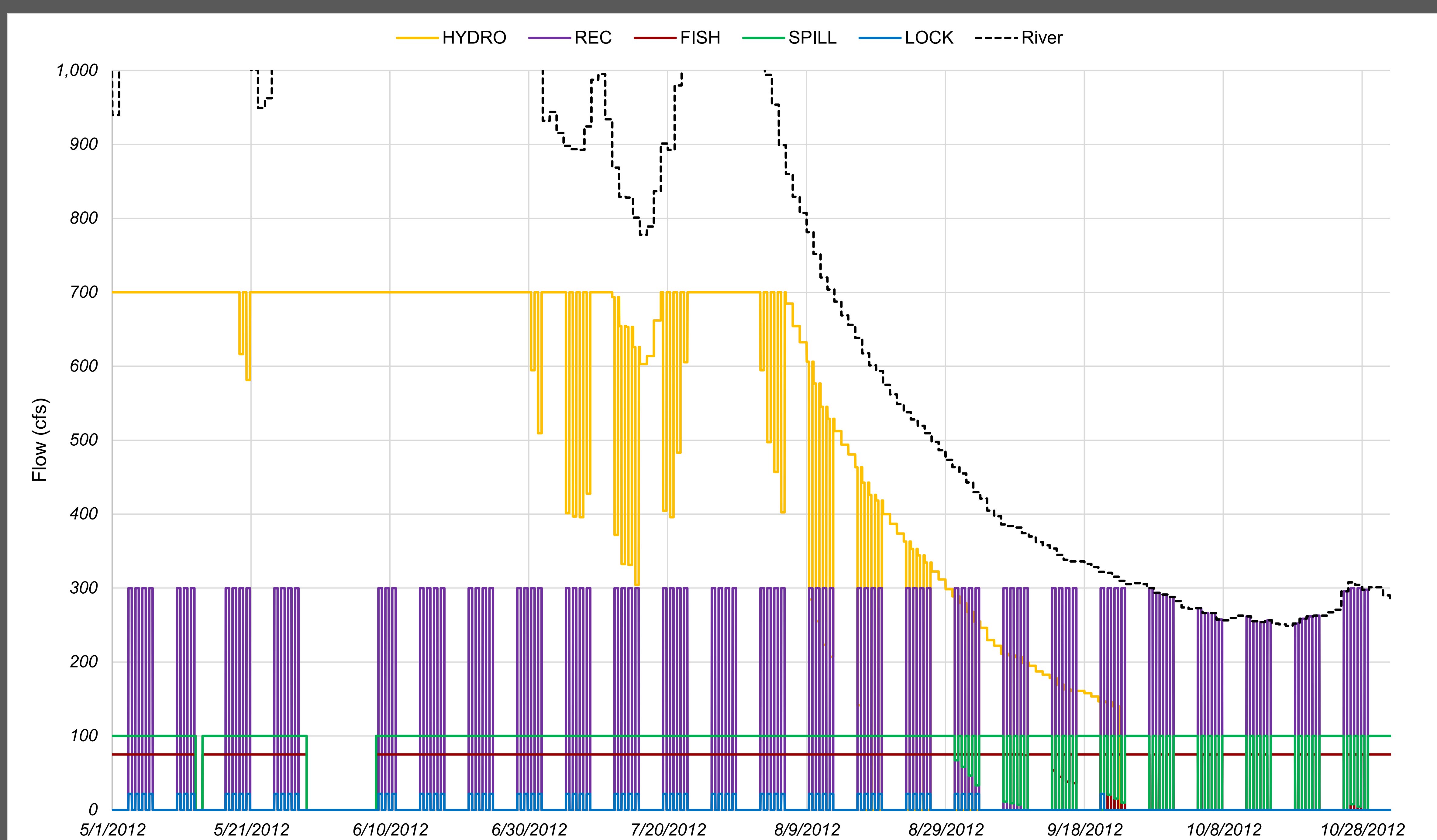
Chart →

Calculate Workbook

SUMMARY

Priority	Feature	Operating?	Target Flow	Start Month	End Month	Start D.O.W.	End D.O.W.	Start T.O.D.	End T.O.D.	Dry Availability	Ave Availability	Wet Availability
1	REC	Yes	300.0	5	10	5	1	8:00	20:00	75%	93%	82%
2	FISH	Yes	75.0	24/7	24/7	24/7	24/7	24/7	24/7	91%	93%	84%
3	LOCK	Yes	21.7	5	10	5	1	8:00	20:00	24%	64%	82%
4	SPILL	Yes	100.0	1	12	1	7	0:00	23:59	75%	92%	84%
5	HYDRO	Yes	700.0	24/7	24/7	24/7	24/7	24/7	24/7	20%	43%	83%

Note: As POR changes, Percent Availability columns must be extended



[redacted]

Appendix B3

Spillway Capacity Model

100 Year Regional Flood Spillway Capacity Analysis (w/Tainter)	18,074.94	848.43	845.2
	cfs	hw, ft	tw, ft

Note, 100 year regional flood assumes flooding also occuring on Mississippi River. Per FEMA, in this condition the tailwater at RRD is affected by Mississippi backwater and is at elevation 845.2 ft.

Computed By	J Dvorak	Date	10/15/2024	Job Number	10393640
Checked By	N Cox	Date	10/16/2024	Subject	Rum River Dam Spillway Capacity Modifica
Revision	0	Date			
Approved By	M Weber	Date	10/31/2024		

Tainter Gate

Original Q	**2,764.82**	cfs
From Rating Curve:	**2,764.82**	cfs
<u>Original Geometry</u>		
Sill	835	ft
Max Gate Opening	847.25	ft
Width	20	ft
Cd	2.81	15.03

Lock (Submerged Orifice)

Q	**3,030.36**	cfs
Sill	832	ft
Width	18	ft
Cd	2.53	

Change in Discharge		
Net	265.54	cfs
	10%	

$$Q = C_d L H^{3/2}$$

$$L = L' - 2(NK_p + K_a)H_e \qquad (4)$$

where:

L = effective length of crest,
L' = net length of crest,
N = number of piers,
K_p = pier contraction coefficient
K_a = abutment contraction coefficient, and
H_e = actual head on crest.

Design of Small Dams, Section 9

Rec/Fish Passage

Original Q (curve)	**4,737.04**	cfs
<u>Original Geometry</u>		
Sill	841.35	ft
Total L	236	ft
Raw Length	73.02	ft
pct	30.9%	
Effective L	69.83	ft

Rec/FP

Q From 2D Ras Mode	**4,545.00**	cfs

Change in Discharge		
Net	-192.04	cfs
	-4%	

Post-Construction Layout

Remaining Spill	162.9802	ft
Piers	0	#
Abutments	2	#
Pier Width	2	ft
Sill	841.85	ft msl
N:	0	#
K_p:	0.01	
K_a:	0.1	
OM Mount	0.5	ft
Tainter Abutment Pie	2	ft

Check - Total Original Q

18,074.94 cfs

Bay 1 - Existing

Existing L'	84.31	ft
Total L	236	ft
pct	35.7%	
Original Q (curve)	**5,469.48**	cfs
Original Q (eq)	**5,469.48**	cfs
Cd	3.4436	

Bay 1 - Post Construction

L'	83.31	ft
L	81.99	ft
Piers	0	#
Abutments	2	#
Q	**4,765.82**	cfs

Change in Discharge		
Net	-703.65	cfs

Flow Deficit for Bay 2

Original Q	18,074.94	cfs
Bay 1	4,765.82	cfs
Tainter	3,030.36	cfs
Rec	4,545.00	cfs
Total Deficit	**5,733.76**	cfs

Bay 2 - Existing

Existing L'	78.67	ft	
Total L'	236	ft	
pct	33.3%	100.0%	
L	78.01		
Original Q (curve	**5,103.60**	cfs	
Original Q (eq)	**5,103.60**	cfs	
Cd	3.4727		

Bay 2 - Post Construction

L'	75.67	ft
L	74.35	ft
Piers	0	#
Abutments	2	#

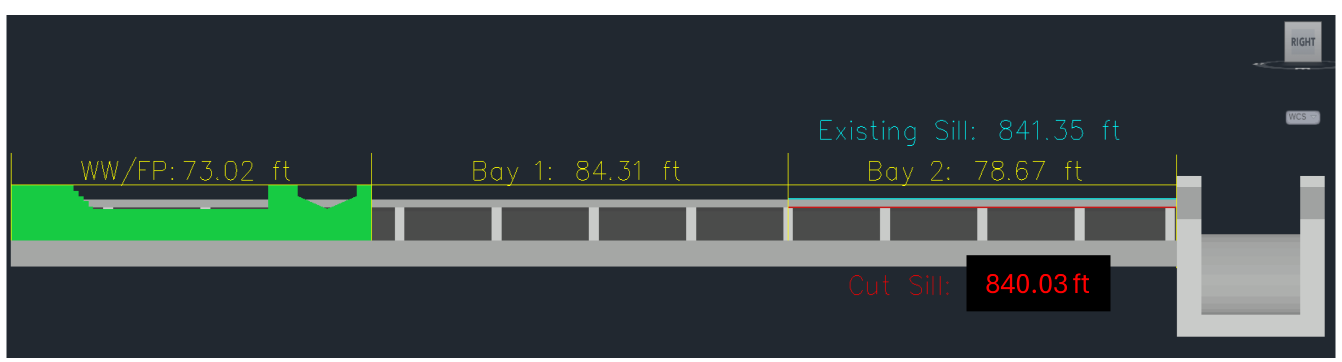
New Sill	**840.53**	ft msl
Required Bay 2	**5,733.76**	cfs

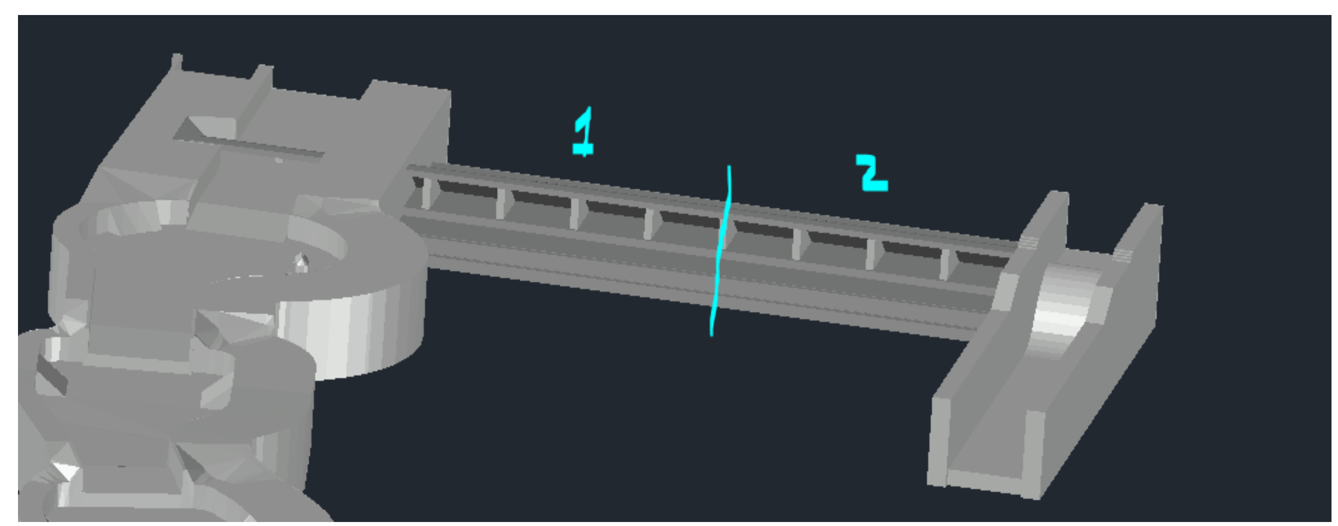
Bay 2 Cut Depth		
Delta	1.32	ft
Delta + Buffer	**1.82**	**ft**

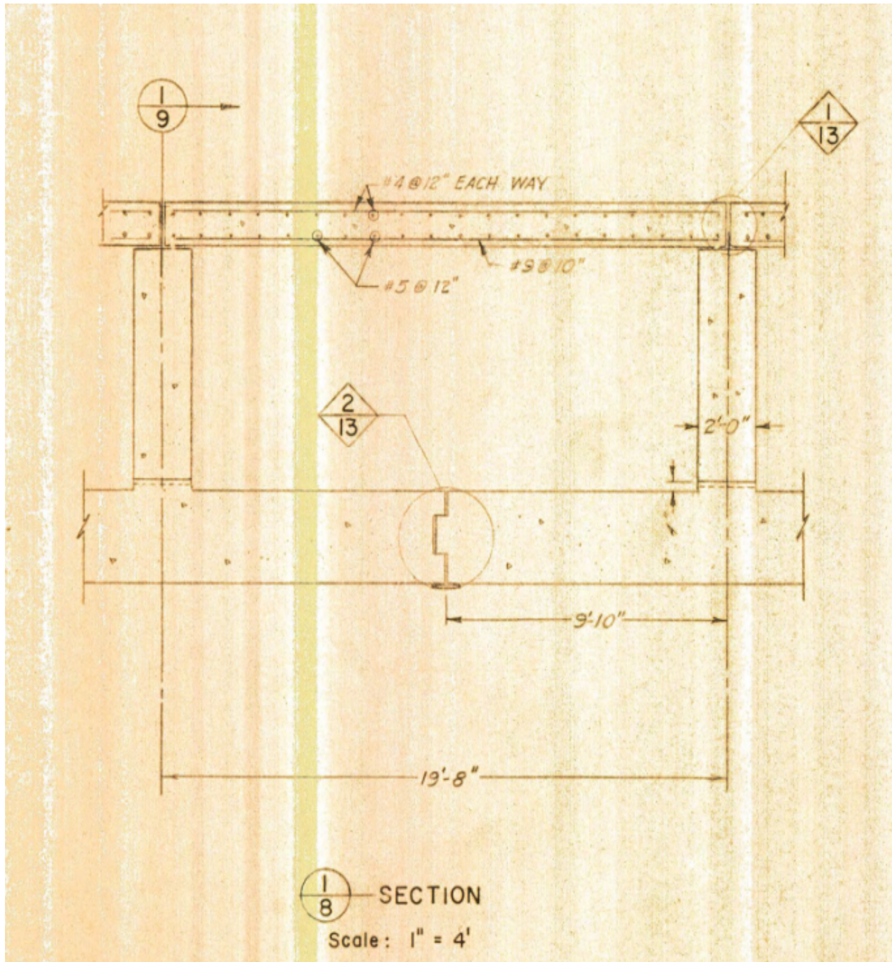
Buffer Sill	840.03	ft msl
Buffer L	74.83	ft
Final Bay 2 Q	**6,326.85**	cfs
Buffer Q	593.09	cfs
Post Construction Effective Len	226.18	ft
Post Construction 100 yr WSE w	849.88	ft

Sanity Check

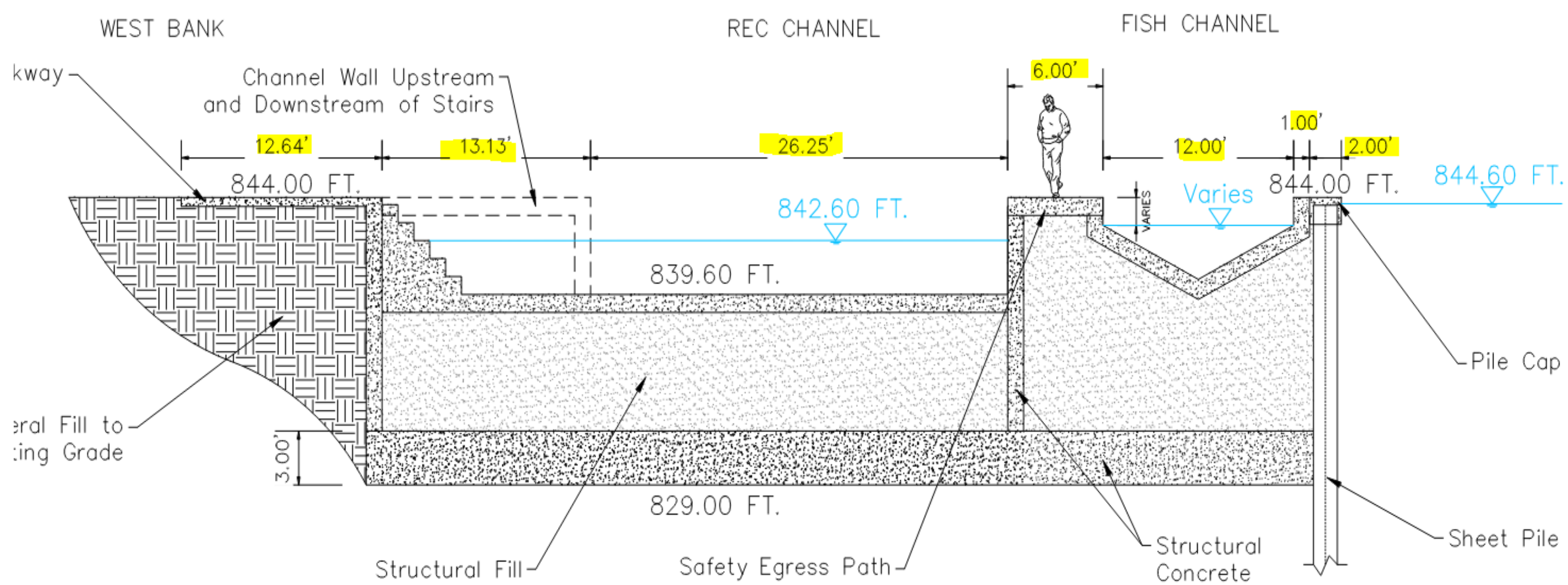
Total Original	**18,074.94**	
Original Tainter	**2,764.82**	
Original Rec	**4,737.04**	
Original Bay 1	**5,469.48**	
Original Bay 2	**5,103.60**	
Delta	**0.001**	
		Delta
Total Original	18,074.94	0.00
New Lock	3,030.36	265.54
New Rec	4,545.00	-192.04
New Bay 1	4,765.82	-703.65
New Bay 2	5,733.76	630.16
Delta	**-0.001**	0.00







1/9
1/13
#4 @ 12" EACH WAY
#5 @ 12"
#9 @ 10"
2/13
2'-0"
9'-10"
19'-8"
1/8 SECTION
Scale: 1" = 4'



WEST BANK
REC CHANNEL
FISH CHANNEL
kway
Channel Wall Upstream
and Downstream of Stairs
6.00'
12.64'
13.13'
26.25'
1.00'
12.00'
2.00'
844.00 FT.
842.60 FT.
Varies
VARIES
844.00 FT.
844.60 FT.
839.60 FT.
Pile Cap
eral Fill to
ing Grade
3.00'
829.00 FT.
Structural Fill
Safety Egress Path
Structural
Concrete
Sheet Pile W

SECTION A–A

Appendix B4

Energy Generation Model

Input:

Max Discharge =	68	*cfs*
Min Discharge =	20%	
Max Gross Head =	13.1	*ft*
Min Gross Head =	52%	
Min Spillway Flow =	100	*cfs*
Headloss =	5%	
Summer Pool =	845.0	*ft-msl*
Winter Pool =	842.0	*ft-msl*
Mean Overall Efficiency =	85%	

Output:

Min Discharge	13.6	*cfs*
Min Gross Head	6.8	*ft*

May thru October:

184 *days*

			Turbine Flow		WSEL		Head				
Time	River Q	Spill Q	Available	Actual	Head	Tail	Gross	Net	Power	Time	Energy
(%)	*(cfs)*	*(cfs)*	*(cfs)*	*(cfs)*	*(ft-msl)*	*(ft-msl)*	*(ft)*	*(ft)*	*(kW)*	*(hr)*	*(MWh)*
0.00	8,368.93	100.00	8,268.9	68.00	845.00	838.67	6.33	0.00	0.00		
5.00	3,239.94	100.00	3,139.9	68.00	845.00	835.06	9.94	9.44	46.20	220.80	5.10
10.00	2,460.16	100.00	2,360.2	68.00	845.00	834.36	10.64	10.11	49.48	220.80	10.56
15.00	1,834.14	100.00	1,734.1	68.00	845.00	833.76	11.24	10.68	52.28	220.80	11.23
20.00	1,471.70	100.00	1,371.7	68.00	845.00	833.39	11.61	11.03	53.97	220.80	11.73
25.00	1,263.03	100.00	1,163.0	68.00	845.00	833.18	11.82	11.23	54.97	220.80	12.03
30.00	1,098.28	100.00	998.3	68.00	845.00	833.00	12.00	11.40	55.77	220.80	12.23
35.00	986.26	100.00	886.3	68.00	845.00	832.89	12.11	11.51	56.32	220.80	12.38
40.00	896.20	100.00	796.2	68.00	845.00	832.79	12.21	11.60	56.77	220.80	12.49
45.00	816.03	100.00	716.0	68.00	845.00	832.70	12.30	11.68	57.17	220.80	12.58
50.00	734.75	100.00	634.8	68.00	845.00	832.62	12.38	11.77	57.58	220.80	12.67
55.00	660.07	100.00	560.1	68.00	845.00	832.53	12.47	11.84	57.96	220.80	12.76
60.00	586.48	100.00	486.5	68.00	845.00	832.45	12.55	11.92	58.34	220.80	12.84
65.00	512.90	100.00	412.9	68.00	845.00	832.37	12.63	12.00	58.72	220.80	12.92
70.00	447.00	100.00	347.0	68.00	845.00	832.30	12.70	12.07	59.06	220.80	13.00
75.00	398.68	100.00	298.7	68.00	845.00	832.24	12.76	12.12	59.31	220.80	13.07

			Turbine Flow		WSEL		Head				
Time	River Q	Spill Q	Available	Actual	Head	Tail	Gross	Net	Power	Time	Energy
(%)	*(cfs)*	*(cfs)*	*(cfs)*	*(cfs)*	*(ft-msl)*	*(ft-msl)*	*(ft)*	*(ft)*	*(kW)*	*(hr)*	*(MWh)*
80.00	353.65	100.00	253.65	68.00	845.00	832.19	12.81	12.17	59.54	220.80	13.12
85.00	311.91	100.00	211.91	68.00	845.00	832.15	12.85	12.21	59.76	220.80	13.17
90.00	263.59	100.00	163.59	68.00	845.00	832.09	12.91	12.26	60.02	220.80	13.22
95.00	207.58	100.00	107.58	68.00	845.00	832.03	12.97	12.32	60.31	220.80	13.28
100.00	100.4930491	100.00	0.49	0.00	845.00	831.91	13.09	12.44	0.00	220.80	6.66

November thru April:

181 days — Turbine Flow — WSEL — Head

Appendix C

Structural

Appendix C1

Spillway Stability Analysis

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision	0	Date			
Approved by		Date			

Description

Stability Calculations for sliding and resultant moment within middle 1/3 of dam

Bolded items are resultant calculations in this spreadsheet, *italized* items are are chosen values (constants or chosen values), normal items are supporting calculations

References

[1] U.S. Bureau of Reclamation. *Design of Small Dams* . 1987.

[2] Minnesota DNR. State Dam Safety Program rules (6115.0300 to 6115.0520)

Caclulations

Case	Category	Description
A	Usual	Dam as Monolith about downstream most point with sediment
B	Usual	Dam as Monolith about dam/spillway joint with sediment
C	Usual	US Dam about dam/spillway joint with sediment
D	Usual	Dam as Monolith about downstream most point without sediment
E	Usual	Dam as Monolith about dam/spillway joint without sediment
F	Usual	US Dam about dam/spillway joint without sediment

Assumptions

[1] Sheet piles do not alter (reduce) the uplift profile. Uplift decreases linearly from US pressure head to DS pressure head.

[2] The contribution of the sheet pile cutoff walls to global stability is conservatively ignored.

[3] Cohesion between the dam and foundation is conservatively ignored (c = 0 psi)

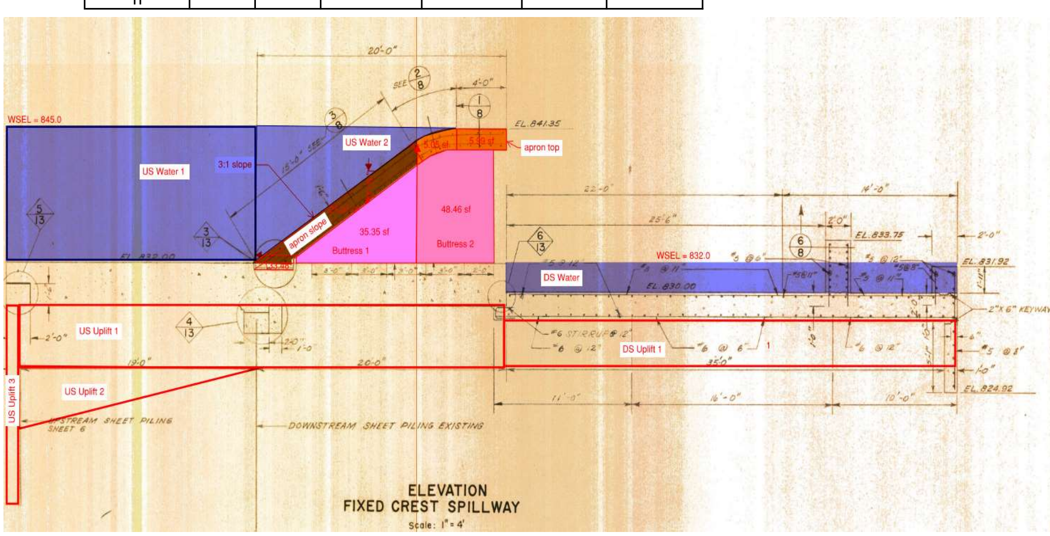
Acceptance Criteria

Recommended Safety Factors			
Category	Usual	Unusual	Extreme
Sliding	3.0	2.0	1.0
Overturning	*Base in 100% Compression*		

Results Summary

Rum River Dam - Stability Analysis Summary Table

Criteria	Calculated Factors of Safety					
	Load Case					
	A	B	C	D	E	F
Sliding	10.2	10.2	6.7	5.3	5.3	3.2
% Base in Compression	100%	100%	100%	100%	100%	100%



Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Description:

Stability Calculations for sliding and resultant moment within middle 1/3 of dam

Bolded items are resultant calculations in this spreadsheet, *italized* items are are chosen values (constants or chosen values), normal items are supporting calculatior

References:

[1] U.S. Bureau of Reclamation. Design of Small Dams. 1987.

[2] Minnesota DNR. State Dam Safety Program rules (6115.0300 to 6115.0520)

Analysis: Sliding and Resultant Moment Calculations

Dam as Monolith about downstream most point with sediment

Vertical Forces & Moments

	Unit Area Calc Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
	(ft)	(ft)	(ft)		(ft^3)	(pcf)		(lb)	(ft)	(lb-ft)
Upstream Base Slab	40	1	3	1	120	145	Down	17,400	56.0	974,400
Spillway Apron Top		11		1	11	145	Down	1,595	39.7	63,372
Spillway Apron Slope		21		1	21	145	Down	3,045	49.7	151,432
Butress Area 1		2.1		1	2	146	Down	303	47.6	14,442
Butress Area 2		2.8		1	3	146	Down	416	39.7	16,518
Downstream Base Slab	36	1	2	1	72	145	Down	10,440	18.0	187,920
U.S. Water 1	20	1	7	1	140	62.4	Down	8,736	66.0	576,576
U.S. Water 2	16	1	7	0.5	56	62.4	Down	3,494	50.7	177,050
D.S. Water	36	1	2	1	72	62.4	Down	4,493	18.0	80,870
DS 'Uplift 1	36	1	3.8	1	136.8	62.4	Down	8,536	18.0	153,654
US 'Uplift 1	39	1	2.8	1	109.2	62.4	Up	(6,814)	55.5	(378,181)
US Uplift 2	19	1	2	0.5	19	62.4	Up	(1,186)	68.7	(81,411)
US Uplift 3	1	1	16	1	16	62.4	Up	(998)	75.5	(75,379)
Silt 1	20	1	6	1	120	120	Down	14,400	66.0	950,400
Silt 2	9.1	1	6	0.5	27	120	Down	3,288	53.0	174,132
Ice	No additional vertical force attributed to normal condition due to Pressurized water undeneath the Ice Sheet									
Totals								67,149		2,985,793

Horizontal Forces & Moments

	Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
Water	N/A		7	1	N/A	62.4	Up	(1,529)	11.3	(17,326)
Silt	N/A		6	1	N/A	85	Up	(1,530)	5.0	(7,650)
Ice	1	1	16	1	16	0	Up	-	75.7	-
Totals								(3,059)		(24,976)

Sliding				
Net Weight	W	67,149	lbs	
Driving Force	F_D	3,059	lbs	
Resisting Force	F_R	31,312	lbs	W tanϕ
Required FOS	SF_{MIN}	3.0		
Safety Factor	**SF**	**10.24**	**OK**	F_R / F_D

Overturning				
Net Moment	M_{OT}	2,960,817	lbs-ft	
Middle 1/3rd Points		25.3	to	50.7
Resultant Location =	**44.09**	**ft**		M_{OT} / W
		OK, 100% Base in Compression		

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Supporting Information:

Piezometer Information				
	HWEL	P1	P2	P3
Reading	845	833.8	831.8	831.8
Bottom Slab	829	829	829	828
delta	16	4.8	2.8	3.8

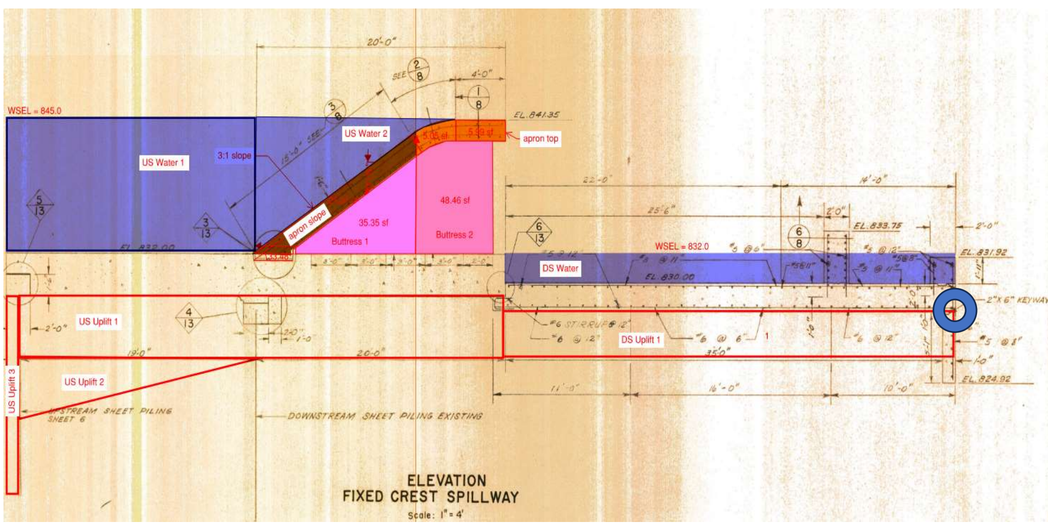
Soil Interaction	
phi	*25*
C	-

Silt Depth	
D	6

Water Surface	
Upstream	*845*
Downstream	*832*

Dam Slab Geometry	
US Slab Thickness	3
DS Slab Thickness	2

Dam Geometry



Moment Arm Calc

	Length (ft)	Arm (ft)
Upstream Base Slab	40	56.0
Spillway Apron Top	4	39.7
Spillway Apron Slope	16	49.7
Butress Area 1	16.0	47.6
Butress Area 2	4.0	39.7
Downstream Base Slab	36	18.0
U.S. Water 1	20	66.0
U.S. Water 2	16	50.7
D.S. Water	36	18.0
DS 'Uplift 1	36	18.0
US 'Uplift 1	39	55.5
US Uplift 2	19	68.7
US Uplift 3	1	75.5
Silt 1	20	66.0
Silt 2	9.1	53.0
Ice	36	58.0

Butress/Spillway Calcs

	x
ApronTop	12.5
Apron Slope	7.5

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Description:

Stability Calculations for sliding and resultant moment within middle 1/3 of dam

Bolded items are resultant calculations in this spreadsheet, *italized* items are are chosen values (constants or chosen values), normal items are supporting calculatior

References:

[1] U.S. Bureau of Reclamation. Design of Small Dams. 1987.

[2] Minnesota DNR. State Dam Safety Program rules (6115.0300 to 6115.0520)

Analysis: Sliding and Resultant Moment Calculations

Dam as Monolith about dam/spillway joint with sediment

Vertical Forces & Moments

	Unit Area Calc									
	Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
	(ft)	(ft)	(ft)		(ft^3)	(pcf)		(lb)	(ft)	(lb-ft)
Upstream Base Slab	40	1	3	1	120	145	Down	17,400	20.0	348,000
Spillway Apron Top		11		1	11	145	Down	1,595	3.7	5,952
Spillway Apron Slope		21		1	21	145	Down	3,045	13.7	41,812
Butress Area 1		2.1		1	2	146	Down	303	11.6	3,529
Butress Area 2		2.8		1	3	146	Down	416	3.7	1,551
Downstream Base Slab	36	1	2	1	72	145	Down	10,440	(18.0)	(187,920)
U.S. Water 1	20	1	7	1	140	62.4	Down	8,736	30.0	262,080
U.S. Water 2	16	1	7	0.5	56	62.4	Down	3,494	14.7	51,251
D.S. Water	36	1	2	1	72	62.4	Down	4,493	(18.0)	(80,870)
DS 'Uplift 1	36	1	3.8	1	136.8	62.4	Down	8,536	(18.0)	(153,654)
US 'Uplift 1	39	1	2.8	1	109.2	62.4	Up	(6,814)	19.5	(132,875)
US Uplift 2	19	1	2	0.5	19	62.4	Up	(1,186)	32.7	(38,730)
US Uplift 3	1	1	16	1	16	62.4	Up	(998)	39.5	(39,437)
Silt 1	20	1	6	1	120	120	Down	14,400	30.0	432,000
Silt 2	9.1	1	6	0.5	27	120	Down	3,288	17.0	55,754
Ice	No additional vertical force attributed to normal condition due to Pressurized water undeneath the Ice Sheet									
Totals								67,149		568,444

Horizontal Forces & Moments

	Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
Water	N/A		7	1	N/A	62.4	Up	(1,529)	11.3	(17,326)
Silt	N/A		6	1	N/A	85	Up	(1,530)	5.0	(7,650)
Ice	1	1	16	1	16	0	Up	-	75.7	-
Totals								(3,059)		(24,976)

Sliding				
Net Weight	W	67,149	lbs	
Driving Force	F_D	3,059	lbs	
Resisting Force	F_R	31,312	lbs	W tanϕ
Required FOS	SF_{MIN}	3.0		
Safety Factor	**SF**	**10.24**	**OK**	F_R / F_D

Overturning				
Net Moment	M_{OT}	543,468	lbs-ft	
Middle 1/3rd Points		-10.7	to	14.7
Resultant Location =		**8.09**	**ft**	M_{OT} / W
		OK, 100% Base in Compression		

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Supporting Information:

Piezometer Information				
	HWEL	P1	P2	P3
Reading	845	833.8	831.8	831.8
Bottom Slab	829	829	829	828
delta	16	4.8	2.8	3.8

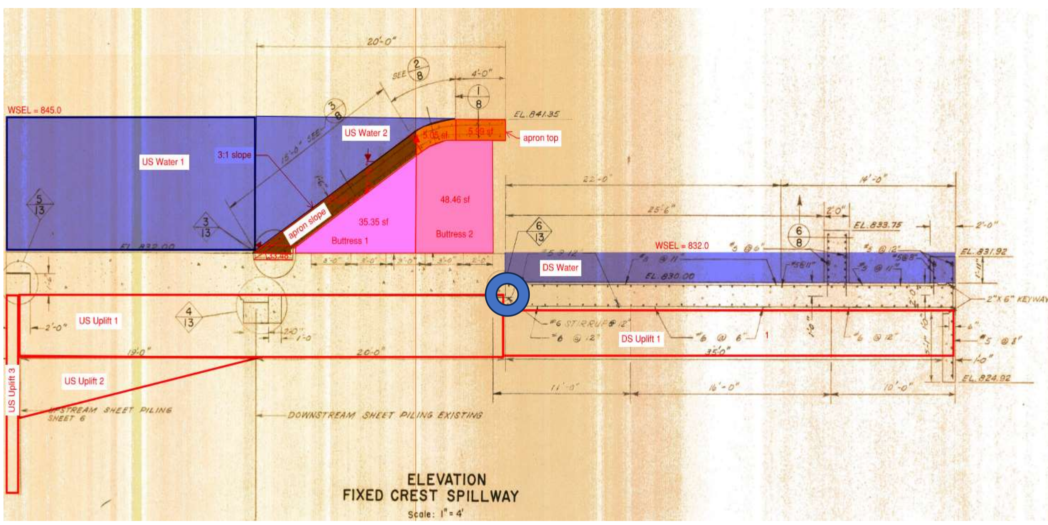
Soil Interaction	
phi	*25*
C	-

Silt Depth	
D	6

Water Surface	
Upstream	*845*
Downstream	*832*

Dam Slab Geometry	
US Slab Thickness	3
DS Slab Thickness	2

Dam Geometry



Moment Arm Calc

	Length (ft)	Arm (ft)
Upstream Base Slab	40	20.0
Spillway Apron Top	4	3.7
Spillway Apron Slope	16	13.7
Butress Area 1	16.0	11.6
Butress Area 2	4.0	3.7
Downstream Base Slab	36	(18.0)
U.S. Water 1	20	30.0
U.S. Water 2	16	14.7
D.S. Water	36	(18.0)
DS 'Uplift 1	36	(18.0)
US 'Uplift 1	39	19.5
US Uplift 2	19	32.7
US Uplift 3	1	39.5
Silt 1	20	30.0
Silt 2	9.1	17.0
Ice	36	22.0

Butress/Spillway Calcs

	x
ApronTop	12.5
Apron Slope	7.5

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Description:

Stability Calculations for sliding and resultant moment within middle 1/3 of dam

Bolded items are resultant calculations in this spreadsheet, *italized* items are are chosen values (constants or chosen values), normal items are supporting calculatior

References:

[1] U.S. Bureau of Reclamation. Design of Small Dams. 1987.
[2] Minnesota DNR. State Dam Safety Program rules (6115.0300 to 6115.0520)

Analysis: Sliding and Resultant Moment Calculations

US Dam about dam/spillway joint with sediment

Vertical Forces & Moments

	Unit Area Calc									
	Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
	(ft)	(ft)	(ft)		(ft^3)	(pcf)		(lb)	(ft)	(lb-ft)
Upstream Base Slab	40	1	3	1	120	145	Down	17,400	20.0	348,000
Spillway Apron Top		11		1	11	145	Down	1,595	3.7	5,952
Spillway Apron Slope		21		1	21	145	Down	3,045	13.7	41,812
Butress Area 1		2.1		1	2	146	Down	303	11.6	3,529
Butress Area 2		2.8		1	3	146	Down	416	3.7	1,551
U.S. Water 1	20	1	7	1	140	62.4	Down	8,736	30.0	262,080
U.S. Water 2	16	1	7	0.5	56	62.4	Down	3,494	14.7	51,251
US 'Uplift 1	39	1	2.8	1	109.2	62.4	Up	(6,814)	19.5	(132,875)
US Uplift 2	19	1	2	0.5	19	62.4	Up	(1,186)	32.7	(38,730)
US Uplift 3	1	1	16	1	16	62.4	Up	(998)	39.5	(39,437)
Silt 1	20	1	6	1	120	120	Down	14,400	30.0	432,000
Silt 2	9.1	1	6	0.5	27	120	Down	3,288	17.0	55,754
Ice	No additional vertical force attributed to normal condition due to Pressurized water undeneath the Ice Sheet									
Totals								43,679		990,888

Horizontal Forces & Moments

	Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
Water	N/A		7	1	N/A	62.4	Up	(1,529)	11.3	(17,326)
Silt	N/A		6	1	N/A	85	Up	(1,530)	5.0	(7,650)
Ice	1	1	16	1	16	0	Up	-	75.7	-
Totals								(3,059)		(24,976)

Sliding				
Net Weight	W	43,679	lbs	
Driving Force	F_D	3,059	lbs	
Resisting Force	F_R	20,368	lbs	W tanϕ
Required FOS	SF_{MIN}	3.0		
Safety Factor	**SF**	**6.66**	**OK**	F_R / F_D

Overturning				
Net Moment	M_{OT}	965,912	lbs-ft	
Middle 1/3rd Points		13.3	to	26.7
Resultant Location =	**22.11**	**ft**		M_{OT} / W
		OK, 100% Base in Compression		

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Supporting Information:

Piezometer Information				
	HWEL	P1	P2	P3
Reading	845	833.8	831.8	831.8
Bottom Slab	829	829	829	828
delta	16	4.8	2.8	3.8

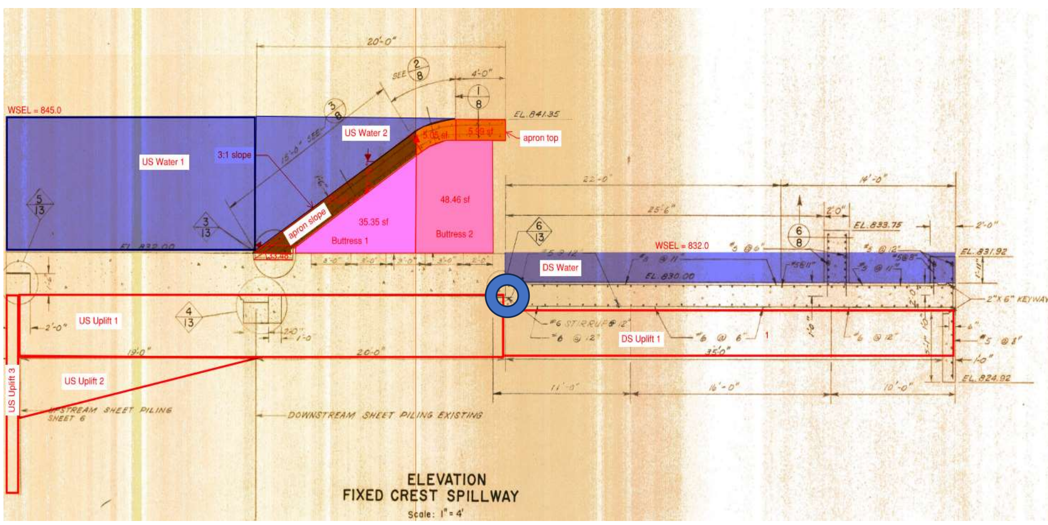
Soil Interaction	
phi	*25*
C	-

Silt Depth	
D	6

Water Surface	
Upstream	*845*
Downstream	*832*

Dam Slab Geometry	
US Slab Thickness	3
DS Slab Thickness	2

Dam Geometry



Moment Arm Calc	Length	Arm
	(ft)	(ft)
Upstream Base Slab	40	20.0
Spillway Apron Top	4	3.7
Spillway Apron Slope	16	13.7
Butress Area 1	16.0	11.6
Butress Area 2	4.0	3.7
Downstream Base Slab	36	(18.0)
U.S. Water 1	20	30.0
U.S. Water 2	16	14.7
D.S. Water	36	(18.0)
DS 'Uplift 1	36	(18.0)
US 'Uplift 1	39	19.5
US Uplift 2	19	32.7
US Uplift 3	1	39.5
Silt 1	20	30.0
Silt 2	9.1	17.0
Ice	36	22.0

Butress/Spillway Calcs	x
ApronTop	12.5
Apron Slope	7.5

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Description:

Stability Calculations for sliding and resultant moment within middle 1/3 of dam

Bolded items are resultant calculations in this spreadsheet, *italized* items are are chosen values (constants or chosen values), normal items are supporting calculatior

References:

[1] U.S. Bureau of Reclamation. Design of Small Dams. 1987.

[2] Minnesota DNR. State Dam Safety Program rules (6115.0300 to 6115.0520)

Analysis: Sliding and Resultant Moment Calculations

Dam as Monolith about downstream most point

Vertical Forces & Moments

	Unit Area Calc Length (ft)	Width (ft)	Height (ft)	Factor	Volume (ft^3)	Unit Wt. (pcf)	Direction	Weight (lb)	Arm (ft)	Moment (lb-ft)
Upstream Base Slab	40	1	3	1	120	145	Down	17,400	56.0	974,400
Spillway Apron Top		11		1	11	145	Down	1,595	39.7	63,372
Spillway Apron Slope		21		1	21	145	Down	3,045	49.7	151,432
Butress Area 1		2.1		1	2	146	Down	303	47.6	14,442
Butress Area 2		2.8		1	3	146	Down	416	39.7	16,518
Downstream Base Slat	36	1	2	1	72	145	Down	10,440	18.0	187,920
U.S. Water 1	20	1	13	1	260	62.4	Down	16,224	66.0	1,070,784
U.S. Water 2	16	1	13	0.5	104	62.4	Down	6,490	50.7	328,806
D.S. Water	36	1	2	1	72	62.4	Down	4,493	18.0	80,870
DS 'Uplift 1	36	1	3.8	1	136.8	62.4	Down	8,536	18.0	153,654
US 'Uplift 1	39	1	2.8	1	109.2	62.4	Up	(6,814)	55.5	(378,181)
US Uplift 2	19	1	2	0.5	19	62.4	Up	(1,186)	68.7	(81,411)
US Uplift 3	1	1	16	1	16	62.4	Up	(998)	75.5	(75,379)
Silt 1	20	1	0	1	0	120	Down	-	66.0	-
Silt 2	0.0	1	0	0.5	0	120	Down	-	56.0	-
Ice	No additional vertical force attributed to normal condition due to Pressurized water undeneath the Ice Sheet									
Totals								59,944		2,507,226

Horizontal Forces & Moments

	Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
Water	N/A		13	1	N/A	62.4	Up	(5,273)	7.3	(38,667)
Silt	N/A		0	1	N/A	85	Up	-	3.0	-
Ice	1	1	16	1	16	0	Up	-	75.7	-
Totals								(5,273)		(38,667)

Sliding				
Net Weight	W	59,944	lbs	
Driving Force	F_D	5,273	lbs	
Resisting Force	F_R	27,952	lbs	W tanϕ
Required FOS	SF_{MIN}	3.0		
Safety Factor	**SF**	**5.30**	**OK**	F_R / F_D

Overturning				
Net Moment	M_{OT}	2,468,559	lbs-ft	
Middle 1/3rd Points		25.3	to	50.7
Resultant Location =	**41.18**	**ft**	M_{OT} / W	
		OK, 100% Base in Compression		

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Supporting Information:

Piezometer Information				
	HWEL	P1	P2	P3
Reading	845	833.8	831.8	831.8
Bottom Slab	829	829	829	828
delta	16	4.8	2.8	3.8

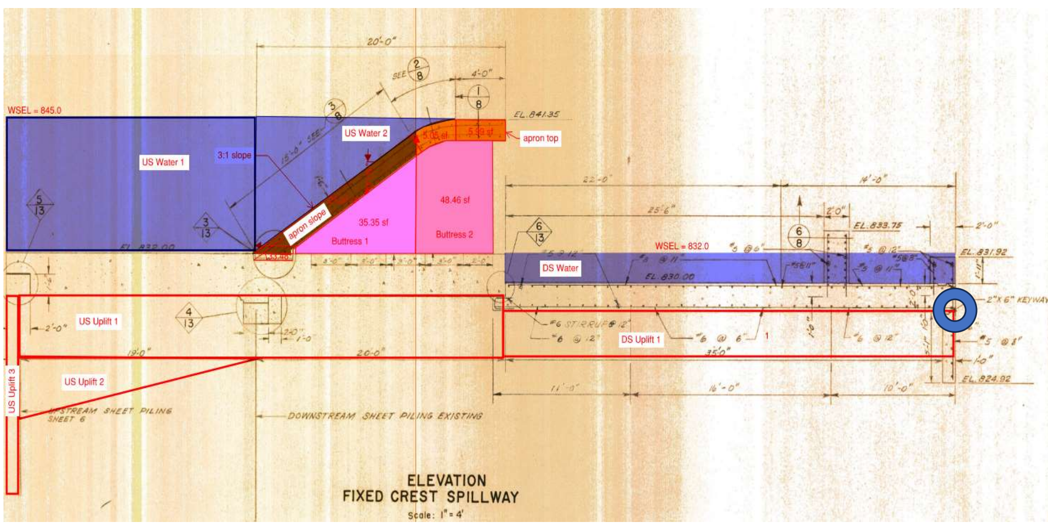
Soil Interaction	
phi	*25*
C	-

Silt Depth	
D	0

Water Surface	
Upstream	*845*
Downstream	*832*

Dam Slab Geometry	
US Slab Thickness	3
DS Slab Thickness	2

Dam Geometry



Moment Arm Calc

	Length	Arm
	(ft)	(ft)
Upstream Base Slab	40	56.0
Spillway Apron Top	4	39.7
Spillway Apron Slope	16	49.7
Butress Area 1	16.0	47.6
Butress Area 2	4.0	39.7
Downstream Base Slab	36	18.0
U.S. Water 1	20	66.0
U.S. Water 2	16	50.7
D.S. Water	36	18.0
DS 'Uplift 1	36	18.0
US 'Uplift 1	39	55.5
US Uplift 2	19	68.7
US Uplift 3	1	75.5
Silt 1	20	66.0
Silt 2	0.0	56.0
Ice	36	58.0

Butress/Spillway Calcs

	x
ApronTop	12.5
Apron Slope	7.5

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Description:

Stability Calculations for sliding and resultant moment within middle 1/3 of dam

Bolded items are resultant calculations in this spreadsheet, *italized* items are are chosen values (constants or chosen values), normal items are supporting calculatior

References:

[1] U.S. Bureau of Reclamation. Design of Small Dams. 1987.

[2] Minnesota DNR. State Dam Safety Program rules (6115.0300 to 6115.0520)

Analysis: Sliding and Resultant Moment Calculations

Dam as Monolith about dam/spillway joint

Vertical Forces & Moments

	Unit Area Calc Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
	(ft)	(ft)	(ft)		(ft^3)	(pcf)		(lb)	(ft)	(lb-ft)
Upstream Base Slab	40	1	3	1	120	145	Down	17,400	20.0	348,000
Spillway Apron Top		11		1	11	145	Down	1,595	3.7	5,952
Spillway Apron Slope		21		1	21	145	Down	3,045	13.7	41,812
Butress Area 1		2.1		1	2	146	Down	303	11.6	3,529
Butress Area 2		2.8		1	3	146	Down	416	3.7	1,551
Downstream Base Slab	36	1	2	1	72	145	Down	10,440	(18.0)	(187,920)
U.S. Water 1	20	1	13	1	260	62.4	Down	16,224	30.0	486,720
U.S. Water 2	16	1	13	0.5	104	62.4	Down	6,490	14.7	95,181
D.S. Water	36	1	2	1	72	62.4	Down	4,493	(18.0)	(80,870)
DS 'Uplift 1	36	1	3.8	1	136.8	62.4	Down	8,536	(18.0)	(153,654)
US 'Uplift 1	39	1	2.8	1	109.2	62.4	Up	(6,814)	19.5	(132,875)
US Uplift 2	19	1	2	0.5	19	62.4	Up	(1,186)	32.7	(38,730)
US Uplift 3	1	1	16	1	16	62.4	Up	(998)	39.5	(39,437)
Silt 1	20	1	0	1	0	120	Down	-	30.0	-
Silt 2	0.0	1	0	0.5	0	120	Down	-	17.0	-
Ice	No additional vertical force attributed to normal condition due to Pressurized water undeneath the Ice Sheet									
Totals								59,944		349,260

Horizontal Forces & Moments

	Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
Water	N/A		13	1	N/A	62.4	Up	(5,273)	7.3	(38,667)
Silt	N/A		0	1	N/A	85	Up	-	3.0	-
Ice	1	1	16	1	16	0	Up	-	75.7	-
Totals								(5,273)		(38,667)

Sliding				
Net Weight	W	59,944	lbs	
Driving Force	F_D	5,273	lbs	
Resisting Force	F_R	27,952	lbs	W tanϕ
Required FOS	SF_{MIN}	3.0		
Safety Factor	**SF**	**5.30**	**OK**	F_R / F_D

Overturning				
Net Moment	M_{OT}	310,593	lbs-ft	
Middle 1/3rd Points		-10.7	to	14.7
Resultant Location =	**5.18**	**ft**	M_{OT} / W	
	OK, 100% Base in Compression			

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Supporting Information:

Piezometer Information				
	HWEL	P1	P2	P3
Reading	845	833.8	831.8	831.8
Bottom Slab	829	829	829	828
delta	16	4.8	2.8	3.8

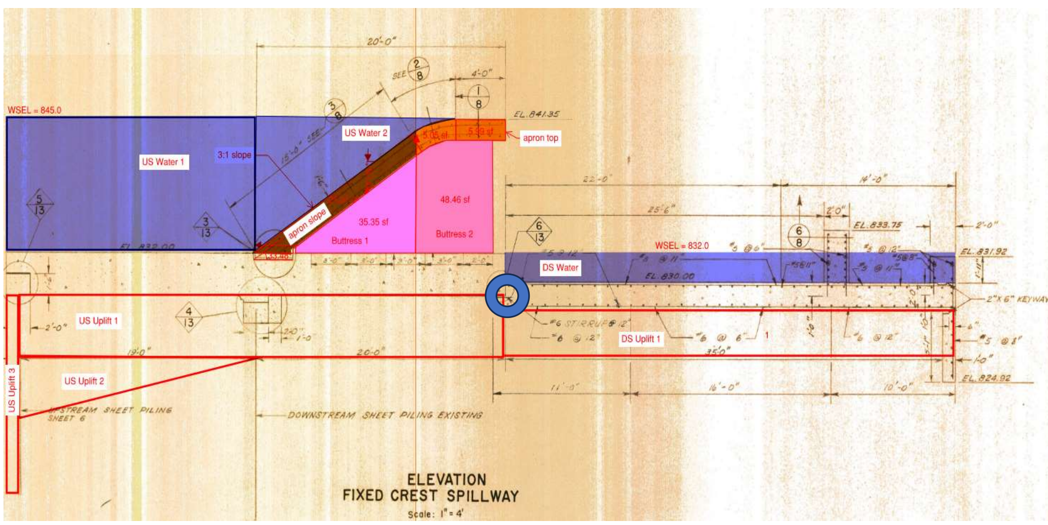
Soil Interaction	
phi	*25*
C	-

Silt Depth	
D	0

Water Surface	
Upstream	*845*
Downstream	*832*

Dam Slab Geometry	
US Slab Thickness	3
DS Slab Thickness	2

Dam Geometry



Moment Arm Calc

	Length	Arm
	(ft)	(ft)
Upstream Base Slab	40	20.0
Spillway Apron Top	4	3.7
Spillway Apron Slope	16	13.7
Butress Area 1	16.0	11.6
Butress Area 2	4.0	3.7
Downstream Base Slab	36	(18.0)
U.S. Water 1	20	30.0
U.S. Water 2	16	14.7
D.S. Water	36	(18.0)
DS 'Uplift 1	36	(18.0)
US 'Uplift 1	39	19.5
US Uplift 2	19	32.7
US Uplift 3	1	39.5
Silt 1	20	30.0
Silt 2	0.0	17.0
Ice	36	22.0

Butress/Spillway Calcs

	x
ApronTop	12.5
Apron Slope	7.5

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Description:

Stability Calculations for sliding and resultant moment within middle 1/3 of dam

Bolded items are resultant calculations in this spreadsheet, *italized* items are are chosen values (constants or chosen values), normal items are supporting calculatior

References:

[1] U.S. Bureau of Reclamation. Design of Small Dams. 1987.

[2] Minnesota DNR. State Dam Safety Program rules (6115.0300 to 6115.0520)

Analysis:

Sliding and Resultant Moment Calculations

US Dam about dam/spillway joint

Vertical Forces & Moments

	Unit Area Calc Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
	(ft)	(ft)	(ft)		(ft^3)	(pcf)		(lb)	(ft)	(lb-ft)
Upstream Base Slab	40	1	3	1	120	145	Down	17,400	20.0	348,000
Spillway Apron Top		11		1	11	145	Down	1,595	3.7	5,952
Spillway Apron Slope		21		1	21	145	Down	3,045	13.7	41,812
Butress Area 1		2.1		1	2	146	Down	303	11.6	3,529
Butress Area 2		2.8		1	3	146	Down	416	3.7	1,551
U.S. Water 1	20	1	13	1	260	62.4	Down	16,224	30.0	486,720
U.S. Water 2	16	1	13	0.5	104	62.4	Down	6,490	14.7	95,181
US 'Uplift 1	39	1	2.8	1	109.2	62.4	Up	(6,814)	19.5	(132,875)
US Uplift 2	19	1	2	0.5	19	62.4	Up	(1,186)	32.7	(38,730)
US Uplift 3	1	1	16	1	16	62.4	Up	(998)	39.5	(39,437)
Silt 1	20	1	0	1	0	120	Down	-	30.0	-
Silt 2	0.0	1	0	0.5	0	120	Down	-	17.0	-
Ice	No additional vertical force attributed to normal condition due to Pressurized water undeneath the Ice Sheet									
Totals								36,474		771,704

Horizontal Forces & Moments

	Length	Width	Height	Factor	Volume	Unit Wt.	Direction	Weight	Arm	Moment
Water	N/A		13	1	N/A	62.4	Up	(5,273)	7.3	(38,667)
Silt	N/A		0	1	N/A	85	Up	-	3.0	-
Ice	1	1	16	1	16	0	Up	-	75.7	-
Totals								(5,273)		(38,667)

Sliding				
Net Weight	W	36,474	lbs	
Driving Force	F_D	5,273	lbs	
Resisting Force	F_R	17,008	lbs	W tanϕ
Required FOS	SF_{MIN}	3.0		
Safety Factor	**SF**	**3.23**	**OK**	F_R / F_D

Overturning				
Net Moment	M_{OT}	733,037	lbs-ft	
Middle 1/3rd Points		13.3	to	26.7
Resultant Location =		**20.10**	**ft**	M_{OT} / W
		OK,	**100% Base in Compression**	

Computed by	D. Kvasnicka	Date	4/5/2024	Job No.	10393640
Checked by	T. Bowen	Date	10/29/2024	Subject	Rum River Dam Stability
Revision		Date			
Approved by		Date			

Supporting Information:

Piezometer Information				
	HWEL	P1	P2	P3
Reading	845	833.8	831.8	831.8
Bottom Slab	829	829	829	828
delta	16	4.8	2.8	3.8

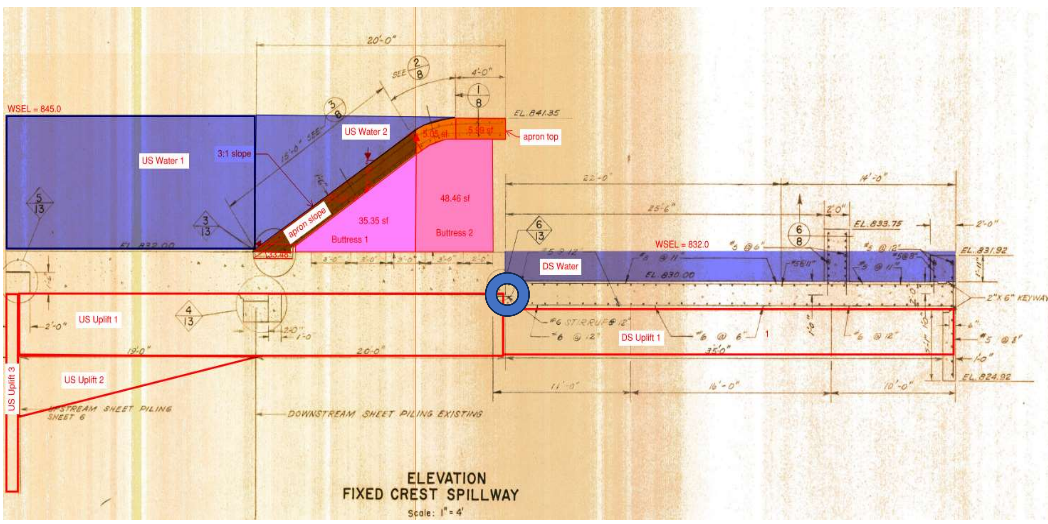
Soil Interaction	
phi	*25*
C	-

Silt Depth	
D	0

Water Surface	
Upstream	*845*
Downstream	*832*

Dam Slab Geometry	
US Slab Thickness	3
DS Slab Thickness	2

Dam Geometry



Moment Arm Calc	Length (ft)	Arm (ft)
Upstream Base Slab	40	20.0
Spillway Apron Top	4	3.7
Spillway Apron Slope	16	13.7
Butress Area 1	16.0	11.6
Butress Area 2	4.0	3.7
Downstream Base Slab	36	(18.0)
U.S. Water 1	20	30.0
U.S. Water 2	16	14.7
D.S. Water	36	(18.0)
DS 'Uplift 1	36	(18.0)
US 'Uplift 1	39	19.5
US Uplift 2	19	32.7
US Uplift 3	1	39.5
Silt 1	20	30.0
Silt 2	0.0	17.0
Ice	36	22.0

Butress/Spillway Calcs	x
ApronTop	12.5
Apron Slope	7.5

Appendix C2

King-Pile Wall Computations

Calculation Summary

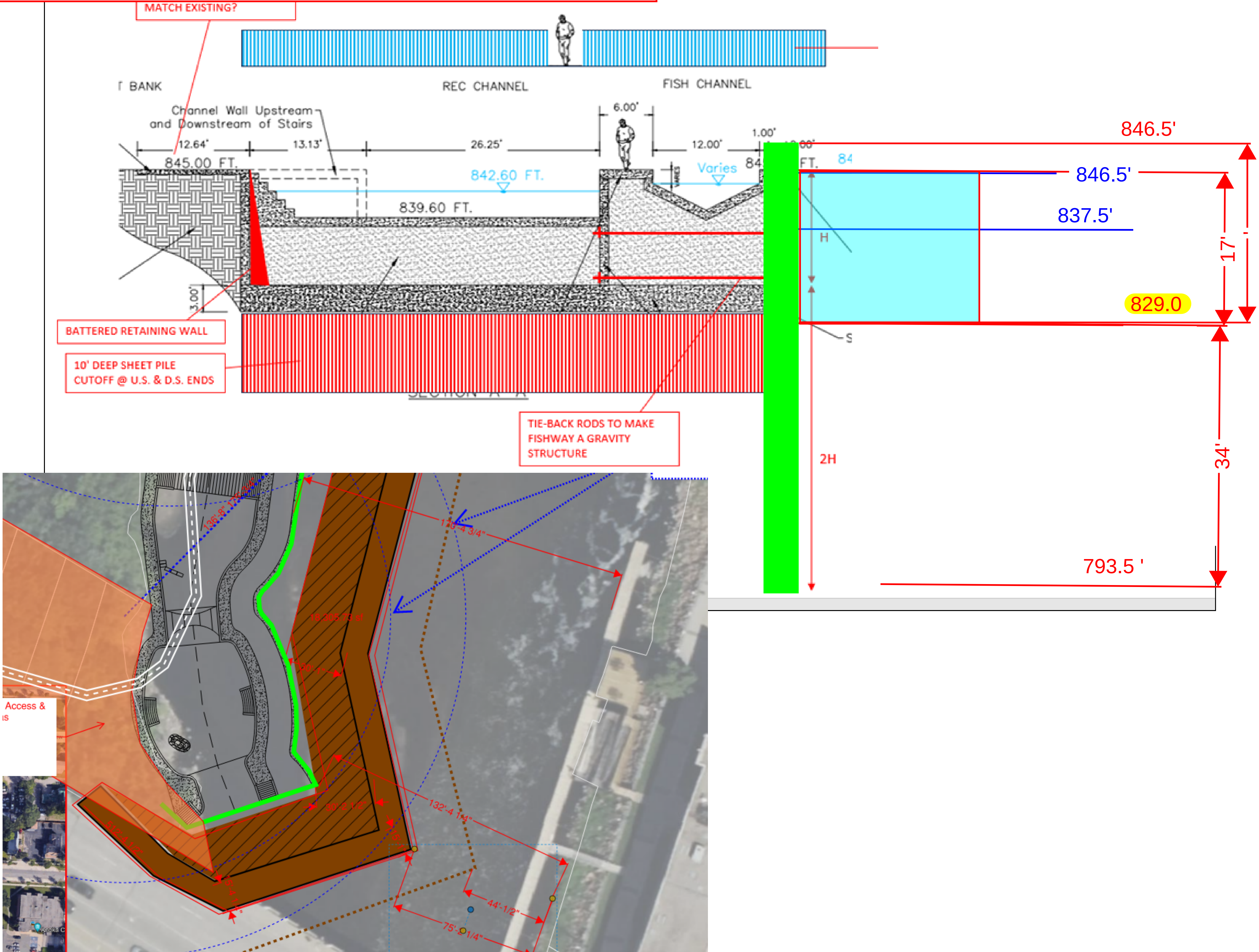
Assumptions:
γ_w = 62.4 pcf
Landside Elevation = 829'
Waterside Upstream Mudline Elevation = 837'
Waterside Downstream Mudline Elevation = 830'
Waterside Upstream Water Elevation - Usual = 842'
Waterside Upstream Water Elevation - Unsual = 847'
Waterside Downstream Water Elevation - Usual = 833.5'
Waterside Downstream Water Elevation - Unusual = 837'
Waterside Downstream Water Elevation - Extreme = 840'
Landside Water Elevation = 829'
Steel Yield Strength = 60 ksi

Results:
Upstream - NZ 26 w/ 48" DIA x 0.75 THK King Pile at 54' length
Downstream - NZ 26 at 37 ' length

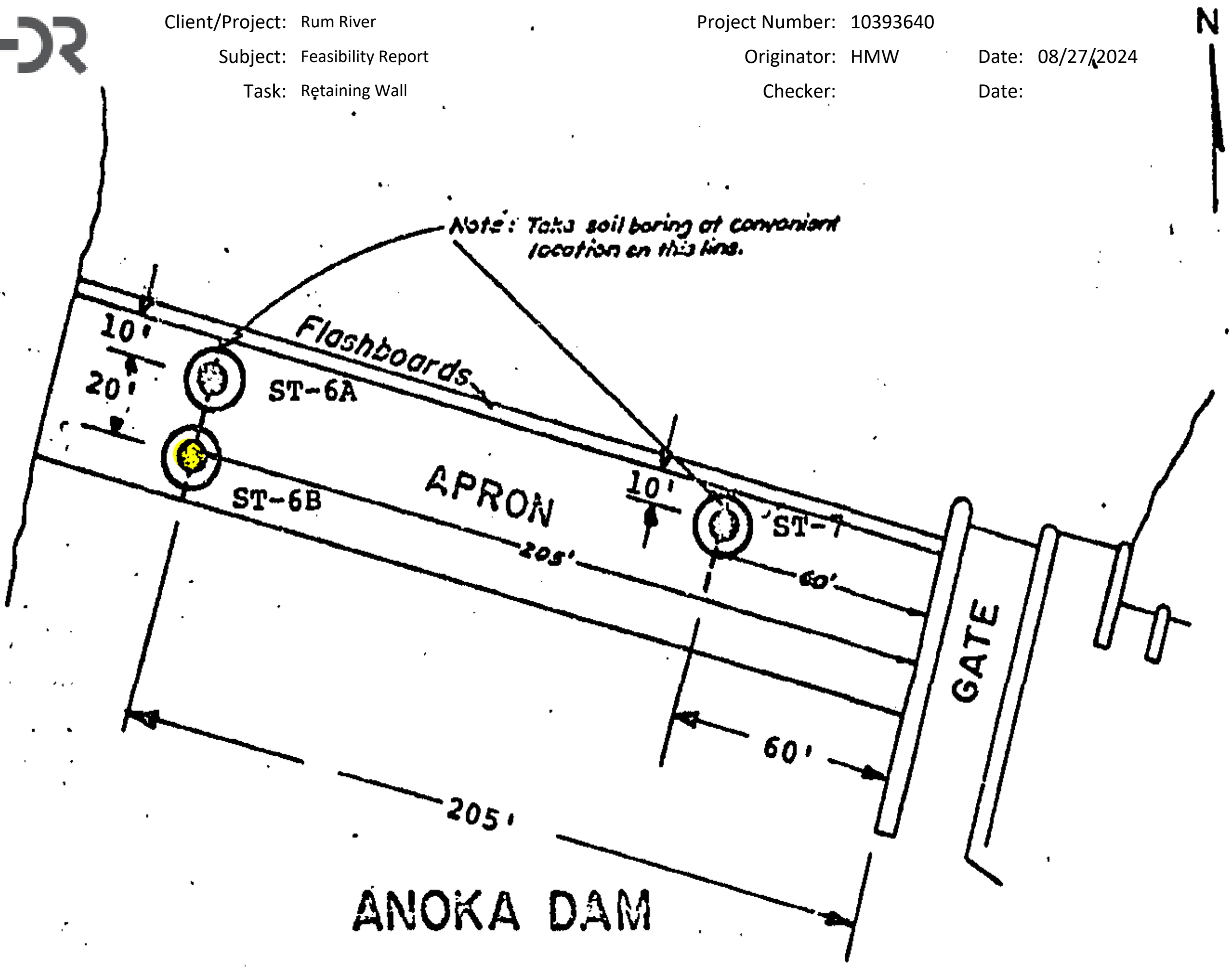
Provided Section View

PROVIDED SECTION VIEW

Alternative Care of Water & Diversion Concept



Geotechnical Parameters



LOCATION SKETCH
for
PROPOSED SOIL BORINGS
ANOKA, MINNESOTA

location of penetration test borings--surface e[illegible]ions determined by City of Anoka surveycrew

BARR 1966
2-4A017

PROJECT: 66-125 SOIL BORINGS
LOCATION: Rum River Dam
Anoka, Minnesota
VERTICAL SCALE: 1" = 6'

ST-6B

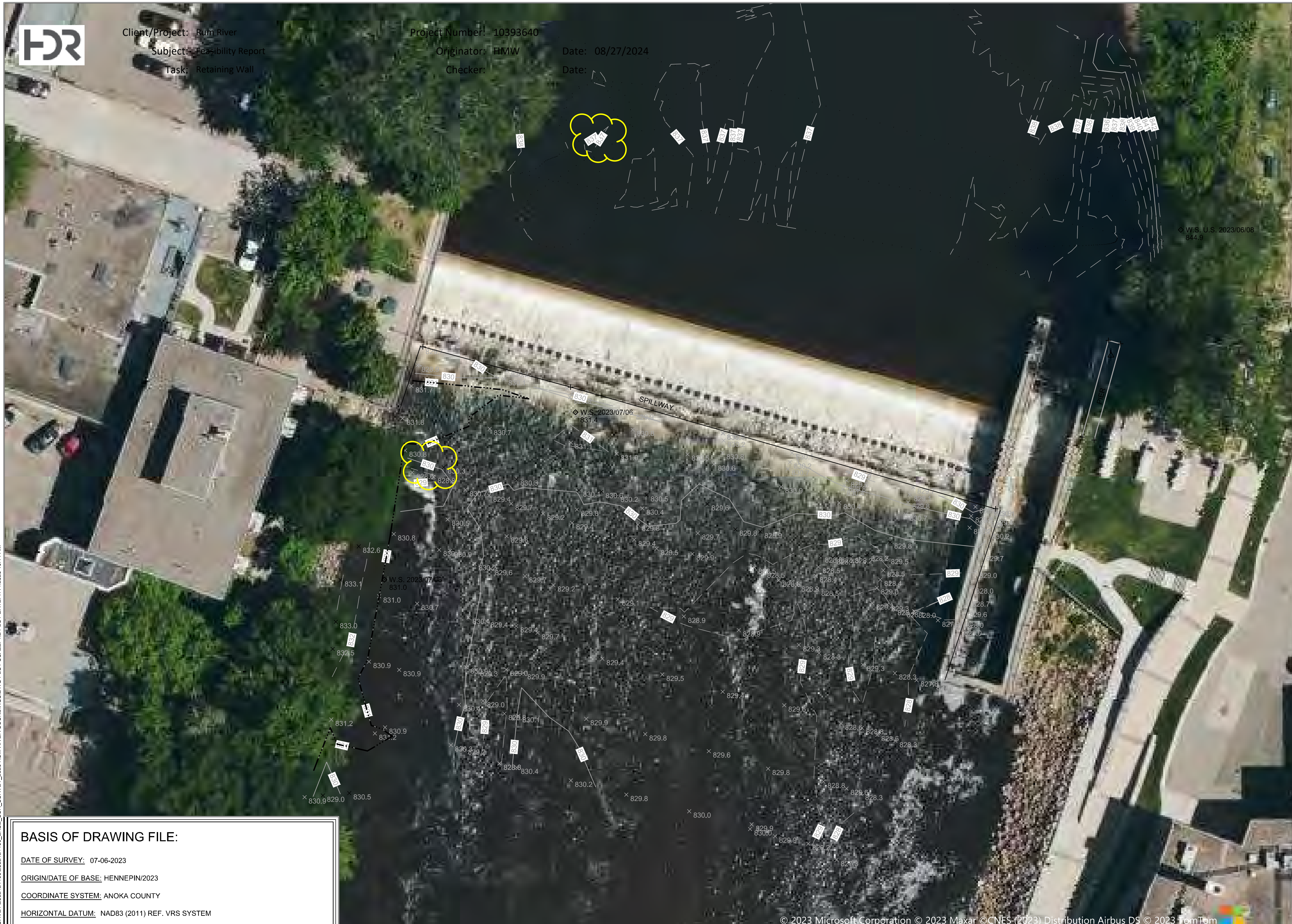
DEPTH			BPF
0'	Surface elevation = 836.94		
	Void		
5.1'	Water		
6' / 829'	Medium-Coarse Sand & Fine Gravel, grey, with an extensive amount of wood	(54)	67
		(55w)	12
	γ = 130, ϕ′ = 28°	(56)	16
			14
	803.94'	(57)	29
33'	Sandy Loam, (SM) non plastic, brown, wet (dense)		38
	γ = 120, ϕ′ = 30°		
41'	Silt Loam, grey, (ML) wet (very stiff)	(58)	27
44'			

DEPTH	ST-6B Con't.		BPF
0'			
44'	Silt Loam, with some fine lenses of Silty Clay Loam, grey, wet (very stiff) (ML)	(59&60)	40
		(61)	43
53'	Coarse Loamy Sand & Fine Gravel, grey-brown, (medium) (SM)	(62)	17
	777.94'		
59'	Fine Loamy Sand, grey-brown, (very dense) (SM) (similar in appearance to loosely cemented sandstone)	(63)	170
	γ = 135, ϕ′ = 32°	(64)	46
	764.94'	(65)	73
72'			

Water level down 5.5' in casing immediately after completion of boring and when rechecked 1 hour later and 6.0' after pulling casing back to 65'

Client/Project: Rum River
Subject: Feasibility Report
Task: Retaining Wall

Project Number: 10393640
Originator: HMW Date: 08/27/2024
Checker: Date:



LEGEND - - SURVEY

1380	MAJOR CONTOUR
1379	MINOR CONTOUR
	SHORELINE
	BATHYMETRIC POINTS

BASIS OF DRAWING FILE:

DATE OF SURVEY: 07-06-2023

ORIGIN/DATE OF BASE: HENNEPIN/2023

COORDINATE SYSTEM: ANOKA COUNTY

HORIZONTAL DATUM: NAD83 (2011) REF. VRS SYSTEM

VERTICAL DATUM: NAVD88 MSL.; REF. VRS SYSTEM

ADDITIONAL FILE INFORMATION:
Bathymetric survey UPSTREAM SOUNDINGS: Using a Remote controlled Z-boat; with a 200 KHz Transducer: DOWNSTREAM: RTK GPS Pole depth survey

1 - PLAN: SURVEY FIGURE

0 1 2
SCALE IN FEET

PRELIMINARY DRAFT
NOT FOR CONSTRUCTION

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION
-	-	-	-		-

RELEASED TO/FOR	A	B	C	0	1	2	3
CLIENT							
BID							
CONSTRUCTION							
RECORD							
	DATE RELEASED						

BARR

Corporate Headquarters:
Minneapolis, Minnesota
Ph: 1-800-632-2277

Project Office:
BARR ENGINEERING CO.
3033 ORCHARD VISTA DR SE
SUITE 200
GRAND RAPIDS, MI 49546
Ph: 1-616-512-7000
Fax: (951) 832-2601
www.barr.com

Scale	AS SHOWN
Date	--/--/--
Drawn	--
Checked	--
Designed	--
Approved	--

ANOKA, CITY OF
ANOKA, MINNESOTA

RUM RIVER DAM
ANOKA, MINNESOTA

2023 BATHYMETRIC SURVEY
BASE MAP

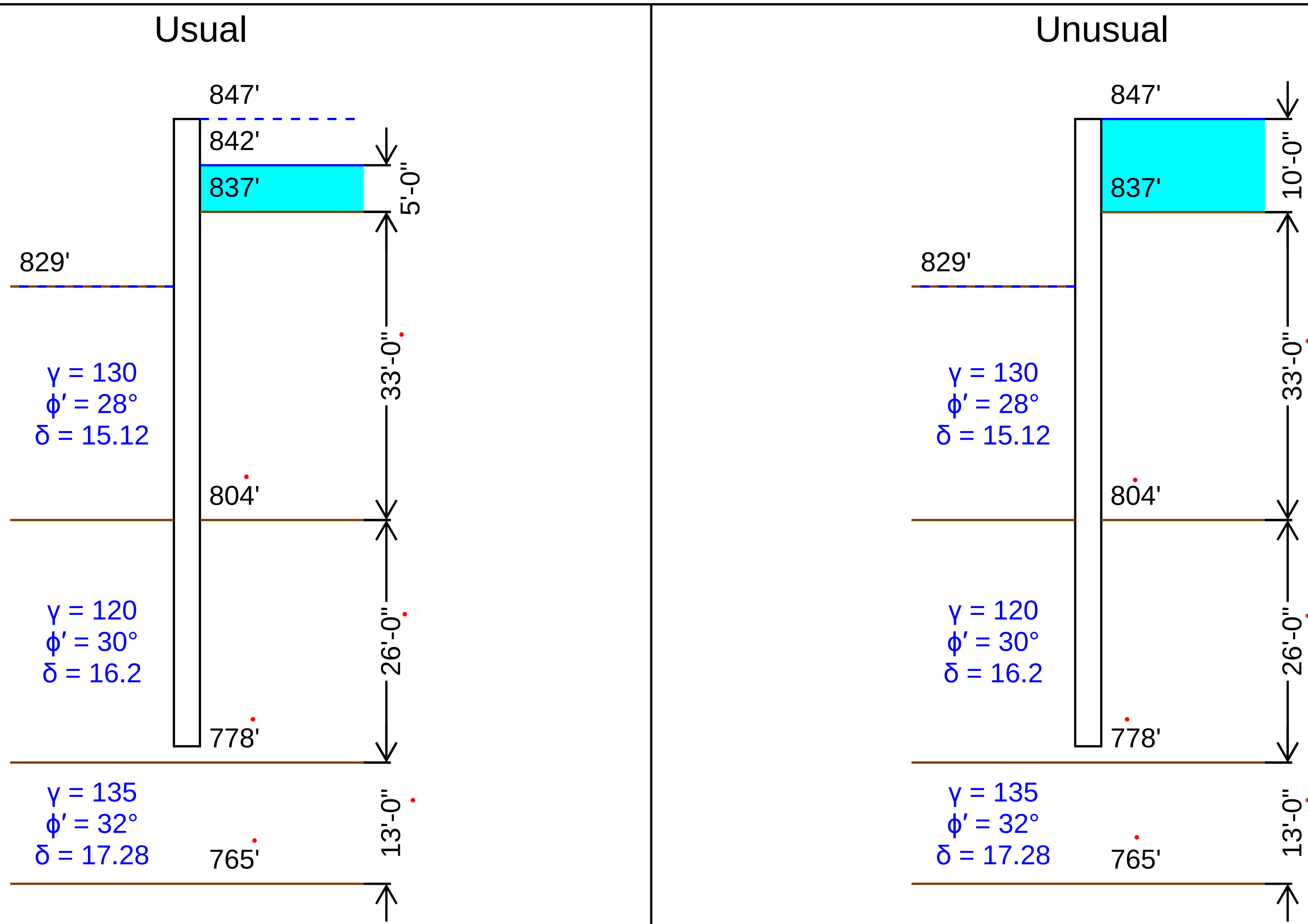
BARR PROJECT No. 23/02-1211.00
CLIENT PROJECT No.
DWG. No. SRVY-1
REV. No. -

CADD USER: JIM STABERG FILE: M:\DESIGN\SURVEY\23021211\00\23021211100_BASE_SUR_SURVEY_2023 RUM RIVER SOUNDINGS.DWG PLOT SCALE: 1:2 PLOT DATE: 7/11/2023 10:14 AM

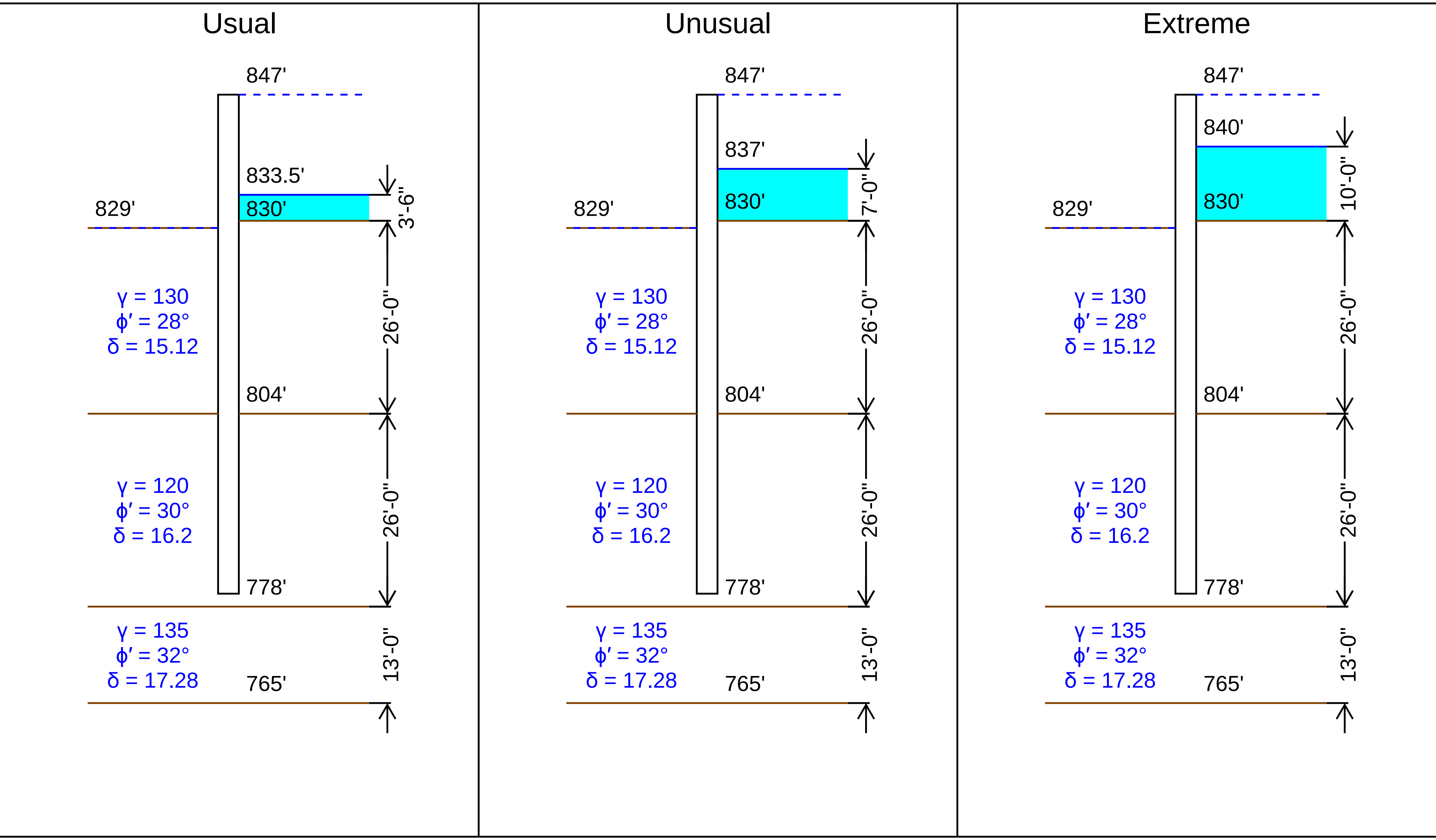
CWALSHT Sections

Client/Project: Rum River
Subject: Feasibility Report
Task: Retaining Wall

Project Number: 10393640
Originator: HMW   Date: 08/27/2024
Checker: Date:



γ_w = 62.4 pcf



$\gamma_w = 62.4$ pcf

CWALSHT Summary

Client/Project:	Rum River	Project Number:	10393640		
Subject:	Feasibility Report	Originator:	HMW	Date:	08/28/2024
Task:	Retaining Wall	Checker:		Date:	

	Location	Upstream		Downstream		
Rum River	**Load Case Type**	**Usual**	**Unusual**	**Usual**	**Unusual**	**Extreme**
	Water Elevation (ft)	842	847	833.5	837	840
	Landside Mudline Elevation (ft)	829	829	829	829	829
	Waterside Mudline Elevation (ft)	837	837	830	830	830
	Tip Elevation (ft)	797.64	793.58	818.81	813.72	810.52
	Penetration (ft)	31.36	35.42	10.19	15.28	18.48
	Yield Strength (ksi)	60	60	60	60	60
	Bending Moment (ft-lb)	8.90E+04	2.16E+05	3.10E+03	1.69E+04	4.37E+04
	Minimum Section Modulus (in^3/ft)	35.59	**72.11**	1.24	5.65	**9.93**
	Maximum Scaled Deflection (lb-in^3)	6.00E+10	2.18E+11	5.34E+08	5.69E+09	2.17E+10
	Assumed Moment of Inertia	3748.0	3748.0	419.9	419.9	419.9
	Maximum Deflection (in)	0.55	2.01	0.04	0.47	1.78
	Section Size	**NZ 26 w/ 48"x 0.75" King Piles**		**NZ 26**		
	Penetration (ft)	**35.42**		**18.48**		
	Length (ft)	**54**		**37**		

*Upstream Unusual Deflection using NZ42 = 9.74 in

Client/Project:	Rum River
Subject:	Feasibility Report
Task:	Retaining Wall
Project Number:	10393640
Originator:	HMW
Date:	08/28/2024
Checker:	
Date:	

Pipe Z Combined Wall System

Input Cells

Pipe		
Diameter:	(in)	48.00 ●
	(mm)	1219
Thickness:	(in)	0.750
	(mm)	19.05
Corrosion Thickness Loss Water Side:	(in/year)	
	(mm/year)	0.000
Corrosion Thickness Loss Backfill Side:	(in/year)	0.00E+00
	(mm/year)	0.000
Internal Corrosion Thickness Loss:	(in/year)	0.00E+00
	(mm/year)	0.000
Design Life	(Years)	60.00
Length:	(ft)	60.00
	(m)	18.29
Pipe Weight:	(lbs/ft)	378.83
	(kg/m)	563.77
Sheet Pile Section:		NZ26 ●
Length:	(ft)	60.00
	(m)	18.29
*No Longer Available		
Connector:		E22
Width:	(in)	1.28
	(mm)	32.51
Weight:	(lbs/ft)	6.87
	(kg/m)	10.22

Base Pipe-Z System Properties

System Width	Cross Sectional Area	Moment of Inertia	Section Modulus	Weight	Both sides of wall	wall surface
in	in^2/ft	in^4/ft	in^3/ft	lb/ft^2	ft^2/ft	ft^2/ft^2
(mm)	(cm^2/m)	(cm^4/m)	(cm^3/m)	(kg/m^2)	m^2/m	m^2/m^2
105.68	17.38	3748	156.2	60.7	25.7	1.46
2684.2	367.8	511791	8396	296.4	7.8	1.46

Corroded Pipe-Z System Properties

System Width	Cross Sectional Area	Moment of Inertia	Section Modulus	Weight
in	in^2/ft	in^4/ft	in^3/ft	lb/ft^2
(mm)	(cm^2/m)	(cm^4/m)	(cm^3/m)	(kg/m^2)
105.68	17.38	3748	156.16	60.7
2684.2	367.8	511802	8396	296.4

Base Sheet Pile Properties

System Width	Height	Thickness		Cross Sectional Area	Weight		Section Modulus		Moment of Inertia	Coating Area	
		Flange	Web		Pile	Wall	Elastic	Plastic		Both Sides	Wall Surface
(w)	(h)	(t_f)	(t_w)								
in	in	in	in	in^2/ft	lb/ft	lb/ft^2	in^3/ft	in^3/ft	in^4/ft	ft^2/ft of single	ft^2/ft^2
(mm)	(mm)	(mm)	(mm)	(cm^2/m)	(kg/m)	(kg/m^2)	(cm^3/m)	(cm^3/m)	(cm^4/m)	(m^2/m)	(m^2/m^2)
27.56	17.32	0.500	0.500	9.08	71	30.99	48.5	57.0	419.9	6.49	1.41
700.0	440.0	12.70	12.70	192.2	105.66	151.30	2608	3065	57340	1.98	1.41

Base Pipe Properties

Diameter	Wall	Weight	Area	Moment of Inertia	Section Modulus	Cover Plate Area	Internal Area	Coating Area	Radius of Gyration
in	in	lb/ft	in^2	in^4	in^3	in^2	in^2	ft^2/ft	in
mm	mm	kg/m	cm^2	cm^4	cm^3	cm^2	cm^2	m^2/m	cm
48.00	0.750	378.83	111.33	31076.78	1294.87	1809.56	1698.23	12.57	16.71
1219.20	19.050	563.83	718.26	1293513.19	21219.05	11674.54	10956.28	3.83	42.44

Continuous Pipe Wall

Diameter	Wall	System Width	Area	Moment of Inertia	Section Modulus	Weight
in	in	in	in^2	in^4/ft	in^3/ft	lb/ft^2
mm	mm	(mm)	cm^2	cm^4/m	cm^3/m	kg/m^2
48.00	0.750	50.56	26.42	7375.82	307.33	93.17
1219.20	19.050	1284.2	170.47	1,007,212.58	16522.52	454.91

Corroded Sheet Pile Properties

Thickness		Cross Sectional Area	Section Modulus	Corroded Weight	Moment of Inertia
Flange	Web				
(t_f)	(t_w)				
in	in	in^2/ft	in^3/ft	lb/ft	in^4/ft
(mm)	(mm)	(cm^2/m)	(cm^3/m)	(kg/m)	(cm^4/m)
0.500	0.500	9.08	48.5	71.0	419.9
12.70	12.70	192.2	2608.0	105.7	57340

Corroded Pipe Properties

Corrodded Diameter	Corrodded Wall	Weight	Area	Moment of Inertia	Section Modulus	Radius of Gyration
in	in	lb/ft	in^2	in^4	in^3	in
mm	mm	kg/m	cm^2	cm^4	cm^3	cm
48.00	0.750	378.83	111.33	31076.78	1294.87	16.71
1219.20	19.050	563.83	718.26	1293513.19	21219.05	42.44

Upstream:
Usual - FS 1

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                      TIME: 15:03:40

                            ****************
                            *  INPUT DATA  *
                            ****************

     I.--HEADING
    'RUM RIVER - 0%
    'UPSTREAM - USUAL
    'FOS 1

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 847.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00        837.00
                50.00        837.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00        829.00
                50.00        829.00

     V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                 ANGLE OF         ANGLE OF                        <-SAFETY->
  SAT.    MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.    WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)    (PCF)   (DEG)    (PSF)    (DEG)   (PSF)   (FT)  (FT/FT)
130.00   130.00   28.00     0.00    15.12    0.00  804.00   0.00   DEF  DEF
120.00   120.00   30.00     0.00    16.20    0.00  778.00   0.00   DEF  DEF
135.00   135.00   32.00     0.00    17.28    0.00                  DEF  DEF

        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 842.00 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:03:41

****
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
****

I.--HEADING
'RUM RIVER - 0%
'UPSTREAM - USUAL
'FOS 1

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
845.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
844.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
843.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
842.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
841.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
840.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
839.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
838.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
837.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
836.0	374.4	0.0	0.0	395.6	668.4	21.2	294.0
835.0	436.8	0.0	0.0	479.2	1024.7	42.4	587.9
834.0	499.2	0.0	0.0	562.8	1381.1	63.6	881.9
833.0	561.6	0.0	0.0	646.4	1737.4	84.8	1175.8
832.0	624.0	0.0	0.0	730.0	2093.8	106.0	1469.8
831.0	686.4	0.0	0.0	813.6	2450.1	127.2	1763.7
830.0	748.8	0.0	0.0	897.2	2806.5	148.4	2057.7
829.0	811.2	0.0	0.0	980.8	3162.8	169.6	2351.6
828.0	811.2	294.0	21.2	708.0	3435.6	190.8	2645.6
827.0	811.2	587.9	42.4	435.3	3708.3	212.0	2939.5
826.0	811.2	881.9	63.6	162.5	3981.1	233.2	3233.5
825.4	811.2	1057.0	76.2	0.0	4143.6	245.8	3408.6
825.0	811.2	1175.8	84.8	-110.2	4253.8	254.4	3527.4
824.0	811.2	1469.8	106.0	-383.0	4526.6	275.6	3821.4
823.0	811.2	1763.7	127.2	-655.7	4799.3	296.8	4115.3
822.0	811.2	2057.7	148.4	-928.5	5072.1	318.0	4409.3
821.0	811.2	2351.6	169.6	-1201.2	5344.8	339.2	4703.2
820.0	811.2	2645.6	190.8	-1474.0	5617.6	360.4	4997.2
819.0	811.2	2939.5	212.0	-1746.7	5890.3	381.6	5291.1
818.0	811.2	3233.5	233.2	-2019.5	6163.1	402.8	5585.1
817.0	811.2	3527.4	254.4	-2292.2	6435.8	424.0	5879.0
816.0	811.2	3821.4	275.6	-2565.0	6708.6	445.2	6173.0
815.0	811.2	4115.3	296.8	-2837.7	6981.3	466.4	6466.9
814.0	811.2	4409.3	318.0	-3110.5	7254.1	487.6	6760.9
813.0	811.2	4703.2	339.2	-3383.2	7526.9	508.8	7054.8
812.0	811.2	4997.2	360.4	-3656.0	7799.6	530.0	7348.8
811.0	811.2	5291.1	381.6	-3928.7	8072.4	551.2	7642.7
810.0	811.2	5585.1	402.8	-4201.5	8345.1	572.4	7936.7
809.0	811.2	5879.0	424.0	-4474.3	8617.9	593.6	8230.6
808.0	811.2	6173.0	445.2	-4747.0	8890.6	614.8	8524.6
807.0	811.2	6466.9	466.4	-5019.8	9163.4	636.0	8818.6
806.0	811.2	6760.9	487.6	-5292.5	9436.1	657.2	9112.5
805.0	811.2	7054.8	508.8	-5565.3	9708.9	678.4	9406.5
804.0	811.2	9398.9	542.1	-7857.3	13340.8	730.4	13071.7
803.0	811.2	10167.4	538.7	-8635.8	14265.2	720.3	13992.7
802.0	811.2	8884.3	520.9	-7396.1	11831.2	677.0	11541.0
801.0	811.2	9175.3	537.5	-7670.5	12105.8	693.6	11832.1
800.0	811.2	9466.1	554.0	-7944.8	12380.2	710.1	12123.1
799.0	811.2	9756.8	570.6	-8218.9	12654.5	726.7	12413.9
798.0	811.2	10047.3	587.5	-8492.8	12928.3	743.3	12704.6
797.0	811.2	10337.6	604.8	-8766.6	13201.5	759.8	12995.2
796.0	811.2	10627.8	621.9	-9039.9	13475.0	776.7	13285.6

795.0	811.2	10918.0	638.5	-9312.5	13748.7	794.3	13576.0
794.0	811.2	11208.0	655.1	-9585.2	14022.4	811.6	13866.2
793.0	811.2	11497.9	671.7	-9858.6	14296.0	828.2	14156.4
792.0	811.2	11787.8	688.3	-10131.8	14569.5	844.8	14446.5
791.0	811.2	12077.6	704.9	-10405.0	14842.9	861.4	14736.6
790.0	811.2	12367.4	721.5	-10678.2	15116.3	878.0	15026.5
789.0	811.2	12657.0	738.1	-10951.3	15389.6	894.6	15316.4
788.0	811.2	12946.7	754.7	-11224.3	15662.8	911.2	15606.3
787.0	811.2	13236.3	771.3	-11497.3	15936.0	927.8	15896.1
786.0	811.2	13525.8	787.9	-11770.3	16209.2	944.4	16185.8
785.0	811.2	13815.3	804.5	-12043.2	16482.3	961.0	16475.6
784.0	811.2	14104.8	821.1	-12316.1	16755.4	977.6	16765.2
783.0	811.2	14394.3	837.7	-12588.9	17028.4	994.2	17054.9
782.0	811.2	14683.7	854.3	-12861.7	17301.4	1010.8	17344.5
781.0	811.2	14973.1	870.9	-13134.5	17574.4	1027.4	17634.0
780.0	811.2	15262.4	887.5	-13407.3	17847.3	1044.0	17923.6
779.0	811.2	15551.8	904.1	-13680.0	18120.2	1060.6	18213.1
778.0	811.2	24847.8	1018.8	-22819.9	30192.7	1216.6	30400.3
777.0	811.2	26299.0	1000.8	-24295.5	31838.1	1192.3	32027.6
776.0	811.2	18809.2	885.9	-16968.0	21748.1	1029.9	21822.8
775.0	811.2	19229.7	905.2	-17369.3	22149.5	1049.2	22243.5
774.0	811.2	19650.3	924.5	-17770.6	22551.0	1068.4	22664.2

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                        TIME: 15:03:44

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

    I.--HEADING
     'RUM RIVER - 0%
     'UPSTREAM - USUAL
     'FOS 1

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      808.00
```

```
      PENETRATION (FT)     :       21.00

   MAX. BEND. MOMENT (LB-FT)  :  8.8967E+04
      AT ELEVATION (FT)    :      817.88

   MAX. SCALED DEFL. (LB-IN^3):  5.9975E+10
      AT ELEVATION (FT)    :      847.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                         TIME: 15:03:44

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************
```

I.--HEADING
'RUM RIVER - 0%
'UPSTREAM - USUAL
'FOS 1

II.--RESULTS0. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	5.9975E+10	0.00
846.00	2.7940E-09	0.	5.7765E+10	0.00
845.00	2.7940E-09	0.	5.5554E+10	0.00
844.00	2.7940E-09	0.	5.3343E+10	0.00
843.00	2.7940E-09	0.	5.1132E+10	0.00
842.00	2.7940E-09	0.	4.8921E+10	0.00
841.00	1.0400E+01	31.	4.6711E+10	62.40
840.00	8.3200E+01	125.	4.4500E+10	124.80
839.00	2.8080E+02	281.	4.2289E+10	187.20
838.00	6.6560E+02	499.	4.0079E+10	249.60
837.00	1.3000E+03	780.	3.7870E+10	312.00
836.00	2.2499E+03	1134.	3.5664E+10	395.60
835.00	3.5955E+03	1571.	3.3461E+10	479.20
834.00	5.4202E+03	2092.	3.1265E+10	562.80
833.00	7.8077E+03	2697.	2.9078E+10	646.40
832.00	1.0842E+04	3385.	2.6904E+10	730.00
831.00	1.4606E+04	4157.	2.4750E+10	813.60

830.00	1.9183E+04	5012.	2.2621E+10	897.20
829.00	2.4658E+04	5951.	2.0525E+10	980.79
828.00	3.1054E+04	6796.	1.8471E+10	708.04
827.00	3.8158E+04	7367.	1.6472E+10	435.29
826.00	4.5698E+04	7666.	1.4539E+10	162.54
825.40	5.0285E+04	7715.	1.3423E+10	0.00
825.00	5.3400E+04	7692.	1.2684E+10	-110.21
824.00	6.0991E+04	7446.	1.0922E+10	-382.97
823.00	6.8200E+04	6926.	9.2653E+09	-655.72
822.00	7.4753E+04	6134.	7.7263E+09	-928.47
821.00	8.0378E+04	5069.	6.3163E+09	-1201.22
820.00	8.4801E+04	3732.	5.0450E+09	-1473.98
819.00	8.7751E+04	2122.	3.9200E+09	-1746.73
818.00	8.8953E+04	238.	2.9465E+09	-2019.48
817.00	8.8136E+04	-1917.	2.1263E+09	-2292.23
816.00	8.5027E+04	-4346.	1.4581E+09	-2564.99
815.00	7.9353E+04	-7047.	9.3648E+08	-2837.74
814.00	7.0842E+04	-10022.	5.5156E+08	-3110.49
813.00	5.9219E+04	-13268.	2.8861E+08	-3383.24
812.92	5.8213E+04	-13523.	2.7325E+08	-3403.74
812.00	4.4579E+04	-15604.	1.2753E+08	-1096.47
811.00	2.8842E+04	-15454.	4.3324E+07	1398.28
810.00	1.4503E+04	-12808.	9.1572E+06	3893.03
809.00	4.0577E+03	-7667.	6.1284E+05	6387.78
808.00	-1.0566E-01	-32.	-1.7691E-03	8882.53
808.00	0.0000E+00	0.	0.0000E+00	8891.61

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	0.	0.	0.	0.	0.
845.00	0.	0.	0.	0.	0.
844.00	0.	0.	0.	0.	0.
843.00	0.	0.	0.	0.	0.
842.00	0.	0.	0.	0.	0.
841.00	62.	0.	0.	0.	0.
840.00	125.	0.	0.	0.	0.
839.00	187.	0.	0.	0.	0.
838.00	250.	0.	0.	0.	0.
837.00	312.	0.	0.	0.	0.
836.00	374.	0.	0.	21.	294.
835.00	437.	0.	0.	42.	588.
834.00	499.	0.	0.	64.	882.
833.00	562.	0.	0.	85.	1176.

832.00	624.	0.	0.	106.	1470.
831.00	686.	0.	0.	127.	1764.
830.00	749.	0.	0.	148.	2058.
829.00	811.	0.	0.	170.	2352.
828.00	811.	294.	21.	191.	2646.
827.00	811.	588.	42.	212.	2940.
826.00	811.	882.	64.	233.	3233.
825.40	811.	1057.	76.	246.	3409.
825.00	811.	1176.	85.	254.	3527.
824.00	811.	1470.	106.	276.	3821.
823.00	811.	1764.	127.	297.	4115.
822.00	811.	2058.	148.	318.	4409.
821.00	811.	2352.	170.	339.	4703.
820.00	811.	2646.	191.	360.	4997.
819.00	811.	2940.	212.	382.	5291.
818.00	811.	3233.	233.	403.	5585.
817.00	811.	3527.	254.	424.	5879.
816.00	811.	3821.	276.	445.	6173.
815.00	811.	4115.	297.	466.	6467.
814.00	811.	4409.	318.	488.	6761.
813.00	811.	4703.	339.	509.	7055.
812.92	811.	4725.	341.	510.	7077.
812.00	811.	4997.	360.	530.	7349.
811.00	811.	5291.	382.	551.	7643.
810.00	811.	5585.	403.	572.	7937.
809.00	811.	5879.	424.	594.	8231.
808.00	811.	6173.	445.	615.	8525.
808.00	811.	6467.	466.	636.	8819.
806.00	811.	6761.	488.	657.	9113.

Upstream:
Usual - FS 1.5

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                      TIME: 15:04:40

                              ****************
                              *  INPUT DATA  *
                              ****************

     I.--HEADING
    'RUM RIVER - 0%
    'UPSTREAM - USUAL
    'FOS 1.5

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 847.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)         (FT)
                 0.00        837.00
                50.00        837.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)         (FT)
                 0.00        829.00
                50.00        829.00

     V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	BOTTOM ELEV. (FT)	BOTTOM SLOPE (FT/FT)	SAFETY FACTOR ACT.	SAFETY FACTOR PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

```
        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH- ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH- ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 842.00 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:04:43

```
**************************
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'RUM RIVER - 0%
'UPSTREAM - USUAL
'FOS 1.5

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
845.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
844.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
843.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
842.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
841.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
840.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
839.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
838.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
837.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
836.0	374.4	0.0	0.0	395.6	547.1	21.2	172.7
835.0	436.8	0.0	0.0	479.2	782.2	42.4	345.4
834.0	499.2	0.0	0.0	562.8	1017.3	63.6	518.1
833.0	561.6	0.0	0.0	646.4	1252.4	84.8	690.8
832.0	624.0	0.0	0.0	730.0	1487.5	106.0	863.5
831.0	686.4	0.0	0.0	813.6	1722.6	127.2	1036.2
830.0	748.8	0.0	0.0	897.2	1957.7	148.4	1208.9
829.0	811.2	0.0	0.0	980.8	2192.8	169.6	1381.6
828.0	811.2	172.7	21.2	829.3	2344.3	190.8	1554.3
827.0	811.2	345.4	42.4	677.8	2495.8	212.0	1727.0
826.0	811.2	518.1	63.6	526.3	2647.3	233.2	1899.7
825.0	811.2	690.8	84.8	374.8	2798.8	254.4	2072.4
824.0	811.2	863.5	106.0	223.3	2950.3	275.6	2245.1
823.0	811.2	1036.2	127.2	71.8	3101.8	296.8	2417.8
822.5	811.2	1118.0	137.2	0.0	3173.6	306.8	2499.6
822.0	811.2	1208.9	148.4	-79.7	3253.3	318.0	2590.5
821.0	811.2	1381.6	169.6	-231.2	3404.8	339.2	2763.2
820.0	811.2	1554.3	190.8	-382.7	3556.3	360.4	2935.9
819.0	811.2	1727.0	212.0	-534.2	3707.8	381.6	3108.6
818.0	811.2	1899.7	233.2	-685.7	3859.3	402.8	3281.3
817.0	811.2	2072.4	254.4	-837.2	4010.8	424.0	3453.9
816.0	811.2	2245.1	275.6	-988.7	4162.3	445.2	3626.6
815.0	811.2	2417.8	296.8	-1140.2	4313.8	466.4	3799.3
814.0	811.2	2590.5	318.0	-1291.7	4465.3	487.6	3972.0
813.0	811.2	2763.2	339.2	-1443.2	4616.8	508.8	4144.7
812.0	811.2	2935.9	360.4	-1594.7	4768.2	530.0	4317.4
811.0	811.2	3108.6	381.6	-1746.2	4919.7	551.2	4490.1
810.0	811.2	3281.3	402.8	-1897.7	5071.2	572.4	4662.8
809.0	811.2	3453.9	424.0	-2049.2	5222.7	593.6	4835.5
808.0	811.2	3626.6	445.2	-2200.7	5374.2	614.8	5008.2
807.0	811.2	3799.3	466.4	-2352.2	5525.7	636.0	5180.9
806.0	811.2	3972.0	487.6	-2503.7	5677.2	657.2	5353.6
805.0	811.2	4144.7	508.8	-2655.2	5828.7	678.4	5526.3
804.0	811.2	4837.8	542.1	-3296.1	6805.3	730.4	6536.2
803.0	811.2	5171.2	538.7	-3639.7	7196.4	720.3	6923.9
802.0	811.2	4978.4	520.9	-3490.2	6758.9	677.0	6468.6
801.0	811.2	5139.3	537.5	-3634.5	6903.2	693.6	6629.5
800.0	811.2	5300.1	554.0	-3778.8	7047.5	710.1	6790.3
799.0	811.2	5460.9	570.6	-3923.0	7191.7	726.7	6951.1
798.0	811.2	5621.6	587.5	-4067.1	7335.6	743.3	7111.9
797.0	811.2	5782.3	604.8	-4211.3	7479.0	759.8	7272.7
796.0	811.2	5942.9	621.9	-4355.0	7622.7	776.7	7433.4

795.0	811.2	6103.6	638.5	-4498.1	7766.8	794.3	7594.1
794.0	811.2	6264.2	655.1	-4641.4	7910.9	811.6	7754.7
793.0	811.2	6424.8	671.7	-4785.4	8054.9	828.2	7915.4
792.0	811.2	6585.3	688.3	-4929.3	8198.9	844.8	8076.0
791.0	811.2	6745.9	704.9	-5073.3	8342.9	861.4	8236.6
790.0	811.2	6906.4	721.5	-5217.2	8486.9	878.0	8397.2
789.0	811.2	7066.9	738.1	-5361.1	8630.9	894.6	8557.7
788.0	811.2	7227.4	754.7	-5505.0	8774.8	911.2	8718.3
787.0	811.2	7387.9	771.3	-5648.9	8918.8	927.8	8878.8
786.0	811.2	7548.4	787.9	-5792.8	9062.7	944.4	9039.4
785.0	811.2	7708.8	804.5	-5936.7	9206.6	961.0	9199.9
784.0	811.2	7869.3	821.1	-6080.5	9350.5	977.6	9360.4
783.0	811.2	8029.7	837.7	-6224.4	9494.4	994.2	9520.9
782.0	811.2	8190.2	854.3	-6368.2	9638.3	1010.8	9681.4
781.0	811.2	8350.6	870.9	-6512.1	9782.2	1027.4	9841.9
780.0	811.2	8511.0	887.5	-6655.9	9926.1	1044.0	10002.3
779.0	811.2	8671.5	904.1	-6799.7	10070.0	1060.6	10162.8
778.0	811.2	10907.1	1018.8	-8879.3	12843.7	1216.6	13051.3
777.0	811.2	11470.8	1000.8	-9467.2	13485.6	1192.3	13675.2
776.0	811.2	9989.1	885.9	-8148.0	11526.0	1029.9	11600.8
775.0	811.2	10209.2	905.2	-8348.9	11726.9	1049.2	11820.9
774.0	811.2	10429.4	924.5	-8549.8	11927.9	1068.4	12041.1

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                           TIME: 15:04:43

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

    I.--HEADING
     'RUM RIVER - 0%
     'UPSTREAM - USUAL
     'FOS 1.5

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      797.64
```

```
      PENETRATION (FT)     :       31.36

   MAX. BEND. MOMENT (LB-FT)  :  1.4367E+05
      AT ELEVATION (FT)    :      811.55

   MAX. SCALED DEFL. (LB-IN^3):  1.6288E+11
      AT ELEVATION (FT)    :      847.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                         TIME: 15:04:43

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************
```

I.--HEADING
'RUM RIVER - 0%
'UPSTREAM - USUAL
'FOS 1.5

II.--RESULTS0. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	1.6288E+11	0.00
846.00	-3.0734E-08	0.	1.5794E+11	0.00
845.00	-3.0734E-08	0.	1.5300E+11	0.00
844.00	-3.0734E-08	0.	1.4806E+11	0.00
843.00	-3.0734E-08	0.	1.4313E+11	0.00
842.00	-3.0734E-08	0.	1.3819E+11	0.00
841.00	1.0400E+01	31.	1.3325E+11	62.40
840.00	8.3200E+01	125.	1.2831E+11	124.80
839.00	2.8080E+02	281.	1.2338E+11	187.20
838.00	6.6560E+02	499.	1.1844E+11	249.60
837.00	1.3000E+03	780.	1.1350E+11	312.00
836.00	2.2499E+03	1134.	1.0857E+11	395.60
835.00	3.5955E+03	1571.	1.0364E+11	479.20
834.00	5.4202E+03	2092.	9.8718E+10	562.80
833.00	7.8077E+03	2697.	9.3805E+10	646.40
832.00	1.0842E+04	3385.	8.8904E+10	730.00
831.00	1.4606E+04	4157.	8.4023E+10	813.60

830.00	1.9183E+04	5012.	7.9167E+10	897.20
829.00	2.4658E+04	5951.	7.4345E+10	980.79
828.00	3.1074E+04	6856.	6.9565E+10	829.30
827.00	3.8320E+04	7610.	6.4839E+10	677.80
826.00	4.6243E+04	8212.	6.0179E+10	526.30
825.00	5.4693E+04	8662.	5.5599E+10	374.80
824.00	6.3517E+04	8961.	5.1114E+10	223.30
823.00	7.2565E+04	9109.	4.6739E+10	71.81
822.53	7.6888E+04	9126.	4.4708E+10	0.00
822.00	8.1685E+04	9105.	4.2489E+10	-79.69
821.00	9.0725E+04	8950.	3.8380E+10	-231.19
820.00	9.9534E+04	8643.	3.4428E+10	-382.69
819.00	1.0796E+05	8184.	3.0647E+10	-534.19
818.00	1.1585E+05	7574.	2.7054E+10	-685.68
817.00	1.2306E+05	6813.	2.3660E+10	-837.18
816.00	1.2943E+05	5900.	2.0479E+10	-988.68
815.00	1.3481E+05	4835.	1.7521E+10	-1140.18
814.00	1.3905E+05	3620.	1.4797E+10	-1291.68
813.00	1.4200E+05	2252.	1.2312E+10	-1443.18
812.00	1.4350E+05	733.	1.0072E+10	-1594.67
811.00	1.4341E+05	-937.	8.0805E+09	-1746.17
810.00	1.4158E+05	-2759.	6.3363E+09	-1897.67
809.00	1.3784E+05	-4733.	4.8364E+09	-2049.17
808.00	1.3206E+05	-6857.	3.5744E+09	-2200.67
807.00	1.2408E+05	-9134.	2.5403E+09	-2352.16
806.00	1.1374E+05	-11562.	1.7202E+09	-2503.66
805.00	1.0090E+05	-14141.	1.0964E+09	-2655.16
804.56	9.4362E+04	-15382.	8.7690E+08	-2939.42
804.00	8.5389E+04	-16786.	6.4652E+08	-2108.51
803.00	6.7797E+04	-18148.	3.4389E+08	-615.46
802.00	4.9590E+04	-18017.	1.5833E+08	877.58
801.00	3.2260E+04	-16393.	5.8584E+07	2370.63
800.00	1.7301E+04	-13276.	1.4925E+07	3863.67
799.00	6.2057E+03	-8666.	1.7195E+06	5356.71
798.00	4.6707E+02	-2563.	8.8027E+03	6849.76
797.64	0.0000E+00	0.	0.0000E+00	7387.25

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		SOIL PRESSURES			
		LEFTSIDE		RIGHTSIDE	
ELEVATION (FT)	WATER PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	0.	0.	0.	0.	0.
845.00	0.	0.	0.	0.	0.
844.00	0.	0.	0.	0.	0.
843.00	0.	0.	0.	0.	0.

842.00	0.	0.	0.	0.	0.
841.00	62.	0.	0.	0.	0.
840.00	125.	0.	0.	0.	0.
839.00	187.	0.	0.	0.	0.
838.00	250.	0.	0.	0.	0.
837.00	312.	0.	0.	0.	0.
836.00	374.	0.	0.	21.	173.
835.00	437.	0.	0.	42.	345.
834.00	499.	0.	0.	64.	518.
833.00	562.	0.	0.	85.	691.
832.00	624.	0.	0.	106.	863.
831.00	686.	0.	0.	127.	1036.
830.00	749.	0.	0.	148.	1209.
829.00	811.	0.	0.	170.	1382.
828.00	811.	173.	21.	191.	1554.
827.00	811.	345.	42.	212.	1727.
826.00	811.	518.	64.	233.	1900.
825.00	811.	691.	85.	254.	2072.
824.00	811.	863.	106.	276.	2245.
823.00	811.	1036.	127.	297.	2418.
822.53	811.	1118.	137.	307.	2500.
822.00	811.	1209.	148.	318.	2590.
821.00	811.	1382.	170.	339.	2763.
820.00	811.	1554.	191.	360.	2936.
819.00	811.	1727.	212.	382.	3109.
818.00	811.	1900.	233.	403.	3281.
817.00	811.	2072.	254.	424.	3454.
816.00	811.	2245.	276.	445.	3627.
815.00	811.	2418.	297.	466.	3799.
814.00	811.	2590.	318.	488.	3972.
813.00	811.	2763.	339.	509.	4145.
812.00	811.	2936.	360.	530.	4317.
811.00	811.	3109.	382.	551.	4490.
810.00	811.	3281.	403.	572.	4663.
809.00	811.	3454.	424.	594.	4836.
808.00	811.	3627.	445.	615.	5008.
807.00	811.	3799.	466.	636.	5181.
806.00	811.	3972.	488.	657.	5354.
805.00	811.	4145.	509.	678.	5526.
804.56	811.	4452.	524.	701.	5974.
804.00	811.	4838.	542.	730.	6536.
803.00	811.	5171.	539.	720.	6924.
802.00	811.	4978.	521.	677.	6469.
801.00	811.	5139.	537.	694.	6629.
800.00	811.	5300.	554.	710.	6790.
799.00	811.	5461.	571.	727.	6951.
798.00	811.	5622.	587.	743.	7112.
797.64	811.	5782.	605.	760.	7273.
796.00	811.	5943.	622.	777.	7433.

Upstream:
Unusual - FS 1

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                       TIME: 15:04:57

                                ****************
                                *  INPUT DATA  *
                                ****************

      I.--HEADING
     'RUM RIVER - 0%
     'UPSTREAM - UNUSUAL
     'FOS 1

     II.--CONTROL
        CANTILEVER WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

    III.--WALL DATA
        ELEVATION AT TOP OF WALL     = 847.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00        837.00
                 50.00        837.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00        829.00
                 50.00        829.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                 ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.    MOIST  INTERNAL  COH-      WALL     ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.    WGHT.  FRICTION  ESION   FRICTION   ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)    (PCF)   (DEG)    (PSF)    (DEG)     (PSF)   (FT)  (FT/FT)
130.00  130.00    28.00     0.00    15.12      0.00  804.00   0.00   DEF  DEF
120.00  120.00    30.00     0.00    16.20      0.00  778.00   0.00   DEF  DEF
135.00  135.00    32.00     0.00    17.28      0.00                  DEF  DEF

         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 847.00 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:05:00

```
*************************
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
*************************
```

I.--HEADING
'RUM RIVER - 0%
'UPSTREAM - UNUSUAL
'FOS 1

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
845.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
844.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
843.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
842.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
841.0	374.4	0.0	0.0	374.4	374.4	0.0	0.0
840.0	436.8	0.0	0.0	436.8	436.8	0.0	0.0
839.0	499.2	0.0	0.0	499.2	499.2	0.0	0.0
838.0	561.6	0.0	0.0	561.6	561.6	0.0	0.0
837.0	624.0	0.0	0.0	624.0	624.0	0.0	0.0
836.0	686.4	0.0	0.0	707.6	980.4	21.2	294.0
835.0	748.8	0.0	0.0	791.2	1336.7	42.4	587.9
834.0	811.2	0.0	0.0	874.8	1693.1	63.6	881.9
833.0	873.6	0.0	0.0	958.4	2049.4	84.8	1175.8
832.0	936.0	0.0	0.0	1042.0	2405.8	106.0	1469.8
831.0	998.4	0.0	0.0	1125.6	2762.1	127.2	1763.7
830.0	1060.8	0.0	0.0	1209.2	3118.5	148.4	2057.7
829.0	1123.2	0.0	0.0	1292.8	3474.8	169.6	2351.6
828.0	1123.2	294.0	21.2	1020.0	3747.6	190.8	2645.6
827.0	1123.2	587.9	42.4	747.3	4020.3	212.0	2939.5
826.0	1123.2	881.9	63.6	474.5	4293.1	233.2	3233.5
825.0	1123.2	1175.8	84.8	201.8	4565.8	254.4	3527.4
824.3	1123.2	1393.3	100.5	0.0	4767.6	270.1	3744.9
824.0	1123.2	1469.8	106.0	-71.0	4838.6	275.6	3821.4
823.0	1123.2	1763.7	127.2	-343.7	5111.3	296.8	4115.3
822.0	1123.2	2057.7	148.4	-616.5	5384.1	318.0	4409.3
821.0	1123.2	2351.6	169.6	-889.2	5656.8	339.2	4703.2
820.0	1123.2	2645.6	190.8	-1162.0	5929.6	360.4	4997.2
819.0	1123.2	2939.5	212.0	-1434.7	6202.3	381.6	5291.1
818.0	1123.2	3233.5	233.2	-1707.5	6475.1	402.8	5585.1
817.0	1123.2	3527.4	254.4	-1980.2	6747.8	424.0	5879.0
816.0	1123.2	3821.4	275.6	-2253.0	7020.6	445.2	6173.0
815.0	1123.2	4115.3	296.8	-2525.7	7293.3	466.4	6466.9
814.0	1123.2	4409.3	318.0	-2798.5	7566.1	487.6	6760.9
813.0	1123.2	4703.2	339.2	-3071.2	7838.9	508.8	7054.8
812.0	1123.2	4997.2	360.4	-3344.0	8111.6	530.0	7348.8
811.0	1123.2	5291.1	381.6	-3616.7	8384.4	551.2	7642.7
810.0	1123.2	5585.1	402.8	-3889.5	8657.1	572.4	7936.7
809.0	1123.2	5879.0	424.0	-4162.3	8929.9	593.6	8230.6
808.0	1123.2	6173.0	445.2	-4435.0	9202.6	614.8	8524.6
807.0	1123.2	6466.9	466.4	-4707.8	9475.4	636.0	8818.6
806.0	1123.2	6760.9	487.6	-4980.5	9748.1	657.2	9112.5
805.0	1123.2	7054.8	508.8	-5253.3	10020.9	678.4	9406.5
804.0	1123.2	9398.9	542.1	-7545.3	13652.8	730.4	13071.7
803.0	1123.2	10167.4	538.7	-8323.8	14577.2	720.3	13992.7
802.0	1123.2	8884.3	520.9	-7084.1	12143.2	677.0	11541.0
801.0	1123.2	9175.3	537.5	-7358.5	12417.8	693.6	11832.1
800.0	1123.2	9466.1	554.0	-7632.8	12692.2	710.1	12123.1
799.0	1123.2	9756.8	570.6	-7906.9	12966.5	726.7	12413.9
798.0	1123.2	10047.3	587.5	-8180.8	13240.3	743.3	12704.6
797.0	1123.2	10337.6	604.8	-8454.6	13513.5	759.8	12995.2
796.0	1123.2	10627.8	621.9	-8727.9	13787.0	776.7	13285.6

795.0	1123.2	10918.0	638.5	-9000.5	14060.7	794.3	13576.0
794.0	1123.2	11208.0	655.1	-9273.2	14334.4	811.6	13866.2
793.0	1123.2	11497.9	671.7	-9546.6	14608.0	828.2	14156.4
792.0	1123.2	11787.8	688.3	-9819.8	14881.5	844.8	14446.5
791.0	1123.2	12077.6	704.9	-10093.0	15154.9	861.4	14736.6
790.0	1123.2	12367.4	721.5	-10366.2	15428.3	878.0	15026.5
789.0	1123.2	12657.0	738.1	-10639.3	15701.6	894.6	15316.4
788.0	1123.2	12946.7	754.7	-10912.3	15974.8	911.2	15606.3
787.0	1123.2	13236.3	771.3	-11185.3	16248.0	927.8	15896.1
786.0	1123.2	13525.8	787.9	-11458.3	16521.2	944.4	16185.8
785.0	1123.2	13815.3	804.5	-11731.2	16794.3	961.0	16475.6
784.0	1123.2	14104.8	821.1	-12004.1	17067.4	977.6	16765.2
783.0	1123.2	14394.3	837.7	-12276.9	17340.4	994.2	17054.9
782.0	1123.2	14683.7	854.3	-12549.7	17613.4	1010.8	17344.5
781.0	1123.2	14973.1	870.9	-12822.5	17886.4	1027.4	17634.0
780.0	1123.2	15262.4	887.5	-13095.3	18159.3	1044.0	17923.6
779.0	1123.2	15551.8	904.1	-13368.0	18432.2	1060.6	18213.1
778.0	1123.2	24847.8	1018.8	-22507.9	30504.7	1216.6	30400.3
777.0	1123.2	26299.0	1000.8	-23983.5	32150.1	1192.3	32027.6
776.0	1123.2	18809.2	885.9	-16656.0	22060.1	1029.9	21822.8
775.0	1123.2	19229.7	905.2	-17057.3	22461.5	1049.2	22243.5
774.0	1123.2	19650.3	924.5	-17458.6	22863.0	1068.4	22664.2

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:05:00

```
***************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
***************************
```

I.--HEADING

'RUM RIVER - 0%
'UPSTREAM - UNUSUAL
'FOS 1

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

WALL BOTTOM ELEV. (FT) : 800.97

```
      PENETRATION (FT)      :       28.03

   MAX. BEND. MOMENT (LB-FT)  :  2.1633E+05
      AT ELEVATION (FT)     :      814.18

   MAX. SCALED DEFL. (LB-IN^3):  2.1822E+11
      AT ELEVATION (FT)     :      847.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                            TIME: 15:05:00

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

     I.--HEADING
     'RUM RIVER - 0%
     'UPSTREAM - UNUSUAL
     'FOS 1

    II.--RESULTS0. (LB))
```

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	2.1822E+11	0.00
846.00	1.0400E+01	31.	2.1097E+11	62.40
845.00	8.3200E+01	125.	2.0371E+11	124.80
844.00	2.8080E+02	281.	1.9645E+11	187.20
843.00	6.6560E+02	499.	1.8919E+11	249.60
842.00	1.3000E+03	780.	1.8194E+11	312.00
841.00	2.2464E+03	1123.	1.7468E+11	374.40
840.00	3.5672E+03	1529.	1.6743E+11	436.80
839.00	5.3248E+03	1997.	1.6019E+11	499.20
838.00	7.5816E+03	2527.	1.5295E+11	561.60
837.00	1.0400E+04	3120.	1.4573E+11	624.00
836.00	1.3846E+04	3786.	1.3853E+11	707.60
835.00	1.7999E+04	4535.	1.3135E+11	791.20
834.00	2.2944E+04	5368.	1.2420E+11	874.80
833.00	2.8764E+04	6285.	1.1709E+11	958.40
832.00	3.5542E+04	7285.	1.1003E+11	1042.00
831.00	4.3362E+04	8369.	1.0304E+11	1125.60

830.00	5.2307E+04	9536.	9.6113E+10	1209.20
829.00	6.2462E+04	10787.	8.9282E+10	1292.79
828.00	7.3850E+04	11944.	8.2559E+10	1020.04
827.00	8.6258E+04	12827.	7.5963E+10	747.29
826.00	9.9414E+04	13438.	6.9517E+10	474.54
825.00	1.1304E+05	13776.	6.3242E+10	201.79
824.26	1.2327E+05	13851.	5.8725E+10	0.00
824.00	1.2688E+05	13842.	5.7163E+10	-70.97
823.00	1.4064E+05	13634.	5.1303E+10	-343.72
822.00	1.5405E+05	13154.	4.5686E+10	-616.47
821.00	1.6685E+05	12401.	4.0336E+10	-889.22
820.00	1.7877E+05	11376.	3.5273E+10	-1161.98
819.00	1.8951E+05	10078.	3.0519E+10	-1434.73
818.00	1.9883E+05	8506.	2.6093E+10	-1707.48
817.00	2.0644E+05	6663.	2.2009E+10	-1980.23
816.00	2.1206E+05	4546.	1.8282E+10	-2252.99
815.00	2.1544E+05	2157.	1.4922E+10	-2525.74
814.00	2.1629E+05	-506.	1.1933E+10	-2798.49
813.00	2.1434E+05	-3440.	9.3174E+09	-3071.24
812.00	2.0931E+05	-6648.	7.0719E+09	-3344.00
811.00	2.0095E+05	-10128.	5.1876E+09	-3616.75
810.00	1.8897E+05	-13882.	3.6500E+09	-3889.50
809.00	1.7309E+05	-17907.	2.4384E+09	-4162.25
808.00	1.5306E+05	-22206.	1.5252E+09	-4435.01
807.37	1.3830E+05	-25032.	1.0910E+09	-4605.52
807.00	1.2862E+05	-26571.	8.7598E+08	-3608.35
806.00	1.0069E+05	-28850.	4.4845E+08	-948.18
805.00	7.1805E+04	-28468.	1.9476E+08	1711.98
804.00	4.4636E+04	-25426.	6.5401E+07	4372.15
803.00	2.1840E+04	-19723.	1.3801E+07	7032.32
802.00	6.0761E+03	-11361.	9.5267E+05	9692.48
801.00	4.6602E+00	-338.	5.1854E-01	12352.65
800.97	0.0000E+00	0.	0.0000E+00	12425.33

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<----SOIL PRESSURES----			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	62.	0.	0.	0.	0.
845.00	125.	0.	0.	0.	0.
844.00	187.	0.	0.	0.	0.
843.00	250.	0.	0.	0.	0.
842.00	312.	0.	0.	0.	0.
841.00	374.	0.	0.	0.	0.
840.00	437.	0.	0.	0.	0.

839.00	499.	0.	0.	0.	0.
838.00	562.	0.	0.	0.	0.
837.00	624.	0.	0.	0.	0.
836.00	686.	0.	0.	21.	294.
835.00	749.	0.	0.	42.	588.
834.00	811.	0.	0.	64.	882.
833.00	874.	0.	0.	85.	1176.
832.00	936.	0.	0.	106.	1470.
831.00	998.	0.	0.	127.	1764.
830.00	1061.	0.	0.	148.	2058.
829.00	1123.	0.	0.	170.	2352.
828.00	1123.	294.	21.	191.	2646.
827.00	1123.	588.	42.	212.	2940.
826.00	1123.	882.	64.	233.	3233.
825.00	1123.	1176.	85.	254.	3527.
824.26	1123.	1393.	100.	270.	3745.
824.00	1123.	1470.	106.	276.	3821.
823.00	1123.	1764.	127.	297.	4115.
822.00	1123.	2058.	148.	318.	4409.
821.00	1123.	2352.	170.	339.	4703.
820.00	1123.	2646.	191.	360.	4997.
819.00	1123.	2940.	212.	382.	5291.
818.00	1123.	3233.	233.	403.	5585.
817.00	1123.	3527.	254.	424.	5879.
816.00	1123.	3821.	276.	445.	6173.
815.00	1123.	4115.	297.	466.	6467.
814.00	1123.	4409.	318.	488.	6761.
813.00	1123.	4703.	339.	509.	7055.
812.00	1123.	4997.	360.	530.	7349.
811.00	1123.	5291.	382.	551.	7643.
810.00	1123.	5585.	403.	572.	7937.
809.00	1123.	5879.	424.	594.	8231.
808.00	1123.	6173.	445.	615.	8525.
807.37	1123.	6357.	458.	628.	8708.
807.00	1123.	6467.	466.	636.	8819.
806.00	1123.	6761.	488.	657.	9113.
805.00	1123.	7055.	509.	678.	9406.
804.00	1123.	9399.	542.	730.	13072.
803.00	1123.	10167.	539.	720.	13993.
802.00	1123.	8884.	521.	677.	11541.
801.00	1123.	9175.	537.	694.	11832.
800.97	1123.	9466.	554.	710.	12123.
799.00	1123.	9757.	571.	727.	12414.

Upstream:
Unusual - FS 1.5

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                       TIME: 15:05:18

                                ****************
                                *  INPUT DATA  *
                                ****************

     I.--HEADING
    'RUM RIVER - 0%
    'UPSTREAM - UNUSUAL
    'FOS 1.25

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.25

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 847.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00        837.00
                50.00        837.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00        829.00
                50.00        829.00

     V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                 ANGLE OF          ANGLE OF                      <-SAFETY->
 SAT.    MOIST   INTERNAL  COH-      WALL    ADH-    <--BOTTOM-->  <-FACTOR->
 WGHT.   WGHT.   FRICTION  ESION   FRICTION  ESION   ELEV.  SLOPE  ACT. PASS.
 (PCF)   (PCF)    (DEG)    (PSF)    (DEG)    (PSF)   (FT)  (FT/FT)
130.00  130.00    28.00     0.00    15.12     0.00  804.00   0.00   DEF  DEF
120.00  120.00    30.00     0.00    16.20     0.00  778.00   0.00   DEF  DEF
135.00  135.00    32.00     0.00    17.28     0.00                  DEF  DEF

        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 847.00 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:05:20

```
**************************
*    SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'RUM RIVER - 0%
'UPSTREAM - UNUSUAL
'FOS 1.25

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
845.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
844.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
843.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
842.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
841.0	374.4	0.0	0.0	374.4	374.4	0.0	0.0
840.0	436.8	0.0	0.0	436.8	436.8	0.0	0.0
839.0	499.2	0.0	0.0	499.2	499.2	0.0	0.0
838.0	561.6	0.0	0.0	561.6	561.6	0.0	0.0
837.0	624.0	0.0	0.0	624.0	624.0	0.0	0.0
836.0	686.4	0.0	0.0	707.6	898.7	21.2	212.3
835.0	748.8	0.0	0.0	791.2	1173.4	42.4	424.6
834.0	811.2	0.0	0.0	874.8	1448.1	63.6	636.9
833.0	873.6	0.0	0.0	958.4	1722.8	84.8	849.2
832.0	936.0	0.0	0.0	1042.0	1997.5	106.0	1061.5
831.0	998.4	0.0	0.0	1125.6	2272.1	127.2	1273.7
830.0	1060.8	0.0	0.0	1209.2	2546.8	148.4	1486.0
829.0	1123.2	0.0	0.0	1292.8	2821.5	169.6	1698.3
828.0	1123.2	212.3	21.2	1101.7	3012.6	190.8	1910.6
827.0	1123.2	424.6	42.4	910.6	3203.7	212.0	2122.9
826.0	1123.2	636.9	63.6	719.5	3394.8	233.2	2335.2
825.0	1123.2	849.2	84.8	528.4	3585.9	254.4	2547.5
824.0	1123.2	1061.5	106.0	337.3	3777.0	275.6	2759.8
823.0	1123.2	1273.7	127.2	146.2	3968.1	296.8	2972.1
822.2	1123.2	1436.2	143.4	0.0	4114.3	313.0	3134.5
822.0	1123.2	1486.0	148.4	-44.8	4159.2	318.0	3184.4
821.0	1123.2	1698.3	169.6	-235.9	4350.2	339.2	3396.6
820.0	1123.2	1910.6	190.8	-427.0	4541.3	360.4	3608.9
819.0	1123.2	2122.9	212.0	-618.1	4732.4	381.6	3821.2
818.0	1123.2	2335.2	233.2	-809.2	4923.5	402.8	4033.5
817.0	1123.2	2547.5	254.4	-1000.3	5114.6	424.0	4245.8
816.0	1123.2	2759.8	275.6	-1191.4	5305.7	445.2	4458.1
815.0	1123.2	2972.1	296.8	-1382.5	5496.8	466.4	4670.4
814.0	1123.2	3184.4	318.0	-1573.6	5687.9	487.6	4882.7
813.0	1123.2	3396.6	339.2	-1764.7	5879.0	508.8	5095.0
812.0	1123.2	3608.9	360.4	-1955.8	6070.1	530.0	5307.3
811.0	1123.2	3821.2	381.6	-2146.8	6261.2	551.2	5519.5
810.0	1123.2	4033.5	402.8	-2337.9	6452.2	572.4	5731.8
809.0	1123.2	4245.8	424.0	-2529.0	6643.3	593.6	5944.1
808.0	1123.2	4458.1	445.2	-2720.1	6834.4	614.8	6156.4
807.0	1123.2	4670.4	466.4	-2911.2	7025.5	636.0	6368.7
806.0	1123.2	4882.7	487.6	-3102.3	7216.6	657.2	6581.0
805.0	1123.2	5095.0	508.8	-3293.4	7407.7	678.4	6793.3
804.0	1123.2	6247.1	542.1	-4393.4	9115.6	730.4	8534.5
803.0	1123.2	6713.6	538.7	-4870.0	9669.1	720.3	9084.7
802.0	1123.2	6235.4	520.9	-4435.1	8703.3	677.0	8101.1
801.0	1123.2	6437.8	537.5	-4621.1	8889.3	693.6	8303.6
800.0	1123.2	6640.2	554.0	-4806.9	9075.2	710.1	8506.1
799.0	1123.2	6842.5	570.6	-4992.6	9261.1	726.7	8708.5
798.0	1123.2	7044.8	587.5	-5178.3	9446.5	743.3	8910.8
797.0	1123.2	7246.9	604.8	-5363.9	9631.4	759.8	9113.1
796.0	1123.2	7449.1	621.9	-5549.2	9816.6	776.7	9315.3

795.0	1123.2	7651.1	638.5	-5733.6	10002.2	794.3	9517.5
794.0	1123.2	7849.4	655.1	-5914.6	10187.7	811.6	9719.6
793.0	1123.2	8047.0	671.7	-6095.6	10373.2	828.2	9921.7
792.0	1123.2	8248.1	688.3	-6280.1	10558.7	844.8	10123.7
791.0	1123.2	8449.6	704.9	-6465.0	10740.5	861.4	10322.1
790.0	1123.2	8651.1	721.5	-6649.9	10920.2	878.0	10518.5
789.0	1123.2	8852.5	738.1	-6834.7	11103.3	894.6	10718.2
788.0	1123.2	9053.9	754.7	-7019.6	11288.3	911.2	10919.7
787.0	1123.2	9255.3	771.3	-7204.4	11473.2	927.8	11121.2
786.0	1123.2	9456.7	787.9	-7389.2	11658.0	944.4	11322.7
785.0	1123.2	9658.1	804.5	-7573.9	11842.9	961.0	11524.1
784.0	1123.2	9859.5	821.1	-7758.7	12027.7	977.6	11725.6
783.0	1123.2	10060.8	837.7	-7943.4	12212.6	994.2	11927.0
782.0	1123.2	10262.1	854.3	-8128.2	12397.4	1010.8	12128.4
781.0	1123.2	10463.5	870.9	-8312.9	12582.2	1027.4	12329.8
780.0	1123.2	10664.8	887.5	-8497.6	12767.0	1044.0	12531.2
779.0	1123.2	10866.1	904.1	-8682.3	12951.7	1060.6	12732.6
778.0	1123.2	14747.5	1018.8	-12407.7	17848.9	1216.6	17744.5
777.0	1123.2	15567.8	1000.8	-13252.2	18779.9	1192.3	18657.4
776.0	1123.2	12748.5	885.9	-10595.4	15037.6	1029.9	14800.3
775.0	1123.2	13030.9	905.2	-10858.5	15300.7	1049.2	15082.8
774.0	1123.2	13313.3	924.5	-11121.7	15564.0	1068.4	15365.2

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:05:21

```
***************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
***************************
```

I.--HEADING

'RUM RIVER - 0%
'UPSTREAM - UNUSUAL
'FOS 1.25

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

WALL BOTTOM ELEV. (FT) : 793.58

```
      PENETRATION (FT)     :       35.42

   MAX. BEND. MOMENT (LB-FT)  :  2.8247E+05
      AT ELEVATION (FT)    :      809.64

   MAX. SCALED DEFL. (LB-IN^3):  3.8827E+11
      AT ELEVATION (FT)    :      847.00

           NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                  ELASTICITY IN PSI TIMES PILE MOMENT
                  OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                  IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                          TIME: 15:05:21

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************
```

I.--HEADING
'RUM RIVER - 0%
'UPSTREAM - UNUSUAL
'FOS 1.25

II.--RESULTS0. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	3.8827E+11	0.00
846.00	1.0400E+01	31.	3.7692E+11	62.40
845.00	8.3200E+01	125.	3.6558E+11	124.80
844.00	2.8080E+02	281.	3.5423E+11	187.20
843.00	6.6560E+02	499.	3.4288E+11	249.60
842.00	1.3000E+03	780.	3.3153E+11	312.00
841.00	2.2464E+03	1123.	3.2019E+11	374.40
840.00	3.5672E+03	1529.	3.0885E+11	436.80
839.00	5.3248E+03	1997.	2.9752E+11	499.20
838.00	7.5816E+03	2527.	2.8619E+11	561.60
837.00	1.0400E+04	3120.	2.7488E+11	624.00
836.00	1.3846E+04	3786.	2.6359E+11	707.60
835.00	1.7999E+04	4535.	2.5232E+11	791.20
834.00	2.2944E+04	5368.	2.4108E+11	874.80
833.00	2.8764E+04	6285.	2.2988E+11	958.40
832.00	3.5542E+04	7285.	2.1873E+11	1042.00
831.00	4.3362E+04	8369.	2.0764E+11	1125.60

830.00	5.2307E+04	9536.	1.9663E+11	1209.20
829.00	6.2462E+04	10787.	1.8571E+11	1292.79
828.00	7.3864E+04	11984.	1.7490E+11	1101.70
827.00	8.6367E+04	12991.	1.6421E+11	910.61
826.00	9.9781E+04	13806.	1.5367E+11	719.52
825.00	1.1391E+05	14430.	1.4331E+11	528.43
824.00	1.2858E+05	14863.	1.3314E+11	337.34
823.00	1.4358E+05	15104.	1.2320E+11	146.25
822.23	1.5516E+05	15160.	1.1576E+11	0.00
822.00	1.5872E+05	15155.	1.1350E+11	-44.84
821.00	1.7382E+05	15015.	1.0408E+11	-235.93
820.00	1.8869E+05	14683.	9.4960E+10	-427.02
819.00	2.0312E+05	14161.	8.6164E+10	-618.11
818.00	2.1694E+05	13447.	7.7719E+10	-809.21
817.00	2.2996E+05	12542.	6.9649E+10	-1000.30
816.00	2.4197E+05	11446.	6.1976E+10	-1191.39
815.00	2.5278E+05	10159.	5.4721E+10	-1382.48
814.00	2.6222E+05	8681.	4.7903E+10	-1573.57
813.00	2.7008E+05	7012.	4.1537E+10	-1764.66
812.00	2.7618E+05	5152.	3.5638E+10	-1955.75
811.00	2.8032E+05	3101.	3.0216E+10	-2146.84
810.00	2.8232E+05	858.	2.5278E+10	-2337.93
809.00	2.8198E+05	-1575.	2.0828E+10	-2529.02
808.00	2.7911E+05	-4200.	1.6864E+10	-2720.11
807.00	2.7351E+05	-7015.	1.3383E+10	-2911.20
806.00	2.6501E+05	-10022.	1.0373E+10	-3102.30
805.00	2.5341E+05	-13220.	7.8213E+09	-3293.39
804.00	2.3836E+05	-17063.	5.7067E+09	-4393.44
803.00	2.1902E+05	-21695.	4.0034E+09	-4870.05
802.33	2.0336E+05	-24870.	3.0733E+09	-4577.74
802.00	1.9497E+05	-26280.	2.6779E+09	-4021.25
801.00	1.6696E+05	-29452.	1.6887E+09	-2324.05
800.00	1.3663E+05	-30928.	9.8769E+08	-626.86
799.00	1.0567E+05	-30706.	5.2266E+08	1070.34
798.00	7.5780E+04	-28787.	2.4038E+08	2767.54
797.00	4.8659E+04	-25171.	8.9442E+07	4464.73
796.00	2.6004E+04	-19858.	2.3233E+07	6161.93
795.00	9.5096E+03	-12847.	2.8455E+06	7859.13
794.00	8.7477E+02	-4140.	2.2179E+04	9556.32
793.58	0.0000E+00	0.	0.0000E+00	10265.21

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
		<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	WATER PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.

846.00	62.	0.	0.	0.	0.
845.00	125.	0.	0.	0.	0.
844.00	187.	0.	0.	0.	0.
843.00	250.	0.	0.	0.	0.
842.00	312.	0.	0.	0.	0.
841.00	374.	0.	0.	0.	0.
840.00	437.	0.	0.	0.	0.
839.00	499.	0.	0.	0.	0.
838.00	562.	0.	0.	0.	0.
837.00	624.	0.	0.	0.	0.
836.00	686.	0.	0.	21.	212.
835.00	749.	0.	0.	42.	425.
834.00	811.	0.	0.	64.	637.
833.00	874.	0.	0.	85.	849.
832.00	936.	0.	0.	106.	1061.
831.00	998.	0.	0.	127.	1274.
830.00	1061.	0.	0.	148.	1486.
829.00	1123.	0.	0.	170.	1698.
828.00	1123.	212.	21.	191.	1911.
827.00	1123.	425.	42.	212.	2123.
826.00	1123.	637.	64.	233.	2335.
825.00	1123.	849.	85.	254.	2547.
824.00	1123.	1061.	106.	276.	2760.
823.00	1123.	1274.	127.	297.	2972.
822.23	1123.	1436.	143.	313.	3135.
822.00	1123.	1486.	148.	318.	3184.
821.00	1123.	1698.	170.	339.	3397.
820.00	1123.	1911.	191.	360.	3609.
819.00	1123.	2123.	212.	382.	3821.
818.00	1123.	2335.	233.	403.	4034.
817.00	1123.	2547.	254.	424.	4246.
816.00	1123.	2760.	276.	445.	4458.
815.00	1123.	2972.	297.	466.	4670.
814.00	1123.	3184.	318.	488.	4883.
813.00	1123.	3397.	339.	509.	5095.
812.00	1123.	3609.	360.	530.	5307.
811.00	1123.	3821.	382.	551.	5520.
810.00	1123.	4034.	403.	572.	5732.
809.00	1123.	4246.	424.	594.	5944.
808.00	1123.	4458.	445.	615.	6156.
807.00	1123.	4670.	466.	636.	6369.
806.00	1123.	4883.	488.	657.	6581.
805.00	1123.	5095.	509.	678.	6793.
804.00	1123.	6247.	542.	730.	8534.
803.00	1123.	6714.	539.	720.	9085.
802.33	1123.	6392.	527.	691.	8424.
802.00	1123.	6235.	521.	677.	8101.
801.00	1123.	6438.	537.	694.	8304.
800.00	1123.	6640.	554.	710.	8506.
799.00	1123.	6843.	571.	727.	8708.
798.00	1123.	7045.	587.	743.	8911.
797.00	1123.	7247.	605.	760.	9113.
796.00	1123.	7449.	622.	777.	9315.

795.00	1123.	7651.	638.	794.	9517.
794.00	1123.	7849.	655.	812.	9720.
793.58	1123.	8047.	672.	828.	9922.
792.00	1123.	8248.	688.	845.	10124.

Downstream:
Usual - FS 1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:05:42

```
****************
*  INPUT DATA  *
****************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - USUAL
'FOS 1

II.--CONTROL
CANTILEVER WALL DESIGN
FACTOR OF SAFETY FOR ACTIVE PRESSURES = 1.00
FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
ELEVATION AT TOP OF WALL = 847.00 FT.

IV.--SURFACE POINT DATA

IV.A.--RIGHTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	830.00
50.00	830.00

IV.B.--LEFTSIDE

DIST. FROM WALL (FT)	ELEVATION (FT)
0.00	829.00
50.00	829.00

V.--SOIL LAYER DATA

V.A.--RIGHTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

V.B.--LEFTSIDE
LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE = DEFAULT
LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 833.50 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:05:44

****
* SOIL PRESSURES FOR *
* CANTILEVER WALL DESIGN *
****

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - USUAL
'FOS 1

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	<---LEFTSIDE---> ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	<------NET------> (SOIL + WATER) PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	<--RIGHTSIDE---> PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
845.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
844.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
843.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
842.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
841.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
840.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
839.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
838.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
837.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
836.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
835.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
834.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
833.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
833.0	31.2	0.0	0.0	31.2	31.2	0.0	0.0
832.0	93.6	0.0	0.0	93.6	93.6	0.0	0.0
831.0	156.0	0.0	0.0	156.0	156.0	0.0	0.0
830.0	218.4	0.0	0.0	218.4	218.4	0.0	0.0
829.0	280.8	0.0	0.0	302.0	574.8	21.2	294.0
828.0	280.8	294.0	21.2	29.2	847.5	42.4	587.9
827.9	280.8	325.5	23.5	0.0	876.8	44.7	619.4
827.0	280.8	587.9	42.4	-243.5	1120.3	63.6	881.9
826.0	280.8	881.9	63.6	-516.3	1393.0	84.8	1175.8
825.0	280.8	1175.8	84.8	-789.0	1665.8	106.0	1469.8
824.0	280.8	1469.8	106.0	-1061.8	1938.5	127.2	1763.7
823.0	280.8	1763.7	127.2	-1334.5	2211.3	148.4	2057.7
822.0	280.8	2057.7	148.4	-1607.3	2484.0	169.6	2351.6
821.0	280.8	2351.6	169.6	-1880.0	2756.8	190.8	2645.6
820.0	280.8	2645.6	190.8	-2152.8	3029.5	212.0	2939.5
819.0	280.8	2939.5	212.0	-2425.5	3302.3	233.2	3233.5
818.0	280.8	3233.5	233.2	-2698.3	3575.0	254.4	3527.4
817.0	280.8	3527.4	254.4	-2971.0	3847.8	275.6	3821.4
816.0	280.8	3821.4	275.6	-3243.8	4120.5	296.8	4115.3
815.0	280.8	4115.3	296.8	-3516.5	4393.3	318.0	4409.3
814.0	280.8	4409.3	318.0	-3789.3	4666.0	339.2	4703.2
813.0	280.8	4703.2	339.2	-4062.0	4938.8	360.4	4997.2
812.0	280.8	4997.2	360.4	-4334.8	5211.5	381.6	5291.1
811.0	280.8	5291.1	381.6	-4607.5	5484.3	402.8	5585.1
810.0	280.8	5585.1	402.8	-4880.3	5757.0	424.0	5879.0
809.0	280.8	5879.0	424.0	-5153.0	6029.8	445.2	6173.0
808.0	280.8	6173.0	445.2	-5425.8	6302.6	466.4	6466.9
807.0	280.8	6466.9	466.4	-5698.6	6575.3	487.6	6760.9
806.0	280.8	6760.9	487.6	-5971.3	6848.1	508.8	7054.8
805.0	280.8	7054.8	508.8	-6244.1	7120.8	530.0	7348.8
804.0	280.8	9398.9	542.1	-8552.8	9579.1	565.3	9840.4
803.0	280.8	10167.4	538.7	-9325.5	10370.0	561.0	10627.9
802.0	280.8	8884.3	520.9	-8063.1	8976.3	540.4	9216.4
801.0	280.8	9175.3	537.5	-8337.5	9250.8	557.0	9507.4
800.0	280.8	9466.1	554.0	-8611.8	9525.0	573.6	9798.3
799.0	280.8	9756.8	570.6	-8885.9	9799.1	590.1	10088.9
798.0	280.8	10047.3	587.5	-9159.7	10072.8	606.8	10379.5
797.0	280.8	10337.6	604.8	-9432.6	10345.8	624.2	10669.8

796.0	280.8	10627.8	621.9	-9705.6	10619.0	641.4	10960.1
795.0	280.8	10918.0	638.5	-9979.1	10892.6	658.0	11250.3
794.0	280.8	11208.0	655.1	-10252.6	11166.1	674.6	11540.3
793.0	280.8	11497.9	671.7	-10525.9	11439.4	691.2	11830.3
792.0	280.8	11787.8	688.3	-10799.2	11712.7	707.8	12120.2
791.0	280.8	12077.6	704.9	-11072.4	11986.0	724.4	12410.0
790.0	280.8	12367.4	721.5	-11345.5	12259.1	741.0	12699.8
789.0	280.8	12657.0	738.1	-11618.6	12532.3	757.6	12989.5
788.0	280.8	12946.7	754.7	-11891.7	12805.3	774.2	13279.2
787.0	280.8	13236.3	771.3	-12164.7	13078.4	790.8	13568.8
786.0	280.8	13525.8	787.9	-12437.6	13351.3	807.4	13858.4
785.0	280.8	13815.3	804.5	-12710.5	13624.3	824.0	14147.9
784.0	280.8	14104.8	821.1	-12983.4	13897.2	840.6	14437.4
783.0	280.8	14394.3	837.7	-13256.2	14170.0	857.2	14726.9
782.0	280.8	14683.7	854.3	-13529.1	14442.9	873.8	15016.3
781.0	280.8	14973.1	870.9	-13801.8	14715.7	890.4	15305.7
780.0	280.8	15262.4	887.5	-14074.6	14988.5	907.0	15595.1
779.0	280.8	15551.8	904.1	-14347.4	15261.2	923.6	15884.5
778.0	280.8	24847.8	1018.8	-23523.8	24783.1	1043.1	25521.1
777.0	280.8	26299.0	1000.8	-24993.9	26274.4	1024.3	26994.3
776.0	280.8	18809.2	885.9	-17624.4	18580.8	903.9	19186.0
775.0	280.8	19229.7	905.2	-18025.6	18982.1	923.2	19606.5
774.0	280.8	19650.3	924.5	-18427.0	19383.5	942.5	20027.1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:05:45

```
***************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
***************************
```

I.--HEADING

'RUM RIVER - 0%
'DOWNSTREAM - USUAL
'FOS 1

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)      :      822.11
      PENETRATION (FT)      :        6.89

MAX. BEND. MOMENT (LB-FT)   :  3.1010E+03
      AT ELEVATION (FT)     :      825.46

MAX. SCALED DEFL. (LB-IN^3):  5.3399E+08
      AT ELEVATION (FT)     :      847.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                    TIME: 15:05:45

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - USUAL
'FOS 1

II.--RESULTS0. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	5.3399E+08	0.00
846.00	1.7462E-10	0.	5.0841E+08	0.00
845.00	1.7462E-10	0.	4.8284E+08	0.00
844.00	1.7462E-10	0.	4.5726E+08	0.00
843.00	1.7462E-10	0.	4.3168E+08	0.00
842.00	0.0000E+00	0.	4.0611E+08	0.00
841.00	0.0000E+00	0.	3.8053E+08	0.00
840.00	0.0000E+00	0.	3.5496E+08	0.00
839.00	0.0000E+00	0.	3.2938E+08	0.00
838.00	0.0000E+00	0.	3.0380E+08	0.00
837.00	0.0000E+00	0.	2.7823E+08	0.00
836.00	0.0000E+00	0.	2.5265E+08	0.00
835.00	0.0000E+00	0.	2.2707E+08	0.00
834.00	8.7311E-11	0.	2.0150E+08	0.00
833.50	0.0000E+00	0.	1.8871E+08	0.00
833.00	1.3000E+00	8.	1.7592E+08	31.20

832.00	3.5100E+01	70.	1.5035E+08	93.60
831.00	1.6250E+02	195.	1.2486E+08	156.00
830.00	4.4590E+02	382.	9.9665E+07	218.40
829.00	9.5123E+02	642.	7.5275E+07	302.00
828.00	1.6992E+03	808.	5.2568E+07	29.25
827.89	1.7859E+03	810.	5.0283E+07	0.00
827.00	2.4764E+03	701.	3.2800E+07	-243.51
826.00	3.0100E+03	321.	1.7277E+07	-516.26
825.00	3.0275E+03	-332.	6.8809E+06	-789.01
824.00	2.2559E+03	-1257.	1.6026E+06	-1061.76
823.97	2.2178E+03	-1289.	1.5135E+06	-1069.92
823.00	7.5207E+02	-1436.	9.6339E+04	766.50
822.11	0.0000E+00	0.	0.0000E+00	2454.48

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	0.	0.	0.	0.	0.
845.00	0.	0.	0.	0.	0.
844.00	0.	0.	0.	0.	0.
843.00	0.	0.	0.	0.	0.
842.00	0.	0.	0.	0.	0.
841.00	0.	0.	0.	0.	0.
840.00	0.	0.	0.	0.	0.
839.00	0.	0.	0.	0.	0.
838.00	0.	0.	0.	0.	0.
837.00	0.	0.	0.	0.	0.
836.00	0.	0.	0.	0.	0.
835.00	0.	0.	0.	0.	0.
834.00	0.	0.	0.	0.	0.
833.50	0.	0.	0.	0.	0.
833.00	31.	0.	0.	0.	0.
832.00	94.	0.	0.	0.	0.
831.00	156.	0.	0.	0.	0.
830.00	218.	0.	0.	0.	0.
829.00	281.	0.	0.	21.	294.
828.00	281.	294.	21.	42.	588.
827.89	281.	325.	23.	45.	619.
827.00	281.	588.	42.	64.	882.
826.00	281.	882.	64.	85.	1176.
825.00	281.	1176.	85.	106.	1470.
824.00	281.	1470.	106.	127.	1764.
823.97	281.	1479.	107.	128.	1772.
823.00	281.	1764.	127.	148.	2058.

822.11	281.	2058.	148.	170.	2352.
821.00	281.	2352.	170.	191.	2646.

Downstream:
Usual - FS 1.5

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                        TIME: 15:06:02

                                ****************
                                *  INPUT DATA  *
                                ****************

      I.--HEADING
     'RUM RIVER - 0%
     'DOWNSTREAM - USUAL
     'FOS 1.5

     II.--CONTROL
        CANTILEVER WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 847.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00        830.00
                 50.00        830.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00        829.00
                 50.00        829.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

```
         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA

UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 833.50 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS

NONE

VIII.--HORIZONTAL LOADS

NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:06:04

```
**************************
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING

'RUM RIVER - 0%
'DOWNSTREAM - USUAL
'FOS 1.5

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
845.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
844.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
843.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
842.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
841.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
840.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
839.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
838.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
837.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
836.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
835.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
834.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
833.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
833.0	31.2	0.0	0.0	31.2	31.2	0.0	0.0
832.0	93.6	0.0	0.0	93.6	93.6	0.0	0.0
831.0	156.0	0.0	0.0	156.0	156.0	0.0	0.0
830.0	218.4	0.0	0.0	218.4	218.4	0.0	0.0
829.0	280.8	0.0	0.0	302.0	453.5	21.2	172.7
828.0	280.8	172.7	21.2	150.5	605.0	42.4	345.4
827.0	280.8	344.3	42.3	0.0	755.5	63.5	517.0
827.0	280.8	345.4	42.4	-1.0	756.5	63.6	518.1
826.0	280.8	518.1	63.6	-152.5	908.0	84.8	690.8
825.0	280.8	690.8	84.8	-304.0	1059.5	106.0	863.5
824.0	280.8	863.5	106.0	-455.5	1211.0	127.2	1036.2
823.0	280.8	1036.2	127.2	-607.0	1362.5	148.4	1208.9
822.0	280.8	1208.9	148.4	-758.5	1514.0	169.6	1381.6
821.0	280.8	1381.6	169.6	-910.0	1665.5	190.8	1554.3
820.0	280.8	1554.3	190.8	-1061.5	1817.0	212.0	1727.0
819.0	280.8	1727.0	212.0	-1213.0	1968.5	233.2	1899.7
818.0	280.8	1899.7	233.2	-1364.5	2120.0	254.4	2072.4
817.0	280.8	2072.4	254.4	-1516.0	2271.5	275.6	2245.1
816.0	280.8	2245.1	275.6	-1667.5	2423.0	296.8	2417.8
815.0	280.8	2417.8	296.8	-1819.0	2574.5	318.0	2590.5
814.0	280.8	2590.5	318.0	-1970.5	2726.0	339.2	2763.2
813.0	280.8	2763.2	339.2	-2122.0	2877.5	360.4	2935.9
812.0	280.8	2935.9	360.4	-2273.5	3029.0	381.6	3108.6
811.0	280.8	3108.6	381.6	-2425.0	3180.5	402.8	3281.3
810.0	280.8	3281.3	402.8	-2576.5	3332.0	424.0	3453.9
809.0	280.8	3453.9	424.0	-2728.0	3483.5	445.2	3626.6
808.0	280.8	3626.6	445.2	-2879.5	3635.0	466.4	3799.3
807.0	280.8	3799.3	466.4	-3031.0	3786.5	487.6	3972.0
806.0	280.8	3972.0	487.6	-3182.5	3938.0	508.8	4144.7
805.0	280.8	4144.7	508.8	-3334.0	4089.5	530.0	4317.4
804.0	280.8	4837.8	542.1	-3991.7	4784.8	565.3	5046.1
803.0	280.8	5171.2	538.7	-4329.4	5128.4	561.0	5386.4
802.0	280.8	4978.4	520.9	-4157.2	4924.6	540.4	5164.7
801.0	280.8	5139.3	537.5	-4301.5	5068.9	557.0	5325.6
800.0	280.8	5300.1	554.0	-4445.8	5213.2	573.6	5486.4
799.0	280.8	5460.9	570.6	-4590.0	5357.4	590.1	5647.2
798.0	280.8	5621.6	587.5	-4734.0	5501.2	606.8	5807.9
797.0	280.8	5782.3	604.8	-4877.3	5644.6	624.2	5968.6

796.0	280.8	5942.9	621.9	-5020.7	5788.2	641.4	6129.3
795.0	280.8	6103.6	638.5	-5164.7	5932.2	658.0	6289.9
794.0	280.8	6264.2	655.1	-5308.7	6076.2	674.6	6450.5
793.0	280.8	6424.8	671.7	-5452.7	6220.2	691.2	6611.1
792.0	280.8	6585.3	688.3	-5596.7	6364.2	707.8	6771.7
791.0	280.8	6745.9	704.9	-5740.6	6508.1	724.4	6932.2
790.0	280.8	6906.4	721.5	-5884.6	6652.1	741.0	7092.7
789.0	280.8	7066.9	738.1	-6028.5	6796.0	757.6	7253.3
788.0	280.8	7227.4	754.7	-6172.4	6939.9	774.2	7413.8
787.0	280.8	7387.9	771.3	-6316.3	7083.8	790.8	7574.3
786.0	280.8	7548.4	787.9	-6460.1	7227.7	807.4	7734.7
785.0	280.8	7708.8	804.5	-6604.0	7371.6	824.0	7895.2
784.0	280.8	7869.3	821.1	-6747.9	7515.4	840.6	8055.7
783.0	280.8	8029.7	837.7	-6891.7	7659.3	857.2	8216.1
782.0	280.8	8190.2	854.3	-7035.6	7803.1	873.8	8376.6
781.0	280.8	8350.6	870.9	-7179.4	7947.0	890.4	8537.0
780.0	280.8	8511.0	887.5	-7323.2	8090.8	907.0	8697.5
779.0	280.8	8671.5	904.1	-7467.0	8234.6	923.6	8857.9
778.0	280.8	10907.1	1018.8	-9583.2	10432.5	1043.1	11170.5
777.0	280.8	11470.8	1000.8	-10165.7	11021.8	1024.3	11741.7
776.0	280.8	9989.1	885.9	-8804.4	9585.4	903.9	10190.6
775.0	280.8	10209.2	905.2	-9005.2	9786.3	923.2	10410.7
774.0	280.8	10429.4	924.5	-9206.1	9987.2	942.5	10630.9

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:06:05

```
****************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - USUAL
'FOS 1.5

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

```
WALL BOTTOM ELEV. (FT)     :      818.81
      PENETRATION (FT)     :       10.19

MAX. BEND. MOMENT (LB-FT)  :  4.8514E+03
      AT ELEVATION (FT)    :      823.48

MAX. SCALED DEFL. (LB-IN^3):  1.2398E+09
      AT ELEVATION (FT)    :      847.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                            TIME: 15:06:05

                        ****************************
                        * COMPLETE OF RESULTS FOR  *
                        *  CANTILEVER WALL DESIGN  *
                        ****************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - USUAL
'FOS 1.5

II.--RESULTS0. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	1.2398E+09	0.00
846.00	1.5280E-10	0.	1.1852E+09	0.00
845.00	1.5280E-10	0.	1.1307E+09	0.00
844.00	1.5280E-10	0.	1.0761E+09	0.00
843.00	1.5280E-10	0.	1.0215E+09	0.00
842.00	1.5280E-10	0.	9.6698E+08	0.00
841.00	1.5280E-10	0.	9.1242E+08	0.00
840.00	-1.9645E-10	0.	8.5786E+08	0.00
839.00	1.5280E-10	0.	8.0329E+08	0.00
838.00	1.5280E-10	0.	7.4873E+08	0.00
837.00	1.5280E-10	0.	6.9417E+08	0.00
836.00	1.5280E-10	0.	6.3961E+08	0.00
835.00	1.5280E-10	0.	5.8505E+08	0.00
834.00	1.5280E-10	0.	5.3049E+08	0.00
833.50	3.0559E-10	0.	5.0320E+08	0.00
833.00	1.3000E+00	8.	4.7592E+08	31.20

832.00	3.5100E+01	70.	4.2137E+08	93.60
831.00	1.6250E+02	195.	3.6689E+08	156.00
830.00	4.4590E+02	382.	3.1271E+08	218.40
829.00	9.5123E+02	642.	2.5934E+08	302.00
828.00	1.7194E+03	869.	2.0764E+08	150.50
827.01	2.6318E+03	943.	1.5925E+08	0.00
827.00	2.6380E+03	943.	1.5895E+08	-1.00
826.00	3.5557E+03	867.	1.1480E+08	-152.50
825.00	4.3208E+03	638.	7.6787E+07	-303.99
824.00	4.7820E+03	259.	4.6192E+07	-455.49
823.00	4.7877E+03	-273.	2.3794E+07	-606.99
822.00	4.1864E+03	-955.	9.5820E+06	-758.49
821.37	3.4282E+03	-1463.	4.4077E+06	-853.88
821.00	2.8373E+03	-1703.	2.4951E+06	-441.33
820.00	1.0995E+03	-1587.	2.4922E+05	672.64
819.00	3.4393E+01	-357.	1.7924E+02	1786.62
818.81	0.0000E+00	0.	0.0000E+00	1997.11

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	0.	0.	0.	0.	0.
845.00	0.	0.	0.	0.	0.
844.00	0.	0.	0.	0.	0.
843.00	0.	0.	0.	0.	0.
842.00	0.	0.	0.	0.	0.
841.00	0.	0.	0.	0.	0.
840.00	0.	0.	0.	0.	0.
839.00	0.	0.	0.	0.	0.
838.00	0.	0.	0.	0.	0.
837.00	0.	0.	0.	0.	0.
836.00	0.	0.	0.	0.	0.
835.00	0.	0.	0.	0.	0.
834.00	0.	0.	0.	0.	0.
833.50	0.	0.	0.	0.	0.
833.00	31.	0.	0.	0.	0.
832.00	94.	0.	0.	0.	0.
831.00	156.	0.	0.	0.	0.
830.00	218.	0.	0.	0.	0.
829.00	281.	0.	0.	21.	173.
828.00	281.	173.	21.	42.	345.
827.01	281.	344.	42.	63.	517.
827.00	281.	345.	42.	64.	518.
826.00	281.	518.	64.	85.	691.

825.00	281.	691.	85.	106.	863.
824.00	281.	863.	106.	127.	1036.
823.00	281.	1036.	127.	148.	1209.
822.00	281.	1209.	148.	170.	1382.
821.37	281.	1318.	162.	183.	1490.
821.00	281.	1382.	170.	191.	1554.
820.00	281.	1554.	191.	212.	1727.
819.00	281.	1727.	212.	233.	1900.
818.81	281.	1900.	233.	254.	2072.
817.00	281.	2072.	254.	276.	2245.

Downstream:
Unusual - FS 1

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                          TIME: 15:06:32

                              ****************
                              *  INPUT DATA  *
                              ****************

     I.--HEADING
    'RUM RIVER - 0%
    'DOWNSTREAM - UNUSUAL
    'FOS 1

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 847.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00       830.00
                50.00       830.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00       829.00
                50.00       829.00

     V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	BOTTOM ELEV. (FT)	BOTTOM SLOPE (FT/FT)	SAFETY FACTOR ACT.	SAFETY FACTOR PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

```
        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 837.00 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:06:33

```
**************************
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - UNUSUAL
'FOS 1

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
845.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
844.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
843.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
842.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
841.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
840.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
839.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
838.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
837.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
836.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
835.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
834.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
833.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
832.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
831.0	374.4	0.0	0.0	374.4	374.4	0.0	0.0
830.0	436.8	0.0	0.0	436.8	436.8	0.0	0.0
829.0	499.2	0.0	0.0	520.4	793.2	21.2	294.0
828.0	499.2	294.0	21.2	247.6	1065.9	42.4	587.9
827.1	499.2	560.8	40.4	0.0	1313.6	61.6	854.8
827.0	499.2	587.9	42.4	-25.1	1338.7	63.6	881.9
826.0	499.2	881.9	63.6	-297.9	1611.4	84.8	1175.8
825.0	499.2	1175.8	84.8	-570.6	1884.2	106.0	1469.8
824.0	499.2	1469.8	106.0	-843.4	2156.9	127.2	1763.7
823.0	499.2	1763.7	127.2	-1116.1	2429.7	148.4	2057.7
822.0	499.2	2057.7	148.4	-1388.9	2702.4	169.6	2351.6
821.0	499.2	2351.6	169.6	-1661.6	2975.2	190.8	2645.6
820.0	499.2	2645.6	190.8	-1934.4	3247.9	212.0	2939.5
819.0	499.2	2939.5	212.0	-2207.1	3520.7	233.2	3233.5
818.0	499.2	3233.5	233.2	-2479.9	3793.4	254.4	3527.4
817.0	499.2	3527.4	254.4	-2752.6	4066.2	275.6	3821.4
816.0	499.2	3821.4	275.6	-3025.4	4338.9	296.8	4115.3
815.0	499.2	4115.3	296.8	-3298.1	4611.7	318.0	4409.3
814.0	499.2	4409.3	318.0	-3570.9	4884.4	339.2	4703.2
813.0	499.2	4703.2	339.2	-3843.6	5157.2	360.4	4997.2
812.0	499.2	4997.2	360.4	-4116.4	5429.9	381.6	5291.1
811.0	499.2	5291.1	381.6	-4389.1	5702.7	402.8	5585.1
810.0	499.2	5585.1	402.8	-4661.9	5975.4	424.0	5879.0
809.0	499.2	5879.0	424.0	-4934.6	6248.2	445.2	6173.0
808.0	499.2	6173.0	445.2	-5207.4	6521.0	466.4	6466.9
807.0	499.2	6466.9	466.4	-5480.2	6793.7	487.6	6760.9
806.0	499.2	6760.9	487.6	-5752.9	7066.5	508.8	7054.8
805.0	499.2	7054.8	508.8	-6025.7	7339.2	530.0	7348.8
804.0	499.2	9398.9	542.1	-8334.4	9797.5	565.3	9840.4
803.0	499.2	10167.4	538.7	-9107.1	10588.4	561.0	10627.9
802.0	499.2	8884.3	520.9	-7844.7	9194.7	540.4	9216.4
801.0	499.2	9175.3	537.5	-8119.1	9469.2	557.0	9507.4
800.0	499.2	9466.1	554.0	-8393.4	9743.4	573.6	9798.3
799.0	499.2	9756.8	570.6	-8667.5	10017.5	590.1	10088.9
798.0	499.2	10047.3	587.5	-8941.3	10291.2	606.8	10379.5
797.0	499.2	10337.6	604.8	-9214.2	10564.2	624.2	10669.8
796.0	499.2	10627.8	621.9	-9487.2	10837.4	641.4	10960.1

795.0	499.2	10918.0	638.5	-9760.7	11111.0	658.0	11250.3
794.0	499.2	11208.0	655.1	-10034.2	11384.5	674.6	11540.3
793.0	499.2	11497.9	671.7	-10307.5	11657.8	691.2	11830.3
792.0	499.2	11787.8	688.3	-10580.8	11931.1	707.8	12120.2
791.0	499.2	12077.6	704.9	-10854.0	12204.4	724.4	12410.0
790.0	499.2	12367.4	721.5	-11127.1	12477.5	741.0	12699.8
789.0	499.2	12657.0	738.1	-11400.2	12750.7	757.6	12989.5
788.0	499.2	12946.7	754.7	-11673.3	13023.7	774.2	13279.2
787.0	499.2	13236.3	771.3	-11946.3	13296.8	790.8	13568.8
786.0	499.2	13525.8	787.9	-12219.2	13569.7	807.4	13858.4
785.0	499.2	13815.3	804.5	-12492.1	13842.7	824.0	14147.9
784.0	499.2	14104.8	821.1	-12765.0	14115.6	840.6	14437.4
783.0	499.2	14394.3	837.7	-13037.8	14388.4	857.2	14726.9
782.0	499.2	14683.7	854.3	-13310.7	14661.3	873.8	15016.3
781.0	499.2	14973.1	870.9	-13583.4	14934.1	890.4	15305.7
780.0	499.2	15262.4	887.5	-13856.2	15206.9	907.0	15595.1
779.0	499.2	15551.8	904.1	-14129.0	15479.6	923.6	15884.5
778.0	499.2	24847.8	1018.8	-23305.4	25001.5	1043.1	25521.1
777.0	499.2	26299.0	1000.8	-24775.5	26492.8	1024.3	26994.3
776.0	499.2	18809.2	885.9	-17406.0	18799.2	903.9	19186.0
775.0	499.2	19229.7	905.2	-17807.2	19200.5	923.2	19606.5
774.0	499.2	19650.3	924.5	-18208.6	19601.9	942.5	20027.1

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                        TIME: 15:06:34

                       ***************************
                       *  SUMMARY OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ***************************

    I.--HEADING
     'RUM RIVER - 0%
     'DOWNSTREAM - UNUSUAL
     'FOS 1

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      816.84
```

```
      PENETRATION (FT)     :      12.16

   MAX. BEND. MOMENT (LB-FT)  :  1.6942E+04
      AT ELEVATION (FT)    :      822.81

   MAX. SCALED DEFL. (LB-IN^3):  5.6859E+09
      AT ELEVATION (FT)    :      847.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                        TIME: 15:06:34

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - UNUSUAL
'FOS 1

II.--RESULTS0. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	5.6859E+09	0.00
846.00	1.2224E-09	0.	5.4390E+09	0.00
845.00	1.2224E-09	0.	5.1920E+09	0.00
844.00	1.2224E-09	0.	4.9451E+09	0.00
843.00	1.2224E-09	0.	4.6981E+09	0.00
842.00	1.2224E-09	0.	4.4511E+09	0.00
841.00	1.2224E-09	0.	4.2042E+09	0.00
840.00	1.2224E-09	0.	3.9572E+09	0.00
839.00	1.2224E-09	0.	3.7103E+09	0.00
838.00	-1.7462E-10	0.	3.4633E+09	0.00
837.00	-1.7462E-10	0.	3.2164E+09	0.00
836.00	1.0400E+01	31.	2.9694E+09	62.40
835.00	8.3200E+01	125.	2.7225E+09	124.80
834.00	2.8080E+02	281.	2.4757E+09	187.20
833.00	6.6560E+02	499.	2.2295E+09	249.60
832.00	1.3000E+03	780.	1.9844E+09	312.00
831.00	2.2464E+03	1123.	1.7417E+09	374.40

830.00	3.5672E+03	1529.	1.5028E+09	436.80
829.00	5.3283E+03	2007.	1.2702E+09	520.40
828.00	7.5505E+03	2391.	1.0469E+09	247.65
827.09	9.7898E+03	2504.	8.5532E+08	0.00
827.00	1.0020E+04	2503.	8.3662E+08	-25.11
826.00	1.2465E+04	2341.	6.4368E+08	-297.86
825.00	1.4612E+04	1907.	4.7224E+08	-570.61
824.00	1.6188E+04	1200.	3.2597E+08	-843.36
823.00	1.6921E+04	220.	2.0754E+08	-1116.12
822.00	1.6538E+04	-1032.	1.1820E+08	-1388.87
821.00	1.4765E+04	-2557.	5.7229E+07	-1661.62
820.27	1.2426E+04	-3849.	2.8872E+07	-1861.56
820.00	1.1338E+04	-4284.	2.1535E+07	-1396.14
819.00	6.6469E+03	-4808.	5.2394E+06	347.29
818.00	2.3031E+03	-3589.	4.7936E+05	2090.72
817.00	4.9994E+01	-627.	1.8071E+02	3834.15
816.84	0.0000E+00	0.	0.0000E+00	4109.21

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	0.	0.	0.	0.	0.
845.00	0.	0.	0.	0.	0.
844.00	0.	0.	0.	0.	0.
843.00	0.	0.	0.	0.	0.
842.00	0.	0.	0.	0.	0.
841.00	0.	0.	0.	0.	0.
840.00	0.	0.	0.	0.	0.
839.00	0.	0.	0.	0.	0.
838.00	0.	0.	0.	0.	0.
837.00	0.	0.	0.	0.	0.
836.00	62.	0.	0.	0.	0.
835.00	125.	0.	0.	0.	0.
834.00	187.	0.	0.	0.	0.
833.00	250.	0.	0.	0.	0.
832.00	312.	0.	0.	0.	0.
831.00	374.	0.	0.	0.	0.
830.00	437.	0.	0.	0.	0.
829.00	499.	0.	0.	21.	294.
828.00	499.	294.	21.	42.	588.
827.09	499.	561.	40.	62.	855.
827.00	499.	588.	42.	64.	882.
826.00	499.	882.	64.	85.	1176.
825.00	499.	1176.	85.	106.	1470.

824.00	499.	1470.	106.	127.	1764.
823.00	499.	1764.	127.	148.	2058.
822.00	499.	2058.	148.	170.	2352.
821.00	499.	2352.	170.	191.	2646.
820.27	499.	2567.	185.	206.	2861.
820.00	499.	2646.	191.	212.	2940.
819.00	499.	2940.	212.	233.	3233.
818.00	499.	3233.	233.	254.	3527.
817.00	499.	3527.	254.	276.	3821.
816.84	499.	3821.	276.	297.	4115.
815.00	499.	4115.	297.	318.	4409.

Downstream:
Unusual - FS 1.25

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                        TIME: 15:06:50

                             ****************
                             *  INPUT DATA  *
                             ****************

      I.--HEADING
     'RUM RIVER - 0%
     'DOWNSTREAM - UNUSUAL
     'FOS 1.25

     II.--CONTROL
        CANTILEVER WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.25

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 847.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       830.00
                 50.00       830.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                  0.00       829.00
                 50.00       829.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

```
         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	<--BOTTOM--> SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	<-SAFETY-> <-FACTOR-> PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 837.00 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:06:51

****
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
****

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - UNUSUAL
'FOS 1.25

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	<---LEFTSIDE---> ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	<------NET------> (SOIL + WATER) PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	<--RIGHTSIDE---> PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
845.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
844.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
843.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
842.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
841.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
840.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
839.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
838.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
837.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
836.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
835.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
834.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
833.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
832.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
831.0	374.4	0.0	0.0	374.4	374.4	0.0	0.0
830.0	436.8	0.0	0.0	436.8	436.8	0.0	0.0
829.0	499.2	0.0	0.0	520.4	711.5	21.2	212.3
828.0	499.2	212.3	21.2	329.3	902.6	42.4	424.6
827.0	499.2	424.6	42.4	138.2	1093.7	63.6	636.9
826.3	499.2	578.1	57.7	0.0	1231.9	78.9	790.4
826.0	499.2	636.9	63.6	-52.9	1284.8	84.8	849.2
825.0	499.2	849.2	84.8	-244.0	1475.9	106.0	1061.5
824.0	499.2	1061.5	106.0	-435.1	1666.9	127.2	1273.7
823.0	499.2	1273.7	127.2	-626.1	1858.0	148.4	1486.0
822.0	499.2	1486.0	148.4	-817.2	2049.1	169.6	1698.3
821.0	499.2	1698.3	169.6	-1008.3	2240.2	190.8	1910.6
820.0	499.2	1910.6	190.8	-1199.4	2431.3	212.0	2122.9
819.0	499.2	2122.9	212.0	-1390.5	2622.4	233.2	2335.2
818.0	499.2	2335.2	233.2	-1581.6	2813.5	254.4	2547.5
817.0	499.2	2547.5	254.4	-1772.7	3004.6	275.6	2759.8
816.0	499.2	2759.8	275.6	-1963.8	3195.7	296.8	2972.1
815.0	499.2	2972.1	296.8	-2154.9	3386.8	318.0	3184.4
814.0	499.2	3184.4	318.0	-2346.0	3577.9	339.2	3396.6
813.0	499.2	3396.6	339.2	-2537.1	3768.9	360.4	3608.9
812.0	499.2	3608.9	360.4	-2728.1	3960.0	381.6	3821.2
811.0	499.2	3821.2	381.6	-2919.2	4151.1	402.8	4033.5
810.0	499.2	4033.5	402.8	-3110.3	4342.2	424.0	4245.8
809.0	499.2	4245.8	424.0	-3301.4	4533.3	445.2	4458.1
808.0	499.2	4458.1	445.2	-3492.5	4724.4	466.4	4670.4
807.0	499.2	4670.4	466.4	-3683.6	4915.5	487.6	4882.7
806.0	499.2	4882.7	487.6	-3874.7	5106.6	508.8	5095.0
805.0	499.2	5095.0	508.8	-4065.8	5297.7	530.0	5307.3
804.0	499.2	6247.1	542.1	-5182.6	6482.5	565.3	6525.4
803.0	499.2	6713.6	538.7	-5653.3	6962.8	561.0	7002.3
802.0	499.2	6235.4	520.9	-5195.7	6446.8	540.4	6468.6
801.0	499.2	6437.8	537.5	-5381.6	6632.8	557.0	6671.1
800.0	499.2	6640.2	554.0	-5567.5	6818.6	573.6	6873.5
799.0	499.2	6842.5	570.6	-5753.2	7004.4	590.1	7075.8
798.0	499.2	7044.8	587.5	-5938.8	7189.7	606.8	7278.0
797.0	499.2	7246.9	604.8	-6123.6	7374.6	624.2	7480.2
796.0	499.2	7449.1	621.9	-6308.4	7559.7	641.4	7682.4

795.0	499.2	7651.1	638.5	-6493.9	7745.2	658.0	7884.4
794.0	499.2	7849.4	655.1	-6675.6	7928.5	674.6	8084.4
793.0	499.2	8047.0	671.7	-6856.6	8109.4	691.2	8281.9
792.0	499.2	8248.1	688.3	-7041.1	8292.2	707.8	8481.3
791.0	499.2	8449.6	704.9	-7226.0	8477.1	724.4	8682.8
790.0	499.2	8651.1	721.5	-7410.8	8662.0	741.0	8884.3
789.0	499.2	8852.5	738.1	-7595.7	8846.9	757.6	9085.7
788.0	499.2	9053.9	754.7	-7780.5	9031.7	774.2	9287.2
787.0	499.2	9255.3	771.3	-7965.3	9216.5	790.8	9488.6
786.0	499.2	9456.7	787.9	-8150.1	9401.3	807.4	9690.0
785.0	499.2	9658.1	804.5	-8334.9	9586.1	824.0	9891.4
784.0	499.2	9859.5	821.1	-8519.6	9770.9	840.6	10092.7
783.0	499.2	10060.8	837.7	-8704.4	9955.6	857.2	10294.1
782.0	499.2	10262.1	854.3	-8889.1	10140.4	873.8	10495.4
781.0	499.2	10463.5	870.9	-9073.8	10325.1	890.4	10696.8
780.0	499.2	10664.8	887.5	-9258.6	10509.8	907.0	10898.1
779.0	499.2	10866.1	904.1	-9443.3	10694.6	923.6	11099.4
778.0	499.2	14747.5	1018.8	-13205.2	14594.8	1043.1	15114.4
777.0	499.2	15567.8	1000.8	-14044.3	15444.7	1024.3	15946.3
776.0	499.2	12748.5	885.9	-11345.4	12618.3	903.9	13005.0
775.0	499.2	13030.9	905.2	-11608.5	12881.4	923.2	13287.4
774.0	499.2	13313.3	924.5	-11871.7	13144.6	942.5	13569.9

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                           TIME: 15:06:52

                       ****************************
                       *   SUMMARY OF RESULTS FOR  *
                       *   CANTILEVER WALL DESIGN  *
                       ****************************

    I.--HEADING
     'RUM RIVER - 0%
     'DOWNSTREAM - UNUSUAL
     'FOS 1.25

   II.--SUMMARY

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

        LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)     :      813.72
```

```
      PENETRATION (FT)     :       15.28

   MAX. BEND. MOMENT (LB-FT)  :  2.1735E+04
      AT ELEVATION (FT)    :       820.95

   MAX. SCALED DEFL. (LB-IN^3):  9.3756E+09
      AT ELEVATION (FT)    :       847.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                        TIME: 15:06:52

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - UNUSUAL
'FOS 1.25

II.--RESULTS0. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	9.3756E+09	0.00
846.00	-8.7311E-10	0.	8.9971E+09	0.00
845.00	-8.7311E-10	0.	8.6185E+09	0.00
844.00	-8.7311E-10	0.	8.2399E+09	0.00
843.00	-8.7311E-10	0.	7.8614E+09	0.00
842.00	-8.7311E-10	0.	7.4828E+09	0.00
841.00	1.9209E-09	0.	7.1042E+09	0.00
840.00	-8.7311E-10	0.	6.7257E+09	0.00
839.00	-8.7311E-10	0.	6.3471E+09	0.00
838.00	-8.7311E-10	0.	5.9685E+09	0.00
837.00	-8.7311E-10	0.	5.5900E+09	0.00
836.00	1.0400E+01	31.	5.2114E+09	62.40
835.00	8.3200E+01	125.	4.8329E+09	124.80
834.00	2.8080E+02	281.	4.4545E+09	187.20
833.00	6.6560E+02	499.	4.0767E+09	249.60
832.00	1.3000E+03	780.	3.7000E+09	312.00
831.00	2.2464E+03	1123.	3.3256E+09	374.40

830.00	3.5672E+03	1529.	2.9551E+09	436.80
829.00	5.3283E+03	2007.	2.5909E+09	520.40
828.00	7.5641E+03	2432.	2.2360E+09	329.31
827.00	1.0129E+04	2666.	1.8942E+09	138.22
826.28	1.2082E+04	2716.	1.6576E+09	0.00
826.00	1.2832E+04	2709.	1.5699E+09	-52.87
825.00	1.5483E+04	2560.	1.2677E+09	-243.96
824.00	1.7889E+04	2221.	9.9231E+08	-435.06
823.00	1.9861E+04	1690.	7.4774E+08	-626.15
822.00	2.1206E+04	968.	5.3741E+08	-817.24
821.00	2.1734E+04	56.	3.6360E+08	-1008.33
820.00	2.1254E+04	-1048.	2.2720E+08	-1199.42
819.00	1.9574E+04	-2343.	1.2735E+08	-1390.51
818.00	1.6504E+04	-3829.	6.1131E+07	-1581.60
817.82	1.5772E+04	-4123.	5.2228E+07	-1616.76
817.00	1.1985E+04	-5016.	2.3207E+07	-570.87
816.00	6.8973E+03	-4946.	5.9105E+06	710.87
815.00	2.5203E+03	-3594.	6.3499E+05	1992.62
814.00	1.3597E+02	-961.	1.5363E+03	3274.36
813.72	0.0000E+00	0.	0.0000E+00	3631.03

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	0.	0.	0.	0.	0.
845.00	0.	0.	0.	0.	0.
844.00	0.	0.	0.	0.	0.
843.00	0.	0.	0.	0.	0.
842.00	0.	0.	0.	0.	0.
841.00	0.	0.	0.	0.	0.
840.00	0.	0.	0.	0.	0.
839.00	0.	0.	0.	0.	0.
838.00	0.	0.	0.	0.	0.
837.00	0.	0.	0.	0.	0.
836.00	62.	0.	0.	0.	0.
835.00	125.	0.	0.	0.	0.
834.00	187.	0.	0.	0.	0.
833.00	250.	0.	0.	0.	0.
832.00	312.	0.	0.	0.	0.
831.00	374.	0.	0.	0.	0.
830.00	437.	0.	0.	0.	0.
829.00	499.	0.	0.	21.	212.
828.00	499.	212.	21.	42.	425.
827.00	499.	425.	42.	64.	637.

826.28	499.	578.	58.	79.	790.
826.00	499.	637.	64.	85.	849.
825.00	499.	849.	85.	106.	1061.
824.00	499.	1061.	106.	127.	1274.
823.00	499.	1274.	127.	148.	1486.
822.00	499.	1486.	148.	170.	1698.
821.00	499.	1698.	170.	191.	1911.
820.00	499.	1911.	191.	212.	2123.
819.00	499.	2123.	212.	233.	2335.
818.00	499.	2335.	233.	254.	2547.
817.82	499.	2374.	237.	258.	2587.
817.00	499.	2547.	254.	276.	2760.
816.00	499.	2760.	276.	297.	2972.
815.00	499.	2972.	297.	318.	3184.
814.00	499.	3184.	318.	339.	3397.
813.72	499.	3397.	339.	360.	3609.
812.00	499.	3609.	360.	382.	3821.

Downstream:
Extreme - FS 1

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                        TIME: 15:07:06

                              ****************
                              *  INPUT DATA  *
                              ****************

     I.--HEADING
    'RUM RIVER - 0%
    'DOWNSTREAM - EXTREME
    'FOS 1

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 847.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00        830.00
                50.00        830.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                 0.00        829.00
                50.00        829.00

     V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.    MOIST  INTERNAL  COH-      WALL     ADH-    <--BOTTOM--> <-FACTOR->
 WGHT.    WGHT.  FRICTION  ESION   FRICTION  ESION    ELEV.  SLOPE  ACT. PASS.
 (PCF)    (PCF)   (DEG)    (PSF)    (DEG)    (PSF)    (FT)  (FT/FT)
130.00   130.00   28.00     0.00    15.12     0.00   804.00   0.00   DEF  DEF
120.00   120.00   30.00     0.00    16.20     0.00   778.00   0.00   DEF  DEF
135.00   135.00   32.00     0.00    17.28     0.00                   DEF  DEF

        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 840.00 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:07:08

```
**************************
*    SOIL PRESSURES FOR    *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - EXTREME
'FOS 1

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
845.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
844.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
843.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
842.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
841.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
840.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
839.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
838.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
837.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
836.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
835.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
834.0	374.4	0.0	0.0	374.4	374.4	0.0	0.0
833.0	436.8	0.0	0.0	436.8	436.8	0.0	0.0
832.0	499.2	0.0	0.0	499.2	499.2	0.0	0.0
831.0	561.6	0.0	0.0	561.6	561.6	0.0	0.0
830.0	624.0	0.0	0.0	624.0	624.0	0.0	0.0
829.0	686.4	0.0	0.0	707.6	980.4	21.2	294.0
828.0	686.4	294.0	21.2	434.8	1253.1	42.4	587.9
827.0	686.4	587.9	42.4	162.1	1525.9	63.6	881.9
826.4	686.4	762.6	55.0	0.0	1688.0	76.2	1056.5
826.0	686.4	881.9	63.6	-110.7	1798.6	84.8	1175.8
825.0	686.4	1175.8	84.8	-383.4	2071.4	106.0	1469.8
824.0	686.4	1469.8	106.0	-656.2	2344.1	127.2	1763.7
823.0	686.4	1763.7	127.2	-928.9	2616.9	148.4	2057.7
822.0	686.4	2057.7	148.4	-1201.7	2889.6	169.6	2351.6
821.0	686.4	2351.6	169.6	-1474.4	3162.4	190.8	2645.6
820.0	686.4	2645.6	190.8	-1747.2	3435.1	212.0	2939.5
819.0	686.4	2939.5	212.0	-2019.9	3707.9	233.2	3233.5
818.0	686.4	3233.5	233.2	-2292.7	3980.6	254.4	3527.4
817.0	686.4	3527.4	254.4	-2565.4	4253.4	275.6	3821.4
816.0	686.4	3821.4	275.6	-2838.2	4526.1	296.8	4115.3
815.0	686.4	4115.3	296.8	-3110.9	4798.9	318.0	4409.3
814.0	686.4	4409.3	318.0	-3383.7	5071.6	339.2	4703.2
813.0	686.4	4703.2	339.2	-3656.4	5344.4	360.4	4997.2
812.0	686.4	4997.2	360.4	-3929.2	5617.1	381.6	5291.1
811.0	686.4	5291.1	381.6	-4201.9	5889.9	402.8	5585.1
810.0	686.4	5585.1	402.8	-4474.7	6162.6	424.0	5879.0
809.0	686.4	5879.0	424.0	-4747.4	6435.4	445.2	6173.0
808.0	686.4	6173.0	445.2	-5020.2	6708.2	466.4	6466.9
807.0	686.4	6466.9	466.4	-5293.0	6980.9	487.6	6760.9
806.0	686.4	6760.9	487.6	-5565.7	7253.7	508.8	7054.8
805.0	686.4	7054.8	508.8	-5838.5	7526.4	530.0	7348.8
804.0	686.4	9398.9	542.1	-8147.2	9984.7	565.3	9840.4
803.0	686.4	10167.4	538.7	-8919.9	10775.6	561.0	10627.9
802.0	686.4	8884.3	520.9	-7657.5	9381.9	540.4	9216.4
801.0	686.4	9175.3	537.5	-7931.9	9656.4	557.0	9507.4
800.0	686.4	9466.1	554.0	-8206.2	9930.6	573.6	9798.3
799.0	686.4	9756.8	570.6	-8480.3	10204.7	590.1	10088.9
798.0	686.4	10047.3	587.5	-8754.1	10478.4	606.8	10379.5
797.0	686.4	10337.6	604.8	-9027.0	10751.4	624.2	10669.8
796.0	686.4	10627.8	621.9	-9300.0	11024.6	641.4	10960.1

795.0	686.4	10918.0	638.5	-9573.5	11298.2	658.0	11250.3
794.0	686.4	11208.0	655.1	-9847.0	11571.7	674.6	11540.3
793.0	686.4	11497.9	671.7	-10120.3	11845.0	691.2	11830.3
792.0	686.4	11787.8	688.3	-10393.6	12118.3	707.8	12120.2
791.0	686.4	12077.6	704.9	-10666.8	12391.6	724.4	12410.0
790.0	686.4	12367.4	721.5	-10939.9	12664.7	741.0	12699.8
789.0	686.4	12657.0	738.1	-11213.0	12937.9	757.6	12989.5
788.0	686.4	12946.7	754.7	-11486.1	13210.9	774.2	13279.2
787.0	686.4	13236.3	771.3	-11759.1	13484.0	790.8	13568.8
786.0	686.4	13525.8	787.9	-12032.0	13756.9	807.4	13858.4
785.0	686.4	13815.3	804.5	-12304.9	14029.9	824.0	14147.9
784.0	686.4	14104.8	821.1	-12577.8	14302.8	840.6	14437.4
783.0	686.4	14394.3	837.7	-12850.6	14575.6	857.2	14726.9
782.0	686.4	14683.7	854.3	-13123.5	14848.5	873.8	15016.3
781.0	686.4	14973.1	870.9	-13396.2	15121.3	890.4	15305.7
780.0	686.4	15262.4	887.5	-13669.0	15394.1	907.0	15595.1
779.0	686.4	15551.8	904.1	-13941.8	15666.8	923.6	15884.5
778.0	686.4	24847.8	1018.8	-23118.2	25188.7	1043.1	25521.1
777.0	686.4	26299.0	1000.8	-24588.3	26680.0	1024.3	26994.3
776.0	686.4	18809.2	885.9	-17218.8	18986.4	903.9	19186.0
775.0	686.4	19229.7	905.2	-17620.0	19387.7	923.2	19606.5
774.0	686.4	19650.3	924.5	-18021.4	19789.1	942.5	20027.1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:07:08

```
***************************
*  SUMMARY OF RESULTS FOR  *
*  CANTILEVER WALL DESIGN  *
***************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - EXTREME
'FOS 1

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

WALL BOTTOM ELEV. (FT) : 812.32

```
       PENETRATION (FT)     :       16.68

   MAX. BEND. MOMENT (LB-FT)  :  4.3671E+04
       AT ELEVATION (FT)    :      820.53

   MAX. SCALED DEFL. (LB-IN^3):  2.1728E+10
       AT ELEVATION (FT)    :      847.00

           NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                  ELASTICITY IN PSI TIMES PILE MOMENT
                  OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                  IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                            TIME: 15:07:08

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

     I.--HEADING
     'RUM RIVER - 0%
     'DOWNSTREAM - EXTREME
     'FOS 1

    II.--RESULTS0. (LB))
```

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	2.1728E+10	0.00
846.00	-2.4447E-09	0.	2.0854E+10	0.00
845.00	-2.4447E-09	0.	1.9981E+10	0.00
844.00	-2.4447E-09	0.	1.9107E+10	0.00
843.00	-2.4447E-09	0.	1.8233E+10	0.00
842.00	-2.4447E-09	0.	1.7360E+10	0.00
841.00	-2.4447E-09	0.	1.6486E+10	0.00
840.00	-2.4447E-09	0.	1.5612E+10	0.00
839.00	1.0400E+01	31.	1.4738E+10	62.40
838.00	8.3200E+01	125.	1.3865E+10	124.80
837.00	2.8080E+02	281.	1.2991E+10	187.20
836.00	6.6560E+02	499.	1.2118E+10	249.60
835.00	1.3000E+03	780.	1.1246E+10	312.00
834.00	2.2464E+03	1123.	1.0377E+10	374.40
833.00	3.5672E+03	1529.	9.5111E+09	436.80
832.00	5.3248E+03	1997.	8.6518E+09	499.20
831.00	7.5816E+03	2527.	7.8017E+09	561.60

830.00	1.0400E+04	3120.	6.9647E+09	624.00
829.00	1.3846E+04	3786.	6.1459E+09	707.60
828.00	1.7940E+04	4357.	5.3510E+09	434.85
827.00	2.2469E+04	4655.	4.5873E+09	162.09
826.41	2.5255E+04	4704.	4.1512E+09	0.00
826.00	2.7160E+04	4681.	3.8623E+09	-110.66
825.00	3.1741E+04	4434.	3.1843E+09	-383.41
824.00	3.5938E+04	3914.	2.5611E+09	-656.16
823.00	3.9478E+04	3122.	1.9999E+09	-928.92
822.00	4.2090E+04	2057.	1.5068E+09	-1201.67
821.00	4.3501E+04	719.	1.0862E+09	-1474.42
820.00	4.3436E+04	-892.	7.4059E+08	-1747.17
819.00	4.1625E+04	-2776.	4.6979E+08	-2019.93
818.00	3.7794E+04	-4932.	2.7062E+08	-2292.68
817.09	3.2323E+04	-7131.	1.4610E+08	-2540.86
817.00	3.1670E+04	-7353.	1.3643E+08	-2388.48
816.00	2.3405E+04	-8896.	5.6644E+07	-696.85
815.00	1.4442E+04	-8747.	1.7199E+07	994.77
814.00	6.4747E+03	-6906.	2.8529E+06	2686.40
813.00	1.1935E+03	-3374.	8.2101E+04	4378.03
812.32	0.0000E+00	0.	0.0000E+00	5530.16

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	0.	0.	0.	0.	0.
845.00	0.	0.	0.	0.	0.
844.00	0.	0.	0.	0.	0.
843.00	0.	0.	0.	0.	0.
842.00	0.	0.	0.	0.	0.
841.00	0.	0.	0.	0.	0.
840.00	0.	0.	0.	0.	0.
839.00	62.	0.	0.	0.	0.
838.00	125.	0.	0.	0.	0.
837.00	187.	0.	0.	0.	0.
836.00	250.	0.	0.	0.	0.
835.00	312.	0.	0.	0.	0.
834.00	374.	0.	0.	0.	0.
833.00	437.	0.	0.	0.	0.
832.00	499.	0.	0.	0.	0.
831.00	562.	0.	0.	0.	0.
830.00	624.	0.	0.	0.	0.
829.00	686.	0.	0.	21.	294.
828.00	686.	294.	21.	42.	588.

827.00	686.	588.	42.	64.	882.
826.41	686.	763.	55.	76.	1057.
826.00	686.	882.	64.	85.	1176.
825.00	686.	1176.	85.	106.	1470.
824.00	686.	1470.	106.	127.	1764.
823.00	686.	1764.	127.	148.	2058.
822.00	686.	2058.	148.	170.	2352.
821.00	686.	2352.	170.	191.	2646.
820.00	686.	2646.	191.	212.	2940.
819.00	686.	2940.	212.	233.	3233.
818.00	686.	3233.	233.	254.	3527.
817.09	686.	3501.	252.	274.	3795.
817.00	686.	3527.	254.	276.	3821.
816.00	686.	3821.	276.	297.	4115.
815.00	686.	4115.	297.	318.	4409.
814.00	686.	4409.	318.	339.	4703.
813.00	686.	4703.	339.	360.	4997.
812.32	686.	4997.	360.	382.	5291.
811.00	686.	5291.	382.	403.	5585.

Downstream:
Extreme - FS 1.1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:07:26

```
****************
*  INPUT DATA  *
****************

 I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - EXTREME
'FOS 1.1

II.--CONTROL
   CANTILEVER WALL DESIGN
   FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
   FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.10

III.--WALL DATA
   ELEVATION AT TOP OF WALL    = 847.00 FT.

IV.--SURFACE POINT DATA

   IV.A.--RIGHTSIDE
      DIST. FROM     ELEVATION
      WALL (FT)        (FT)
          0.00        830.00
         50.00        830.00

   IV.B.--LEFTSIDE
      DIST. FROM     ELEVATION
      WALL (FT)        (FT)
          0.00        829.00
         50.00        829.00

 V.--SOIL LAYER DATA

   V.A.--RIGHTSIDE
      LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
      LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

```
   V.B.--LEFTSIDE
      LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
      LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT
```

SAT. WGHT. (PCF)	MOIST WGHT. (PCF)	ANGLE OF INTERNAL FRICTION (DEG)	COH-ESION (PSF)	ANGLE OF WALL FRICTION (DEG)	ADH-ESION (PSF)	<--BOTTOM--> ELEV. (FT)	SLOPE (FT/FT)	<-SAFETY-> <-FACTOR-> ACT.	PASS.
130.00	130.00	28.00	0.00	15.12	0.00	804.00	0.00	DEF	DEF
120.00	120.00	30.00	0.00	16.20	0.00	778.00	0.00	DEF	DEF
135.00	135.00	32.00	0.00	17.28	0.00			DEF	DEF

VI.--WATER DATA
UNIT WEIGHT = 62.40 (PCF)
RIGHTSIDE ELEVATION = 840.00 (FT)
LEFTSIDE ELEVATION = 829.00 (FT)
NO SEEPAGE

VII.--VERTICAL SURCHARGE LOADS
NONE

VIII.--HORIZONTAL LOADS
NONE

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS
DATE: 27-AUGUST-2024 TIME: 15:07:28

```
**************************
*   SOIL PRESSURES FOR   *
* CANTILEVER WALL DESIGN *
**************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - EXTREME
'FOS 1.1

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

ELEV. (FT)	NET WATER (PSF)	<---LEFTSIDE---> PASSIVE (PSF)	ACTIVE (PSF)	<------NET------> (SOIL + WATER) ACTIVE (PSF)	PASSIVE (PSF)	<--RIGHTSIDE---> ACTIVE (PSF)	PASSIVE (PSF)

847.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
846.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
845.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
844.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
843.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
842.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
841.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
840.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
839.0	62.4	0.0	0.0	62.4	62.4	0.0	0.0
838.0	124.8	0.0	0.0	124.8	124.8	0.0	0.0
837.0	187.2	0.0	0.0	187.2	187.2	0.0	0.0
836.0	249.6	0.0	0.0	249.6	249.6	0.0	0.0
835.0	312.0	0.0	0.0	312.0	312.0	0.0	0.0
834.0	374.4	0.0	0.0	374.4	374.4	0.0	0.0
833.0	436.8	0.0	0.0	436.8	436.8	0.0	0.0
832.0	499.2	0.0	0.0	499.2	499.2	0.0	0.0
831.0	561.6	0.0	0.0	561.6	561.6	0.0	0.0
830.0	624.0	0.0	0.0	624.0	624.0	0.0	0.0
829.0	686.4	0.0	0.0	707.6	939.2	21.2	252.8
828.0	686.4	252.8	21.2	476.0	1170.9	42.4	505.7
827.0	686.4	505.7	42.4	244.3	1402.5	63.6	758.5
826.0	686.4	758.5	63.6	12.7	1634.2	84.8	1011.4
825.9	686.4	772.4	64.8	0.0	1646.8	86.0	1025.2
825.0	686.4	1011.4	84.8	-219.0	1865.8	106.0	1264.2
824.0	686.4	1264.2	106.0	-450.6	2097.4	127.2	1517.0
823.0	686.4	1517.0	127.2	-682.2	2329.1	148.4	1769.9
822.0	686.4	1769.9	148.4	-913.9	2560.7	169.6	2022.7
821.0	686.4	2022.7	169.6	-1145.5	2792.4	190.8	2275.6
820.0	686.4	2275.6	190.8	-1377.2	3024.0	212.0	2528.4
819.0	686.4	2528.4	212.0	-1608.8	3255.6	233.2	2781.2
818.0	686.4	2781.2	233.2	-1840.4	3487.3	254.4	3034.1
817.0	686.4	3034.1	254.4	-2072.1	3718.9	275.6	3286.9
816.0	686.4	3286.9	275.6	-2303.7	3950.6	296.8	3539.8
815.0	686.4	3539.8	296.8	-2535.4	4182.2	318.0	3792.6
814.0	686.4	3792.6	318.0	-2767.0	4413.8	339.2	4045.4
813.0	686.4	4045.4	339.2	-2998.6	4645.5	360.4	4298.3
812.0	686.4	4298.3	360.4	-3230.3	4877.1	381.6	4551.1
811.0	686.4	4551.1	381.6	-3461.9	5108.8	402.8	4803.9
810.0	686.4	4803.9	402.8	-3693.6	5340.4	424.0	5056.8
809.0	686.4	5056.8	424.0	-3925.2	5572.0	445.2	5309.6
808.0	686.4	5309.6	445.2	-4156.8	5803.7	466.4	5562.5
807.0	686.4	5562.5	466.4	-4388.5	6035.3	487.6	5815.3
806.0	686.4	5815.3	487.6	-4620.1	6267.0	508.8	6068.1
805.0	686.4	6068.1	508.8	-4851.8	6498.6	530.0	6321.0
804.0	686.4	7783.9	542.1	-6532.2	8285.3	565.3	8141.0
803.0	686.4	8397.4	538.7	-7150.0	8916.9	561.0	8769.2
802.0	686.4	7544.8	520.9	-6318.0	7992.4	540.4	7826.9
801.0	686.4	7790.9	537.5	-6547.5	8222.0	557.0	8073.0
800.0	686.4	8036.9	554.0	-6777.0	8451.4	573.6	8319.1
799.0	686.4	8282.8	570.6	-7006.3	8680.8	590.1	8565.0
798.0	686.4	8528.6	587.5	-7235.4	8909.7	606.8	8810.8
797.0	686.4	8774.3	604.8	-7463.7	9138.0	624.2	9056.5
796.0	686.4	9019.8	621.9	-7692.0	9366.6	641.4	9302.1

795.0	686.4	9265.4	638.5	-7920.9	9595.5	658.0	9547.6
794.0	686.4	9510.8	655.1	-8149.8	9824.4	674.6	9793.1
793.0	686.4	9756.2	671.7	-8378.6	10053.2	691.2	10038.5
792.0	686.4	10001.5	688.3	-8607.3	10282.0	707.8	10283.8
791.0	686.4	10246.8	704.9	-8836.0	10510.7	724.4	10529.1
790.0	686.4	10491.9	721.5	-9064.4	10739.3	741.0	10774.4
789.0	686.4	10730.4	738.1	-9286.4	10965.0	757.6	11016.7
788.0	686.4	10968.8	754.7	-9508.2	11186.6	774.2	11254.8
787.0	686.4	11213.3	771.3	-9736.1	11410.7	790.8	11495.6
786.0	686.4	11457.8	787.9	-9964.0	11638.6	807.4	11740.1
785.0	686.4	11702.3	804.5	-10191.9	11866.5	824.0	11984.6
784.0	686.4	11946.8	821.1	-10419.8	12094.4	840.6	12229.1
783.0	686.4	12191.2	837.7	-10647.6	12322.3	857.2	12473.5
782.0	686.4	12435.6	854.3	-10875.4	12550.1	873.8	12718.0
781.0	686.4	12680.1	870.9	-11103.2	12777.9	890.4	12962.4
780.0	686.4	12924.4	887.5	-11331.0	13005.8	907.0	13206.8
779.0	686.4	13168.8	904.1	-11558.8	13233.5	923.6	13451.2
778.0	686.4	19334.1	1018.8	-17604.6	19500.2	1043.1	19832.6
777.0	686.4	20451.9	1000.8	-18741.2	20652.4	1024.3	20966.8
776.0	686.4	15701.3	885.9	-14110.9	15816.9	903.9	16016.5
775.0	686.4	16050.8	905.2	-14441.2	16147.2	923.2	16366.0
774.0	686.4	16400.4	924.5	-14771.5	16477.5	942.5	16715.6

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 27-AUGUST-2024 TIME: 15:07:28

```
*****************************
*  SUMMARY OF RESULTS FOR   *
*  CANTILEVER WALL DESIGN   *
*****************************
```

I.--HEADING
'RUM RIVER - 0%
'DOWNSTREAM - EXTREME
'FOS 1.1

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

WALL BOTTOM ELEV. (FT) : 810.52

```
      PENETRATION (FT)     :       18.48

   MAX. BEND. MOMENT (LB-FT)  :  4.8642E+04
      AT ELEVATION (FT)    :      819.46

   MAX. SCALED DEFL. (LB-IN^3):  2.7242E+10
      AT ELEVATION (FT)    :      847.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 27-AUGUST-2024                                            TIME: 15:07:28

                       ****************************
                       * COMPLETE OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

     I.--HEADING
     'RUM RIVER - 0%
     'DOWNSTREAM - EXTREME
     'FOS 1.1

    II.--RESULTS0. (LB))
```

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN^3)	NET PRESSURE (PSF)
847.00	0.0000E+00	0.	2.7242E+10	0.00
846.00	-4.8894E-09	0.	2.6189E+10	0.00
845.00	-4.8894E-09	0.	2.5136E+10	0.00
844.00	-4.8894E-09	0.	2.4083E+10	0.00
843.00	-4.8894E-09	0.	2.3030E+10	0.00
842.00	-4.8894E-09	0.	2.1977E+10	0.00
841.00	-4.8894E-09	0.	2.0925E+10	0.00
840.00	-4.8894E-09	0.	1.9872E+10	0.00
839.00	1.0400E+01	31.	1.8819E+10	62.40
838.00	8.3200E+01	125.	1.7766E+10	124.80
837.00	2.8080E+02	281.	1.6713E+10	187.20
836.00	6.6560E+02	499.	1.5661E+10	249.60
835.00	1.3000E+03	780.	1.4610E+10	312.00
834.00	2.2464E+03	1123.	1.3561E+10	374.40
833.00	3.5672E+03	1529.	1.2516E+10	436.80
832.00	5.3248E+03	1997.	1.1477E+10	499.20
831.00	7.5816E+03	2527.	1.0448E+10	561.60

830.00	1.0400E+04	3120.	9.4320E+09	624.00
829.00	1.3846E+04	3786.	8.4339E+09	707.60
828.00	1.7947E+04	4378.	7.4598E+09	475.96
827.00	2.2524E+04	4738.	6.5168E+09	244.32
826.00	2.7345E+04	4866.	5.6128E+09	12.68
825.95	2.7612E+04	4867.	5.5646E+09	0.00
825.00	3.2179E+04	4763.	4.7560E+09	-218.96
824.00	3.6794E+04	4428.	3.9548E+09	-450.60
823.00	4.0958E+04	3862.	3.2171E+09	-682.24
822.00	4.4441E+04	3064.	2.5501E+09	-913.88
821.00	4.7009E+04	2034.	1.9598E+09	-1145.52
820.00	4.8432E+04	773.	1.4505E+09	-1377.16
819.00	4.8477E+04	-720.	1.0247E+09	-1608.80
818.00	4.6914E+04	-2445.	6.8249E+08	-1840.44
817.00	4.3510E+04	-4401.	4.2104E+08	-2072.08
816.00	3.8035E+04	-6589.	2.3448E+08	-2303.72
815.68	3.5810E+04	-7337.	1.8921E+08	-2377.74
815.00	3.0345E+04	-8614.	1.1332E+08	-1376.21
814.00	2.1288E+04	-9254.	4.4390E+07	95.67
813.00	1.2326E+04	-8423.	1.2262E+07	1567.55
812.00	4.9326E+03	-6119.	1.6604E+06	3039.43
811.00	5.7827E+02	-2344.	1.9689E+04	4511.31
810.52	0.0000E+00	0.	0.0000E+00	5220.35

NOTE: DIVIDE SCALED DEFLECTION MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN^4 TO OBTAIN DEFLECTION IN INCHES.

III.--WATER AND SOIL PRESSURES

		<-------------SOIL PRESSURES-------------->			
	WATER	<----LEFTSIDE----->		<---RIGHTSIDE---->	
ELEVATION (FT)	PRESSURE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
847.00	0.	0.	0.	0.	0.
846.00	0.	0.	0.	0.	0.
845.00	0.	0.	0.	0.	0.
844.00	0.	0.	0.	0.	0.
843.00	0.	0.	0.	0.	0.
842.00	0.	0.	0.	0.	0.
841.00	0.	0.	0.	0.	0.
840.00	0.	0.	0.	0.	0.
839.00	62.	0.	0.	0.	0.
838.00	125.	0.	0.	0.	0.
837.00	187.	0.	0.	0.	0.
836.00	250.	0.	0.	0.	0.
835.00	312.	0.	0.	0.	0.
834.00	374.	0.	0.	0.	0.
833.00	437.	0.	0.	0.	0.
832.00	499.	0.	0.	0.	0.
831.00	562.	0.	0.	0.	0.
830.00	624.	0.	0.	0.	0.

829.00	686.	0.	0.	21.	253.
828.00	686.	253.	21.	42.	506.
827.00	686.	506.	42.	64.	759.
826.00	686.	759.	64.	85.	1011.
825.95	686.	772.	65.	86.	1025.
825.00	686.	1011.	85.	106.	1264.
824.00	686.	1264.	106.	127.	1517.
823.00	686.	1517.	127.	148.	1770.
822.00	686.	1770.	148.	170.	2023.
821.00	686.	2023.	170.	191.	2276.
820.00	686.	2276.	191.	212.	2528.
819.00	686.	2528.	212.	233.	2781.
818.00	686.	2781.	233.	254.	3034.
817.00	686.	3034.	254.	276.	3287.
816.00	686.	3287.	276.	297.	3540.
815.68	686.	3368.	282.	304.	3621.
815.00	686.	3540.	297.	318.	3793.
814.00	686.	3793.	318.	339.	4045.
813.00	686.	4045.	339.	360.	4298.
812.00	686.	4298.	360.	382.	4551.
811.00	686.	4551.	382.	403.	4804.
810.52	686.	4804.	403.	424.	5057.
809.00	686.	5057.	424.	445.	5310.

References

Water Elevations

From: McCoy, Scott
Sent: Monday, August 26, 2024 11:36 AM
To: Walters, Hannah
Subject: FW: Rum River Sheet Piling

Scott A. McCoy, P.E.
D 361.696.3355 **M** 954.401.2448

hdrinc.com/follow-us

From: Dvorak, Joe <Joe.Dvorak@hdrinc.com>
Sent: Monday, August 26, 2024 6:58 AM
To: Williams, Justin (Colorado) <Justin.Williams@hdrinc.com>; Weber, Martin <Martin.Weber@hdrinc.com>
Cc: McCoy, Scott <Scott.McCoy@hdrinc.com>
Subject: RE: Rum River Sheet Piling

<u>Headwater</u>

- Normal full pond is 844.35 in the summer and 841.35 in the winter, when flashboards are down.
- Per FEMA, the 100-year flood HW is 848.43.

<u>Tailwater</u>

- 99% annual exceedance for TW is 831.9, 50% is 832.5.
- Annual exceedance for TW 837 is about 1%.
- Per FEMA the 100-year flood on the Mississippi results in tailwater elevations of 845.2.
- 100-year flood on ONLY the Rum results in tailwater elevation 842.

Joe Dvorak, MS
Hydropower Specialist

HDR
1601 Utica Avenue South, Suite 600
St. Louis Park, MN 55416-3400
D 704.248.3655 **M** 414.218.7801
hdrinc.com/follow-us

From: McCoy, Scott
Sent: Monday, August 26, 2024 11:36 AM
To: Walters, Hannah
Subject: FW: Rum River Sheet Piling
Attachments: Flood elevation record data.pdf

Scott A. McCoy, P.E.
D 361.696.3355 **M** 954.401.2448

hdrinc.com/follow-us

From: Williams, Justin (Colorado) <Justin.Williams@hdrinc.com>
Sent: Friday, August 23, 2024 12:51 PM
To: Weber, Martin <Martin.Weber@hdrinc.com>; Dvorak, Joe <Joe.Dvorak@hdrinc.com>
Cc: McCoy, Scott <Scott.McCoy@hdrinc.com>
Subject: Rum River Sheet Piling

Hello Marty and Joe,

I Spoke with Scott today to give he a better idea of the project and what we are looking for. I have some questions for you both highlighted in **BLUE** below. I Took a first shot at elevations based on the attachment.

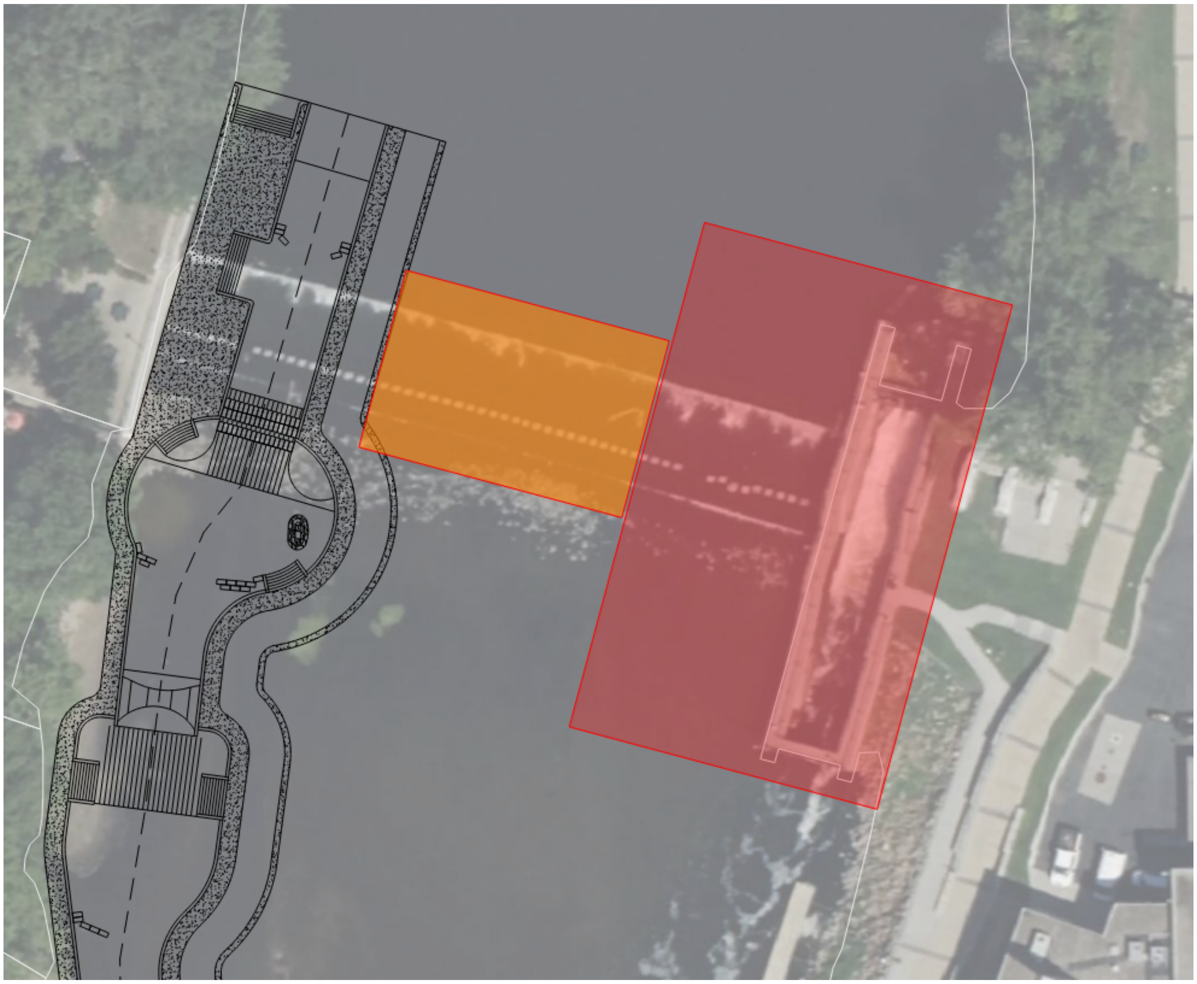
I will be proving Scott the following documents: (Scott I dropped these in your T-drive)

- Soil Exploration Company Geotech report 1962
- Rum River Stream Stats Report 3/12/2024
- Flood Elevation and Stage Curves
- Barr 2023 Dam Inspection report Bathymetry Survey
- OPCC Reference Figures 6.14.2024

Charge Code: 10393640 – City of Anoka Rum River Design: Task 004- feasibility report

I specifically asked him to help us with the following:

- Determine Initial Pile Loading and required depth
- Selection of wall type , Z-wall, combi-wall, etc.
- Constructability approach being that coffer dams will still be required for installation of the center and lock areas as pictured below. However, it does sound like a cantilevered sheet pile wall without support from embankment on the dry side is a strong possibility, is we can "reach" the pile dividing locations from the shore or a Flexi-Float barge with a crane on it. So this would be a decent potential cost savings to the project, as well as utilizing the waterpark sheet pile as a cofferdam.



In return he asked us for the following information. Please Verify these water elevations.

1. Reference data as listed above
2. Water pool elevations
    a. US
        i. Normal elevation = **835-842**
        ii. Unusual Case **847 & % Recurrence**
    b. DS (understanding that the elevation will drop as we go downstream, so let's choose location to be near toe of dam)
        i. Normal elevation **831.5- 833.5 or under**
        ii. Unusual case **837 & % Recurrence**
        iii. Extreme Case from Mississippi back flooding **840 & % Recurrence**

Thanks,

Justin Williams, P.E. (CO), CEP
Civil Engineer

HDR
1670 Broadway, Suite 3400
Denver, CO 80202
D 303.318.6283
Justin.Williams@HDRInc.com

hdrinc.com/follow-us

References

Geotechnical Report

MIDWAY 6-7361

Soil Exploration Company

FORMERLY OPERATED AS A DEPARTMENT OF
TWIN CITY TESTING AND ENGINEERING LABORATORY, INC.

OFFICERS
CHARLES W. BRITZIUS - President
ROBERT F. WITTMAN - Executive Vice-President
NORMAN E. HENNING - Vice-President
CLINTON R. EUE - Secretary
JOHN F. GISLASON - Treasurer

2440 FRANKLIN AVENUE
ST. PAUL 14, MINN.

April 2, 1962

COPY

Mr. Douglas W. Barr
Consulting Hydraulic Engineer
204 Baker Building
Minneapolis 2, Minnesota

Re: Soil borings, Proposed Dam Repair, City of Anoka

Dear Sir:

On March 28 and 29, 1962, we put down a soil test boring at the downstream side of the existing dam near the city hall at Anoka, Minnesota.

The boring was put down at the location discussed with you and is shown on the attached sketch. The surface elevation was referenced to the top of the oil filler pipe where shown, taken as 850.36' (an elevation furnished by the city engineer). The log of the boring, and a sheet giving our method of soil classification (U. S. Bureau of Soils) are attached. The soil was visually classified in accordance with the above method.

The boring was cased with 2½ inch pipe which was cleaned and advanced by standard jetting methods. Soil samples were taken with a 2-inch O. D. split sampler, and the blows per foot (B P F) as given along the right side of the logs were recorded on this sampler driven by a 140 lb. weight falling 30 inches.

The boring was put down through the apron of the dam at the location shown on the attached sketch. It may be seen by the log of the boring that the soil is all sandy in nature, varying in classification from sand to sandy loam. The penetration resistance of the sandy soils varies generally from fairly low in the upper portion of the boring to moderately good at greater depth. Attached is a tabulation of the water level information.

All of the soil samples will be delivered to your office for your personal inspection.

Proposed Dam Repair,
City of Anoka

Because the area of the boring in relation to the entire area is very small, and for other reasons, we do not warrant conditions below the depths of our boring, or that the strata logged from our boring are necessarily typical of the entire site.

Very truly yours,

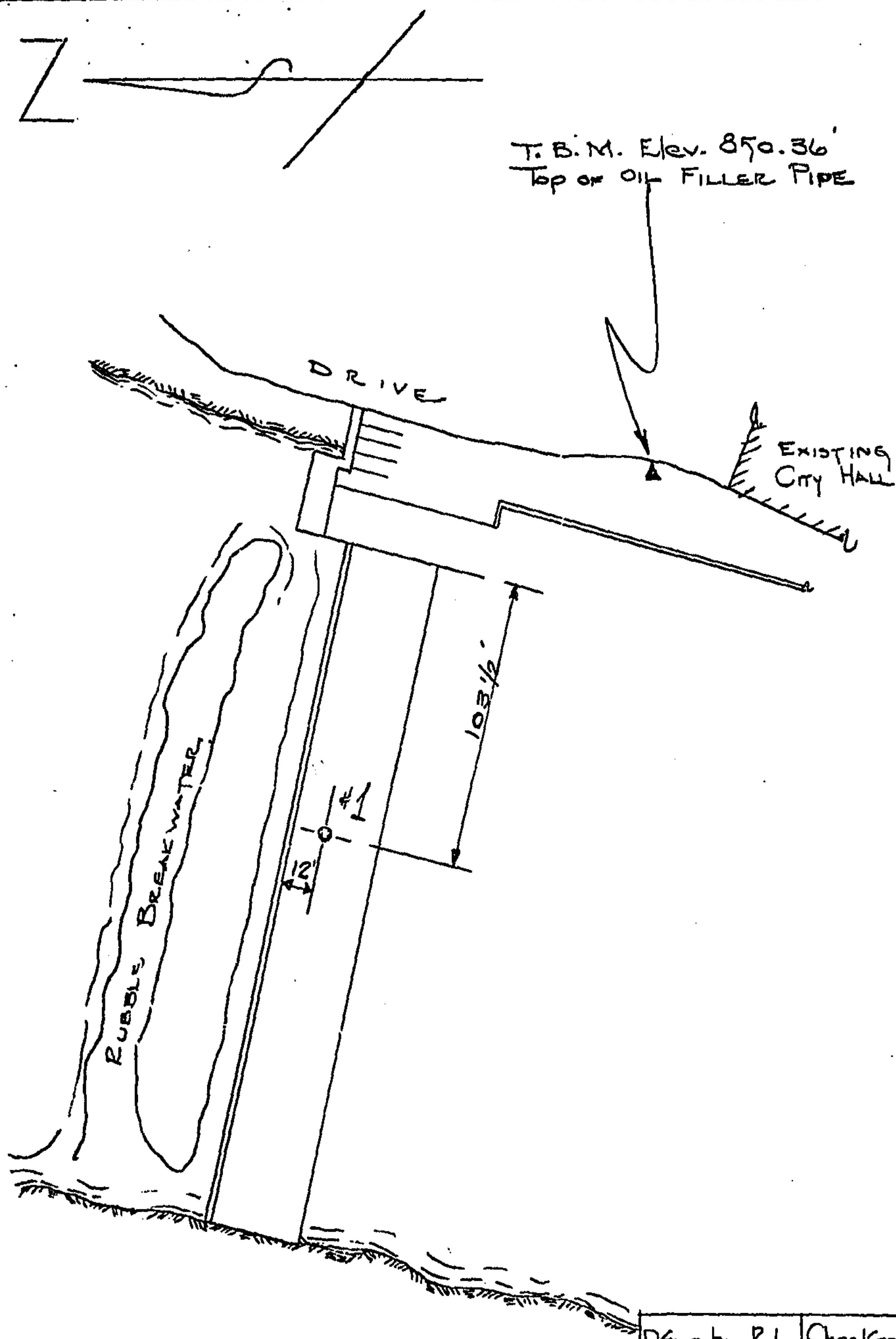
SOIL EXPLORATION COMPANY

Robert F. Wittman

WAW:cr
encs.

WATER LEVEL INFORMATION

Date	Time	Casing Ground	Depth Sampled To	Water Level	Bailed From	Bailed To
3-28	2:25	14½	19½		6.7	14.0
3-28	2:40	14½	19½	13.0		
3-28	3:55	24½	24½		4.9	18.2
3-29	9:00	24½	24½	12.3		
3-29	9:30	24½	27	8.0		
3-29	10:15	27½	27		7.8	22.0
3-29	10:30	27½	27	12.8		
3-29	12:00	34½	34½		9.3	32.7
3-29	12:30	34½	34½			26.8
3-29	1:15	37	39½		12	34.3
3-29	2:30	37	39½	32.4		
3-29	3:05	37	42		4.5	31.1
3-29	3:20	37	42	17.9		
3-29	3:25	34½	42	14.9		
3-29	3:30	30	42	14.0		
3-29	3:35	30	42		14.0	22.9
3-29	3:45	30	42	11.9		
3-29	3:50	20	42		9.3	13.2
3-29	4:00	14½	42	9.4		
3-29	4:05	14½	42	10.0		



	Drwn by- R.L. | Checked by- W.W.
SOIL TEST BORINGS	JOB No. 4219

LOG OF TEST BORINGS

SOIL EXPLORATION COMPANY

PROJECT: PROPOSED DAM REPAIR, CITY OF ANOKA, MINNESOTA

LABORATORY NO.: 4219 **VERTICAL SCALE:** 1" = 4'

BORING NO. 1 **SURFACE ELEV.** 838.34'

DEPTH	Description	BPF
0'	Void	
7'	Water	
8½'	Grayish brown coarse sand (waterbearing) with gravel	13
10½'	Brown sandy loam (wet) with a little gravel and a few lenses of sand (waterbearing)	5, 8, 7, 13
	Brown medium sand (waterbearing) with a little gravel and lenses of sandy loam	16
22'	Brown sandy loam (wet) with a little gravel	21
25'	Brown medium sand (waterbearing) with a little gravel	19
27'	Brown sandy loam (wet) with a little gravel	7
30'	Brown coarse sand (waterbearing) with gravel	11
33'	Brown sandy loam (wet) with a little gravel	13, 13
36'	Brown coarse sand (waterbearing) with a little gravel	
	Brown sandy loam (wet) with a little gravel	16, 17

BORING NO. ____ **SURFACE ELEV.** ____

DEPTH	Description	BPF

SEP 2 1966

SOIL ENGINEERING SERVICES, INC.
615 NORTH COUNTY RD. 18 MINNEAPOLIS, MINN. 55427 • 544-2739

J. S. BRAUN, P.E.

August 31, 1966

Mr. Robert B. Johnson, P. E.
City Engineer
City Hall
Anoka, Minnesota

Re: 66-125 SOIL BORINGS
Rum River Dam
Anoka, Minnesota

Mr. Johnson:

The additional soil borings requested to assist in defining foundation conditions for the proposed new dam were taken between August 16 and 26.

The borings were taken generally at locations indicated on the sketch furnished by the Barr Engineering Company. A copy of that sketch is attached.

The borings were taken using equipment, procedures, and classification techniques described in the July 14, 1966 report. Representative samples were selected from major soil strata for laboratory testing. Other representative samples are being submitted to the Barr Engineering Company.

RESULTS

Logs of soils encountered and penetration resistances are plotted on the attached soil boring log sheets. Results of laboratory tests are plotted on the attached grain size accumulation curves or shown on the attached tabulation.

Boring ST-6A, taken at the specified location, encountered grey medium to coarse sand with an extensive amount of wood between about elevations 830 and 820. This wood was mostly a coarse grained type, probably either pine or fir, and could have resulted from previous lumbering operations on the river. The "rubbery" nature of the wood made jetting very difficult. Two other attempts just west of this location met refusal on the wood at a shallower elevation so the boring was shifted about 20 feet downstream on the apron.

The replacement boring, ST-6B, encountered a similar sand strata with extensive amounts of wood between about elevation 831 and 804. Dense brown sandy loams were encountered between elevations 804 and 796. Very stiff silt loams extended from immediately below the sandy loams to about elevation 784, with coarse loamy sand then being encountered to elevation 778. Between about elevations 778 and 765, this boring encountered a grey-brown fine grained granular material. Laboratory tests indicate the material to be a fine loamy sand, or SM by the Unified Classification System. However, the material is similar in appearance to a loosely cemented sandstone.

Boring ST-7, to the east of boring ST-6A and 6B, indicated the stratum of greyish granular material with wood to be considerably thinner, terminating at about elevation 822. Dense sandy loams and sands similar to those in boring ST-6B and the previous ST-5 were encountered between elevations 822 and 780 and contained a thin sand lense. However, the silty stratum was not indicated in this boring or in the adjacent boring, ST-5. The grey-brown fine grained granular material was encountered between about elevations 780 and 769. It is significant that a brown medium sand was encountered below the latter elevation.

If we can be of further assistance, kindly contact us at your convenience.

Very truly yours,

SOIL ENGINEERING SERVICES, INC.

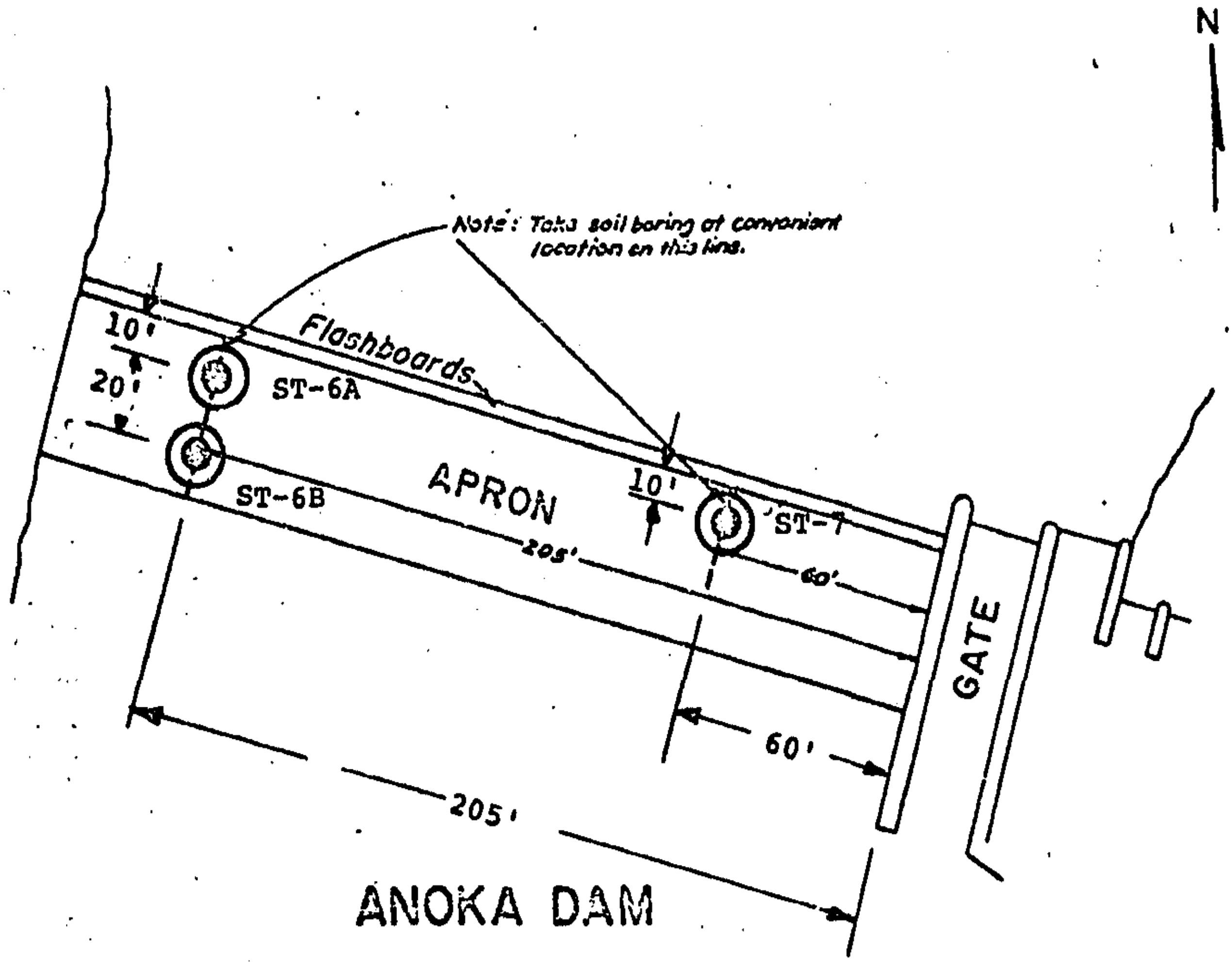
J. S. Braun, P. E.
Soils Engineer

JSB:kvh

Enclosure

cc: Barr Engineering Company
440 Roanoke Building
Minneapolis, Minnesota 55402

SOIL ENGINEERING SERVICES, INC.



LOCATION SKETCH
for
PROPOSED SOIL BORINGS
ANOKA, MINNESOTA

◎ location of penetration test borings--surface e[illegible]ions determined by City of Anoka surveycrew

BARR 1966
2-4A017

66-125

LABORATORY TEST RESULTS

Sample #	58	59	63	66
Boring #	ST-6B	ST-6B	ST-6B	ST-7
Depth	41-42'	46-47'	61-62'	15-16'
Soil Separates				
Sand, %	14	17	86	79
Silt, %	67	65	12	12
Clay, %	19	18	2	9
Sieve Analysis	Total Percent Passing			
#4	100	100	100	74
#10	96	99	99	66
#20	94	97	95	59
#40	93	96	90	49
#60	92	95	84	39
#100	91	93	76	30
#200	86	83	14	21
Liquid Limit	24	22	non pl.	non pl.
Plasticity Index	3	1	non pl.	non pl.
Classification				
U. S. Bureau of Soils	Silt Loam	Silt Loam	Fine Loamy Sand	Sandy Loam
Unified	ML	ML	SM	SM

LOG OF TEST BORINGS

SOIL ENGINEERING SERVICES, INC.

PROJECT: 66-125 SOIL BORINGS
LOCATION: Rum River Dam
Anoka, Minnesota

VERTICAL SCALE: 1" = 6'

ST-6A

DEPTH		BPF
0'	Surface elevation = 840.26	
	Void	
8.5'	Water	
	Medium-Coarse Sand, grey, with an extensive amount of wood	
	(52)	7
20.4'	(Refusal at 20.4')	157 in 0.4'
	Two other attempts 4 and 6' west of this location met refusal at depth of 16 and 18' respectively on wood.	

DEPTH		BPF
0'		

(**) = Sample number

w = Sample taken from wash water

(SM) = Classification by Unified System

LOG OF TEST BORINGS

SOIL ENGINEERING SERVICES, INC

PROJECT: 66-125 SOIL BORINGS
LOCATION: Rum River Dam
Anoka, Minnesota

VERTICAL SCALE: 1" = 6'

ST-6B

DEPTH			BPF
0'	Surface elevation = 836.94		
	Void		
5.1'	Water		
6'	Medium-Coarse Sand & Fine Gravel, grey, with an extensive amount of wood	(54)	67
		(55w)	12
		(56)	16
			14
		(57)	29
33'	Sandy Loam, (SM) non plastic, brown, wet (dense)		38
41'	Silt Loam, grey, (ML) wet (very stiff)	(58)	27
44'			

ST-6B Con't.

DEPTH			BPF
0'			
44'	Silt Loam, with some fine lenses of Silty Clay Loam, grey, wet (very stiff) (ML)	(59&60)	40
		(61)	43
53'	Coarse Loamy Sand & Fine Gravel, grey-brown, (medium) (SM)	(62)	17
59'	Fine Loamy Sand, grey-brown, (very dense) (SM) (similar in appearance to loosely cemented sandstone)	(63)	170
		(64)	46
		(65)	73
72'	Water level down 5.5' in casing immediately after completion of boring and when rechecked 1 hour later and 6.0' after pulling casing back to 65'		

LOG OF TEST BORINGS

SOIL ENGINEERING SERVICES, INC.

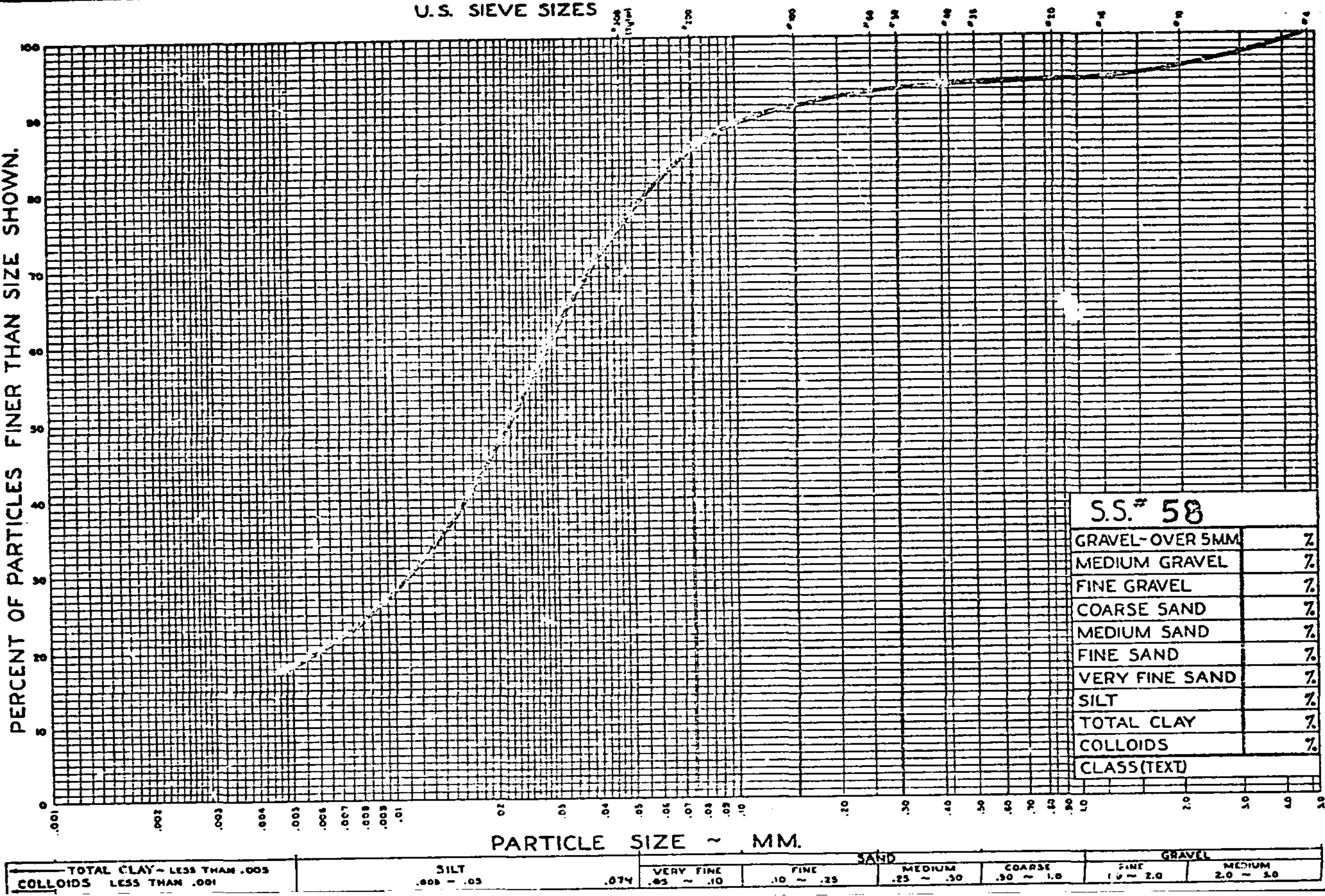
PROJECT: 66-125 SOIL BORINGS
LOCATION: Rum River Dam
Anoka, Minnesota
VERTICAL SCALE: 1" = 6'

ST-7

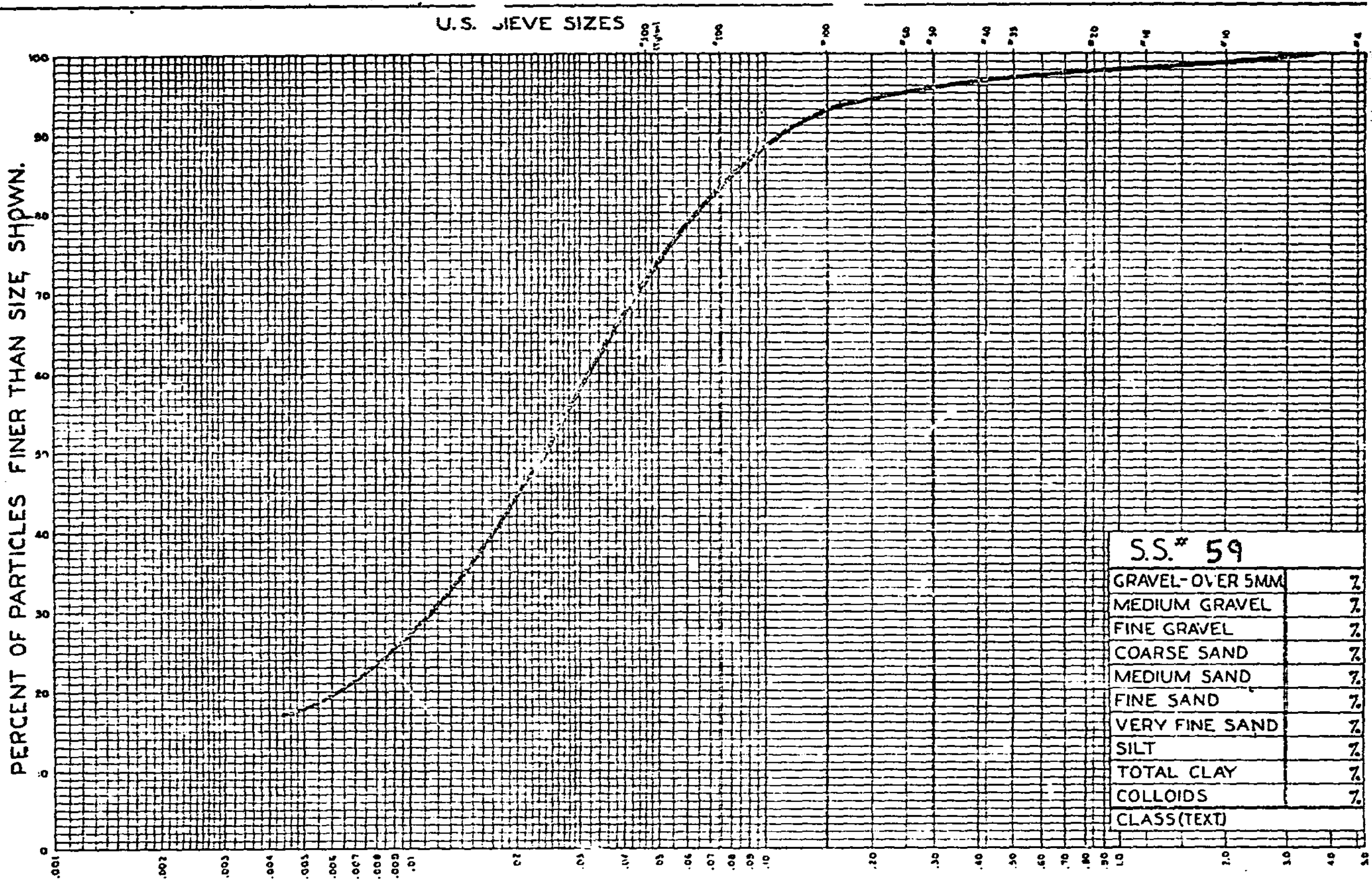
DEPTH	Description	Sample	BPF
0	Surface elevation = 836.82		
	Void		
5'	Water		
9 5'	Medium-Coarse Sand & Fine Gravel, dark grey, with an extensive amount of wood		
15'	Sandy Loam lensed with Loamy Sand & with some Fine Gravel, reddish brown, (dense)	(66)	33
		(67)	43
23'	Medium-Coarse Sand with some Fine Gravel, brown, (medium to dense)	(68w) (SW)	24
			47
33'	Sandy Loam, non plastic, lensed with Loamy Sand & with a little Fine Gravel reddish brown, moist (medium to dense)	(69) (SM)	17
			58
45'			

DEPTH	ST-7 Con't.	Sample	BPF
0'			
45'	(same from 33')	(70)	63
		(71)	132
		(72)	77
57'	Fine Loamy Sand, grey, (very dense) (similar in appearance to loosely cemented sandstone)	(SM) (73)	30
		(74)	193
68'	Medium Sand, brown, wet ~~(very dense)~~	(SP) ~~(75)~~	64
72'	Water level down 6.0' in casing immediately after completion of boring and 7.0' after pulling casing back to 65'.		

GRAIN SIZE ACCUMULATION CURVE



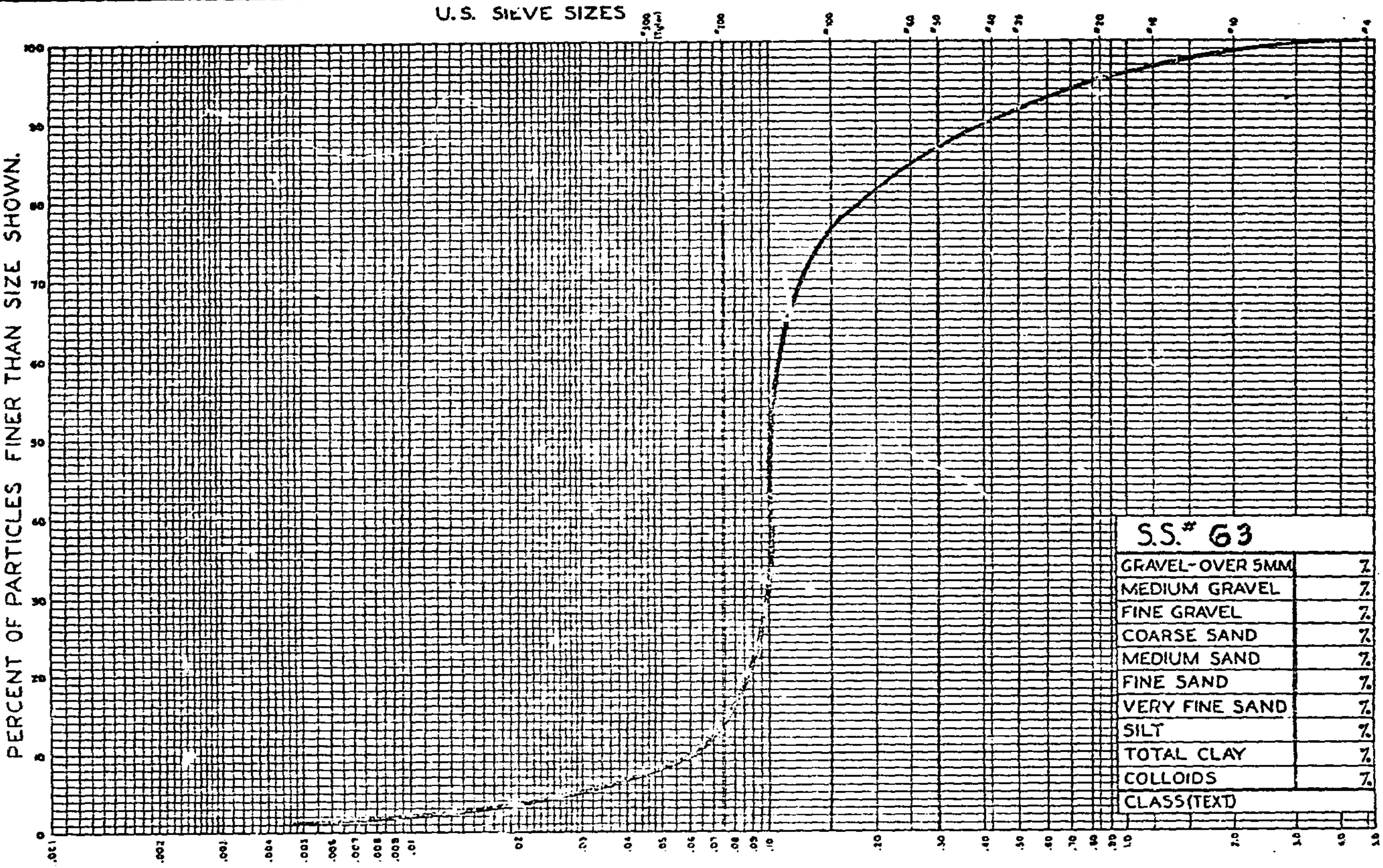
GRAIN SIZE ACCUMULATION CURVE



TOTAL CLAY ~ LESS THAN .005	SILT	SAND				GRAVEL	
COLLOIDS LESS THAN .001	.005 ~ .05 .074	VERY FINE .05 ~ .10	FINE .10 ~ .25	MEDIUM .25 ~ .50	COARSE .50 ~ 1.0	FINE 1.0 ~ 2.0	MEDIUM 2.0 ~ 3.0

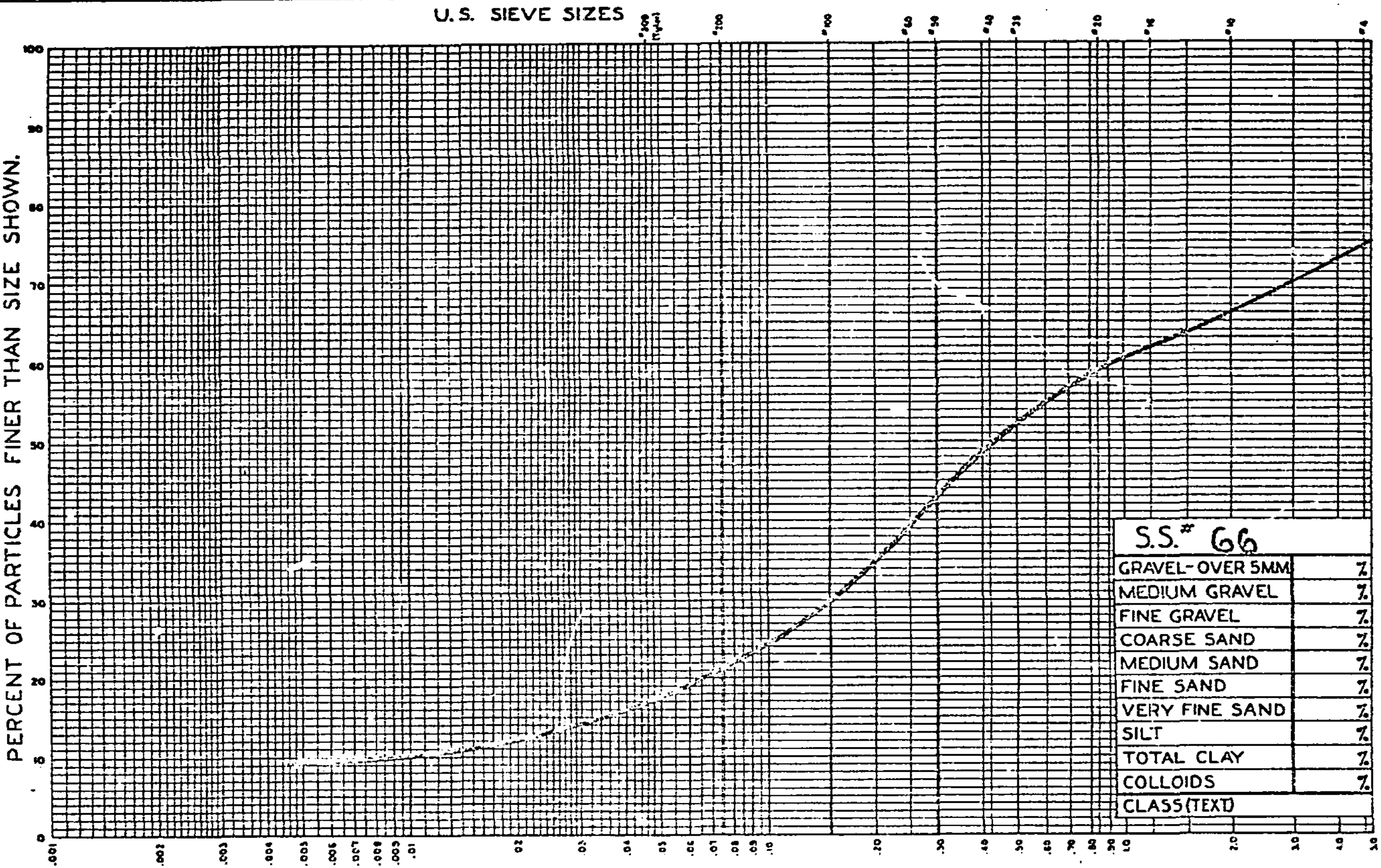
Form 1098 5M 1-41 656K

GRAIN SIZE ACCUMULATION CURVE



	SILT		SAND				GRAVEL	
TOTAL CLAY ~ LESS THAN .005 COLLOIDS LESS THAN .001	.005 ~ .05	.074	VERY FINE .05 ~ .10	FINE .10 ~ .25	MEDIUM .25 ~ .50	COARSE .50 ~ 1.0	FINE 1.0 ~ 2.0	MEDIUM 2.0 ~ 5.0

GRAIN S'ZE ACCUMULATIC'N CURVE



TOTAL CLAY – LESS THAN .005 / COLLOIDS LESS THAN .001	SILT .005 ~ .05 .074	SAND: VERY FINE .05 ~ .10	SAND: FINE .10 ~ .25	SAND: MEDIUM .25 ~ .50	SAND: COARSE .50 ~ 1.0	GRAVEL: FINE 1.0 ~ 2.0	GRAVEL: MEDIUM 2.0 ~ 5.0

SOIL ENGINEERING SERVICES, INC

615 NORTH COUNTY RD. 18 | MINNEAPOLIS, MINN. 55427 • 544-2739

J. S. PRAUN, P.E.

June 25, 1968

Mr. Robert B. Johnson, P.E.
City Engineer
City Hall
Anoka, Minnesota

Re: 66-125 ADDITIONAL SOIL BORINGS
Rum River Dam and Bank Stabilization
Anoka, Minnesota

Mr. Johnson:

One of the borings indicated on the Location Map furnished with the June 7 letter from Mr. Reynold Hokenson, of the Barr Engineering Company, was completed between June 17 and 19, 1968. This report is supplemental to two previous reports, dated July 14 and August 31, 1966.

One boring was requested on the downstream apron. Recent heavy rains make it impossible to lower the River pool sufficiently to take that boring. However, the location of the boring requested approximately 4 feet west of the west end of the dam, near the junction of the dam and the proposed retaining wall, was accessible. The boring location is shown on the attached sketch. The surface elevation was determined by the City's survey crew.

The boring was taken using a track-mounted core and auger drill equipped with hollow-stem augers. Samples were obtained using the standard 2 inch OD split sampler, driven by a 140 pound hammer falling 30-inches, thru the hollow stem augers. Blows per foot of penetration (BPF) were recorded. The use of the hollow-stem augers eliminates the driving of casing; however, jetting procedures were used when necessary to clean the augers.

As requested by Mr. Hokenson, mineral soils encountered in the borings were visually classified in accordance with the U.S. Bureau of Chemistry and Soils Classification System. A copy of that chart is attached. Since previous laboratory tests have been performed on representative samples of the materials obtained from the borings, Mr. Hokenson indicated that additional tests to help identify the soils would not be necessary. All samples retained from the borings are being submitted to the Barr Engineering Company for examination.

One hour after completion, the boring was probed to check for the presence of ground water.

RESULTS

Logs of soils encountered, penetration resistances, and the water level recorded in the boring, are plotted on the attached soil boring log sheets.

Borings ST-8A and ST-8B encountered fill, which was mostly a non plastic dark brown sandy loam with pieces of wood, concrete, and coal to the 26 and 17-foot depths respectively. At these depths, boring ST-8A met refusal on what appeared to be a large boulder while boring ST-8B met refusal on what appeared to be a large slab of concrete.

Boring ST-8C was then taken to the north of the previous two attempts and was able to penetrate the fill material. The fill material encountered in this boring was similar to that indicated in the first two attempts and extended to the 27-foot depth. A brown soft clay loam with lenses of fine sand and medium sand was encountered between the 27 and 33-foot depths while a grey-brown silty clay loam was indicated between the 33 and 42-foot depths. A non to slightly plastic reddish brown sandy loam with some fine gravel was encountered between the 42 and 63-foot depths. A greenish-grey fine loamy sand, which appeared to be loosely cemented sandstone, with some shale and limestone interbedding, was encountered between the 63-foot depth and 95-foot termination depths.

Soils encountered in this supplemental boring (ST-8C) were somewhat different in texture and color than those indicated in the previous boring ST-6B, which was taken about 65 feet southeast of the current boring ST-8C. Penetration resistances recorded in this additional boring were considerably lower than those indicated in the previous adjacent boring. Penetration resistances recorded in the fill material encountered in boring ST-8C ranged from 3 to 6 BPF. Penetration resistances recorded in the underlying natural materials ranged from 3 to 44 BPF as compared with a range of 12 to 170 BPF in boring ST-6B. Available geological information indicates that the first bedrock is probably the Jordon or St. Lawrence formations. The material gives the appearance of being from the St. Lawrence formation but the elevation at which it exists does not completely correlate with all available geological information. Penetration resistances recorded in the sandstone-type materials encountered in lower portions of boring ST-8C are considerably lower than would normally be anticipated in the undisturbed formations. It is conceivable that the material has been reworked and redeposited, or that it has been subject to leaching, which is know to remove greater portions of the carbonates from the St. Lawrence formation thus leaving it pourous with a higher void ratio. Additional conclusions should await completion of boring ST-9, which will be taken when a lower river stage permits.

Water was indicated at the 17-foot depth when measured one hour after completion, just prior to leaving the site. If given additional time to stabilize, it is conceivable that the water level could rise somewhat.

If we can be of further assistance, kindly contact us at your convenience.

Very truly yours,

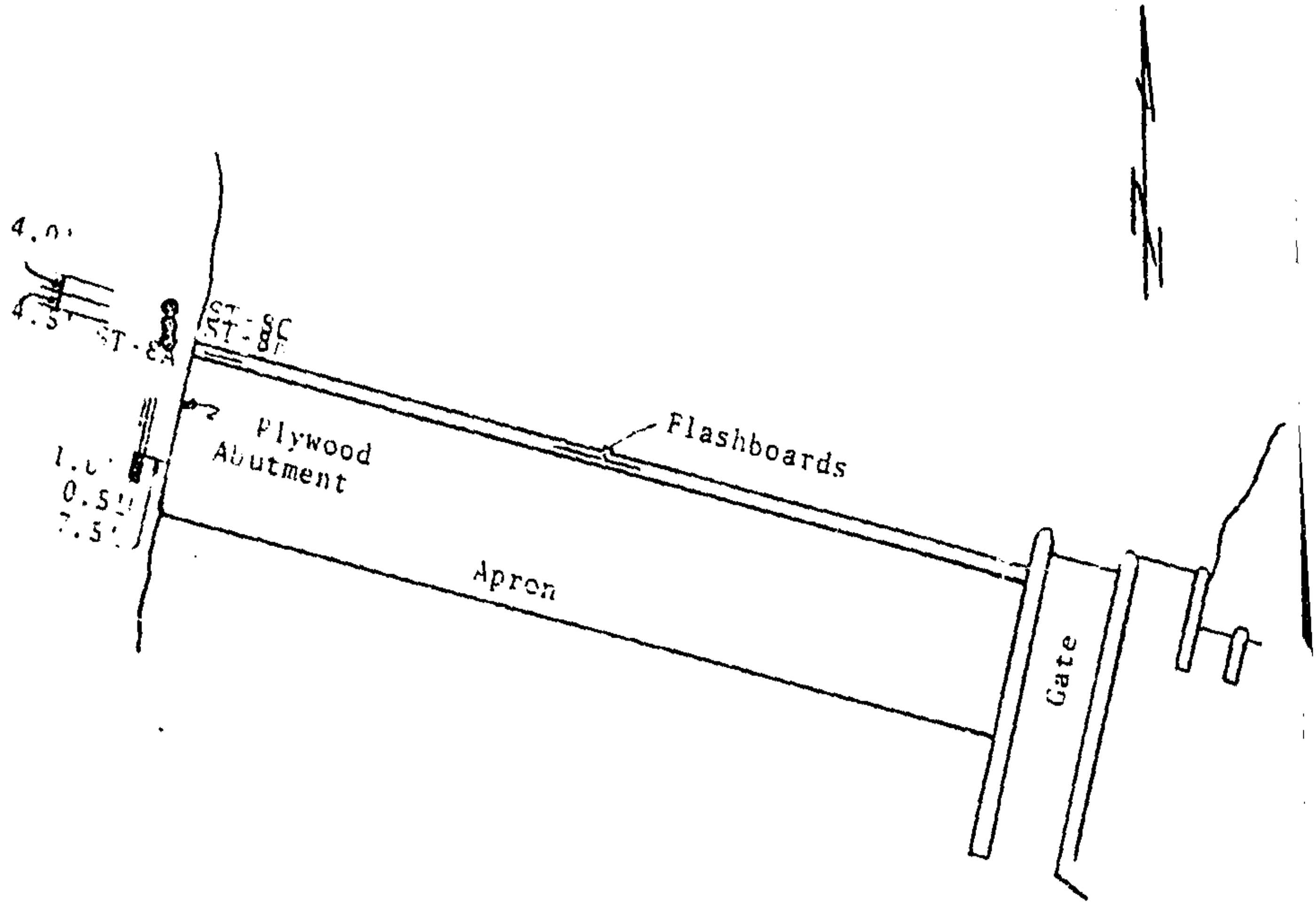
SOIL ENGINEERING SERVICES, INC.

J.S. Braun, P.E.
Soils Engineer

JSB/DLG:js
cc: Barr Engineering Co.
Consulting Hydraulic Engineers
440 Roanoke Building
Minneapolis, Minnesota 55402

66-125

SKETCH SHOWING LOCATION OF PENETRATION TEST BORINGS



● Location of Penetration Test Boring
Surface elevations determined by City of Anoka survey crew

LOG OF TEST BORINGS

SOIL ENGINEERING SERVICES, INC.

PROJECT #: 66-125
DESCRIPTION: Additional Soil Borings
Rum River Dam
Anoka, Minnesota

VERTICAL SCALE: 1" = 6'

ST-8A (First Attempt)

DEPTH		BPF
0'	SURFACE ELEVATION:	
	Fill, mostly Sandy Loam, non plastic, dark brown with pieces of wood, concrete, coal, etc. moist to wet (boulders encountered between 12 and 26-foot depths)	10
		12
		14
		100 in 0.7'
		53
26'	Boring met refusal at 26-foot depth on what appeared to be a large boulder.	

ST-8B (Second Attempt)

DEPTH		BPF
0'	SURFACE ELEVATION:	
	Fill, mostly Sandy Loam, non plastic, dark brown with pieces of wood, concrete, coal, etc. moist to wet	4
		16
		14
17'	Boring met refusal at 17-foot depth on what appeared to be a large slab of concrete.	

LOG OF TEST BORINGS

SOIL ENGINEERING SERVICES, INC.

PROJECT #: 66-125
DESCRIPTION: Additional Soil Borings
Rum River Dam
Anoka, Minnesota

VERTICAL SCALE: 1" = 6'

ST-8C
(Third Attempt)

DEPTH		BPF
0'	SURFACE ELEVATION: 849.9*	
	Fill, mostly Sandy Loam, non plastic, dark brown with pieces of concrete, brick, wood, cinders, etc. moist to wet	4
		6
		4
	(Water Level)	
		3
		3
27'	Clay Loam, with lenses of Fine Sand and Medium Sand, brown, wet (soft)	3
33'	Silty Clay Loam, grey-brown, wet (rather stiff to stiff)	9
		14
42'	Sandy Loam, non to slightly plastic, with some Fine Gravel, reddish brown, wet (loose to medium)	6
50'		6

Log of boring ST-8C continued at right

ST-8C continued

DEPTH		BPF
50'	SURFACE ELEVATION:	
	(Same soil classification as from 42 to 50-foot depths)	10
		12
63'	Fine Loamy Sand, greenish-grey, wet (Appears to be loosely cemented Sandstone with some shale and limestone interbedding -- possibly St. Lawrence Formation) (loose to dense)	14
		12
		6
		13
		11
		32
95'		44

Water level down 17' when measured 1 hour after completion of boring.
*Surface elevation referenced by City of Anoka survey crew.

SOIL ENGINEERING SERVICES, INC.
615 NORTH COUNTY RD. 18 MINNEAPOLIS, MINN. 55427 • 544-2739

J. S. BRAUN, P.E.

August 14, 1968

Mr. Robert B. Johnson, P.E.,
City Engineer
City Hall
Anoka, Minnesota 55303

Re: 66-125 ADDITIONAL SOIL BORINGS
Rum River Dam
Anoka, Minnesota

Mr. Johnson:

This report is supplemental to three previous reports, dated July 14 and August 31, 1966 and June 25, 1968 and reports the results of the second boring requested in the June 7 letter by Mr. Reynold Hokenson of the Barr Engineering Company. As indicated in the June 25, 1968 report, the taking of this boring was delayed until lower river stages would permit access to the dam apron.

The boring was taken as close to the desired location as conditions of the dam apron would permit. The actual boring location was referenced to the dam flashboards and the plywood abutment, as shown on the attached sketch.

This additional boring was taken between August 5 and 9 with a skid-mounted sampling machine similar to that used for the 1966 borings. The boring was taken in accordance with ASTM D1586 procedures utilizing the standard 2-inch OD split sampler driven by a 140-pound hammer falling 30-inches. Blows per foot of penetration (BPF) were recorded, after setting the sampler 6-inches. The borings were cased with a 2½-inch pipe casing, which was advanced by driving, and were cleaned and advanced by standard jetting methods.

As requested by Mr. Hokenson, mineral soils in the borings were visually classified in accordance with the U.S. Bureau of Chemistry and Soils Classification System. A copy of that chart is attached. Since previous laboratory tests have been performed on representative samples of the material obtained from the borings, Mr. Hokenson indicated that laboratory tests to verify field classifications of the soils would not be necessary. All samples retained from the borings are being submitted to the Barr Engineering Company for examination.

The depth to water was recorded in the completed boring with the casing advanced to 70 feet, immediately before beginning pulling the casing, and after the casing had been pulled back to the 60-foot depth, about 1 hour later.

RESULTS

The log of soils encountered, penetration resistances, and water levels recorded in the boring, are plotted on the attached soil boring log sheet.

This boring encountered stratified sands and sandy loams thruout most of its depth. A thin stratum of silt loam was encountered between depths of 35 and 39 feet. Most of these generally granular materials were reddish brown in color. Penetration resistances generally increased with depth; however, the penetration resistances were somewhat erratic above about the 45-foot depth. The erratic penetration resistances are probably a result of the stratified soils of varying texture as well as the presence of gravel in some of these materials.

Uniformly graded loamy sand which gives the appearance of loosely cemented sandstone was encountered in the lower portion of this boring.

The water level was recorded at the 8.5-foot depth when measured in the casing, with 70 feet of casing inplace, immediately before pulling the casing. Rechecking after the casing had been pulled back to the 60-foot depth indicated the water level at the 11-foot depth. Retention of jetting water in the casing above the river elevation would indicate that the very dense granular materials encountered in lower portions of the boring are relatively impermeable.

In comparing the results of all borings taken to date, both by our crews and another firm, it appears that marked variations in both soil textures and penetration resistances exist over the width of the dam itself as well as into the area of the recently completed building southeast of the dam. It is likely that these variations are principally a function of repeated erosion and subsequent backfilling of the river channel.

These variable conditions, as well as the presence of wood in one of the borings, appear to dictate the use of piling for the dam itself and high retaining wall planned along the east bank.

If we can be of further assistance in evaluating these data to either you or the Barr Engineering Company, as the design operation progress, kindly contact us at your convenience.

Very truly yours,

SOIL ENGINEERING SERVICES, INC.

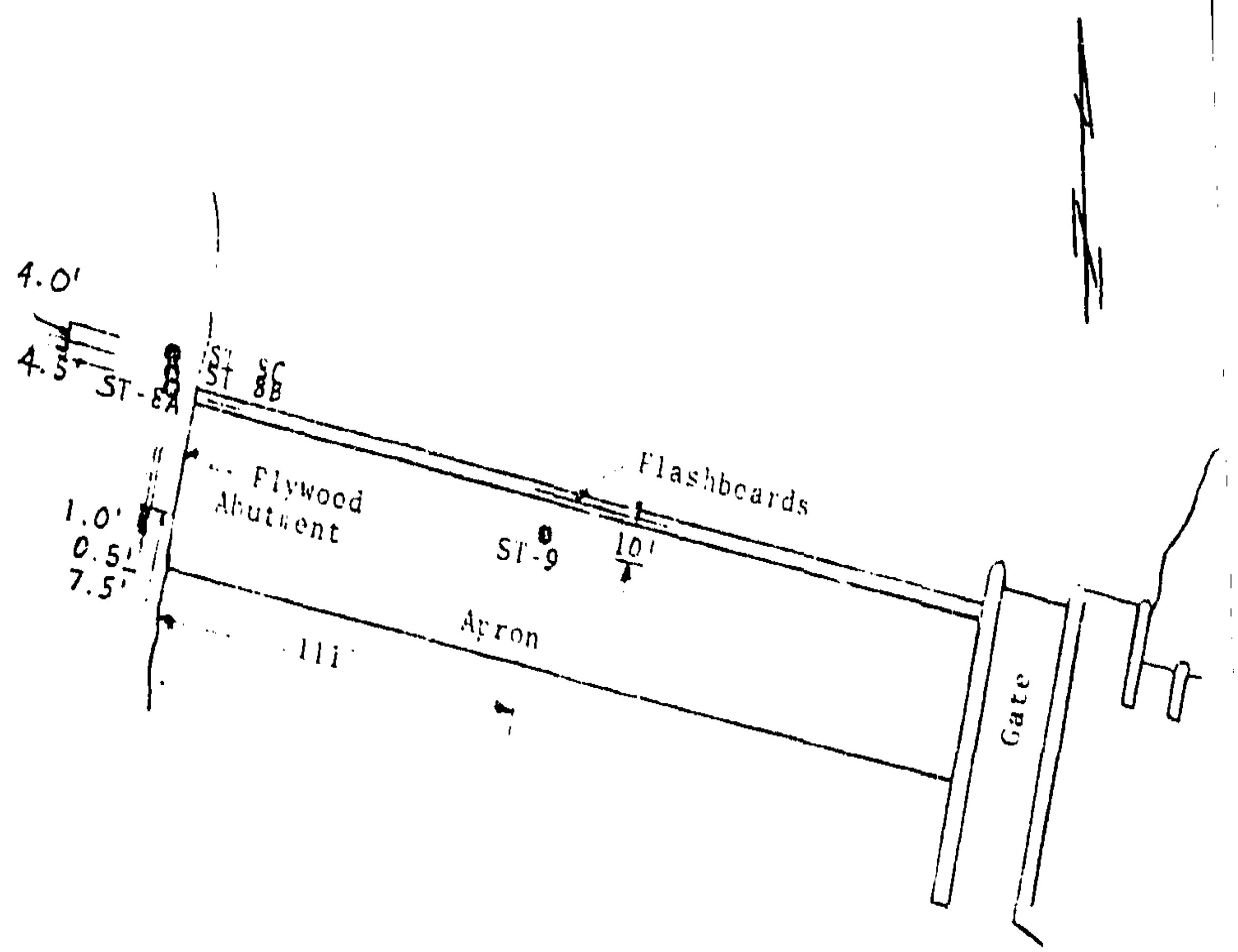
J. S. Braun, P.E.
Soils Engineer

JSB:mlk
Enclosures
cc: Barr Engineering Company
Consulting Hydraulic Engineers
440 Roanoke Building
Minneapolis, Minnesota 55402

SOIL ENGINEERING SERVICES, INC.

66-125

SKETCH SHOWING LOCATION OF PENETRATION TEST BORINGS



● Location of Penetration Test Boring
Surface elevations determined by City of Anoka survey crew

LOG OF TEST BORINGS

SOIL ENGINEERING SERVICES, INC.

PROJECT #: 66-125
DESCRIPTION: Additional Soil Boring
Rum River Dam
Anoka, Minnesota

VERTICAL SCALE: 1" = 5'

ST-9

DEPTH		BPF
0'	SURFACE ELEVATION: 841.8	
	Void and Water	
14'	Medium to Coarse Sand and Fine Gravel, grey, wet (medium)	24
19'	Medium Sandy Loam, slightly plastic, with some Fine Gravel, reddish brown, wet (loose to medium)	9 23
30'	Sandy Loam, non to slightly plastic, greenish grey, mottled with reddish brown, wet (very dense)	33
33'	Fine to Medium Sand, and Fine Gravel, grey-brown, wet	
35'	Silt Loam, non to slightly plastic, greenish grey, wet (very dense)	95
39'	(see right column for log below 39') (Log of boring ST-9 continued at right)	
40'		

(ST-9 Continued)

DEPTH		BPF
40'	SURFACE ELEVATION:	
	Sandy Loam, non to slightly plastic, with some Sand lenses and a little Fine Gravel, reddish brown to reddish grey-brown, wet	33 78 95
53'	Medium to Coarse Sand and Fine Gravel, reddish grey-brown, wet (very dense)	110
58'	Sandy Loam, non to slightly plastic, with a little Fine Gravel, grey-brown, moist to wet (very dense)	150 in 0.3… 150 in 0.4…
	773.8	
68'	Loamy Sand, with a trace of Fine Gravel, grey and grey-* brown, moist to wet (very dense)	
70.2'	Water level down 8.5' when measured in the casing with 70' of casing in the ground and 11' when casing pulled back to 60' depth. * (similar in appearance to loosely cemented sandstone)	150 in 0.3…

Appendix C3

Lock Wall Computations

1. BASIS OF DESIGN

Applicable Codes and Reference Standards:

- 2020 Minnesota Building Code (IBC 2018)
- ACI 318-14 - Building Code Requirements for Structural Concrete
- ACI 350-06 - Code Requirements for Environmental Engineering Concrete Structures
- USACE EM 1110-2-2104 - Reinforced Concrete Hydraulic Structures
- Project Specifications: *"Specifications for the Construction of the Rum River Dam, Anoka, Minnesota"*

Site Data:
- Anoka, Minnesota

Structural Systems:
- Walls and Foundation: Structural CIP Concrete - LRFD

Materials:
- Adhesive or Mechanical Anchors:
  * Stainless Steel
  * As specified in design documents

- Dead Loads:
  * Structure Selfweight

- Hydrostatic Loads:
  * Water: $\gamma_{water} := 62.4\ pcf$

- Concrete Strength:
  * $f'_c := 4000\ psi$ *(Per Specifications for Concrete - Materials, page 12)*

- Reinforcing Steel:
  * $f_y := 60000\ psi$ *(Per Specifications for Reinforcing Steel - Materials, page 21.)*

- Reduction Factors:
  * Bending Moment: $\phi_b := 0.9$ *(Moment reduction factor - ACI 318 - Table 21.2.1)*
  * Shear: $\phi_v := 0.75$ *(Shear reduction factor - ACI 318 - Table 21.2.1)*

- Concrete Cover:
  * $cc := 3\ in$ *(Per construction drawing 11/19 Tainter Gate Spillway notes)*

- Load Case R1 Load Factor:
  * $LF := 2.2$ *(USACE EM 1110-2-2104 - Table E-1, Usual - Conservative)*

2. CALCULATIONS - Tainter Gate Spillway:

Load Classification:

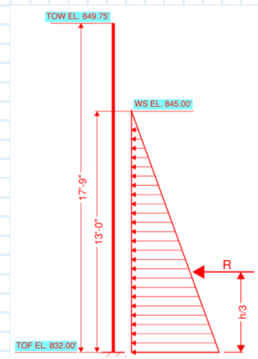
$L_p :=$ "Permanent – Lateral Earth Pressure or Normal Pool Level"
$L_t :=$ "Temporary – Flood Loads, Maintenance Dewatering, or Operation Live Loads"
$L_d :=$ "Dynamic – Vessel and Ice Impact, Earthquake, and Wave"

Subscripts: $U :=$ "Usual" $N :=$ "Unusual" $X :=$ "Extreme" $i :=$ "Principal Action Loads"

Load Definitions:

$D :=$ "Dead Load"
$L :=$ "Live Load"
$EQ :=$ "Earthquake Load"
$Hs :=$ "Hydrostatic Load"
$Hw :=$ "Wave Loads"
$IM :=$ "Impact from Debris or Floating Ice"
$IX :=$ "Forces from Thermal Expansion of Ice"
$BI :=$ "Barge (boat or vessel) Impact"

$EH :=$ "Moist or Effective Lateral Earth Pressure"
$EV :=$ "Vertical Earth – Moist or Buoyant Soil"
$ES :=$ "Lateral Soil Pressure from Temporary Surcharge Forces"
$G :=$ "Non–permanent Gravity Loads (silt, debris, and atm. ice)"
$HA :=$ "Hawser Forces – Nominal Breaking Strength of a Single Line"
$Q :=$ "Reactions from Operating Equipment and Hydraulic Gates"
$Hd :=$ "Dynamic & Hydrodynamic Loads from Thrust from Vessels"



Unit Weight of Water: $\gamma_{water} := 62.4\ pcf$

Water Height and Pressure Coefficient: $k := 1.0$ $h_{water\_up} := 13\ ft$

Tainter Gate Geometry - Upstream 27ft.: $h_{wall\_up} := 17.75\ ft$ $t_{wall} := 5\ ft$

Wall Reinforcement: "#9 @ 4" OC" *Vertical IF: 0 - 5 ft.* "#9 @ 8" OC" *Vertical IF: 3 - 17.75 ft.*

$Bar\_Size := \#9$

Bar diameter: $d_b = 1.128\ in$ $b := 12\ in$ *Per foot basis*

Effective depth: $d := t_{wall} - cc - \frac{d_b}{2} = 56.436\ in$

Area of Steel: $A_{s@4} = 3\ in^2$

Water Force on Wall - Upstream: $R_{up} := 0.5 \cdot k \cdot \gamma_{water} \cdot h_{water\_up}{}^2 \cdot ft = 5.273\ kip$ *Total Force per ft. of Wall*

Check Moment: $M_u := LF \cdot R_{up} \cdot \frac{h_{water\_up}}{3} = 50.267\ ft \cdot kip$ *Overturning Moment*

$\phi M_n := \phi_b \cdot A_{s@4} \cdot f_y \cdot \left(d - \frac{A_{s@4} \cdot f_y}{1.7 \cdot f'_c \cdot b}\right) = 732.107\ ft \cdot kip$ *Wall Moment Capacity*

$Check := \text{if}\left(\phi M_n > M_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

$UT_{RATIO} := \frac{M_u}{\phi M_n} = 0.069$

Check Shear:

$V_u := LF \cdot k \cdot \gamma_{water} \cdot \frac{h_{water\_up}^2}{2} \cdot ft = 11.6\ kip$ *Shear Demand*

$\phi V := \phi_v \cdot 2 \cdot \sqrt{f'_c \cdot psi} \cdot d \cdot b = 64.248\ ft \cdot klf$ *Shear Capacity*

$Check := \text{if}\left(\phi V > V_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

$UT_{RATIO} := \frac{V_u}{\phi V} = 0.181$

Check Minimum Steel:

$A_{s\_min} := 0.0033 \cdot b \cdot d = 2.235\ in^2$

$Check := \text{if}\left(A_{s@4} > A_{s\_min}, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

Check Hook Development Length:
Per ACI 318 - 14 - Section 25.4.3.1

$Bar\_Size := \#9$

Bar Diameter: $d_b = 1.128\ in$

$\lambda := 1.0$ *Normal-weight Concrete*

$\Psi_e := 1.0$ *Epoxy Coating*

$\Psi_c := \frac{f'_c}{15000} + 0.6 = 0.867$ *Concrete Strength: $f'_c < 6000$ psi*

$\Psi_r := 1.0$ *Confining Reinforcement*

$l_{dh} := \max\left(\frac{f_y \cdot \Psi_e \cdot \Psi_c \cdot \Psi_r}{50 \cdot \lambda \cdot \sqrt{f'_c}} \cdot d_b, 8 \cdot d_b, 6\ in\right) = 18.549\ in$

Check Hook Length:
Per ACI 318 - 14 - Table 25.3.1

$l_{ext} := 12 \cdot d_b = 13.536\ in$

Note: Per construction drawings, hook length = 2'-0" (see Attachment #1)

$Check := \text{if}\left(l_{ext} < 2\ ft, \text{"OK"}, \text{"NG"}\right) = \text{"OK"}$

Check Lap Development Length:
Per ACI 318 - 14 - Section 25.4.2.2

$\Psi_t := 1.3$ *Casting position: More than 12" of fresh concrete placed below horizontal reinforcement (foundation = 36" - see Attachment #1)*

Note: Per construction drawings, #9 bars transition in spacing from 4" to 8" OC. Based on this statement, it is assumed that these are dowels with lap length of 5'-0". (see Attachment #1)

$l_d := \left(\frac{f_y \cdot \Psi_t \cdot \Psi_e}{20 \cdot \lambda \cdot \sqrt{f'_c}}\right) \cdot d_b = 5.796\ ft$

$Check := \text{if}\left(l_d < 5\ ft, \text{"OK"}, \text{"NG"}\right) = \text{"NG"}$ *Revise*

Check Tension Lap Splice Length:

Per ACI 318 - 14 - Section 25.5.2.1

Note:
As required has not been calculated, therefore, conservatively assume ratio As,provided / As,req'd < 2.0.

$l_{st} := \max\left(1.3 \cdot l_d, 12\ in\right) = 7.535\ ft$

$Check := \text{if}\left(l_{st} < 5\ ft, \text{"OK"}, \text{"NG"}\right) = \text{"NG"}$ Revise

Check Shear Friction:

Per ACI 318 - 14 - Table 22.9.4.2: (Coefficient of Friction)

$\mu := 1.0 \cdot \lambda = 1$

Assumed that concrete is placed against hardened concrete that is clean, free of laitance, and intentionally roughened to a full amplitude of approximately 1/4 inches.

Per ACI 318 - 14 - Section R22.9.4.2:

$A_{vf\_req'd} := \frac{V_u}{\phi_v \cdot f_y \cdot \mu} = 0.258\ in^2$ *Required Shear-Friction Reinforcement*

$A_{vf} := A_{s@4} = 3\ in^2$ *Area of steel at the base of wall*

$\phi V_{n\_cl} := \phi_v \cdot \mu \cdot A_{vf} \cdot f_y = 135\ kip$ *Clamping Shear Friction Capacity*

$Check := \text{if}\left(\phi V_{n\_cl} > V_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

$UT_{RATIO} := \frac{V_u}{\phi V_{n\_cl}} = 0.086$

Check Base Slab Critical Section:

$M_u = 50.267\ ft \cdot kip$ *Moment Demand - see page 2*

$t_{slab} := 36\ in$ *Slab Thickness - see Attachment #1 below*

$A_{s@4} = 3\ in^2$ *Top Reinforcement #9 @ 4" OC*

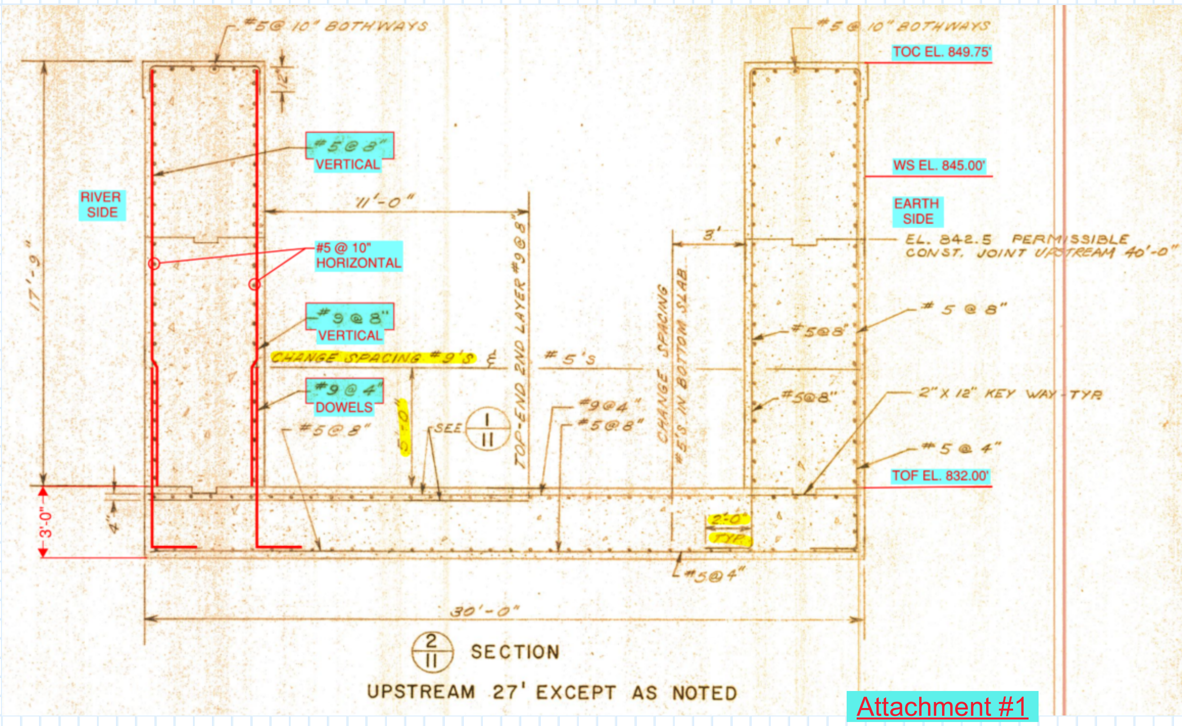
$d := t_{slab} - cc - \frac{d_b}{2} = 32.436\ in$

$\phi M_n := \phi_b \cdot A_{s@4} \cdot f_y \cdot \left(d - \frac{A_{s@4} \cdot f_y}{1.7 \cdot f'_c \cdot b}\right) = 408.107\ ft \cdot kip$ *Moment Capacity*

$Check := \text{if}\left(\phi M_n > M_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

$UT_{RATIO} := \frac{M_u}{\phi M_n} = 0.123$

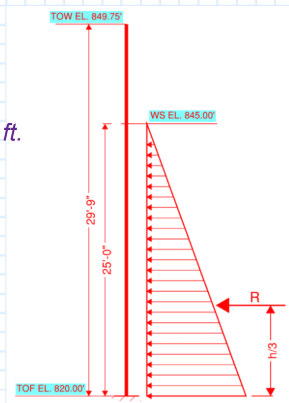
Notes:
1. *Per Rum River Dam Construction Plans, drawing 11/19 (see attachment below), ldh appears to be longer than calculated since the foundation is 36 in deep.*
2. *Assumption of the lap splices (5 ft.) was derived based on the layout shown - as stated "change in spacing #9's".*



Attachment #1

Tainter Gate Geometry-Downstream 35ft.:

$h_{wall\_dwn} := 29.75\ ft$ $t_{wall} := 5\ ft$



Wall Reinforcement: "#9 @ 4" OC" "#9 @ 8" OC" "#5 @ 8" OC"

Vertical IF: 0 - 6 ft. *Vertical IF: 3.33 - 12.5 ft.* *Vertical IF: 12.5 - 29.75 ft.*

$Bar\_Size := \#9$

Bar diameter: $d_b = 1.128\ in$

Effective depth: $d := t_{wall} - cc - \frac{d_b}{2} = 56.436\ in$

Area of Steel: $A_{s@4} = 3\ in^2$

Water height: $h_{water\_dwn} := 25\ ft$

Water Force on Wall - Downstream: $R_{dwn} := 0.5 \cdot k \cdot \gamma_{water} \cdot h_{water\_dwn}{}^2 \cdot ft = 19.5\ kip$ *Total Force per ft. of Wall*

Check Moment:

$M_u := LF \cdot R_{dwn} \cdot \frac{h_{water\_dwn}}{3} = 357.5\ ft \cdot kip$ *Overturning Moment Demand*

$\phi M_n := \phi_b \cdot A_{s@4} \cdot f_y \cdot \left(d - \frac{A_{s@4} \cdot f_y}{1.7 \cdot f'_c \cdot b}\right) = 732.107\ ft \cdot kip$ *Moment Capacity*

$Check := \text{if}\left(\phi M_n > M_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

$UT_{RATIO} := \frac{M_u}{\phi M_n} = 0.488$

Check Shear:

$V_u := LF \cdot k \cdot \gamma_{water} \cdot \frac{{h_{water\_dwn}}^2}{2} \cdot ft = 42.9\ kip$ — *Shear Demand*

$\phi V := \phi_v \cdot 2 \cdot \sqrt{f'_c \cdot psi} \cdot b \cdot d = 64.248\ kip$ — *Shear Capacity*

$Check := \text{if}\left(\phi V > V_u, \text{“OK”}, \text{“Redesign”}\right) = \text{“OK”}$

$UT_{RATIO} := \frac{V_u}{\phi V} = 0.668$

Check Minimum Steel:

$A_{s\_min} := 0.0033 \cdot b \cdot d = 2.235\ in^2$

$Check := \text{if}\left(A_{s@4} > A_{s\_min}, \text{“OK”}, \text{“Redesign”}\right) = \text{“OK”}$

Check Hook Development Length:

Per ACI 318 - 14 - Section 25.4.3.1

$\lambda := 1.0$ — *Normal-weight Concrete*

$\Psi_e := 1.0$ — *Epoxy Coating*

$\Psi_c := \frac{f'_c}{15000} + 0.6 = 0.867$ — *Concrete Strength: $f'_c < 6000\ psi$*

$\Psi_r := 1.0$ — *Confining Reinforcement*

$l_{dh} := \max\left(\frac{f_y \cdot \Psi_e \cdot \Psi_c \cdot \Psi_r}{50 \cdot \lambda \cdot \sqrt{f'_c}} \cdot d_b, 8 \cdot d_b, 6\ in\right) = 18.549\ in$

Check Hook Length:

Per ACI 318 - 14 - Table 25.3.1

$l_{ext} := 12 \cdot d_b = 13.536\ in$

Note: Per construction drawings, hook length = 2'-0" (see Attachment #2)

$Check := \text{if}\left(l_{ext} < 2\ ft, \text{“OK”}, \text{“NG”}\right) = \text{“OK”}$

Check Lap Development Length:

Per ACI 318 - 14 - Section 25.4.2.2

$\Psi_t := 1.3$ — *Casting position: More than 12" of fresh concrete placed below horizontal reinforcement (foundation = 40" - see Attachment #2)*

Note: Per construction drawings, #9 bars transition in spacing from 4" to 8" OC. Based on this statement, it is assumed that these are dowels with lap length of 6'-0". (see Attachment #2)

$l_d := \left(\frac{f_y \cdot \Psi_t \cdot \Psi_e}{20 \cdot \lambda \cdot \sqrt{f'_c}}\right) \cdot d_b = 5.796\ ft$

$Check := \text{if}\left(l_d < 6\ ft, \text{“OK”}, \text{“NG”}\right) = \text{“OK”}$

Check Tension Lap Splice Length:

Per ACI 318 - 14 - Section 25.5.2.1

Note:
As required has not been calculated, therefore, conservatively assume ratio As,provided / As,req'd < 2.0.

$l_{st} := \max\left(1.3 \cdot l_d, 12\ in\right) = 7.535\ ft$

$Check := \text{if}\left(l_{st} < 6\ ft, \text{“OK”}, \text{“NG”}\right) = \text{“NG”}$

Check Shear Friction:

Per ACI 318 - 14 - Table 22.9.4.2: (Coefficient of Friction)

$$\mu := 1.0 \cdot \lambda = 1$$

Assumed that concrete is placed against hardened concrete that is clean, free of laitance, and intentionally roughened to a full amplitude of approximately 1/4 inches.

Per ACI 318 - 14 - Section R22.9.4.2:

$$A_{vf\_req'd} := \frac{V_u}{\phi_v \cdot f_y \cdot \mu} = 0.953\ in^2$$

Required Shear-Friction Reinforcement

$$A_{vf} := A_{s@4} = 3\ in^2$$

Area of steel at the base of wall

$$\phi V_{n\_cl} := \phi_v \cdot \mu \cdot A_{vf} \cdot f_y = 135\ kip$$

Clamping Shear Friction Capacity

$$Check := \text{if}\left(\phi V_{n\_cl} > V_u, \text{“OK”}, \text{“Redesign”}\right) = \text{“OK”}$$

$$UT_{RATIO} := \frac{V_u}{\phi V_{n\_cl}} = 0.318$$

Check Base Slab Critical Section:

$$M_u = 357.5\ ft \cdot kip$$

Moment Demand - see page 5

$$t_{slab} := 40\ in$$

Slab Thickness - see Attachment #3 below

$$2 \cdot A_{s@4} = 6\ in^2$$

Top Reinforcement 2 layers of #9 @ 4" OC with 4" CC - see Attachment #3

$$d := t_{slab} - cc - 2\ in = 35\ in$$

Moment Capacity

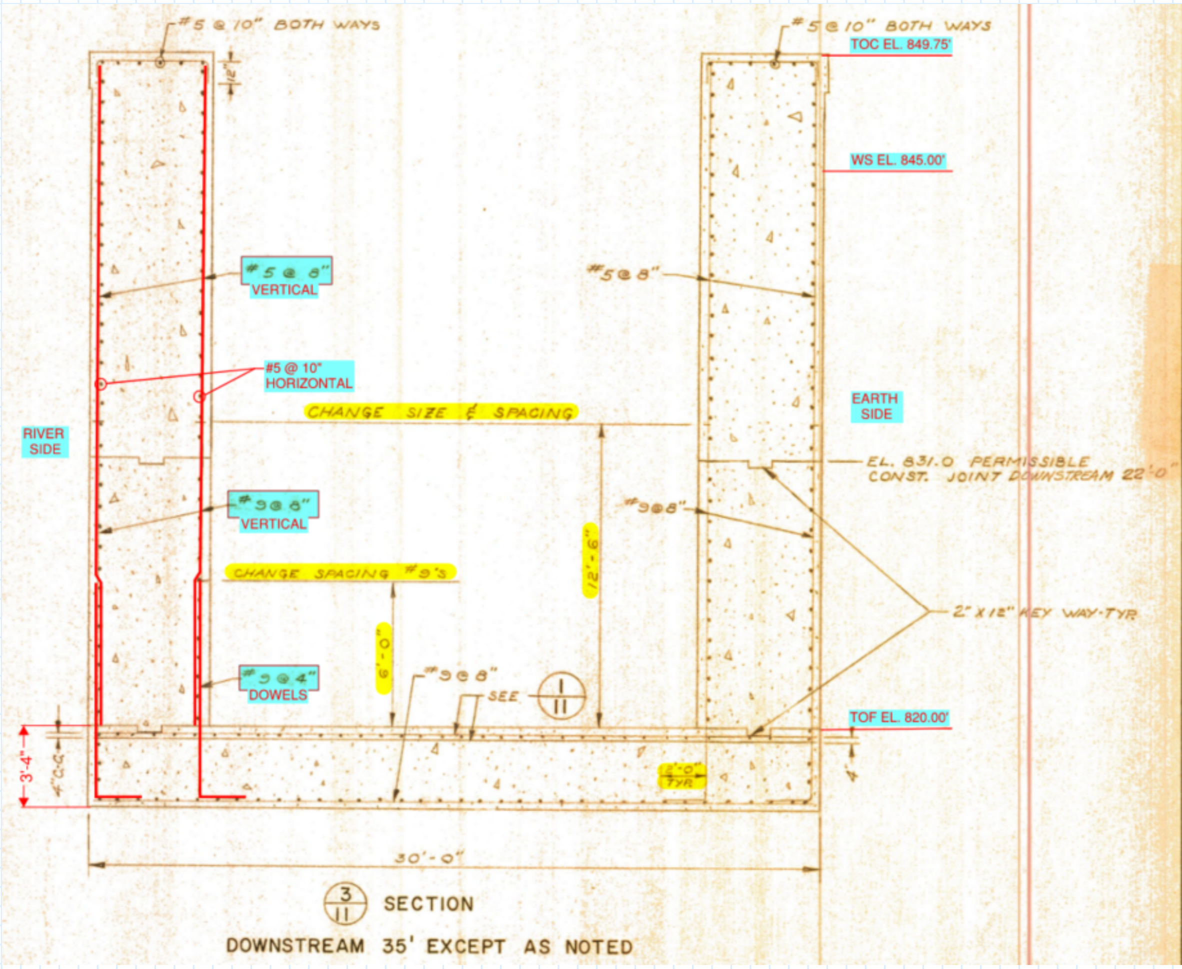
$$\phi M_n := \phi_b \cdot 2 \cdot A_{s@4} \cdot f_y \cdot \left(d - \frac{2 \cdot A_{s@4} \cdot f_y}{1.7 \cdot f'_c \cdot b}\right) = 825.882\ ft \cdot kip$$

$$Check := \text{if}\left(\phi M_n > M_u, \text{“OK”}, \text{“Redesign”}\right) = \text{“OK”}$$

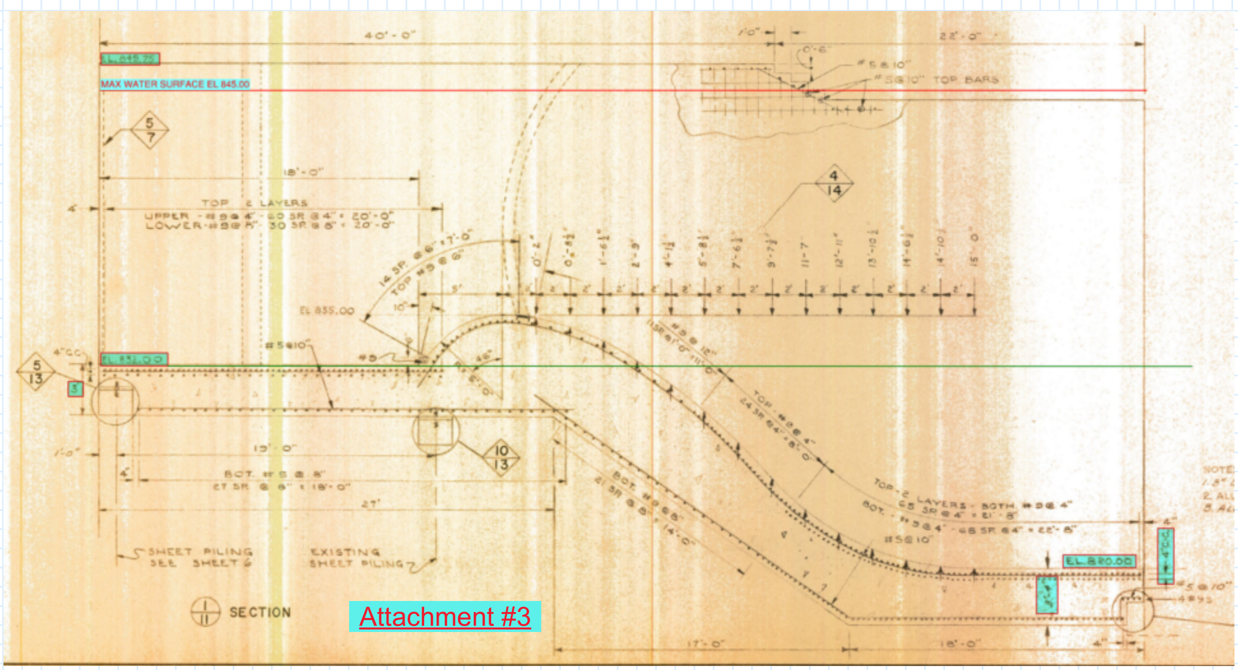
$$UT_{RATIO} := \frac{M_u}{\phi M_n} = 0.433$$

Notes:

1. *Per Rum River Dam Construction Plans, drawing 11/19 (see attachment below), ldh appears to be longer than calculated since the foundation is 40 in deep.*
2. *Assumption of the lap splices (6 ft.) was derived based on the layout shown - as stated "change in spacing #9's".*



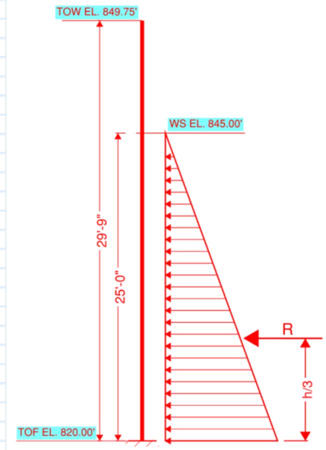
Attachment #2



Attachment #3

Stilling Basin:

$h_{wall\_stlb} := 29.75\ ft$ $t_{wall} := 5\ ft$



Wall Reinforcement: "#5 @ 4″ OC" *Vertical EF: 0 - 7 ft.* "#5 @ 8″ OC" *Vertical IF: 4 - 29.75 ft.*

$Bar\_Size := \#5$

Bar Diameter: $d_b = 0.625\ in$

Effective Depth: $d := t_{wall} - cc - \frac{d_b}{2} = 56.688\ in$

Area of Steel: $A_{s@4} = 0.921\ in^2$

Water height: $h_{water\_stlb} := 25\ ft$

Water Force on Wall - Basin: $R_{stlb} := 0.5 \cdot k \cdot \gamma_{water} \cdot h_{water\_stlb}{}^2 \cdot ft = 19.5\ kip$ *Total Force per ft. of Wall*

Check Moment:

$M_u := LF \cdot R_{stlb} \cdot \frac{h_{water\_stlb}}{3} = 357.5\ ft \cdot kip$ *Overturning Moment Demand*

$\phi M_n := \phi_b \cdot A_{s@4} \cdot f_y \cdot \left(d - \frac{A_{s@4} \cdot f_y}{1.7 \cdot f'_c \cdot b}\right) = 232.135\ ft \cdot kip$ *Moment Capacity*

$Check := \text{if}\left(\phi M_n > M_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"Redesign"}$ Revise

$UT_{RATIO} := \frac{M_u}{\phi M_n} = 1.54$

Check Shear:

$V_u := LF \cdot k \cdot \gamma_{water} \cdot \frac{h_{water\_stlb}{}^2}{2} \cdot ft = 42.9\ kip$ *Shear Demand*

$\phi V := \phi_v \cdot 2 \cdot \sqrt{f'_c \cdot psi} \cdot b \cdot d = 64.534\ kip$ *Shear Capacity*

$Check := \text{if}\left(\phi V > V_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$ Revise

$UT_{RATIO} := \frac{V_u}{\phi V} = 0.665$

Check Minimum Steel:

$A_{s\_min} := 0.0033 \cdot b \cdot d = 2.245\ in^2$

$Check := \text{if}\left(A_{s@4} > A_{s\_min}, \text{"OK"}, \text{"Redesign"}\right) = \text{"Redesign"}$ Revise

Check Hook Development Length:

Per ACI 318 - 14 - Section 25.4.3.1

$\lambda := 1.0$ — *Normal-weight Concrete*

$\Psi_e := 1.0$ — *Epoxy Coating*

$\Psi_c := \frac{f'_c}{15000} + 0.6 = 0.867$ — *Concrete Strength: $f'_c < 6000$ psi*

$\Psi_r := 1.0$ — *Confining Reinforcement*

$$l_{dh} := \max\left(\frac{f_y \cdot \Psi_e \cdot \Psi_c \cdot \Psi_r}{50 \cdot \lambda \cdot \sqrt{f'_c}} \cdot d_b, 8 \cdot d_b, 6\ in\right) = 10.277\ in$$

Check Hook Length:

Per ACI 318 - 14 - Table 25.3.1

$l_{ext} := 12 \cdot d_b = 7.5\ in$

Note: Per construction drawings, hook length = 2'-0" (see Attachment #4)

$Check := \text{if}\left(l_{ext} < 2\ ft, \text{“OK”}, \text{“NG”}\right) = \text{“OK”}$

Check Lap Development Length:

Per ACI 318 - 14 - Section 25.4.2.2

$\Psi_t := 1.3$ — *Casting position: More than 12" of fresh concrete placed below horizontal reinforcement (foundation = 48" - see Attachment #4)*

Note: Per construction drawings, #5 bars transition in spacing from 4" to 8" OC. Based on this statement, it is assumed that these are dowels with lap length of 7'-0". (see Attachment #4)

$$l_d := \left(\frac{f_y \cdot \Psi_t \cdot \Psi_e}{25 \cdot \lambda \cdot \sqrt{f'_c}}\right) \cdot d_b = 2.569\ ft$$

$Check := \text{if}\left(l_d < 7\ ft, \text{“OK”}, \text{“NG”}\right) = \text{“OK”}$

Check Tension Lap Splice Length:

Per ACI 318 - 14 - Section 25.5.2.1

Note:
As required has not been calculated, therefore, conservatively assume ratio As,provided / As,req'd < 2.0.

$l_{st} := \max\left(1.3 \cdot l_d, 12\ in\right) = 3.34\ ft$

$Check := \text{if}\left(l_{st} < 7\ ft, \text{“OK”}, \text{“NG”}\right) = \text{“OK”}$

Check Shear Friction:

Per ACI 318 - 14 - Table 22.9.4.2: (Coefficient of Friction)

$\mu := 1.0 \cdot \lambda = 1$ — *Assumed that concrete is placed against hardened concrete that is clean, free of laitance, and intentionally roughened to a full amplitude of approximately 1/4 inches.*

Per ACI 318 - 14 - Section R22.9.4.2:

$A_{vf\_req'd} := \frac{V_u}{\phi_v \cdot f_y \cdot \mu} = 0.953\ in^2$ — *Required Shear-Friction Reinforcement*

$A_{vf} := A_{s@4} = 0.921\ in^2$ — *Area of steel at the base of wall*

$\phi V_{n\_cl} := \phi_v \cdot \mu \cdot A_{vf} \cdot f_y = 41.445\ kip$ — *Clamping Shear Friction Capacity*

$UT_{RATIO} := \frac{V_u}{\phi V_{n\_cl}} = 1.035$

$Check := \text{if}\left(\phi V_{n\_cl} > V_u, \text{“OK”}, \text{“Redesign”}\right) = \text{“Redesign”}$ — Revise

Check Base Slab Critical Section:

$M_u = 357.5\ ft \cdot kip$ — *Moment Demand - see page 8*

$t_{slab} := 48\ in$ — *Slab Thickness - see Attachment #4 below*

$Bar\_Size := \#10$

Bar Diameter: $d_b = 1.27\ in$

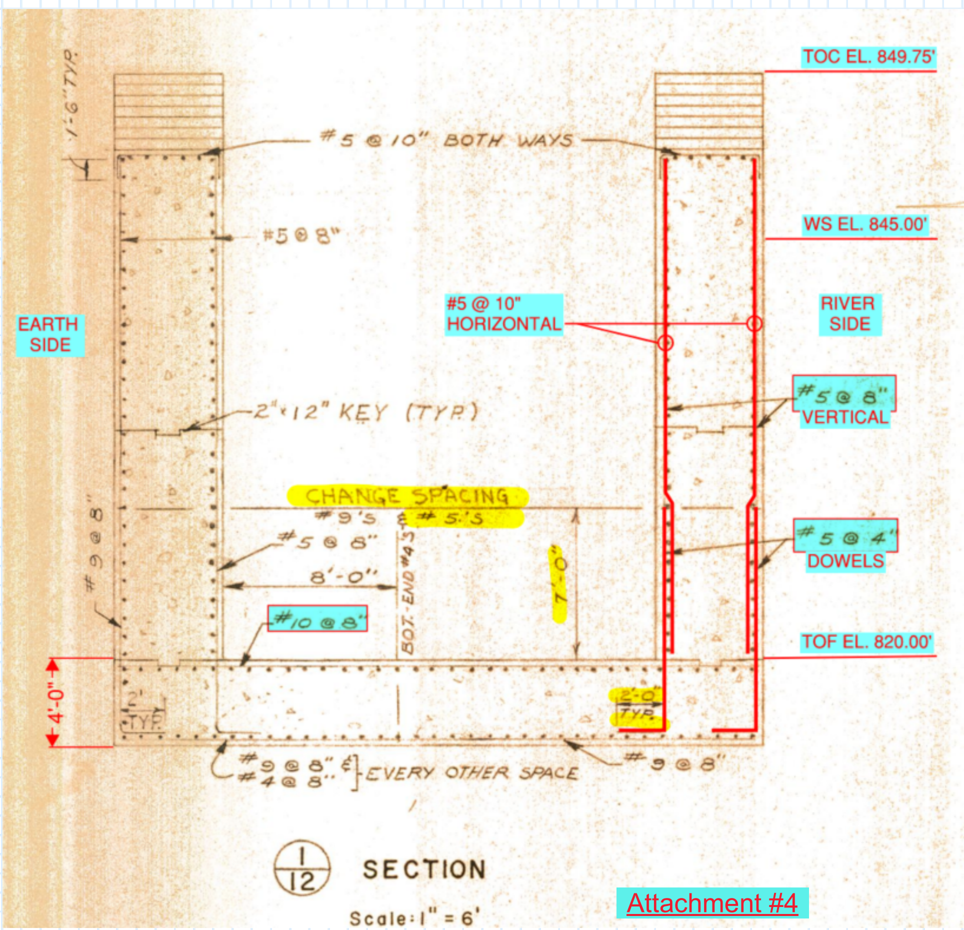
Effective Depth: $d := t_{slab} - cc - \dfrac{d_b}{2} = 44.365\ in$

Area of Steel: $A_{s@8} = 1.901\ in^2$

$\phi M_n := \phi_b \cdot 2 \cdot A_{s@8} \cdot f_y \cdot \left(d - \dfrac{2 \cdot A_{s@8} \cdot f_y}{1.7 \cdot f'_c \cdot b}\right) = 711.211\ ft \cdot kip$ — *Moment Capacity*

$Check := \text{if}\left(\phi M_n > M_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

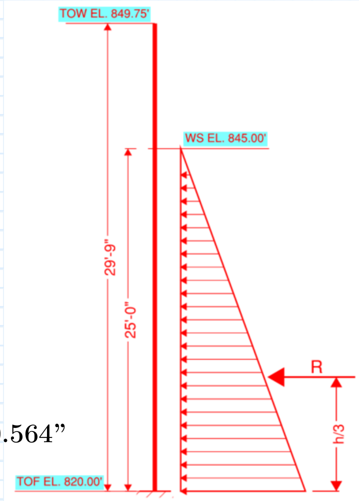
$UT_{RATIO} := \dfrac{M_u}{\phi M_n} = 0.503$



Attachment #4

Stilling Basin - Update:

$h_{wall\_stlb} := 29.75\ ft$ $\quad t_{wall} := 6\ ft$



Wall Reinforcement: "#8 @ 6" OC" *Epox. Dowels : 0 - 7 ft.* "#8 @ 12" OC" *Vertical: 4 - 29.75 ft.*

$Bar\_Size := \#8$

Bar Diameter: $d_b = 1\ in$

Effective Depth: $d := t_{wall} - cc - \dfrac{d_b}{2} = 68.5\ in$

"0.564"

Area of Steel: $A_{s@6} = 1.57\ in^2$

Water height: $h_{water\_stlb} := 25\ ft$

Water Force on Wall - Basin: $R_{stlb} := 0.5 \cdot k \cdot \gamma_{water} \cdot h_{water\_stlb}{}^2 \cdot ft = 19.5\ kip$ *Total Force per ft. of Wall*

Check Moment: $M_u := LF \cdot R_{stlb} \cdot \dfrac{h_{water\_stlb}}{3} = 357.5\ ft \cdot kip$ *Overturning Moment Demand*

$\phi M_n := \phi_b \cdot A_{s@6} \cdot f_y \cdot \left(d - \dfrac{A_{s@6} \cdot f_y}{1.7 \cdot f'_c \cdot b}\right) = 475.797\ ft \cdot kip$ *Moment Capacity*

$Check := \text{if}\left(\phi M_n > M_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

$UT_{RATIO} := \dfrac{M_u}{\phi M_n} = 0.751$

Check Shear: $V_u := LF \cdot k \cdot \gamma_{water} \cdot \dfrac{h_{water\_stlb}{}^2}{2} \cdot ft = 42.9\ kip$ *Shear Demand*

$\phi V := \phi_v \cdot 2 \cdot \sqrt{f'_c \cdot psi} \cdot b \cdot d = 77.982\ kip$ *Shear Capacity*

$Check := \text{if}\left(\phi V > V_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

$UT_{RATIO} := \dfrac{V_u}{\phi V} = 0.55$

Check Minimum Steel: $A_{s\_min} := 0.0033 \cdot b \cdot d = 2.713\ in^2$

$Check := \text{if}\left(A_{s@6} > A_{s\_min}, \text{"OK"}, \text{"Redesign"}\right) = \text{"Redesign"}$ TBD

Check Deformed Bar Development Length:

Per ACI 318 - 14 - Section 25.4.3.1

$\lambda := 1.0$ *Normal-weight Concrete*

$\Psi_e := 1.0$ *Epoxy Coating*

$\Psi_c := \frac{f'_c}{15000} + 0.6 = 0.867$ *Concrete Strength: $f'_c < 6000$ psi*

$\Psi_r := 1.0$ *Confining Reinforcement*

$$l_{dh} := \max\left(\frac{f_y \cdot \Psi_e \cdot \Psi_c \cdot \Psi_r}{50 \cdot \lambda \cdot \sqrt{f'_c}} \cdot d_b, 8 \cdot d_b, 6\ in\right) = 16.444\ in$$

Note: New bar to be epoxied into the base slab minimum of 17".

Check Lap Development Length:

Per ACI 318 - 14 - Section 25.4.2.2

$\Psi_t := 1.3$ *Casting position: More than 12" of fresh concrete placed below horizontal reinforcement (foundation = 48" - see Attachment #5)*

$$l_d := \left(\frac{f_y \cdot \Psi_t \cdot \Psi_e}{20 \cdot \lambda \cdot \sqrt{f'_c}}\right) \cdot d_b = 5.139\ ft$$

$Check := \text{if}\left(l_d < 7\ ft, \text{“OK”}, \text{“NG”}\right) = \text{“OK”}$

Check Tension Lap Splice Length:

Per ACI 318 - 14 - Section 25.5.2.1

Note:
As required has not been calculated, therefore, conservatively assume ratio As,provided / As,req'd < 2.0.

$l_{st} := \max\left(1.3 \cdot l_d, 12\ in\right) = 6.68\ ft$

$Check := \text{if}\left(l_{st} < 7\ ft, \text{“OK”}, \text{“NG”}\right) = \text{“OK”}$

Check Shear Friction:

Per ACI 318 - 14 - Table 22.9.4.2:
(Coefficient of Friction)

$\mu := 1.0 \cdot \lambda = 1$ *Assumed that concrete is placed against hardened concrete that is clean, free of laitance, and intentionally roughened to a full amplitude of approximately 1/4 inches.*

Per ACI 318 - 14 - Section R22.9.4.2:

$A_{vf\_req'd} := \frac{V_u}{\phi_v \cdot f_y \cdot \mu} = 0.953\ in^2$ *Required Shear-Friction Reinforcement*

$A_{vf} := A_{s@4} = 2.355\ in^2$ *Area of steel at the base of wall*

$\phi V_{n\_cl} := \phi_v \cdot \mu \cdot A_{vf} \cdot f_y = 105.975\ kip$ *Clamping Shear Friction Capacity*

$Check := \text{if}\left(\phi V_{n\_cl} > V_u, \text{“OK”}, \text{“Redesign”}\right) = \text{“OK”}$

$$UT_{RATIO} := \frac{V_u}{\phi V_{n\_cl}} = 0.405$$

Check Base Slab Critical Section:

$M_u = 357.5\ ft \cdot kip$ — *Moment Demand - see page 12*

$t_{slab} := 48\ in$ — *Slab Thickness - see Attachment #5 below*

$Bar\_Size := \#10$ $d_b := 1.270\ in$ — *Top Reinforcement #10 @ 8" OC*

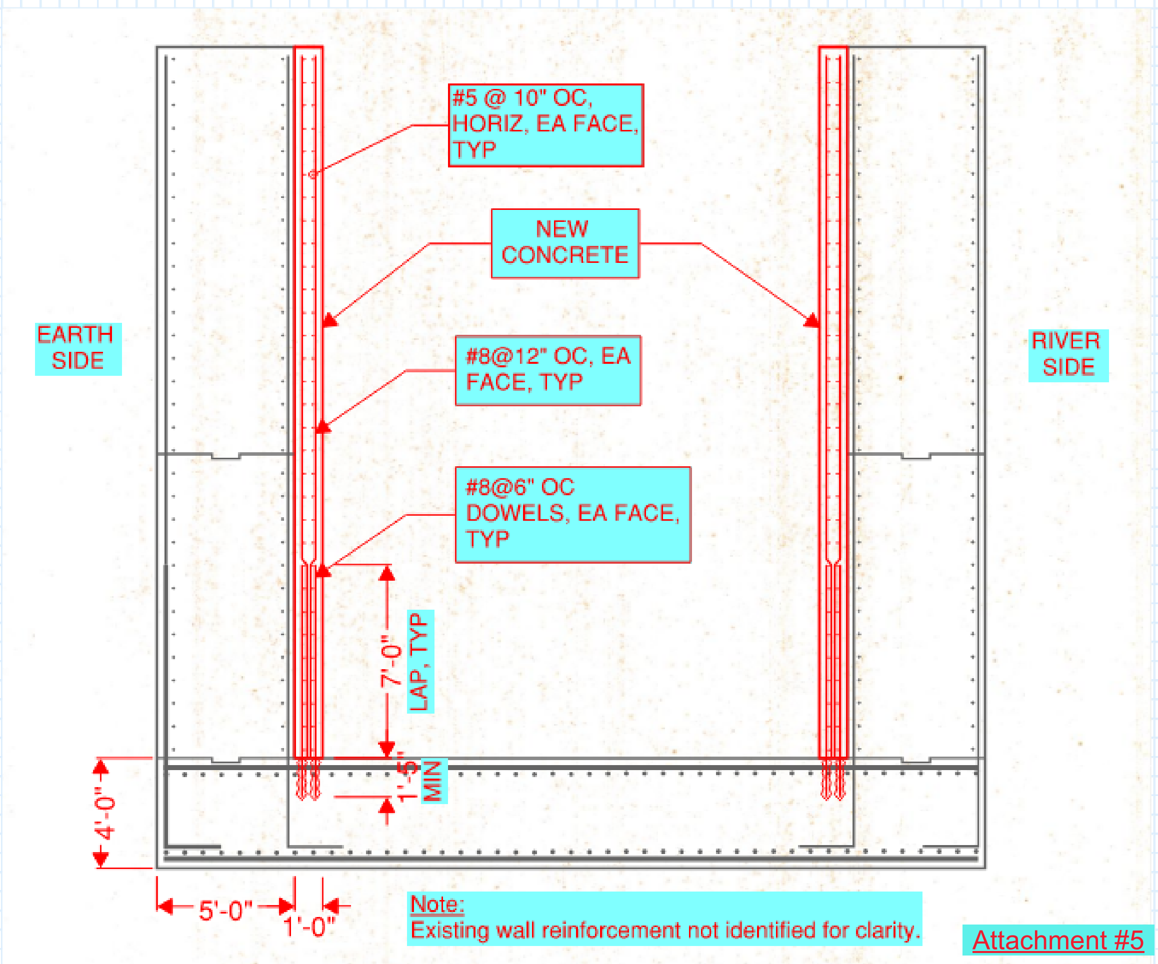
$A_{s@8} = 1.901\ in^2$

$d := t_{slab} - cc - \frac{d_b}{2} = 44.365\ in$

$\phi M_n := \phi_b \cdot 2 \cdot A_{s@8} \cdot f_y \cdot \left(d - \frac{2 \cdot A_{s@8} \cdot f_y}{1.7 \cdot f'_c \cdot b}\right) = 711.211\ ft \cdot kip$ — *Moment Capacity*

$Check := \text{if}\left(\phi M_n > M_u, \text{"OK"}, \text{"Redesign"}\right) = \text{"OK"}$

$UT_{RATIO} := \frac{M_u}{\phi M_n} = 0.503$



Appendix D

Solar Power

Appendix D1

Solar Simulation Modeling

Version 7.4.5

PVsyst - Simulation report

Grid-Connected System

Project: City of Anoka - Rum River Dam

Variant: NBCD Parking Ramp

Unlimited sheds

System power: 380 kWp

Anoka - United States

Author

HDR Inc. (United States)

Project summary

Geographical Site		Situation		Project settings	
Anoka		Latitude	45.21 °N	Albedo	0.20
United States		Longitude	-93.38 °W		
		Altitude	270 m		
		Time zone	UTC-6		

Meteo data
Anoka
NREL NSRDB Typ. Met. Year PSMv3 - TMY

System summary

Grid-Connected System — **Unlimited sheds**

PV Field Orientation		Near Shadings	User's needs
Sheds		Mutual shadings of sheds	Unlimited load (grid)
Tilt	30 °		
Azimuth	0 °		

System information

PV Array		Inverters	
Nb. of modules	784 units	Nb. of units	6 units
Pnom total	380 kWp	Pnom total	300 kWac
		Pnom ratio	1.267

Results summary

Produced Energy	557729 kWh/year	Specific production	1467 kWh/kWp/year	Perf. Ratio PR	83.65 %

Table of contents

General parameters

Grid-Connected System — **Unlimited sheds**

PV Field Orientation

Orientation		**Sheds configuration**		**Models used**	
Sheds		Nb. of sheds	30 units	Transposition	Perez
Tilt	30 °	Unlimited sheds		Diffuse	Imported
Azimuth	0 °	**Sizes**		Circumsolar	separate
		Sheds spacing	2.00 m		
		Collector width	1.05 m		
		Ground Cov. Ratio (GCR)	52.3 %		
		Top inactive band	0.02 m		
		Bottom inactive band	0.02 m		
		Shading limit angle			
		Limit profile angle	26.3 °		

Horizon	**Near Shadings**	**User's needs**
Free Horizon	Mutual shadings of sheds	Unlimited load (grid)

Bifacial system

Model: 2D Calculation unlimited sheds

Bifacial model geometry		**Bifacial model definitions**	
Sheds spacing	2.00 m	Ground albedo	0.20
Sheds width	1.09 m	Bifaciality factor	70 %
Limit profile angle	27.1 °	Rear shading factor	10.0 %
GCR	54.3 %	Rear mismatch loss	3.0 %
Height above ground	3.05 m	Shed transparent fraction	0.0 %

PV Array Characteristics

PV module		**Inverter**	
Manufacturer	Hanwha Q Cells	Manufacturer	SMA
Model	Q.PEAK DUO XL-G10.3&.d 485/BFG	Model	Sunny Tripower_Core1 50-US-41_pre
(Custom parameters definition)		(Custom parameters definition)	
Unit Nom. Power	485 Wp	Unit Nom. Power	50.0 kWac
Number of PV modules	784 units	Number of inverters	6 units
Nominal (STC)	380 kWp	Total power	300 kWac
Modules	49 string x 16 In series	Operating voltage	150-1000 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	1.27
Pmpp	348 kWp	Power sharing within this inverter	
U mpp	664 V		
I mpp	524 A		

Total PV power		**Total inverter power**	
Nominal (STC)	380 kWp	Total power	300 kWac
Total	784 modules	Number of inverters	6 units
Module area	1816 m²	Pnom ratio	1.27
Cell area	1685 m²		

Array losses

Array Soiling Losses
Average loss Fraction 5.3 %

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
12.0%	10.0%	8.0%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	5.0%	8.0%	12.0%

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 6.9 mΩ
Loss Fraction 0.5 % at STC

LID - Light Induced Degradation
Loss Fraction 2.0 %

Module Quality Loss
Loss Fraction 0.0 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.2 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	20°	30°	40°	50°	60°	70°	80°	90°
1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.750	0.000

System losses

Auxiliaries loss
Proportionnal to Power 4.0 W/kW
0.0 kW from Power thresh.

AC wiring losses

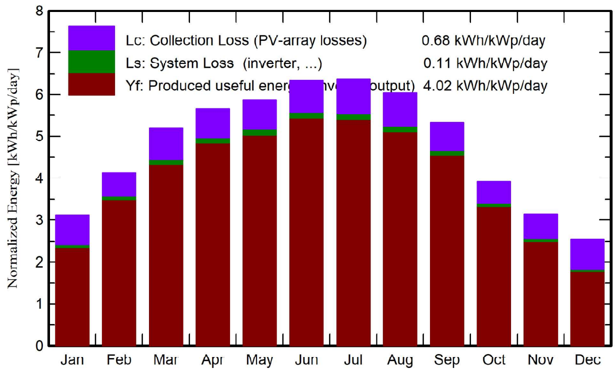
Inv. output line up to injection point
Inverter voltage 480 Vac tri
Loss Fraction 0.00 % at STC
Inverter: Sunny Tripower_Core1 50-US-41_pre
Wire section (6 Inv.) Copper 6 x 3 x 16 mm²
Average wires length 0 m

Main results

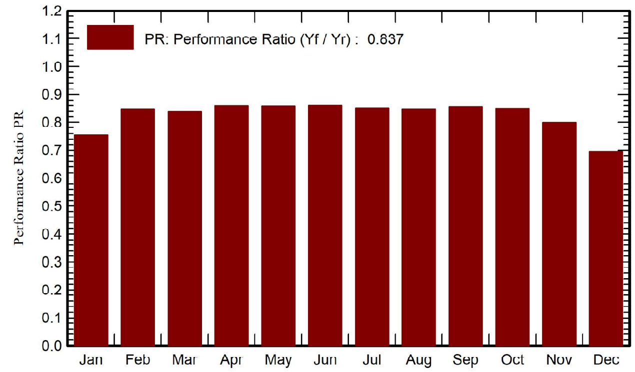
System Production

Produced Energy 557729 kWh/year
Specific production 1467 kWh/kWp/year
Perf. Ratio PR 83.65 %

Normalized productions (per installed kWp)



Performance Ratio PR



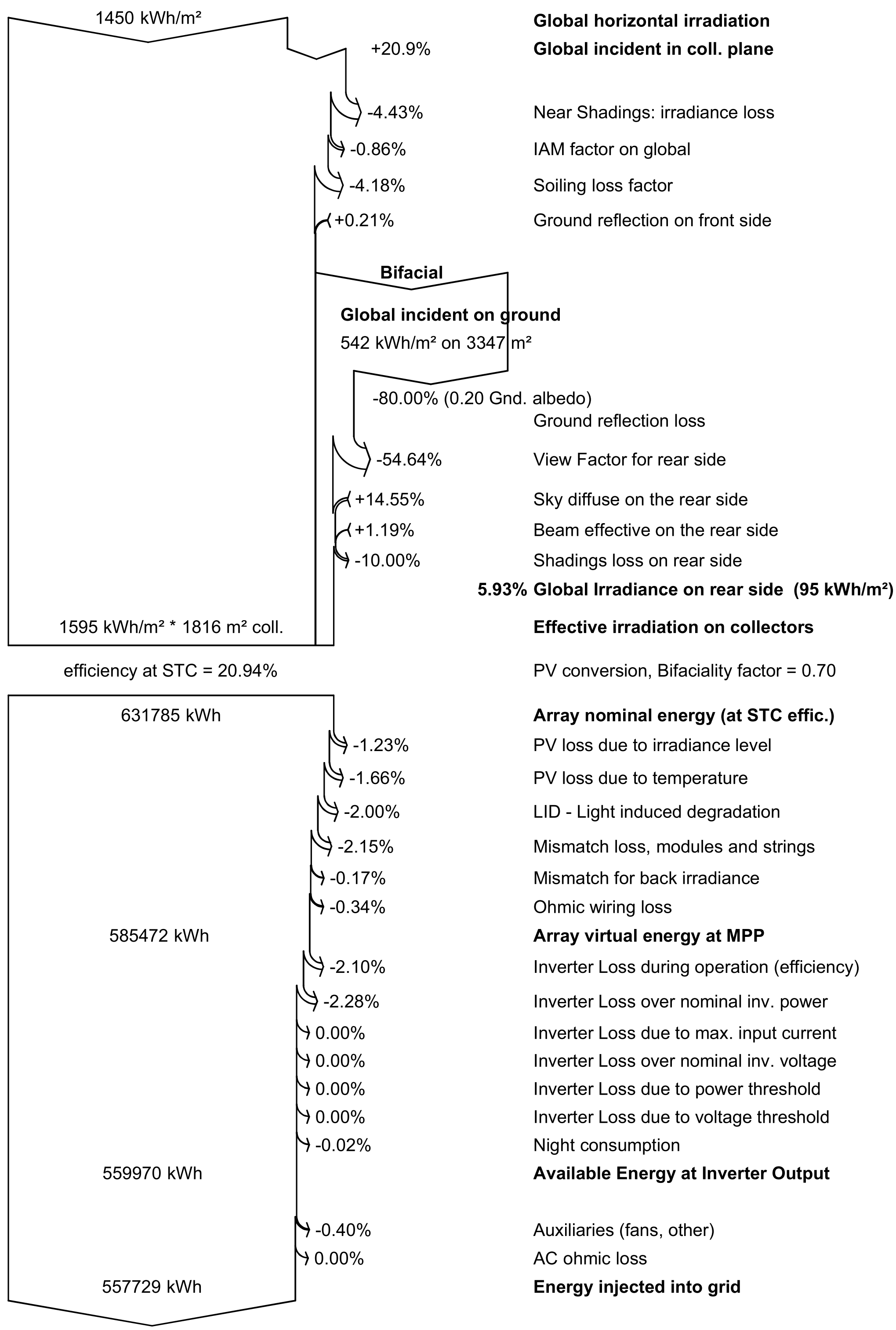
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	52.5	20.77	-12.33	96.7	72.5	28429	27717	0.754
February	75.2	27.56	-13.23	115.7	100.1	38165	37232	0.846
March	122.9	44.02	-4.27	160.6	143.6	52525	51231	0.839
April	148.4	50.12	7.33	169.4	161.9	56768	55293	0.858
May	178.3	73.55	16.75	182.2	173.1	60938	59368	0.857
June	194.0	77.73	19.46	190.0	180.2	63753	62110	0.860
July	197.2	75.71	23.90	197.2	187.3	65517	63815	0.851
August	172.2	56.53	21.03	187.3	178.6	61906	60304	0.847
September	129.6	44.35	15.21	159.8	152.5	53311	51949	0.855
October	84.6	29.60	9.58	121.4	111.8	40230	39182	0.849
November	53.9	20.26	-1.11	94.1	78.0	29372	28619	0.800
December	41.1	17.10	-5.13	79.0	55.8	21476	20910	0.696
Year	1449.9	537.31	6.55	1753.4	1595.3	572389	557729	0.837

Legends

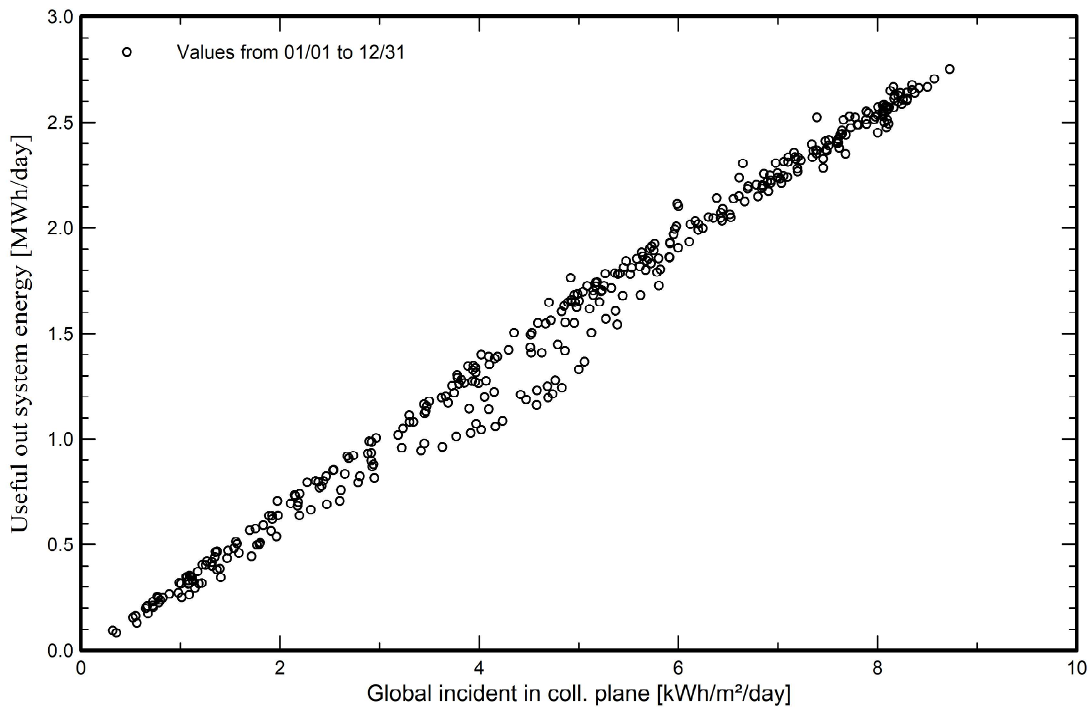
GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

Loss diagram

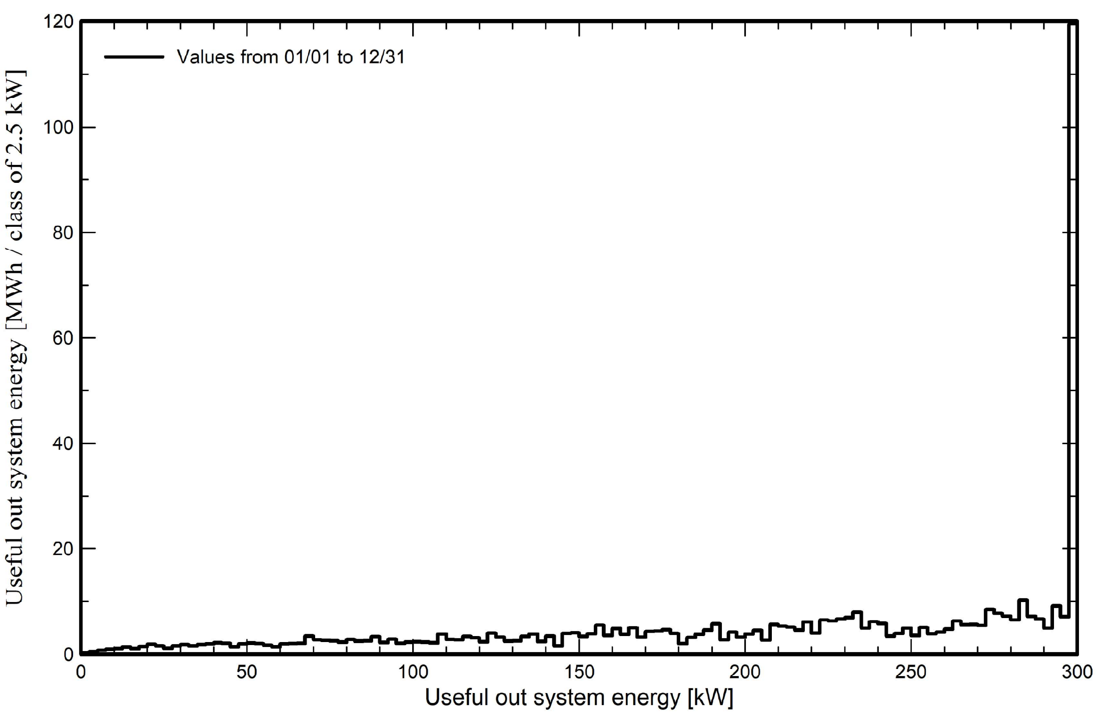


Predef. graphs

Daily Input/Output diagram

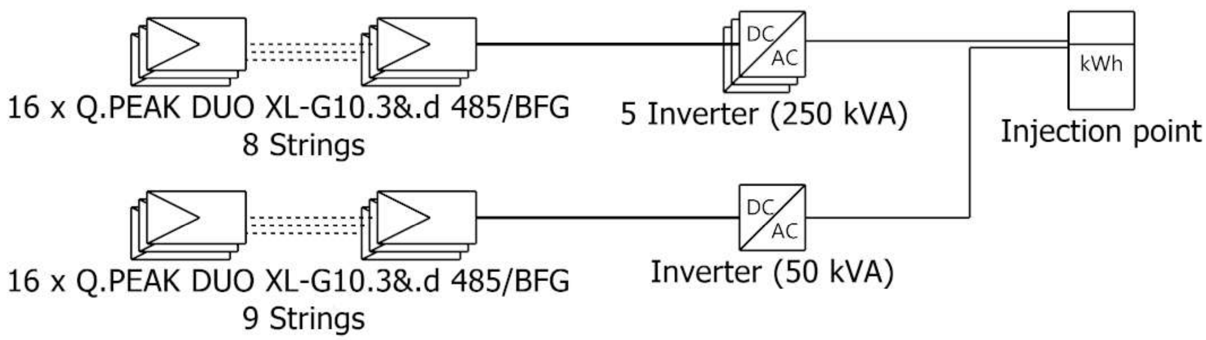


System Output Power Distribution



Single-line diagram

PVsyst V7.4.5
VC0, Simulation date:
08/12/24 17:00
with v7.4.5



PV module	Q.PEAK DUO XL-G10.3&.d 485/BFG
Inverter	Sunny Tripower_Core1 50-US-41_pre
String	16 x Q.PEAK DUO XL-G10.3&.d 485/BFG

City of Anoka - Rum River Dam	HDR Inc. (United States)
VC0 : NBCD Parking Ramp	08/12/24

Appendix D2

Solar Structural Quote

BUDGET PLANNING PROPOSAL FOR:
City of Anoka
Anoka MN

terrasmart™

CLIENT: **HDR Engineering**

DATE: August 20, 2024

PARKING RBI-CANOPY SPECIFICATIONS, PROJECT SPECIFIC		
• Quote Number:	09020	
• Total System Size (DC):	378.30	kW
• Number Of Modules Supported:	780	modules
• Module Tilt (Long Span):	10	degrees
• Module Manufacturer/Model Number:	Hanwha	
• Module Wattage:	485	watts
• Module Orientation:	Landscape	
• Minimum Long Span Structure Clearance (At Drive Aisle):	9	ft.
Bay Size / Column Spacing (Long Span):	30 by 70	ft.
• Column Type - Long Span:	Wide Flange	
• Top Beam Type - Long Span:	Wide Flange	
• Purlin Type	Z-Purlin	
• Structure Type:	Garage	
• Structure Finish:	All Galvanized	

ENGINEERING CRITERIA (PENDING LOCAL VERIFICATION)		
• Design Code:	IBC2018	
• Ground Snow:	50	psf
• Wind Load:	109	mph
• Wind Exposure:	Exposure B	
• Risk Category:	II	

Structure	Geometry	Length (ft.)	Width (ft.)	Panels/ Length	Panels/ Width	Panels/ Structure	Structure kW	Structure Type
1	Long Span	300	140	39	20	780	378.30	Louvered

GENERAL PROPOSAL NOTES:

- Terrasmart, Inc. is NOT responsible for PV system design or shading analysis as related to PV system production.
- Layouts are subject to customer review and approval. All layouts shall be approved by customer prior to placement for orders of any materials.

ESTIMATED PROJECT TIMELINE:

- 6 - 8 Weeks - Design and Engineering upon receipt of critical information.
- 12-16 Weeks Estimated - Material Procurement (Based on Mill Availability) and Fabrication upon receipt of "Release for Fabrication", within the Contiguous US.
- Installation Schedule TBD after "Release for Fabrication".

MATERIALS & DESIGN ONLY SCOPE OF WORK:

- Terrasmart, Inc. shall provide drawings signed and sealed by a Professional Engineer registered in the State of MN. Submittal process, special inspections and fees are not included.
- All connections and analysis of the existing structures to be by others. Terrasmart, Inc. to supply reactions and suggested connection details.
- Columns and Top Beams (superstructure) for a canopy system.
- Racking system, including all hardware and module mounting hardware.
- All members and hardware are galvanized steel with Columns and Top Beams hot dipped to ASTM A123 and purlins pregalvanized to a G165 minimum. Module hardware is stainless steel.
- All member connections shall be bolted. No on-site welding shall be required.
- Modules are to be mounted by four (4) mounting points.
- Lights, electrical wiring and grounding/bonding material (unless called-out in Pricing section below) are NOT included.
- Canopy structure is not waterproof.
- Shipping date changes must be provided before at least 8 working days in advance.
- Sales/Use Tax and Permit Fees, NOT included unless specifically called-out in Pricing section below.
- May be subject to local taxes to be applied at contract
- Freight to site is included. Hoisting (labor and crane rental) to work level is by others unless called out in pricing below.

INSTALLATION SCOPE OF WORK:

- Labor for installation is assumed to be non-union/non-prevailing wage rates.
- Any special labor requirements including the use of electricians or unions is not included unless stated in the pricing section below.
- Unloading of material with unimpeded access for semi trucks and other large equipment. Crane excluded.
- Hydro vac foundations are NOT included.
- Resurfacing, restriping or any repairs to the parking lot is excluded.
- Columns to be connected to concrete piers with chemical anchors or wet set anchor bolts, if wet set, anchor to be installed by others.
- Attachment to garage to be verified by third party engineer.
- Uninterrupted access to the entire parking area shall be provided. Access is assumed to be at least 12 hours per day and 6 days per week. Restrictions to the working hours and area may result in additional cost.
- Temporary fencing, barricades or storage trailers necessary to secure site are NOT included.
- General Contractor shall provide dumpster or provide for trash removal from site. Terrasmart to put debris in dumpster.
- Installation Scope does not include demolition and replacement/repair of existing curbs and landscaping. This scope can be added once final design documents are approved.
- Module installation is excluded, unless specifically called-out in Pricing section below. Module installation, by Terrasmart, Inc., is not available if decking is being installed.
- Punch list must be provided before crew demobilization.
- Dumpsters, portalets and temporary electric are NOT included.

GROUNDING AND WIRE MANAGEMENT:

- Grounding hardware for modules and racking is NOT included (unless called-out in Pricing section below).
- Module grounding to be per module manufacturer's installation instructions. Terrasmart, Inc.'s racking is WEEB compatible for certain applications please check with the AHJ and the module manufacturer's installation manual.
- Base design includes prepunched holes in the purlin for wire management.
- Electrical conduit will be installed outside of concrete piers and/or baseplates. Other options are available at additional cost.

CUSTOMER RESPONSIBILITIES:

- Third party engineer to supply analysis of existing structure.
- All special inspections.
- As built survey including topographic information and xray/GPR of existing structure
- Design and Engineering of connection to existing structure by others. Terrasmart to coordinate with 3rd party Engineer. 3rd party Engineer contracted by others.

DEFAULT ASSUMPTIONS:

Terrasmart makes assumptions when preparing your quote if certain information is not provided

- In-sequence work.
- Adequate staggering between each phase of construction.
- Adequate lay down area and reasonable lay down proximity to site.
- Non-winter work conditions. Winter conditions defined as unsafe site conditions causing safety hazard and/or extreme cold, snow, ice, mud, rain or standing water.

CONTRACT TERMS AND CONDITIONS:

- Reference Attachment "Terrasmart, Inc. Terms and Conditions". Available upon request.

PRICING: Pricing, per scope of work as defined above in this proposal:

Taxes, Permit Fees, Bonds and Special Inspections, if applicable, are not included.		**$$/Watt**
Design & Engineering (Required for Material Purchase):	$25,000	$0.066

Budget Pricing is based on our extensive experience as Design/Builders of similar Canopy projects and will be refined as the design phase and scope are finalized

BUDGET Materials:	$689,800	$1.823

Price includes:

- WEEBs for Module Grounding
- Anchor Bolts
- Rail
- Super Structure & Racking System
- Freight

BUDGET Installation of Racking (Non-Prevailing Wage Rates):	$387,800	$1.025

Price includes material & labor for:

- Setting Anchor Bolts
- Steel Erection
- Equipment Rental (Crane for Hoisting Material to Deck Excluded)

Total:	$1,102,600	$2.915

CONTRACT PAYMENT TERMS:

Material Terms

Contract Value	Description of Work
15%	Deposit Upon Order Placement, Net 10
35%	Upon Release to Fabrication Execution, Net 30
50%	Upon Initial Delivery, Net 30

Installation Terms

Contract Value	Description of Work
100%	Monthly Progress Billing, Net 30
	*Terms for Design & Engineering will be on the Design & Engineering Contract

Steel based product pricing used within this estimate is based on current material availability, and costs, as of the date of this quotation. Due to the inherent volatility in steel plate product costs, Terrasmart, Inc. reserves the right to modify pricing after 10 days from the date of this proposal. Additional price modifications may be applied at the same time of "release to fabricate" should it not occur within 60 days of the last authorized signature on the executed contract. The Terrasmart, Inc. quote and related contract will be subject to repricing if the compound average monthly inflation rate, as determined by the source* below, between the date of the quote and the delivery date are equal to or greater than 10% which is extremely rare and non-typical in the structural steel market. If the customer and Terrasmart, Inc. are unable to mutually agree on the price change, the quote and related contract shall be terminated for convenience in accordance with the terms of the contract. Additionally, labor prices may increase if the project requires increased labor rates (ex. prevailing, union, etc.).

Source*: Published, documented price increases from the three domestic mills that currently offer structural steel for Terrasmart, Inc. canopy projects: Steel Dynamics Inc or Gerdau or Nucor.

In the event fuel costs increase by at least 10 percent (10%) after the issuance of a Purchase Order pursuant to the US Energy Information Administration (https://www.eia.gov/petroleum/gasdiesel/), then Seller may increase the Purchase Price (the fuel cost line item) to cover the fuel price increase.

Thank you for your interest in Terrasmart, Inc., if you have any questions about this proposal or Terrasmart, Inc., please contact:

Contact: Amanda Bostelman **Email:** abostelman@terrasmart.com **Phone:** 440-465-2692

Please contact your Terrasmart Salesperson to request a final proposal for contract execution.

Appendix E

Communications

COUNCIL WORKSESSION MEMO

Agenda Items #3.1

Meeting Date: July 29, 2024

Agenda Section: Council Business and/or Discussion Items

Item Description: Discussion; Anoka Rum River Dam Reconstruction and Modification Project; Feasibility Study Update and Select Preferred Alternative

Submitted By: Ben Nelson, Assistant City Engineer & Lisa LaCasse, Public Services Administrator

---

BACKGROUND INFORMATION

The dam on the Rum River located in the historic downtown Anoka has existed since the early 1850's. The old timber dams provided power for the saw mills, wood working plants, and copper shops operating along the east bank of the Rum River. In 1935, the City of Anoka was granted and deeded the flowage rights to the Rum River, and purchased the Anoka Rum River Dam becoming the sole owner. As the owner, the city has been and continues to be responsible for the ongoing operations, maintenance, repairs, and replacement of the dam.

In 1969, the City of Anoka replaced the existing log timber dam from the late 18th century. The dam was completed in 1970 and is the current structure across the Rum River.

On May 24, 2023, Governor Dayton signed the State Bonding Bill into law awarding the City of Anoka with a $500,000 grant for feasibility studies for the design, engineering, and environmental analysis for the repair and reconstruction of the Rum River Dam. This appropriation was for one-time and available until June of 2027.

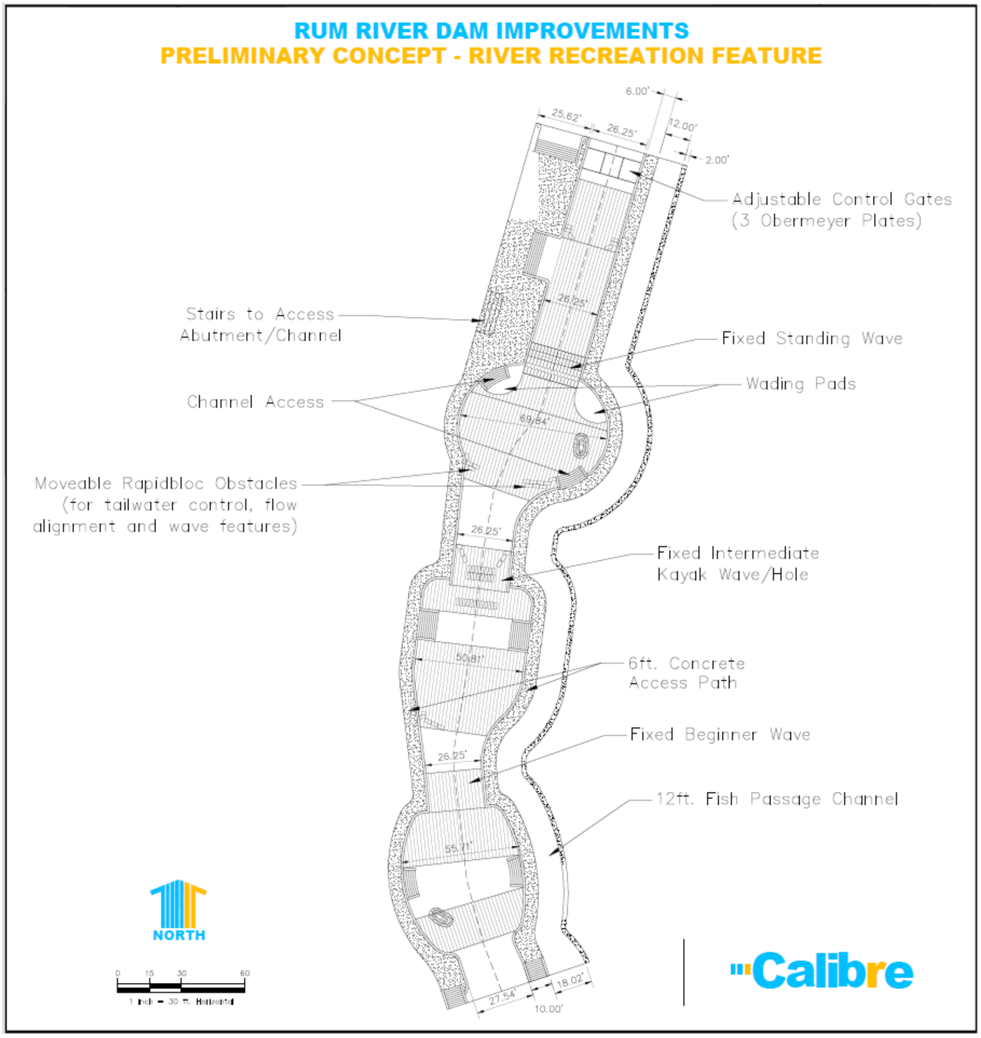
On the 16th day of January, 2024, the City Council adopted a resolution awarding a professional service contract to HDR Engineering, Inc. for the concept development and feasibility analysis of the Anoka Rum River Dam.

The Anoka Rum River Dam is a key asset to the region with the recreational pool extending over six miles upstream. Recreational opportunities will be further enhanced through this project as it will re-establish the connection from the upper pool of the Rum River to the Mississippi River, thus benefiting multiple communities within Anoka County and Hennepin County.

The feasibility studies of the concept development and feasibility analysis will examine the cost and benefit for various elements of the Anoka Rum River Dam Reconstruction and Modification Project. The proposed modification includes new automated crest gates, maintenance platform/trailway, hydroelectric power generation, recreational and river surfing, a new lock or boat portage system, fish passage, and enhanced environmental benefits.

DISCUSSION

City staff, along with Martin Weber, hydropower/dam engineer & lead feasibility manager with HDR; Riley Adams, river recreation and whitewater construction with Calibre; and Dan Coyle, our city's consultant project manager with Kimley-Horn; will present a PowerPoint on the proposed modifications, selection of alternatives, and will address any questions that City Council has on the Anoka Rum River Dam Reconstruction and Modification Project.



Selection of Alternatives – Should the Council wish to complete the feasibility study for the Anoka Rum River Dam Reconstruction and Modification Project; the next step is the selection of alternatives to finalize in the study. Based on the initial findings of the study, staff has developed three alternatives for further consideration. The modifications included in each alternatives are the following:

BASE	=	Dam Safety and Automated Crest Gates
OPTION A	=	Dam Safety, Automated Crest Gates, Trailway/Bridge, Lock System
OPTION B	=	Dam Safety, Automated Crest Gates, Trailway/Bridge, Lock System, Recreational Features, and Fish Passage

City Council shall be aware, given hydropower generation did not provide a sustainable rate of return for the energy produced by a turbine, other renewable energy options are being considered with the study. Possible "green" sources of energy include solar power generation and heat pumps. Also, aesthetic spillway flow (the water curtain spilling off the dam) is part of the base to preserve the continuous flow over the spillway it is today.

FINANCIAL IMPACT

Cost associated with the feasibility study is funded by the 2023 State Bonding Bill. As part of the bill, there was $500,000 granted to the City of Anoka for feasibility studies for the design, engineering, and environmental analysis for the repair and reconstruction of the Rum River Dam. A future Capital Budget General Obligation Bonding from the state will be required for the pre-design, engineering, design, permitting, construction, utility infrastructure and relocation, and public engagement for the proposed modifications. A preliminary cost range for each alternative is the following:

BASE	=	$4.3M to $9.3M
OPTION A	=	$18.8M to $40.2M
OPTION B	=	$25.6M to $54.8M

It's noteworthy of mentioning, total cost range above is based on AACE International *Cost Estimate Classification system* ~ Class 4 plus a 25% contingency. An estimate class 4 has a 1% to 15% level of project development with an expected accuracy range of -30% to +50%. A Class 4 typical purpose of estimate is for a study or feasibility which the consultant HDR has used to determine the preliminary cost estimates. The preliminary cost estimate is subject to change based on the final findings of the feasibility study.

REQUESTED COUNCIL ACTION

Staff is seeking direction on the selection of base and alternative options for further study to complete the feasibility study. Staff and members of the consultant team will be present to answer questions associated with the feasibility report, processes, and determinations made to date for the Anoka Rum River Dam Reconstruction and Modification Project.

CITY OF ANOKA
RUM RIVER DAM CONCEPT DEVELOPMENT AND FEASIBILITY ANALYSIS
PMT MEETING #3 – SELECT ALTERNATIVES
JUNE 12, 2024 at 10:00 AM

SUMMARY

Lisa LaCasse - City
Ben Nelson – City
Mark Anderson – City
Del Vancura – City
Jon Holmes - City
Warren Magnus - City
Dan Coyle – KH
Ben Sporer – KH
Katie Leise – KH
Marty Weber – HDR
Faith Powell – HDR
Dan Kvasnicka - HDR
Joe Dvorak - HDR
Don Pereira - HDR
Scott Shipley - Calibre
Riley Adams - Calibre
Mike Lynn - DOC

1) INTRODUCTIONS

2) REVIEW / UPDATE PROJECT ELEMENTS – ***See PPT slides***

   A. Solar Power in lieu of Hydropower
      - ***Solar generally received well by City as an alternative to hydropower***
      - ***Solar concepts are in process and will be ready for review at July 10 meeting***

   B. Automatic Crest Gate System
      - ***Designed to maintain flow without significant change to current normal pool elevation***

   C. Maintenance Platform / Trail Bridge
      - ***Evaluated to design options for the trail bridge interaction on the east side of the river. Option 1 (higher) keeps bridge high to connect into the parking lot and has a spur that connects to the north to the riverwalk. Option 2 (lower) provides a switch back off the bridge to connect to the back side of the City Hall building at the riverwalk level***
         - ***City prefers Option 1 – stronger link to framework plan, potential development near Riverfront Memorial Park, better connection to parking garage***
         - ***City noted that delivery area/garage could be removed if needed. Could consider adding public restrooms in its place***
      - ***Vehicular access on bridge to accommodate small maintenance vehicles (Gator, would access from Hwy 169). Bridge loading is however an important factor, i.e., higher loading could translate to additional structural elements and higher project costs.***
      - ***Primary function of the bridge is pedestrian access across river***
      - ***Consider easements on west side of river for trail access where they currently do maintenance already. <u>ACTION ITEM: City to identify if there is an existing easement on west side of river</u>***

   D. Standing Surfing Wave / River Recreation
      - ***Design assumes 3 drops (advanced upstream end, beginner downstream end) – 400' long, 26' wide, 3' deep flow. The design stays within the existing banks of the river.***
      - ***Recreation options include kayaking, wading, fixed standing wave, and tubing***
         - ***Fixed wave: 'set and forget' – more difficult to adjust because it requires a full shut down to change. Significantly more cost effective than adjustable.***
         - ***Adjustable wave: Needs manned when open. Allows different schedules based on real-time feedback. Significantly more expensive than fixed***

- ***Automatic crest gates at upstream end to control flow through river recreation system***
- ***Location of the feature – does shifting further north of south offer more benefits? Further north takes advantage of more public property along the riverfront but has greater impact to the existing dam structure and therefore increases costs. Shifting further south may allow better on/off access to trails but puts feature closer to Main Street bridge ACTION ITEM: Design team coordinate trail entrance/exits with feature to determine best placement***
- ***Consider connection, signage, or acknowledgement to Stone House***

E. Boat Passage / Portage System
- ***Recommendation to bolster interior walls of Taintor gate chamber versus exterior, i.e., cost savings. Approximately 1' additional wall thickness needed, which should not impact the size of vessel that can navigate lock.***
- ***A full lock cycle would take approximately 15 minutes (includes opening/closing and filling/emptying). Filling/emptying approx. 8-9 minutes***
- ***System is gravity fed, no pumps required***
- ***Current design accommodates space for 2 pontoon boats, end to end. City to consider implications (e.g., safety) of allowing multiple boats to pass at the same time.***

F. Fish Passage
- ***City wants fish passage included in project. Recommend to reach out to DNR for their input specifically relating to invasive carp and if design should prevent their passage. ACTION ITEM: Don has meeting with DNR and will ask the question***

G. Repairs and Safety Improvements
H. Environmental Benefit / Flood Control
I. Decorative Lighting

3) REVIEW PROJECT ALTERNATIVES DEVELOPED AT DESIGN CHARRETTE

A. Base Project for All Alternatives: Repairs and safety improvements; environmental benefit / flood control; decorative lighting; ***automatic crest gate system***
B. Alternative ***A*** – ***Base Project*** plus boat passage / portage system and ***maintenance platform and trail***
C. Alternative ***B*** – Alternative ***A*** plus river recreation ***and fish passage***

4) DEVELOP ADDITIONAL ALTERNATIVES – ***No new alternatives developed. Solar and river heat pump ideas will be discussed at a later date and will likely be separate alternatives.***

5) FINALIZE ALTERNATIVES FOR COUNCIL WORKSESSION – ***See Item #3 above. ACTION ITEM: Dan and Marty develop draft agenda and rough order magnitude construction costs for worksession.***

6) SCHEDULE

Council Presentation Preparation Meeting	July 10, 2024
Council Worksession – Select Preferred Alternative	July 22, 2024
PMT #4 - Finalize Feasibility Report	November 6, 2024
Council Meeting – Present Feasibility Report	December 9, 2024

Rum River Dam
Concept Development and Feasibility Analysis

PMT Meeting 3 - Select Alternatives for Council Work Session
June 12, 2024

HDR

ANOKA REAL. CLASSIC.

Kimley»Horn

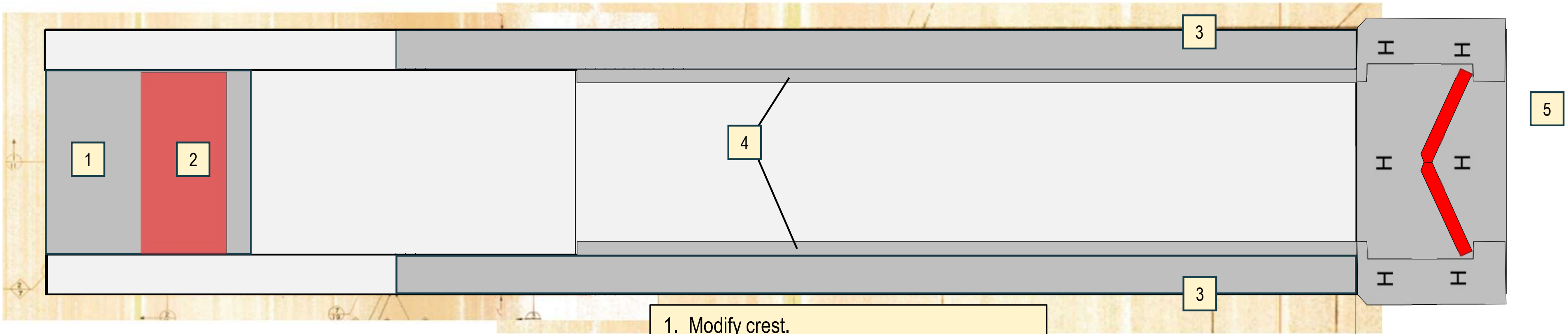
Agenda

1. Background Information Review
2. Lock
3. Recreation / Fish Feature
4. Overall Configuration
5. Construction Sequence
6. Schedule
7. Cost Opinion

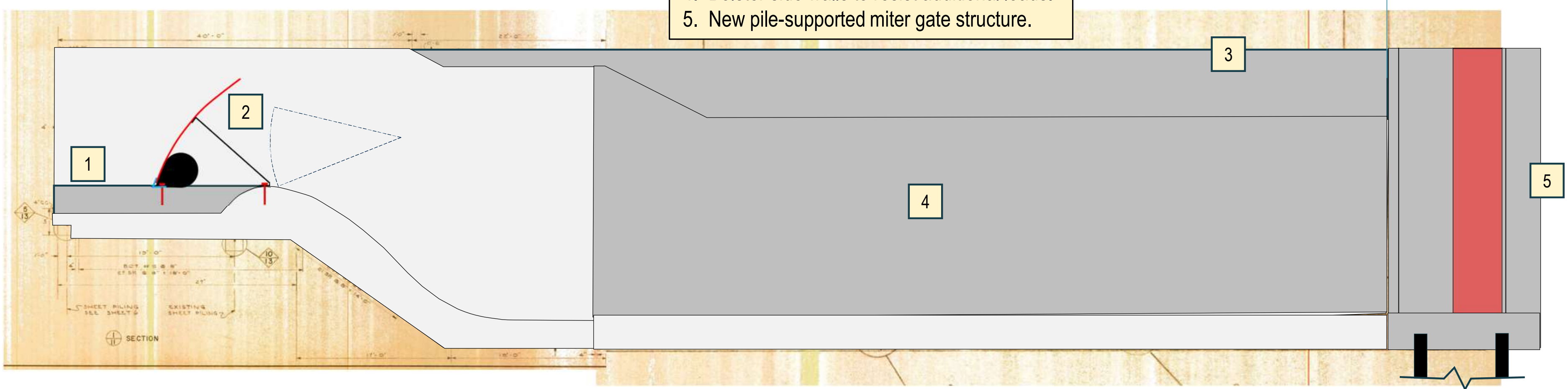
1. Background Information Review

1. Hydrology
2. Water Allocation Model
3. Maintain Spillway Capacity
4. Spillway Bridge
5. Crest Gates
6. Hydropower
7. Other Renewable Energy
8. Lock
9. Recreation Feature
10. Fish Passage

2. Navigation Lock - Structural

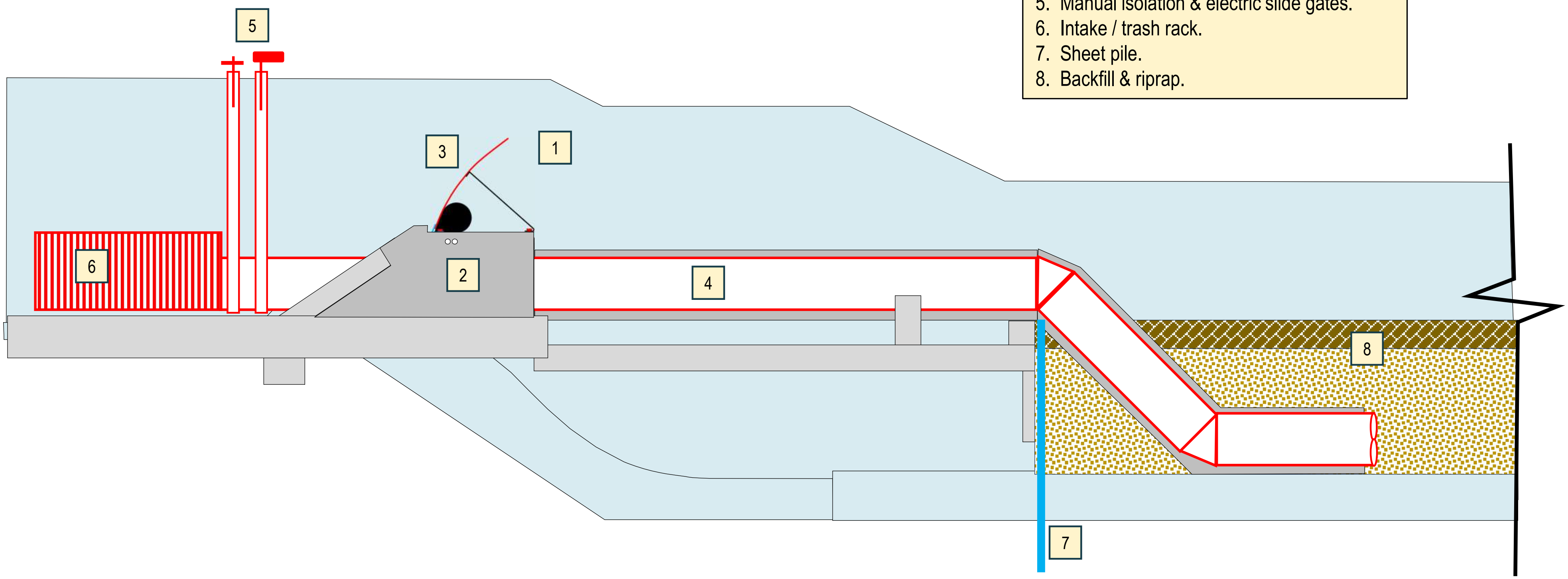


1. Modify crest.
2. Replace Tainter gate w/ crest gate.
3. Raise side walls to Elevation 850.
4. Bolster side walls to resist additional loads.
5. New pile-supported miter gate structure.



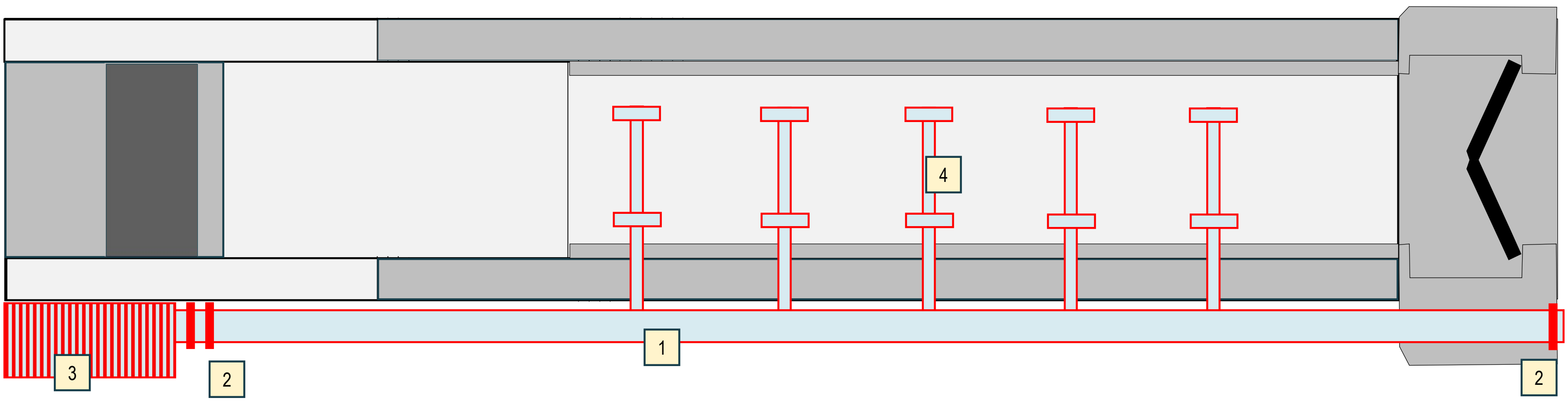
2. Navigation Lock - Water System

1. Demo portion of spillway.
2. New concrete w/ lower crest (838.8).
3. Crest gate.
4. 48" Lock filling pipe, encased in concrete.
5. Manual isolation & electric slide gates.
6. Intake / trash rack.
7. Sheet pile.
8. Backfill & riprap.

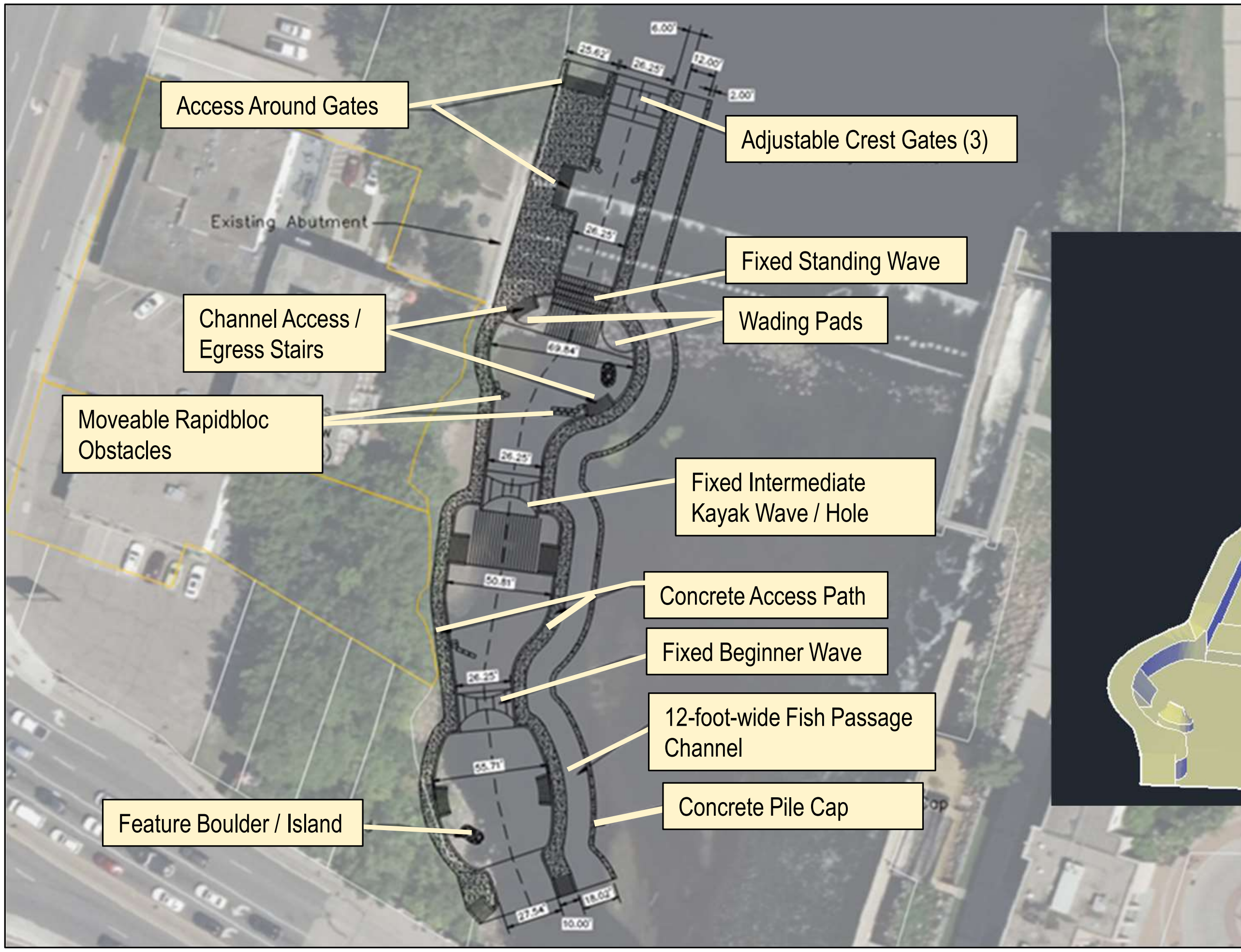


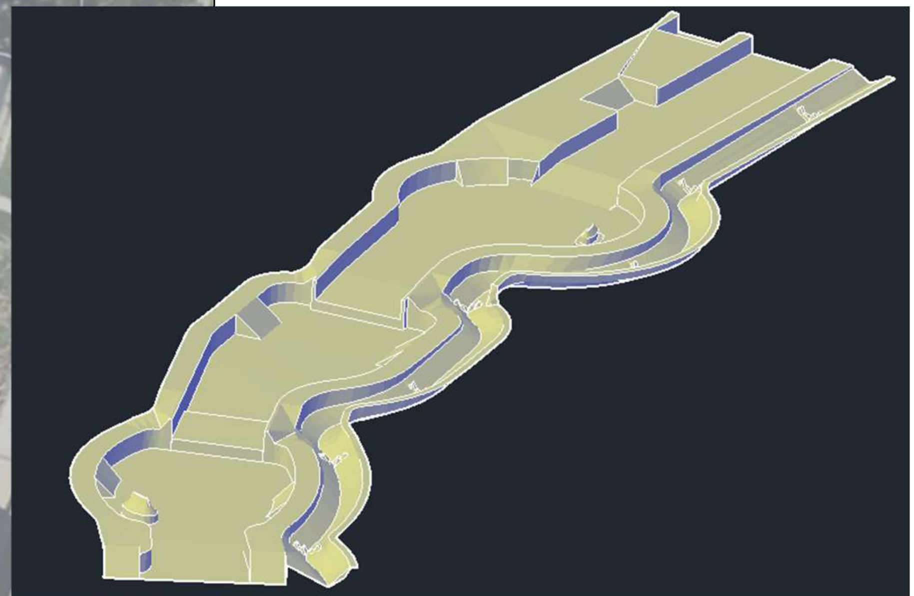
2. Navigation Lock - Water System

1. 48" Lock filling pipe, encased in concrete.
2. Electric slide gates.
3. Intake / trash rack.
4. Chamber diffusers.

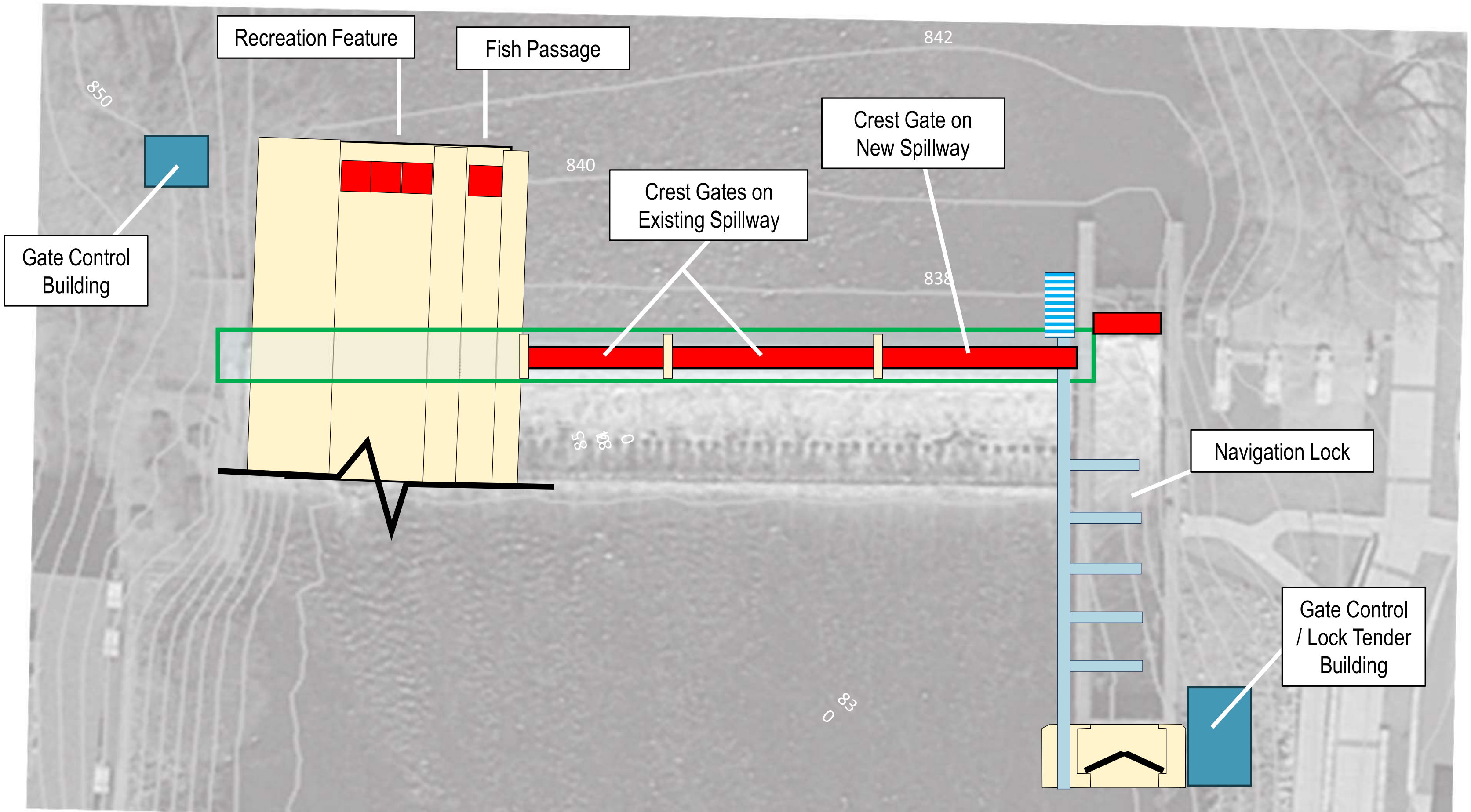


3. Recreation / Fish Passage Feature

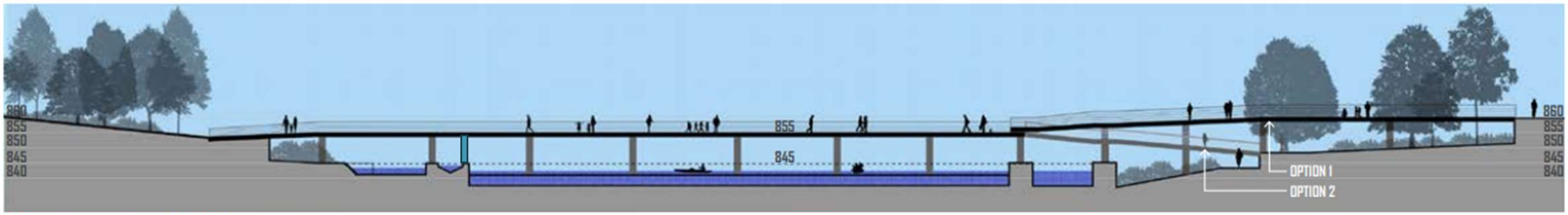




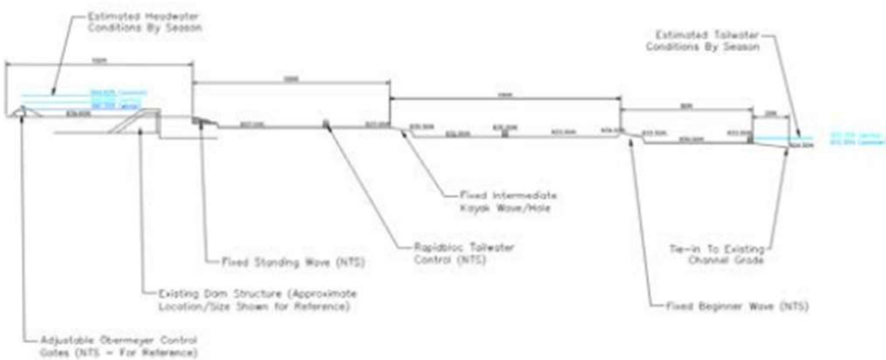
4. Overall Configuration



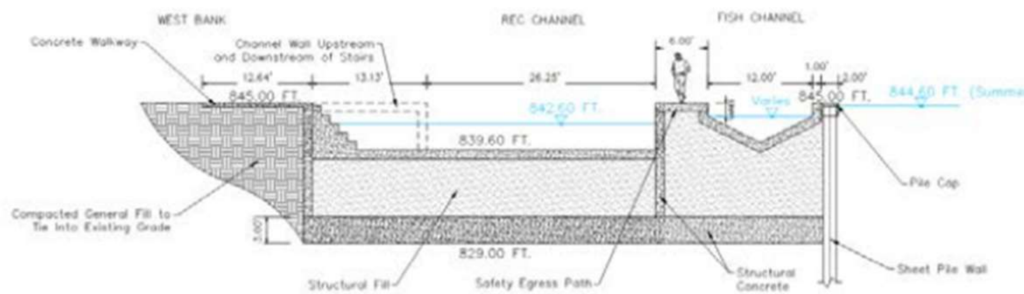
4. Overall Configuration



A CONCEPT SECTION ACCESS BRIDGE SECTION

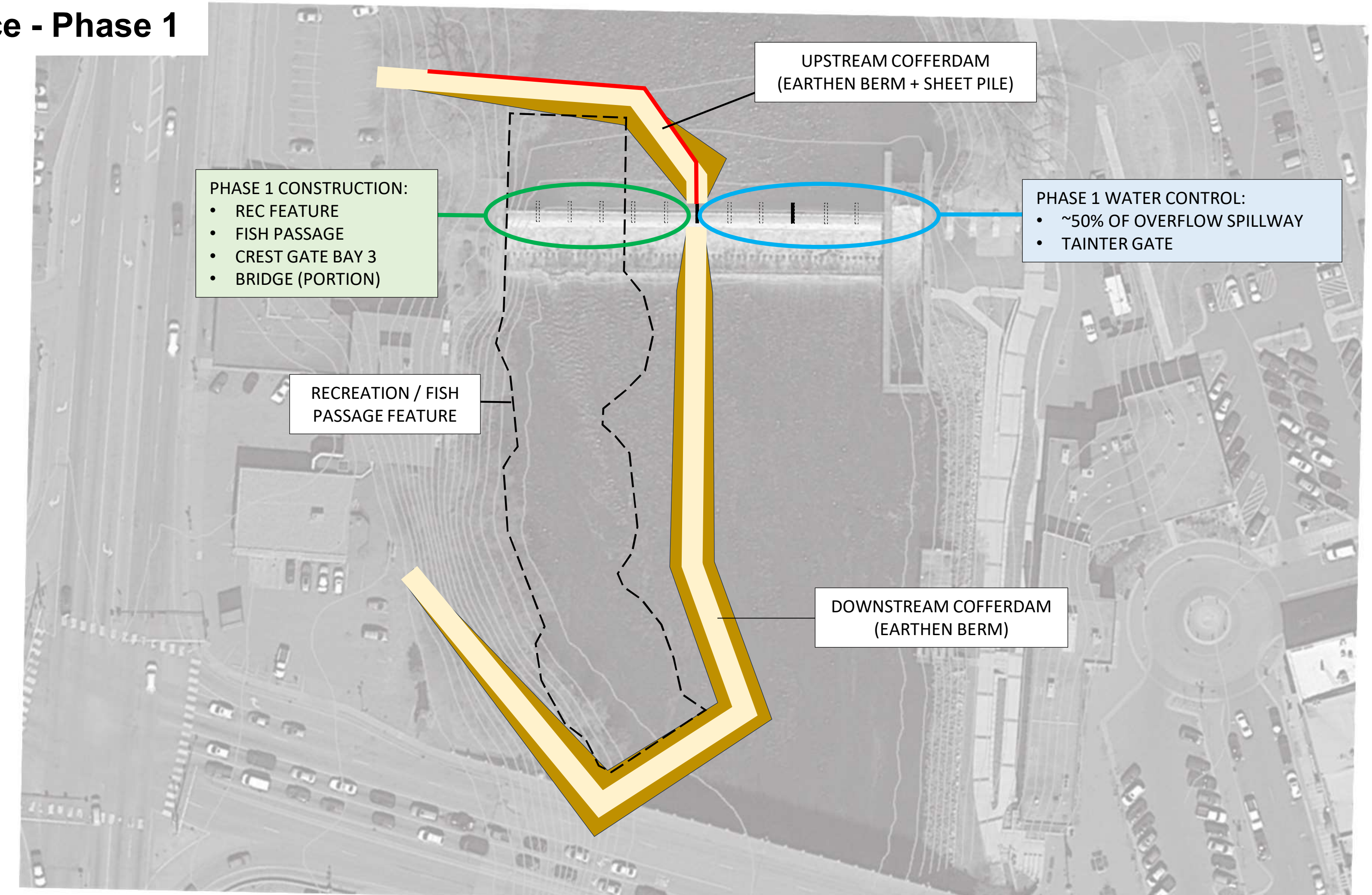


B CONCEPT RECREATION CHANNEL PROFILE (NTS)

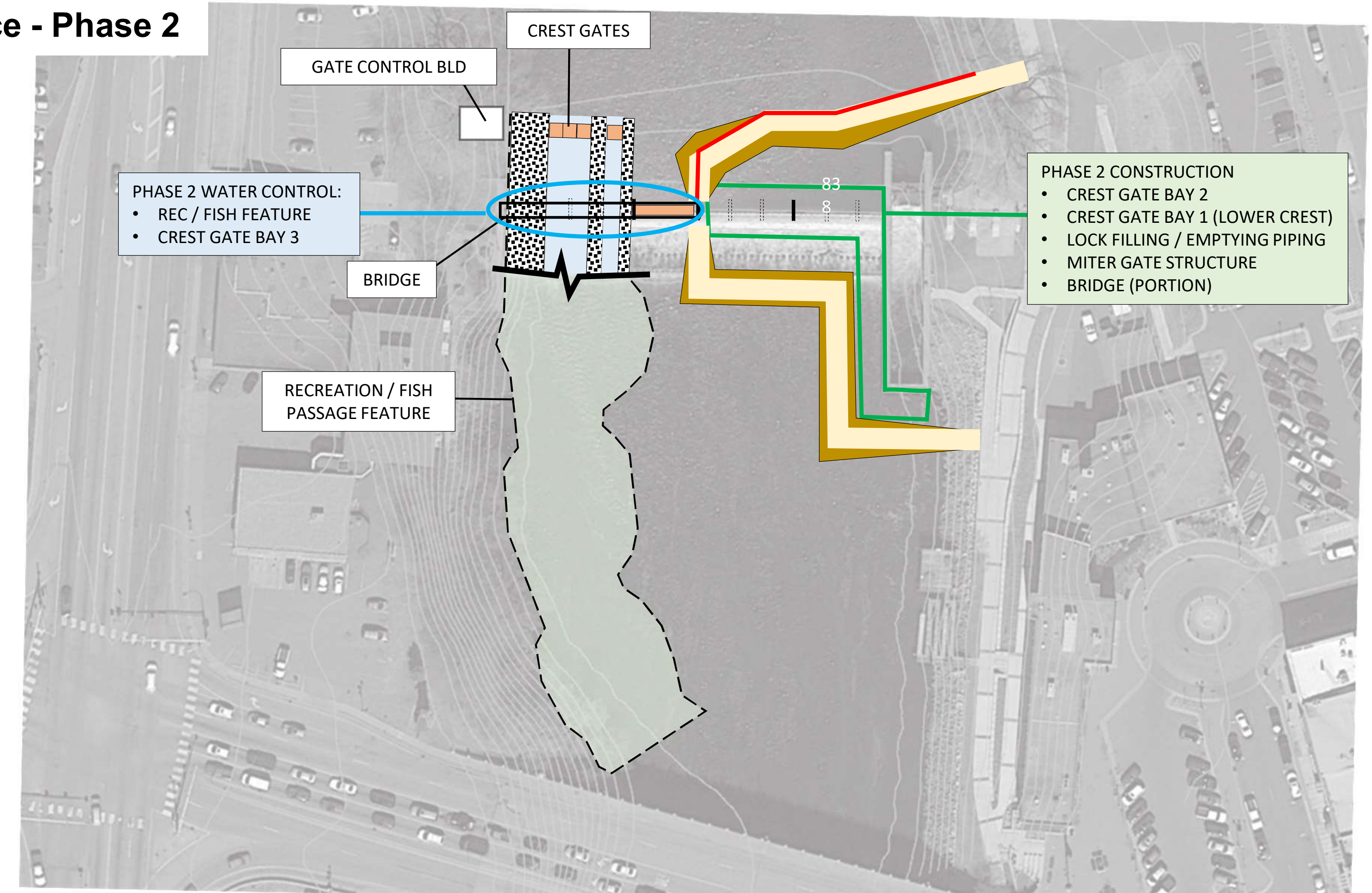


C CONCEPT RECREATION CHANNEL SECTION (NTS)

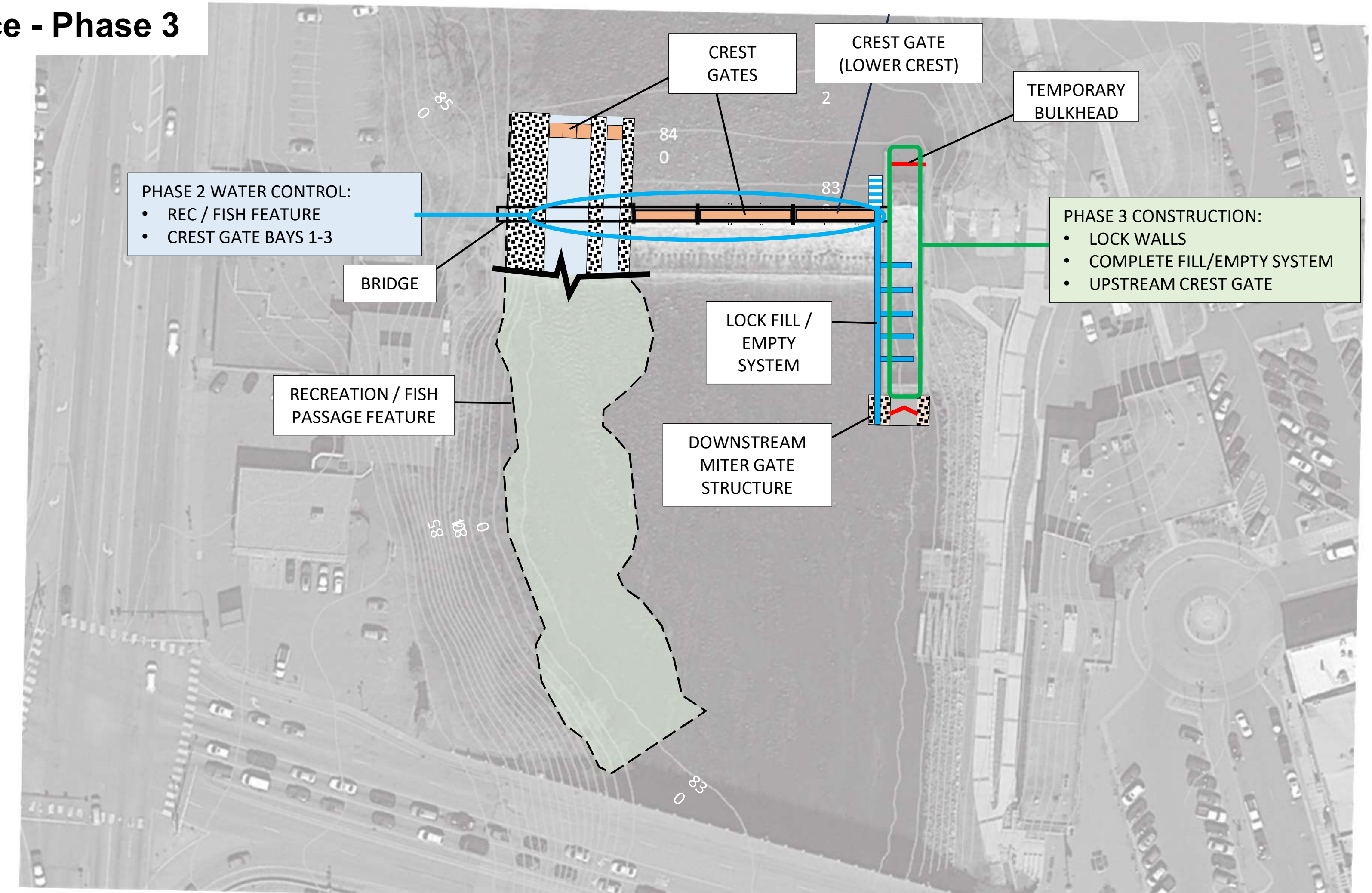
5. Construction Sequence - Phase 1



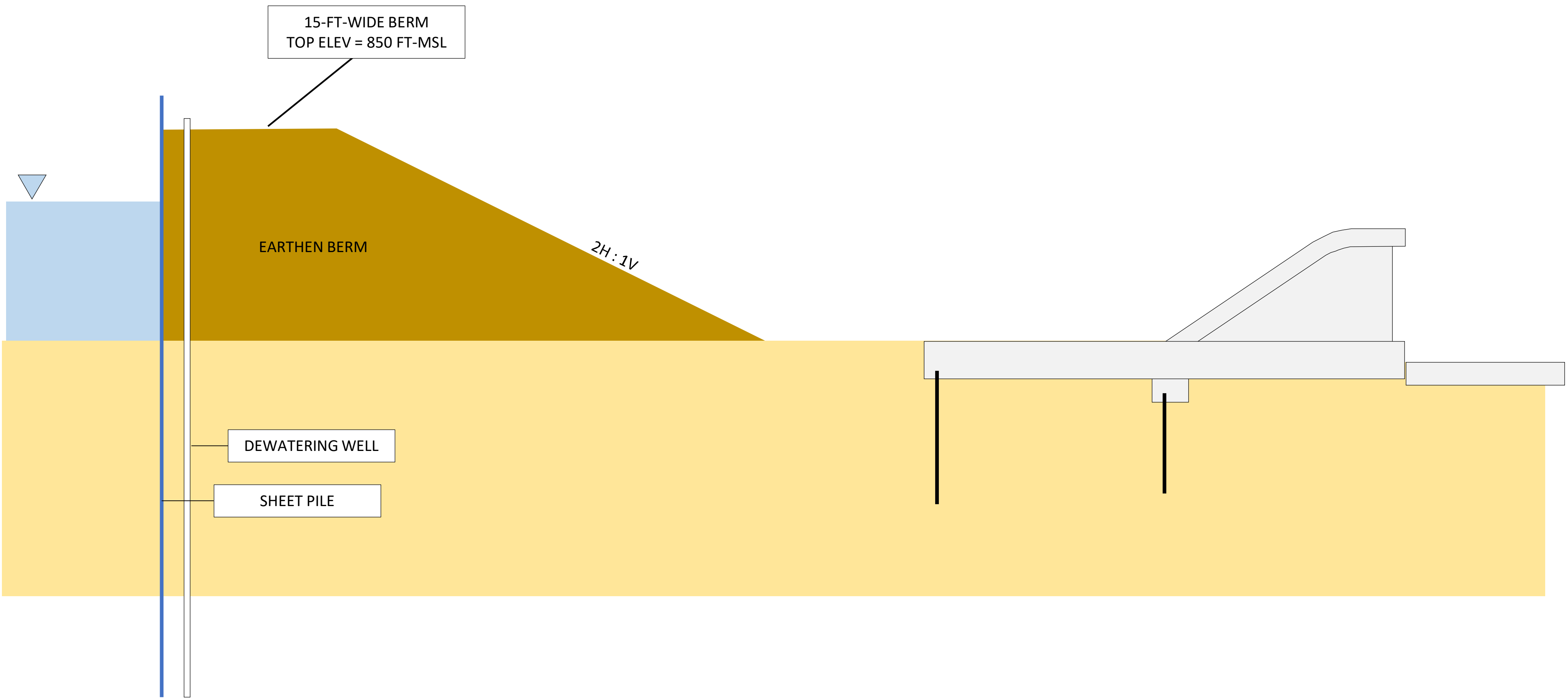
5. Construction Sequence - Phase 2



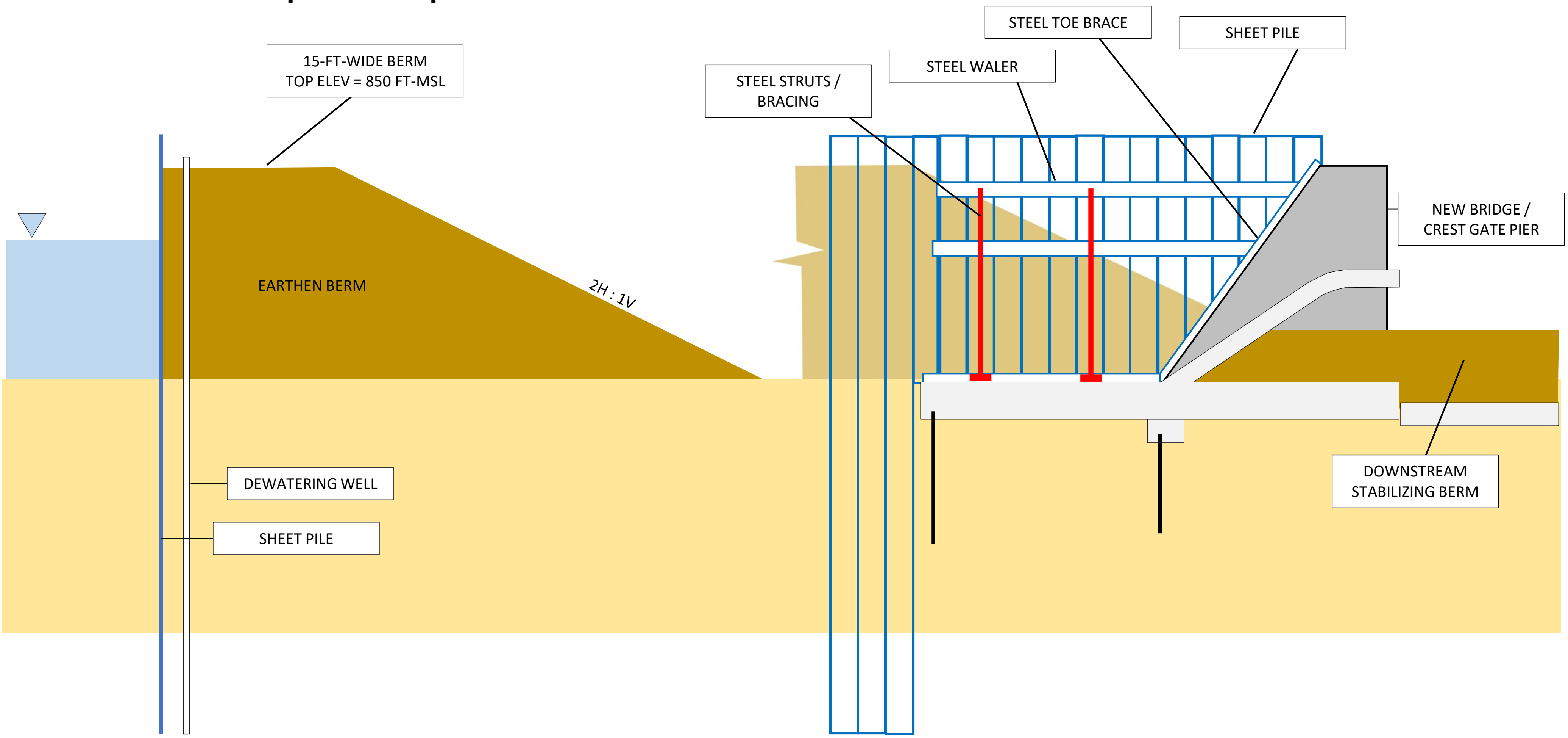
5. Construction Sequence - Phase 3



5. Construction Sequence - Upstream Cofferdam

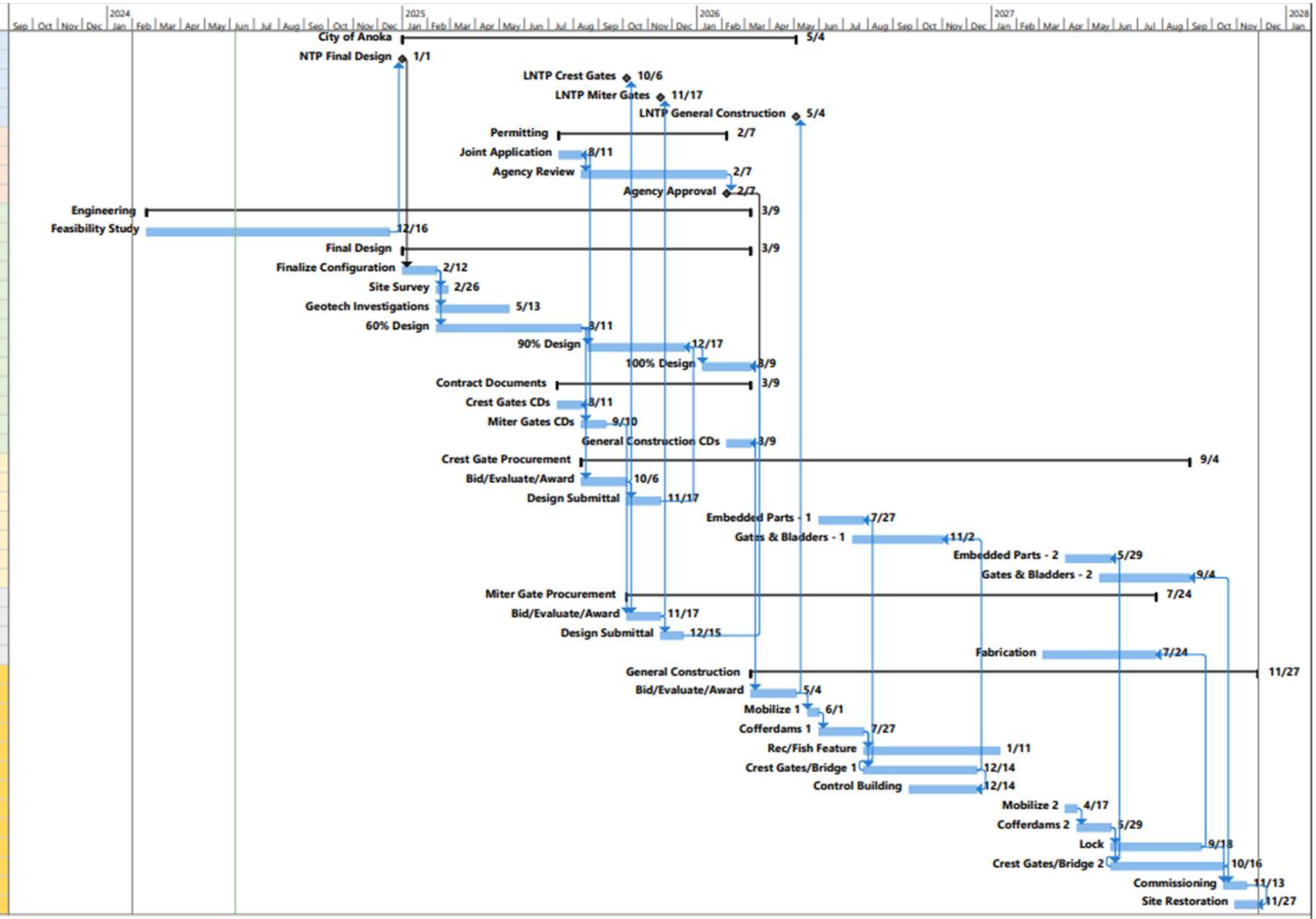


5. Construction Sequence - Upstream Cofferdam



6. Schedule

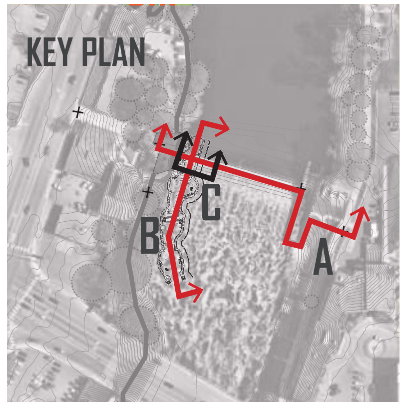
ID	Task Name
1	City of Anoka
2	NTP Final Design
3	LNTP Crest Gates
4	LNTP Miter Gates
5	LNTP General Construction
6	Permitting
7	Joint Application
8	Agency Review
9	Agency Approval
10	Engineering
11	Feasibility Study
12	Final Design
13	Finalize Configuration
14	Site Survey
15	Geotech Investigations
16	60% Design
17	90% Design
18	100% Design
19	Contract Documents
20	Crest Gates CDs
21	Miter Gates CDs
22	General Construction CDs
23	Crest Gate Procurement
24	Bid/Evaluate/Award
25	Design Submittal
26	Embedded Parts - 1
27	Gates & Bladders - 1
28	Embedded Parts - 2
29	Gates & Bladders - 2
30	Miter Gate Procurement
31	Bid/Evaluate/Award
32	Design Submittal
33	Fabrication
34	General Construction
35	Bid/Evaluate/Award
36	Mobilize 1
37	Cofferdams 1
38	Rec/Fish Feature
39	Crest Gates/Bridge 1
40	Control Building
41	Mobilize 2
42	Cofferdams 2
43	Lock
44	Crest Gates/Bridge 2
45	Commissioning
46	Site Restoration

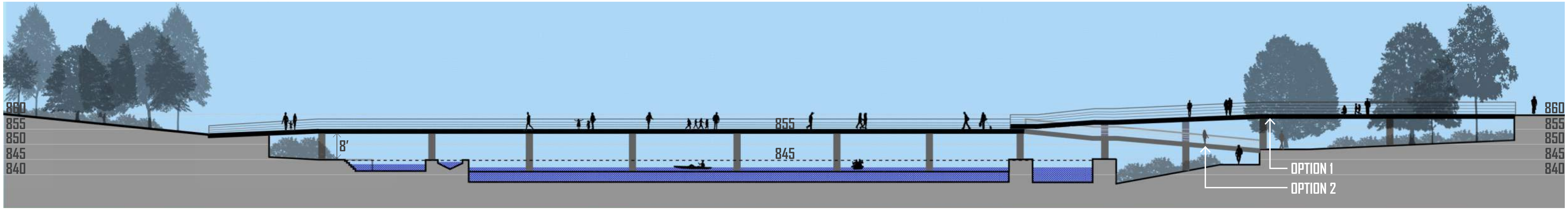


Concept Option 1

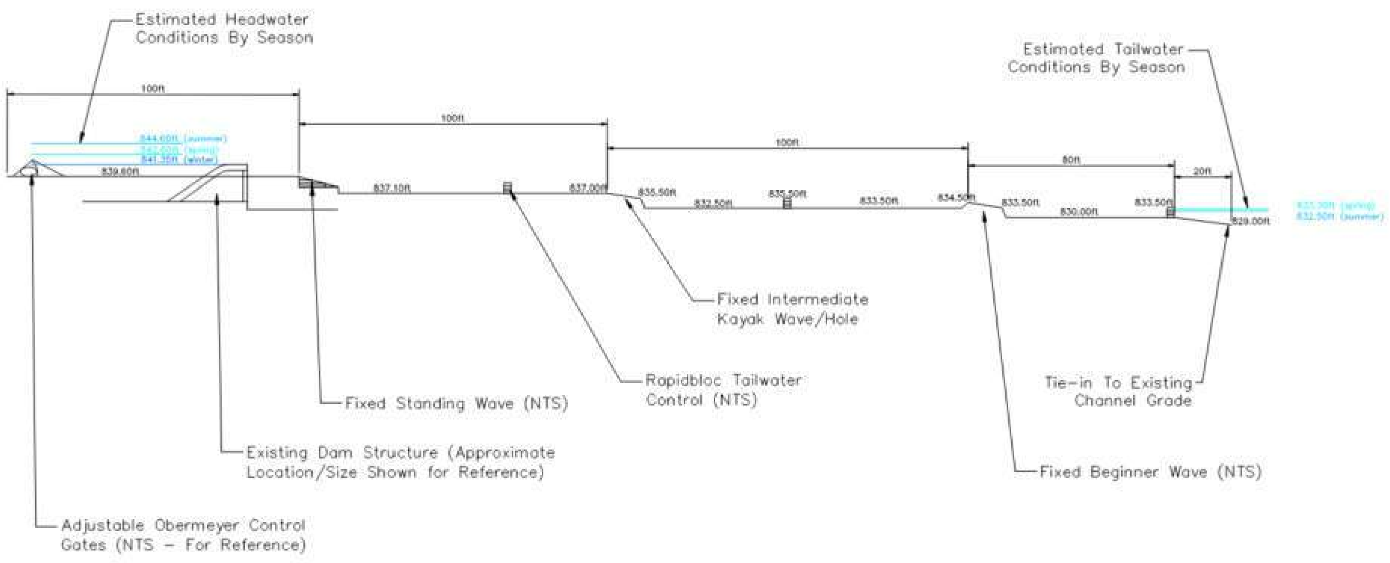
Concept Option 2

Concept Sections

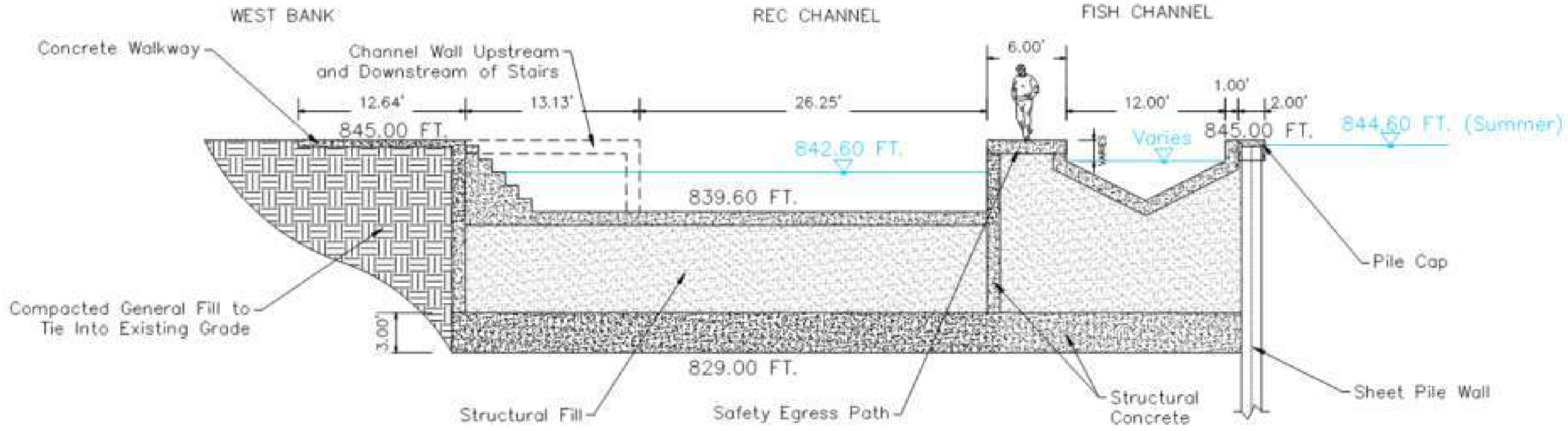




A CONCEPT SECTION ACCESS BRIDGE SECTION



B CONCEPT RECREATION CHANNEL PROFILE (NTS)



C CONCEPT RECREATION CHANNEL SECTION (NTS)

Calibre

Calibre

CITY OF ANOKA
RUM RIVER DAM CONCEPT DEVELOPMENT AND FEASIBILITY ANALYSIS
PMT MEETING #2 – DESIGN CHARRETTE
MARCH 27, 2024 at 10:00 AM

SUMMARY

Lisa LaCasse - City	***Marty Weber - HDR***	***Scott Shipley - Calibre***
Ben Nelson - City	***Dan Kvasnicka - HDR***	***Riley Adams - Calibre***
Jon Holmes - City	***Joe Dvorak - HDR***	***Chris Lord – ACD***
Warren Magnus - City	***Don Pereira - HDR***	***Mike Lynn - DOC***
Dan Coyle - KH	***Corey Geiseke - HDR***	

1) INTRODUCTIONS

2) OVERVIEW OF PROJECT ELEMENTS – ***See PPT slides***

3) REVIEW PRIORITIES

A. Hydropower ***(#4)***
B. Automatic Crest Gate System ***(#1a)***
C. Maintenance Platform / Trail Bridge ***(#1b)***
D. River Recreation / White Water Park / Standing Waves ***(#3)***
E. Boat Passage / Portage System ***(#2)***
F. Fish Passage ***(assumed in any project)***
G. Repairs and Safety Improvements ***(assumed in any project)***
H. Environmental Benefit / Flood Control ***(assumed in any project)***
I. Decorative Lighting ***(assumed in any project)***

4) DISCUSS PROJECT ELEMENTS AND POSSIBLE COMBINATIONS

Hydropower

- ***In its current contract with the Minnesota Municipal Power Agency (MMPA) any generation asset greater than 100 kW developed in the Anoka Municipal Utilities area is required to be contracted by MMPA. Large hydropower option would generate 600kW peak and small hydropower option would generate 60kW peak. <u>ACTION ITEM: Determine if MMPA would make financial contribution to project.</u>***
- ***FERC project development process would take approximately 5 years, regardless of large or small hydropower option. Anoka doesn't qualify as non-jurisdictional with respect to the FERC because the Rum River is a navigable water.***
- ***Large hydropower option would use the majority of the available flow and make whitewater recreation non-viable.***
- ***HDR preliminary results indicate that both large and small hydropower options would have 50 – 60 year payback periods. <u>ACTION ITEM: Determine if State of MN has an interest in subsidizing costs for renewable energy.</u>***
- ***40 kW is the controlling number for net metering solar generated electricity. Below 40 kW is connected downstream of the account meter. Paid at retail rates minus grid charges. Between 40 kW and 100 kW are connected up-stream of the account meter and paid at the MMPA tariff rate minus grid charges. Above 100 kW is contracted with MMPA.***

Whitewater Recreation

- ***Biggest challenge is the approximate 12' drop from the upstream water surface to the downstream water surface of the summer seasonal pools. Powerful standing wave only needs 2-3' drop. Should consider multiple drops and pools in between.***
- ***Considering a 26' wide typical channel section, with around 300 cfs. Slope between pools and next drop feature would be in the 1% - 2% range for typical recreation channel***
- ***2% slope is maximum suggested by L. Aadland for fish passage, and suitable for whitewater recreation, but formal fish passage design criteria will need to be established in preliminary design phase.***
- ***Flow into the spillway would be controlled by adjustable crest gates (similar to rest of the dam) to regulate flow in recreation channel, and allow for maintenance "in the dry", and improved safety/potential for swift water training***
- ***Steamboat Springs CO has 40,000 people that use the recreation channel for tubing. Whitewater recreation can be a significant destination recreation activity and economic impact to the community. ACTION ITEM: Calibre provide economic impact data for a couple past projects in similar size cities.***
- ***Swift water rescue training is a potential use of the recreation channel***
- ***Duke Power example (the "paper clip") had an estimated cost of approximately $6 million, the paper clip could also be rotated 90 degrees to limit in channel impacts.***
- ***Location (east vs. west bank) of the recreationn feature warrants further evaluation. East bank has better access and supporting infrastructure but may impact existing dock/deck facility, and historic mill remnants.***

Boat Passage / Portage System

- ***Preferred concept remains re-purposing of existing Tainter gate bay.***
- ***Clearance at Pleasant St bridge is about 10' at normal pool elevation. Maintenance platform / trail bridge needs to provide at least 10' clearance. Consider routing the trail around the Tainter gate area so that trail crosses at downstream of the lower lock doors. ACTION ITEM: HDR to communicate with USACE, and determine USACE involvement/ownership if a lock is involved.***
- ***If a lock is involved, an exclusionary area for boat traffic will likely be required, which is likely buoys connected with steel cable***

Fish Passage

- ***Based on input from DNR and Anoka County Conservation District (ACCD), fish passage would ideally accommodate a variety of species.***
- ***Fish are generally most active in low-light conditions (generally dawn and dusk), with some species travelling in the fall to wintering habitat and in the spring to spawning habitat. If fish passage is combined with a whitewater park, may need to consider restricting use during these times/seasons.***

Overall

- ***Allocation of water is a significant component in determining which project elements can be combined into viable sets of alternatives.***
- ***There appears to be adequate real estate for all project elements, especially if the larger hydropower facility is off the table .***
- ***Using the existing Tainter gate bay for a feature that cannot double as a spillway would add significant cost to the project.***
- ***Adding additional features on the western half of the channel would likely be more cost effective, and presumably less, if any, SHPO impacts.***

Functionality of the existing downstream dock/platform/access needs to remain unchanged.

5) IDENTIFY 3 – 4 PROJECT ALTERNATIVES

- ***Base Project for All Alternatives: Repairs and safety improvements; environmental benefit / flood control; decorative lighting; fish passage***
- ***Alternative 1 – Automatic crest gate system with maintenance platform and trail***
- ***Alternative 2 – Alternative 1 plus boat passage / portage system***
- ***Alternative 3 – Alternative 2 plus river recreation***
- ***Alternative 4 – Alternative 1 plus large hydropower option***
- ***Alternative 5 – Alternative 3 plus small hydropower option***

6) SUMMARIZE ALTERNATIVES AND NEXT STEPS

- ***ACTION ITEM: Ben / Lisa provide Greg Lee with high level summary and determine what input might be desired at this point regarding hydropower and whitewater recreation, given results of design charrette.***

7) TENTATIVE SCHEDULE

PMT #3 – Select Alternatives for Council Worksession	***June 12, 2024***
Council Worksession – Select Preferred Alternative	July 22, 2024
PMT #4 - Finalize Feasibility Report	November 6, 2024
Council Meeting – Present Feasibility Report	December 9, 2024

Rum River Dam
Concept Development and Feasibility Analysis

PMT Meeting 2 - Design Charrette
March 27, 2024

HDR ANOKA REAL. CLASSIC. Kimley»Horn

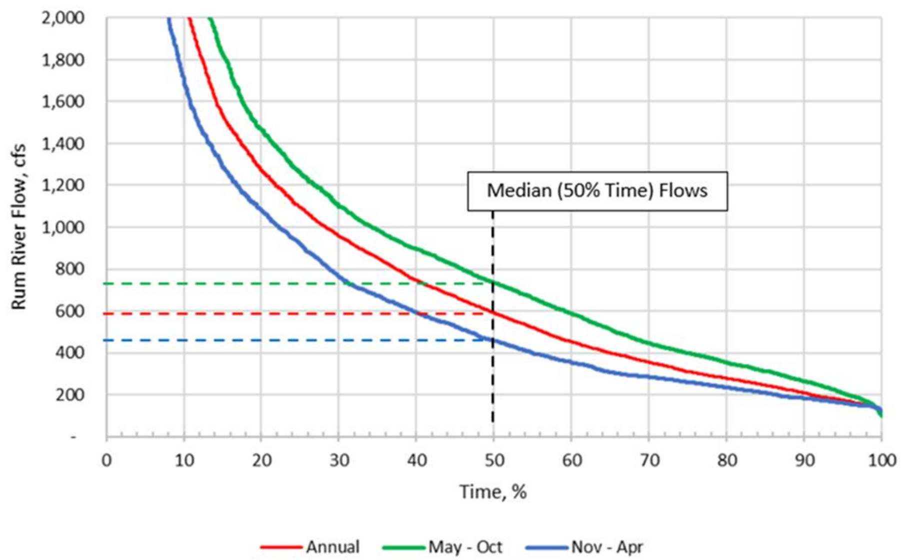
Background Information

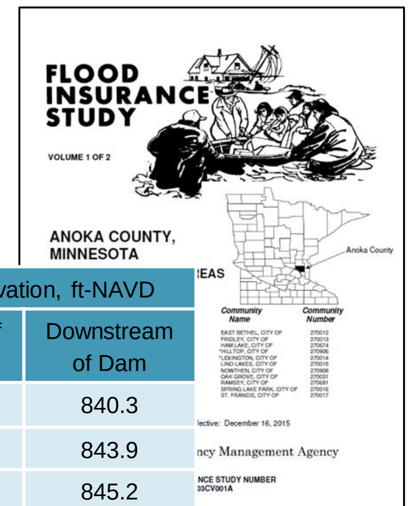
1. Rum River Hydrology
2. Dam Hydraulics
3. Crest Gates
4. Spillway Bridge / Platform
5. Spillway Capacity
6. Boat Passage
7. Hydropower
8. Fish Passage
9. River Surfing
10. Supplemental Channel

1. Rum River Hydrology

USGS Gage 05286000 - Rum River near St. Francis:

Period	River Flow, cfs		
	Min	Max	Mean
Jan	144	1,439	356
Feb	134	2,669	329
Mar	121	6,787	873
Apr	256	10,335	2,061
May	390	8,369	1,835
Jun	190	7,600	1,379
Jul	112	5,810	842
Aug	100	3,833	700
Sep	132	4,712	711
Oct	182	6,348	916
Nov	208	3,778	716
Dec	144	3,031	467
Annual	100	10,335	934





Recurrence Interval, years	Rum River Flow, cfs	Water Elevation, ft-NAVD	
		Upstream of Dam	Downstream of Dam
10	9,080	845.8	840.3
50	13,300	847.1	843.9
100	15,300	848.0	845.2
500	19,800	850.2	848.9

1. Rum River Hydrology - Water Allocation Model

User Operational Period Controls (Periods are Inclusive)

Fish Passage			Minimum Aesthetic Spill			Lock			Recreation			Hydropower		
	On	Off		On	Off		On	Off		On	Off		On	Off
Month	1	12	Month	1	12	Month	5	10	Month	5	10	Month	1	12
Day of Week	1	7	Day of Week	1	7	D.O.W.	5	7	D.O.W.	5	7	D.O.W.	1	7
Time of Day	0:00	23:59	Time of Day	0:00	23:59	T.O.D.	8:00	20:00	T.O.D.	8:00	20:00	T.O.D.	0:00	23:59
Cutoff River Q	3,000	cfs	Cutoff River Q	3,000	cfs	Cutoff River Q	3,000	cfs	Cutoff River Q	3,000	cfs	Cutoff River Q	7,500	cfs
Target Flow	75.0	cfs	Spill	100.0	cfs	Lock Fill Rate/Hr	21.7	cfs	Target Flow	300	cfs			
Min Flow	25.0	cfs				Lockages/Hr	4	OK	Min Flow	100	cfs			
0	< Loop Days		0	< Loop Days		1	< Loop Days		1	< Loop Days		0	< Loop Days	
0	< Loop Months		0	< Loop Months		0	< Loop Months		0	< Loop Months		0	< Loop Months	

FYI: Day of Week Excel Codes

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7

FYI: Feature Codes for Control Panel

FISH SPILL LOCK REC HYDRO

USER INPUTS

User Lock Controls

Depth (ft)	Length (ft)	Width (ft)	Volume (ft3)	Seconds	Q (cfs)
13	75	20	19,500	900	21.7

User Hydropower Controls

Min Q (cfs)	Max Q (cfs)	Efficiency (%)	Headloss (%)	Headwater Elevation
140	700	85%	5%	845

User Priority Controls

On (1) / Off (0)	1	1	1	1	1
Priority	1	2	3	4	5
	FISH	SPILL	LOCK	REC	HYDRO

User Chart Controls

X Axis		Y Axis	
Start Date	1/1/2019	Low Flow	0.0
End Date	12/31/2020	High Flow	1000.0

Update Chart (May take a minute)

Chart →

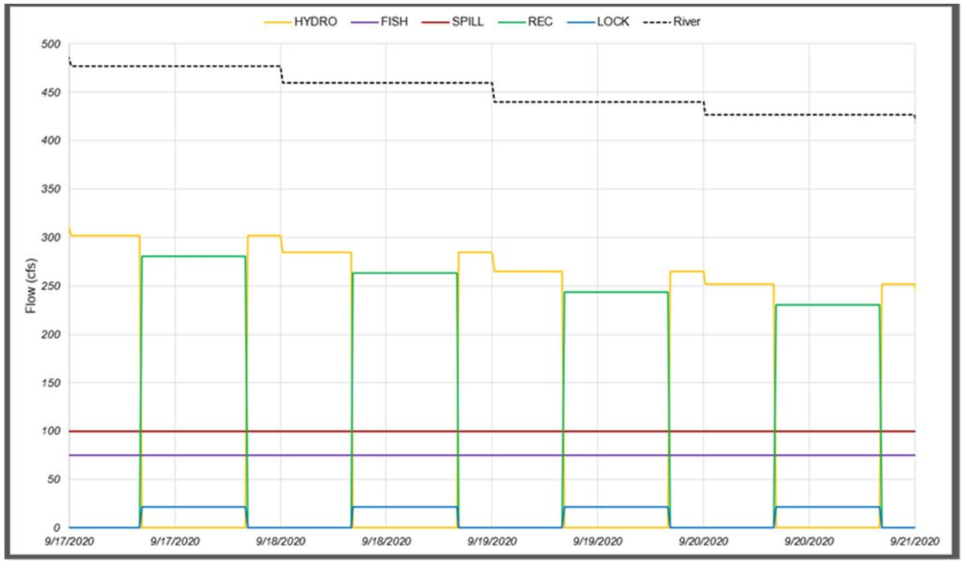
Calculate Workbook

SUMMARY

Priority	Feature	Operating?	Required Flow	Start Month	End Month	Start D.O.W.	End D.O.W.	Start T.O.D.	End T.O.D.	Dry Availability	Ave Availability	Wet Availability
1	FISH	Yes	75.0	24/7	24/7	24/7	24/7	24/7	24/7	100%	97%	84%
2	SPILL	Yes	100.0	1	12	1	7	0:00	23:59	84%	97%	84%
3	LOCK	Yes	21.7	5	10	5	1	8:00	20:00	61%	94%	82%
4	REC	Yes	300.0	5	10	5	1	8:00	20:00	33%	70%	82%
5	HYDRO	Yes	140.0	24/7	24/7	24/7	24/7	24/7	24/7	20%	43%	83%

Note: As POR changes, Percent Availability columns must be extended

1. Rum River Hydrology - Water Allocation Model



Priority	Feature	Flow Range, cfs	Availability Time, %		
			Dry Year	Ave Year	Wet Year
1	Rec	100 - 300	75	93	82
2	Fish	25 - 75	91	93	84
3	Lock	22	24	64	82
4	Spill	100	75	92	84
5	Hydro	140 - 700	20	43	83

Priority	Feature	Flow Range, cfs	Availability Time, %		
			Dry Year	Ave Year	Wet Year
1	Hydro	140 - 700	41	67	91
2	Spill	100	30	34	58
3	Lock	22	8	47	82
4	Fish	25 - 75	9	30	55
5	Rec	100 - 300	0	32	60

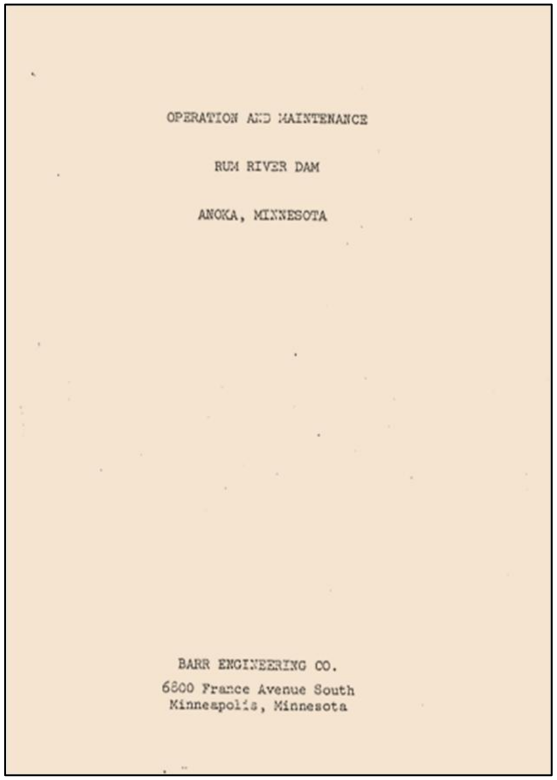
$$\text{Availability} = \sum Q_{actual} / \sum Q_{theoretical}$$

HDR

ANOKA REAL. CLASSIC.

Kimley»Horn

2. Dam Hydraulics

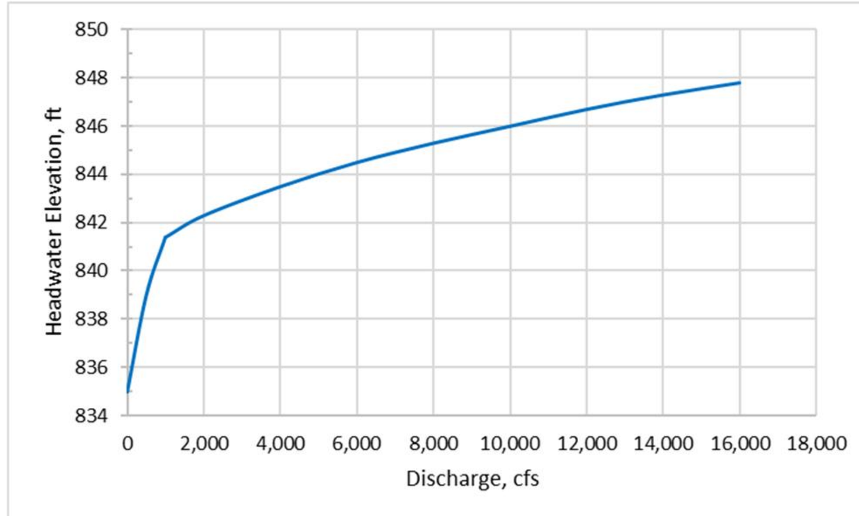


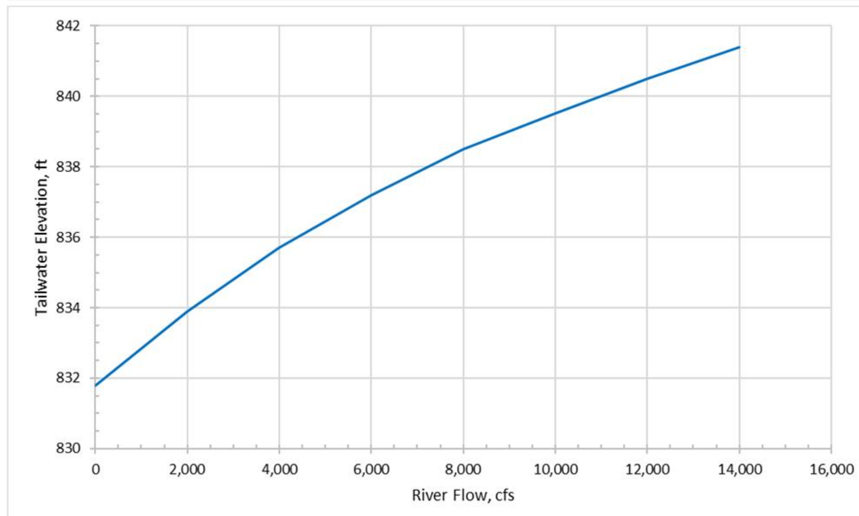
OPERATION AND MAINTENANCE

RUM RIVER DAM

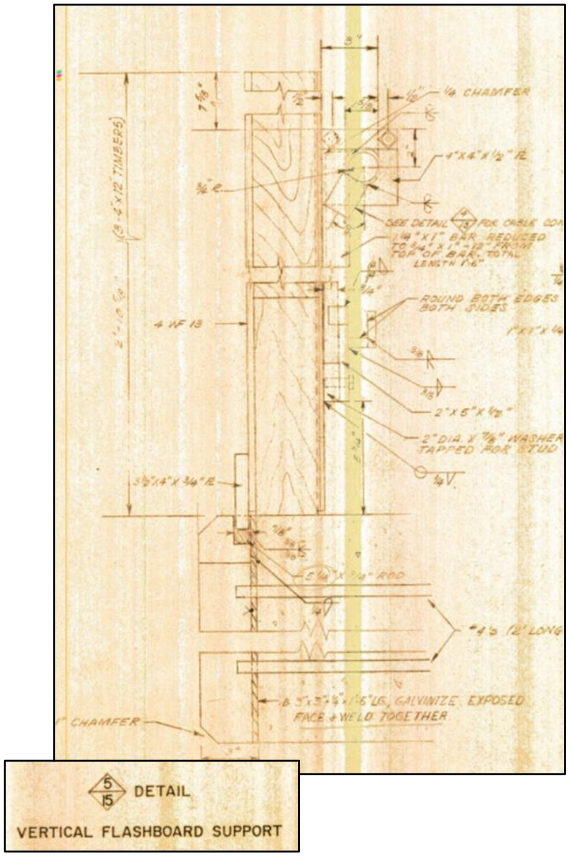
ANOKA, MINNESOTA

BARR ENGINEERING CO.
6800 France Avenue South
Minneapolis, Minnesota





3. Crest Gates



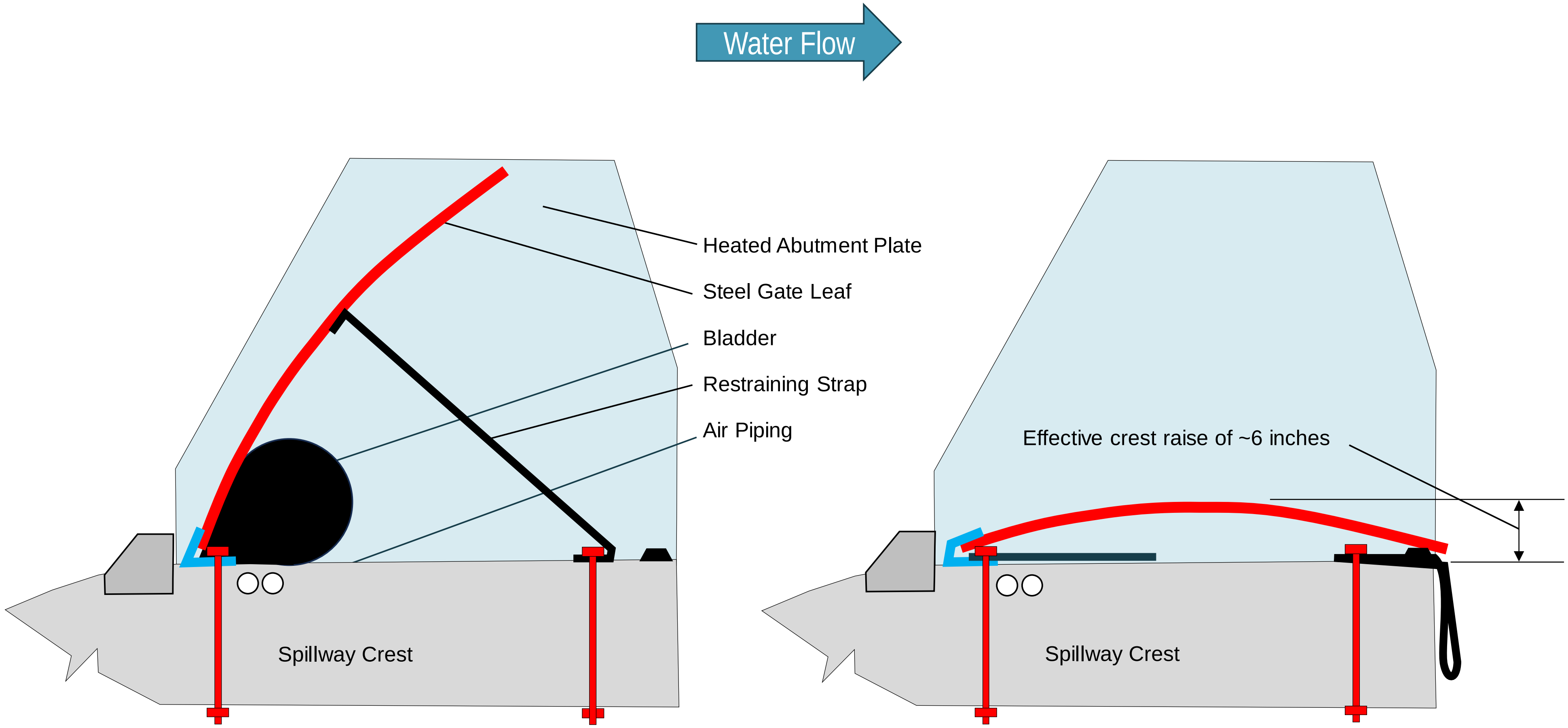
Existing Flashboards

Hydraulic Gates (Coon Rapids Dam)

Pneumatic Gates (Lock & Dam 1)

Obermeyer Gates (St. Cloud)

3. Crest Gates



3. Crest Gates (Obermeyer)

Recent Project 1 (2021)

- Dimensions = 19.0' x 9.5' = 180.5 ft^2
- Cost = $325,000
- Cost = $1800 / sf

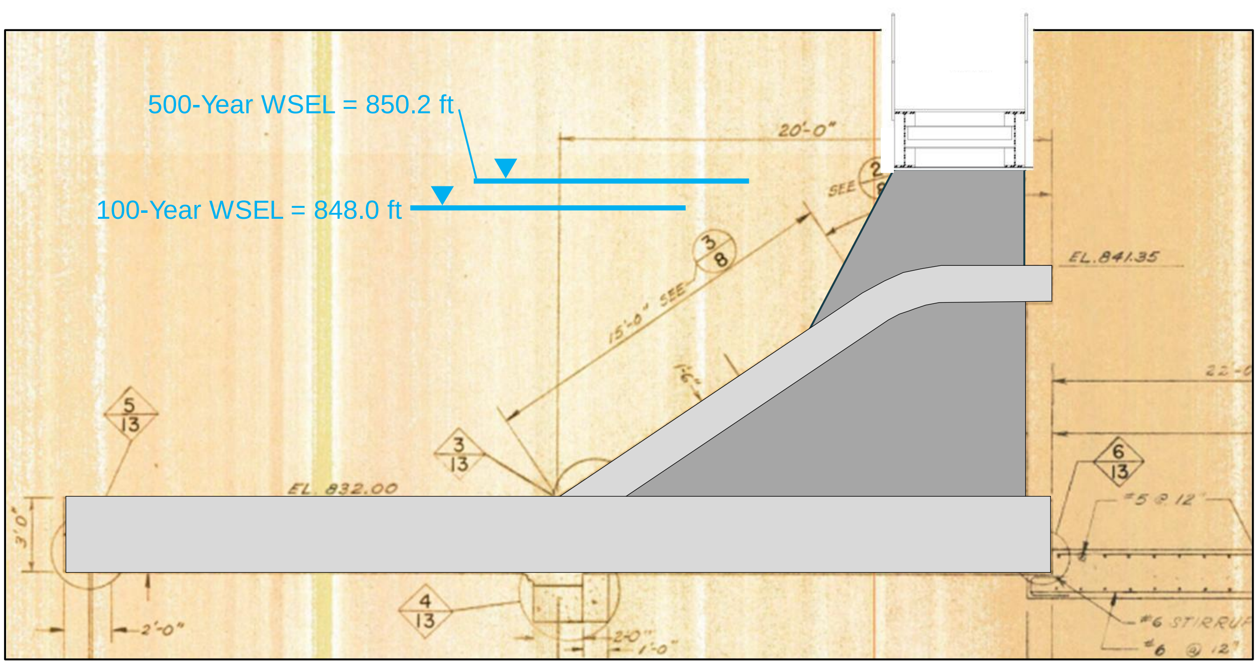
Recent Project 1 (2022)

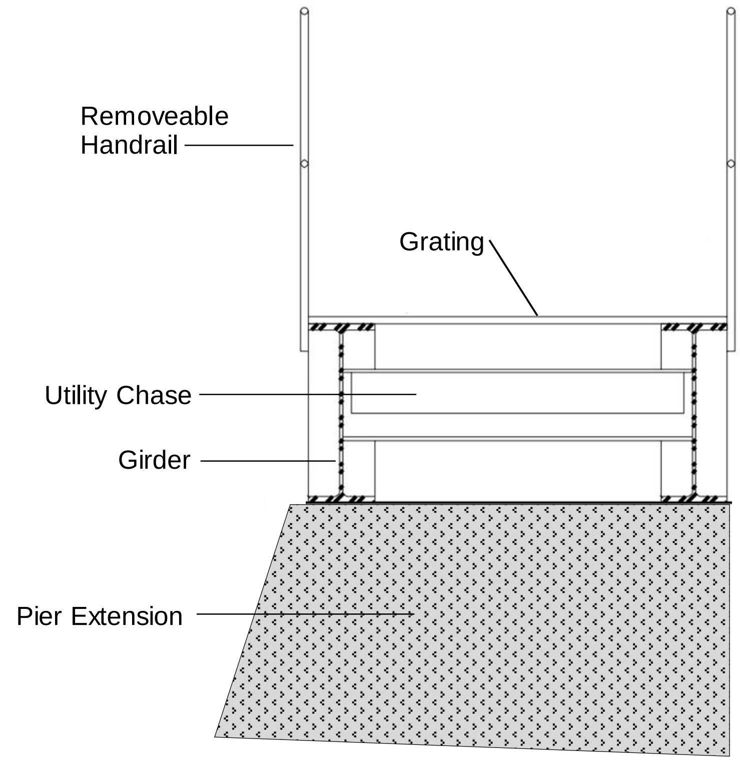
- Dimensions = 48.7' x 6.0' = 292.2 ft^2
- Cost = $453,734
- Cost = $1550 / sf

Rum River Dam:

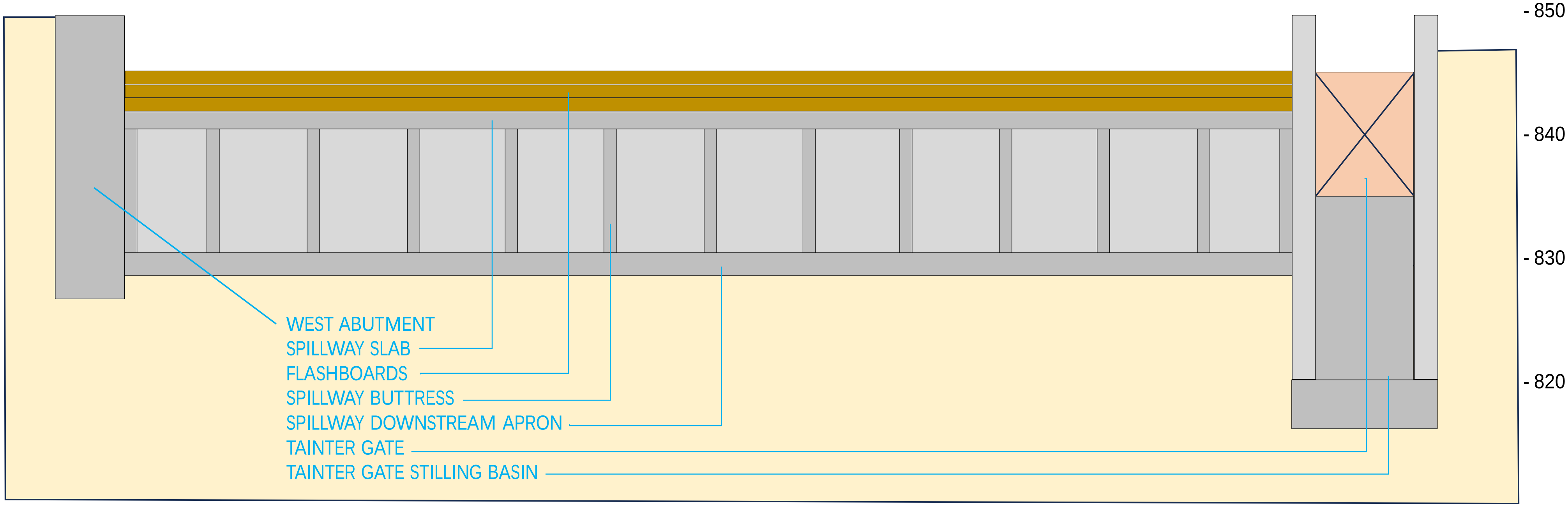
- Dimensions = 236' x 3' = 708 ft^2
- Gate Cost = $1.1 million
- + Control + Civil = ~$2 million

4. Spillway Bridge / Platform

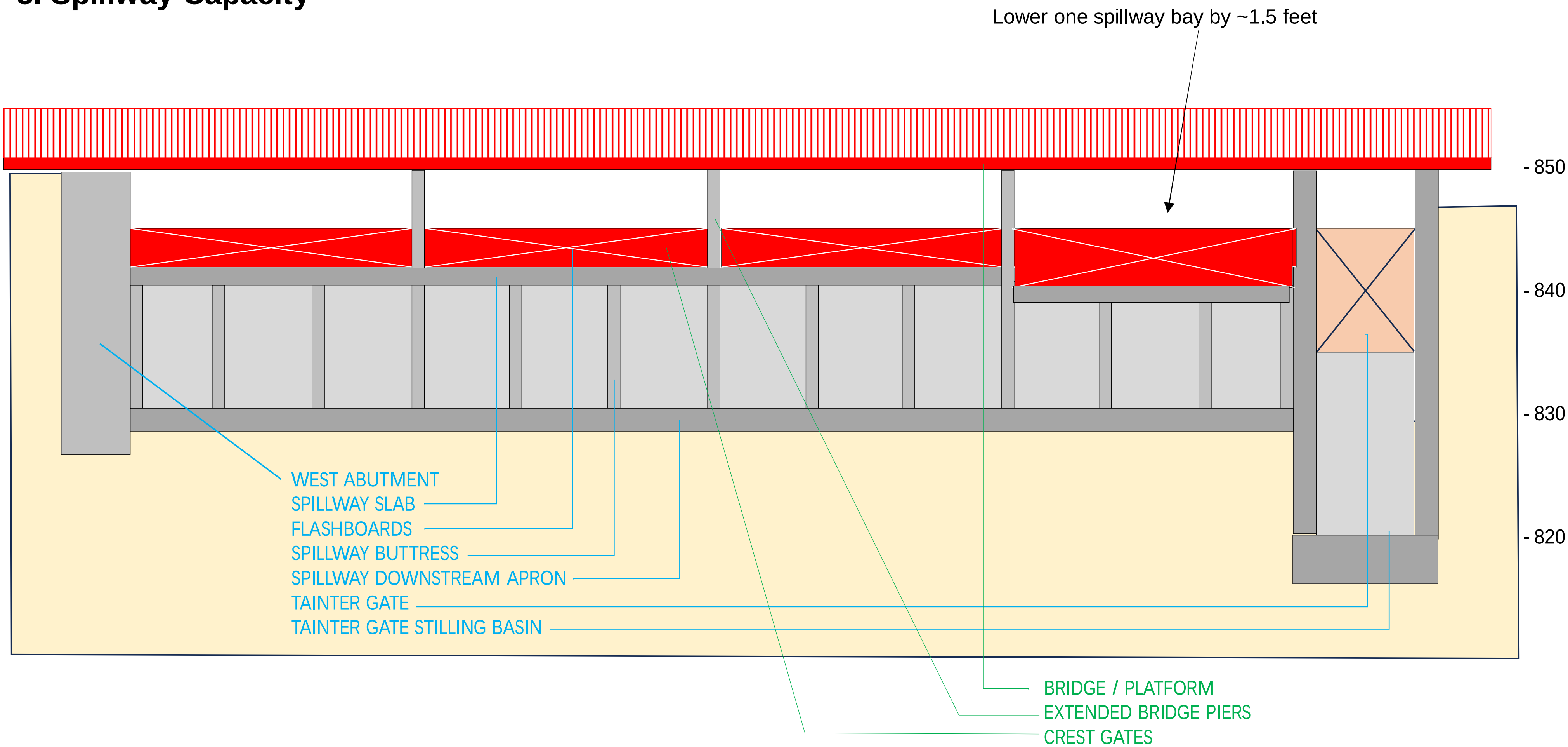




5. Spillway Capacity

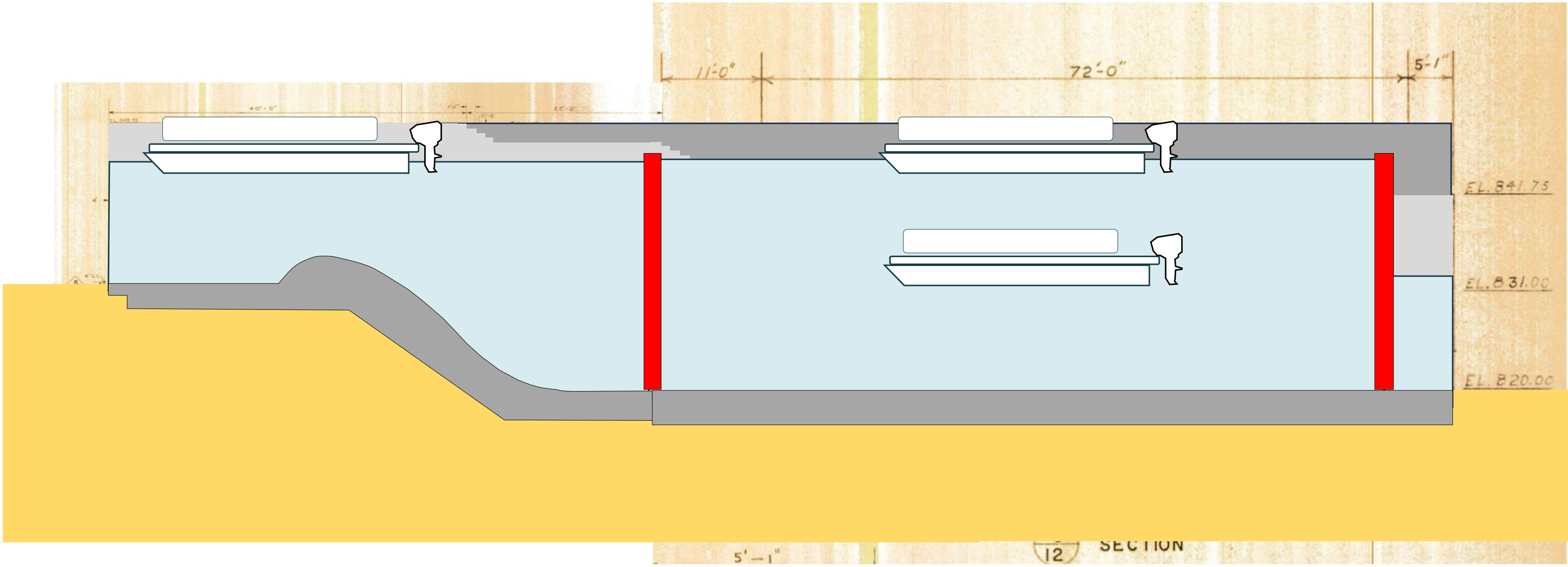


5. Spillway Capacity

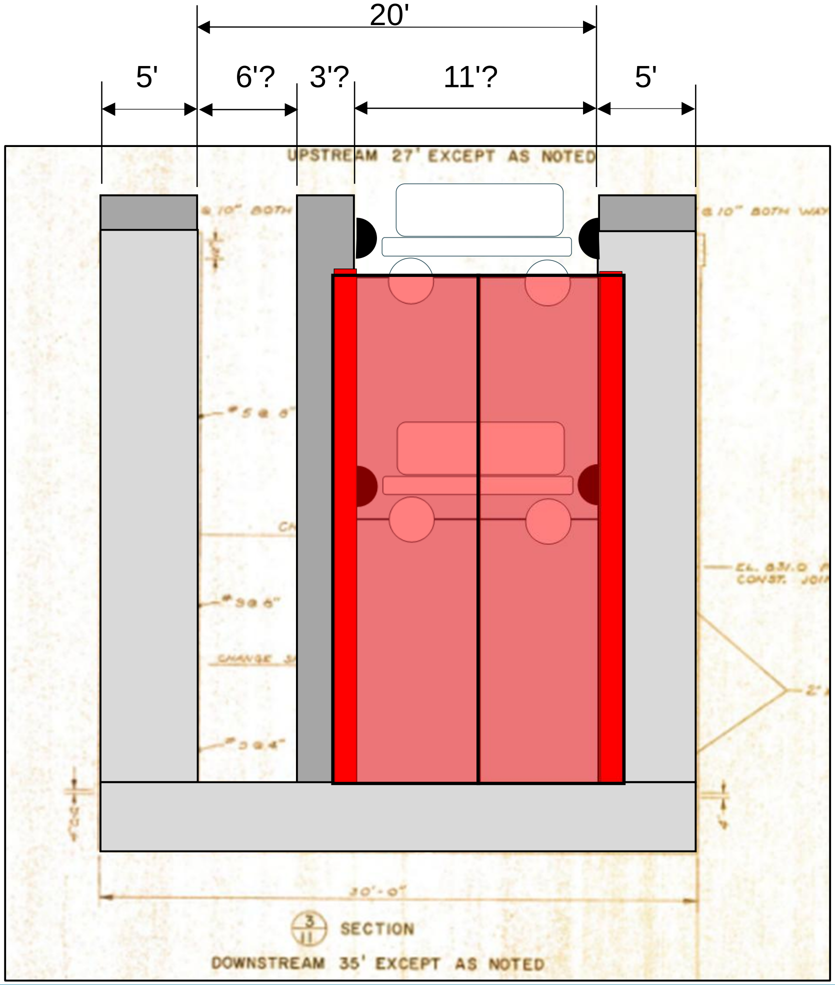


6. Boat Passage

Design Vessel:
- 27 feet long
- 8.5 feet wide
- 2.0 feet draft



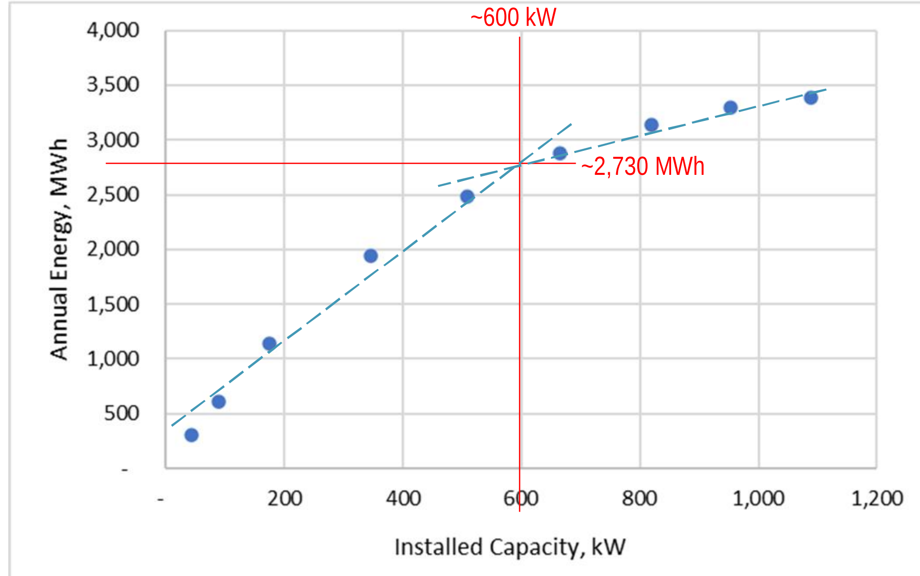
6. Boat Passage

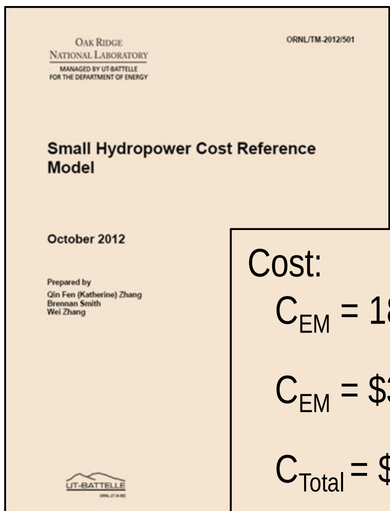


7. Hydropower

Study	Capacity (kW)	Annual Energy (MWh)	Capital Cost		
			Study Year ($MM)	2024 [a] ($MM)	2024 ($/kW)
SAFHL 1981	650	2,830	$1.7	$6.5	$10,100
SAFHL 1982	565	2,320	$2.0	$6.8	$12,100
	552	2,440	$2.1	$7.2	$13,000
	603	2,570	$2.1	$7.2	$11,900
Stanley 2002	550	2,290	$3.2	$7.1	$12,800

[a] Costs escalated to 4th quarter 2024 based on USACE construction cost index.




Oak Ridge National Laboratory
Managed by UT-Battelle for the Department of Energy

ORNL/TM-2012/501

Small Hydropower Cost Reference Model

October 2012

Prepared by
Qin Fen (Katherine) Zhang
Brennan Smith
Wei Zhang

Cost:

$C_{EM} = 18{,}872 \times H^{-0.546} \times P^{0.761}$

C_{EM} = \$3.0 million

C_{Total} = \$6.0 million

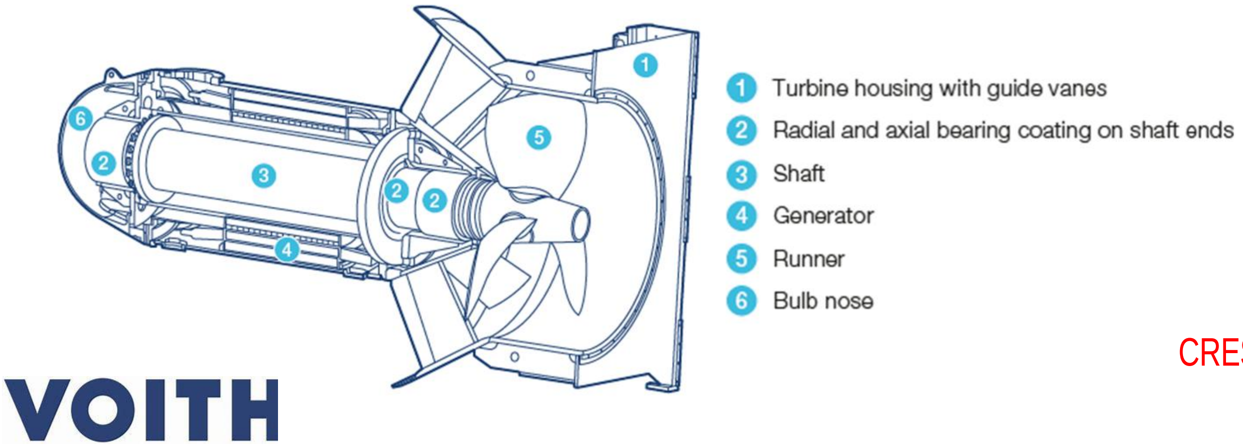
Annual Revenue:

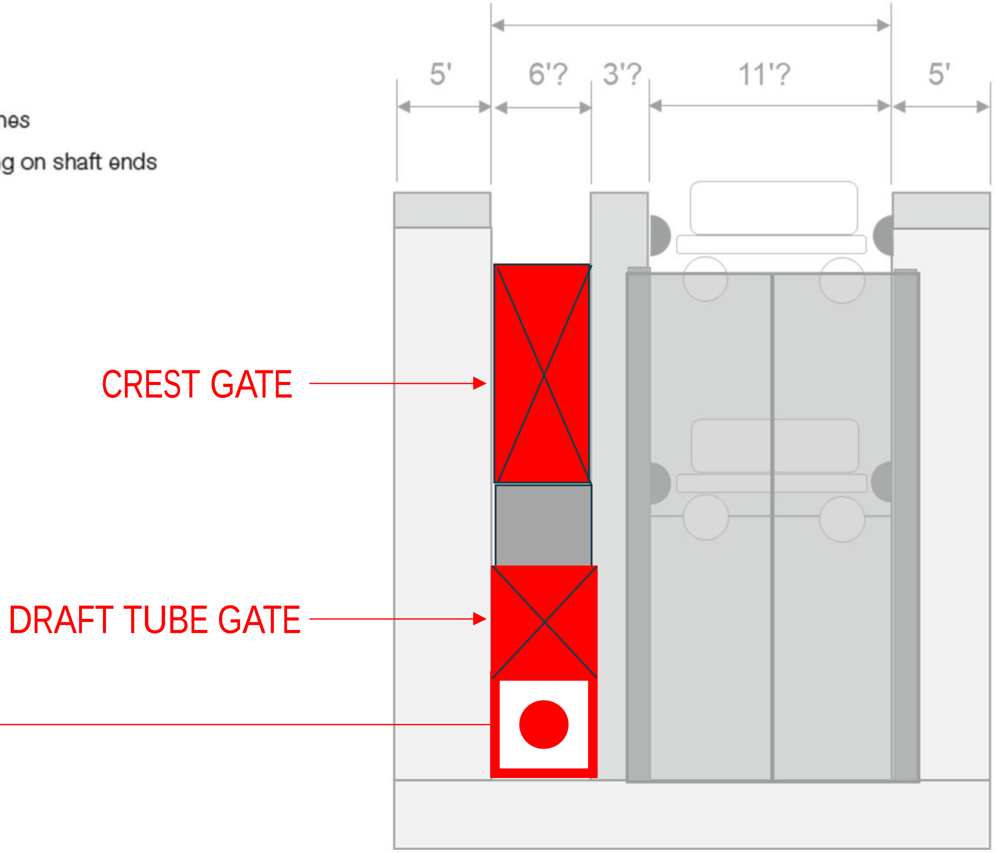
R = 2,730 MWh x \$40/MWh = \$109,200

Simplified Payback Period:

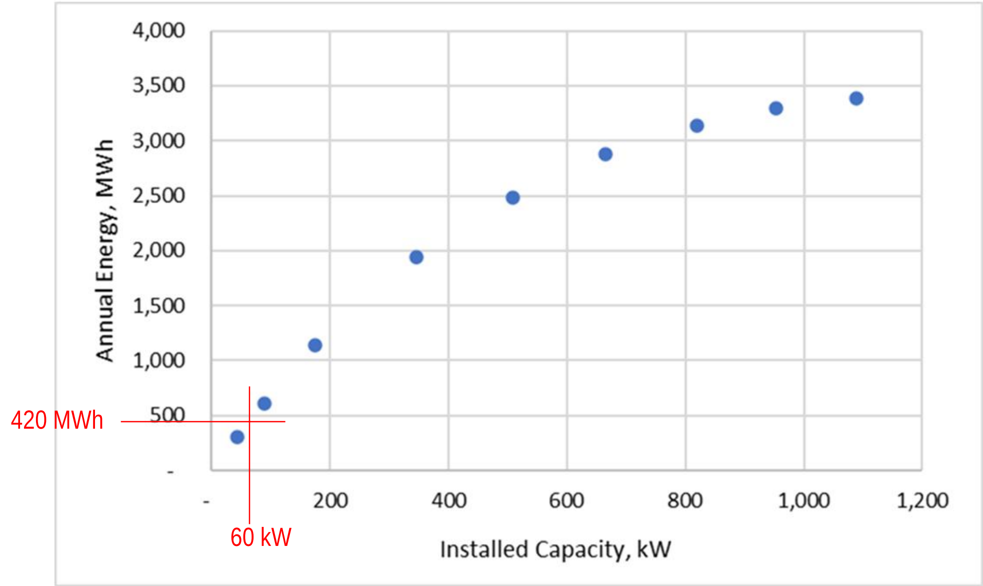
P = \$6,000,000 ÷ \$109,200 ~ 55 years

7. Hydropower





7. Hydropower



Cost:
C_{EM} = $750,000 (Voith)

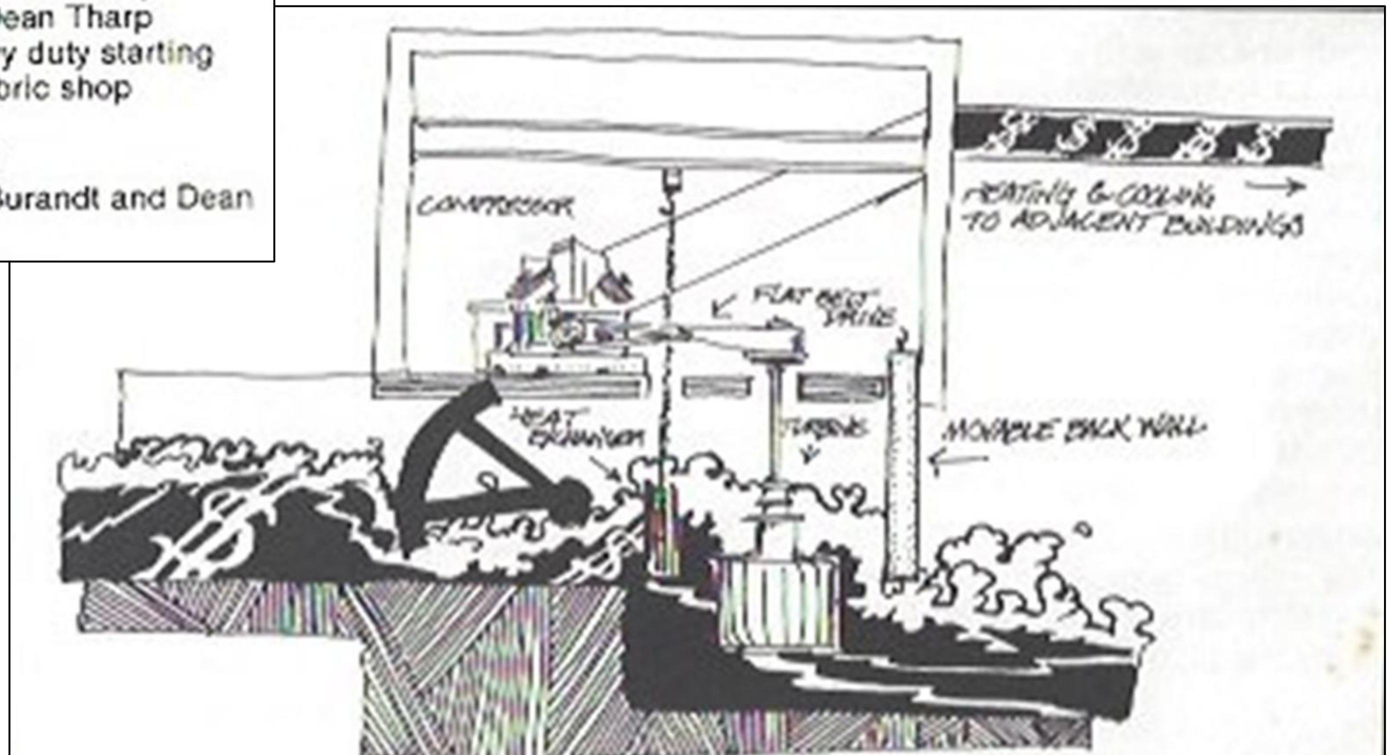
C_{Total} = $1.0 million (est.)

Annual Revenue:
R = 420 MWh x $40/MWh ~ $16,800

Simplified Payback Period:
P = $1,000,000 ÷ $14,600 ~ 60 years

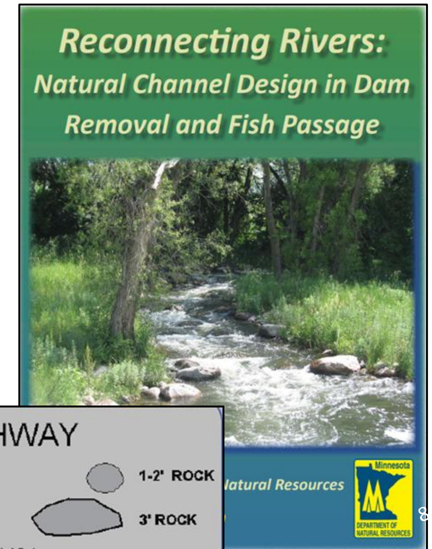
7. Hydropower

A Water Powered Heat Pump
Cob Burandt and Dean Tharp
Manufacturer, heavy duty starting units; co-owner, fabric shop
Stillwater
Honorable Mention



Dam with Heat Pump

8. Fish Passage



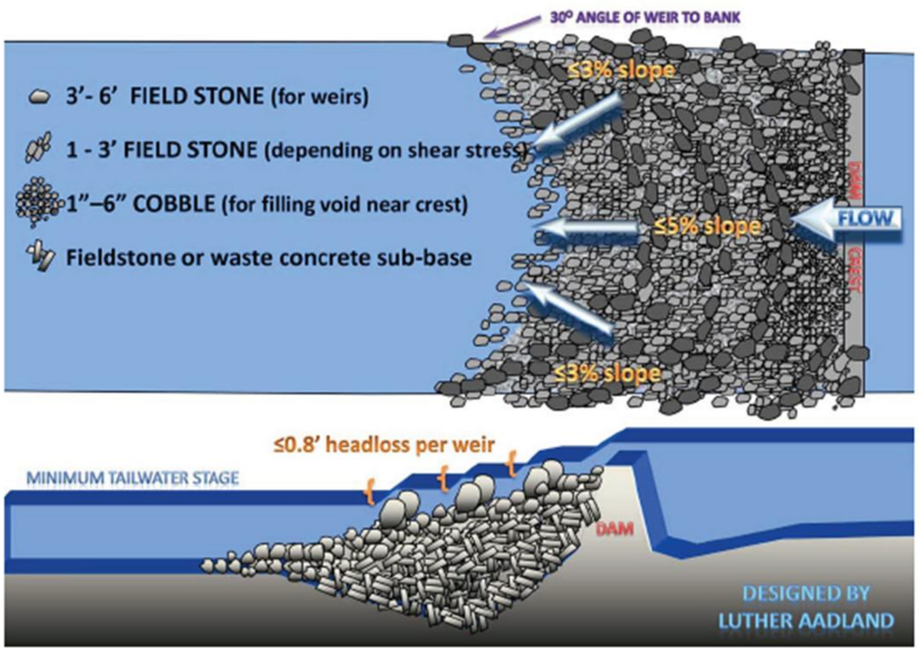
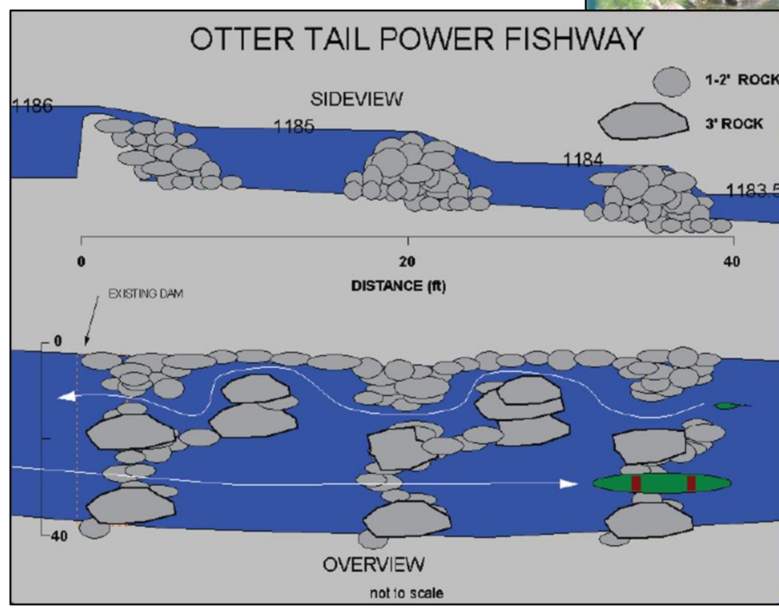
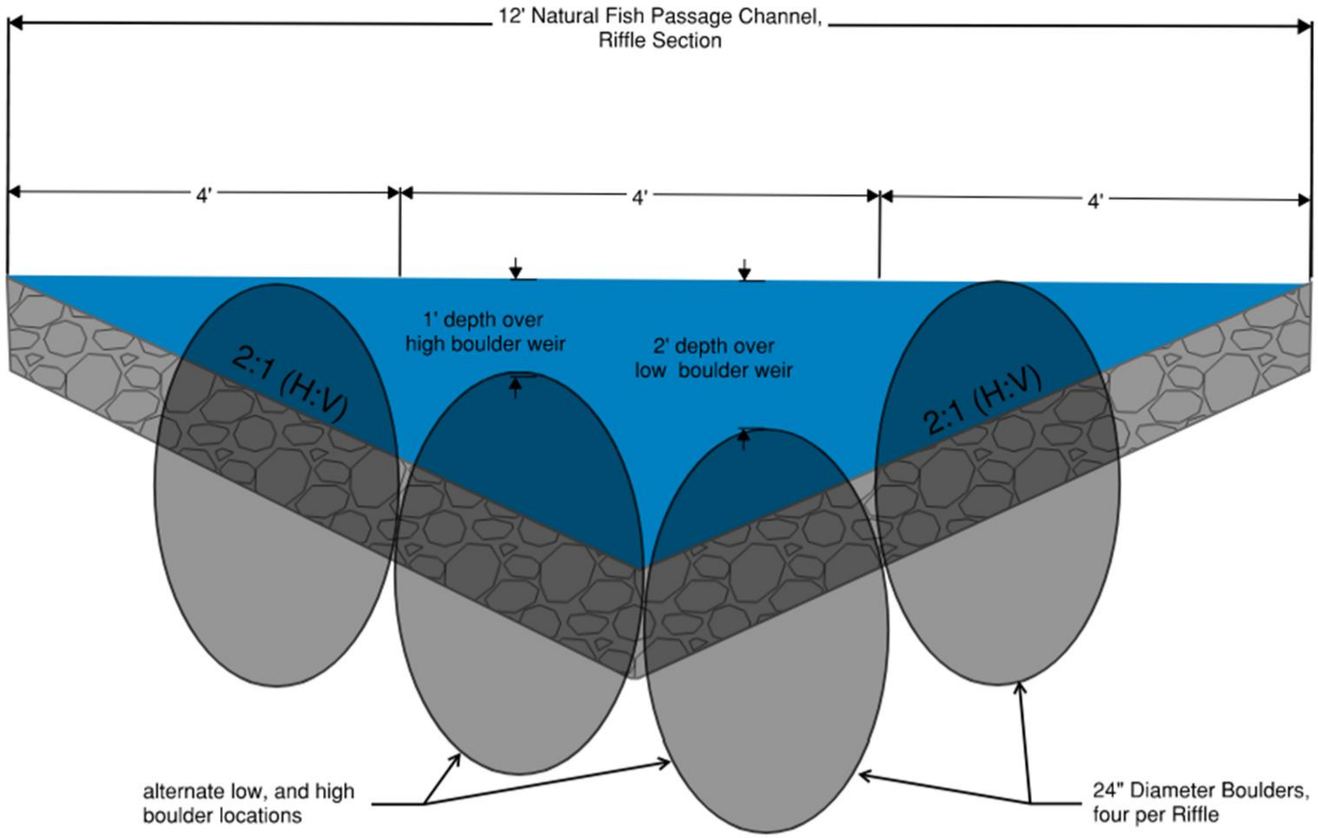


Figure 54. Generalized conceptual design of the Rock Arch Rapids developed by the author.

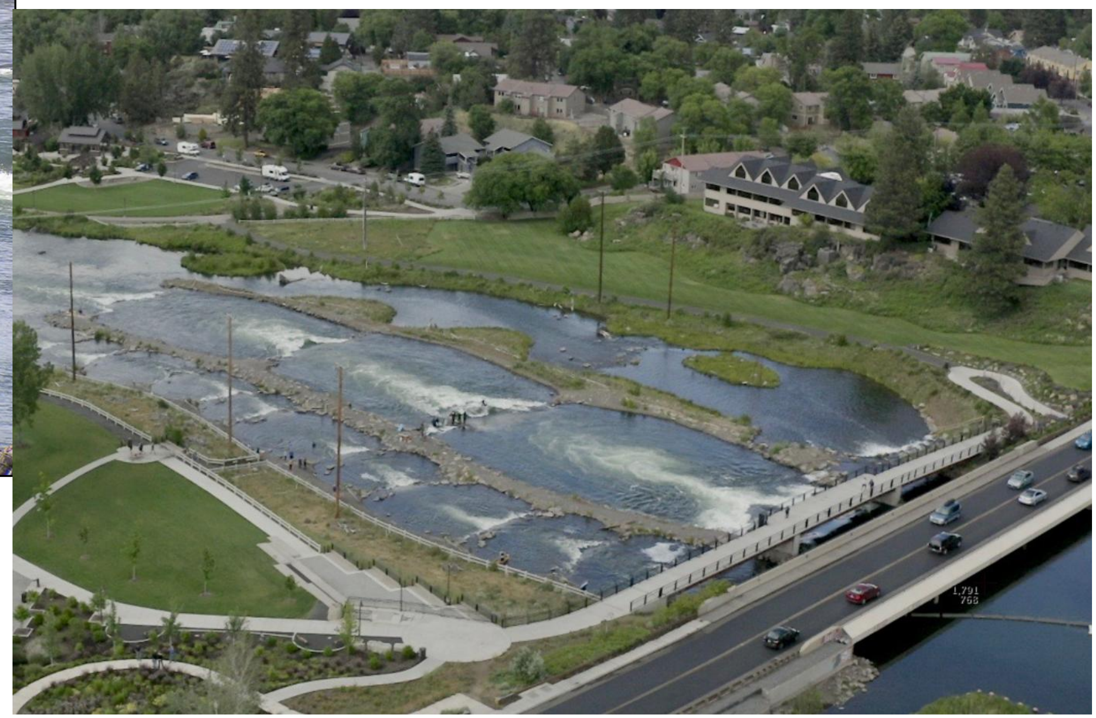


8. Fish Passage

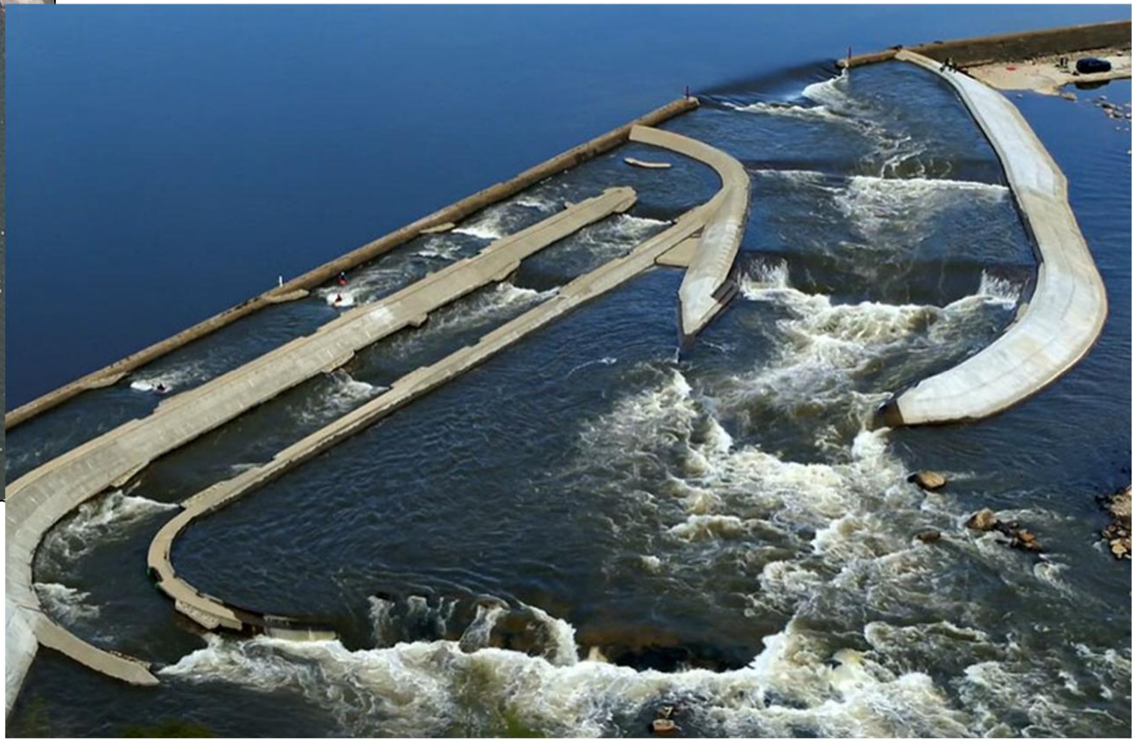


8. Fish Passage

9. River Surfing



9. River Surfing



9. River Surfing

9. River Surfing

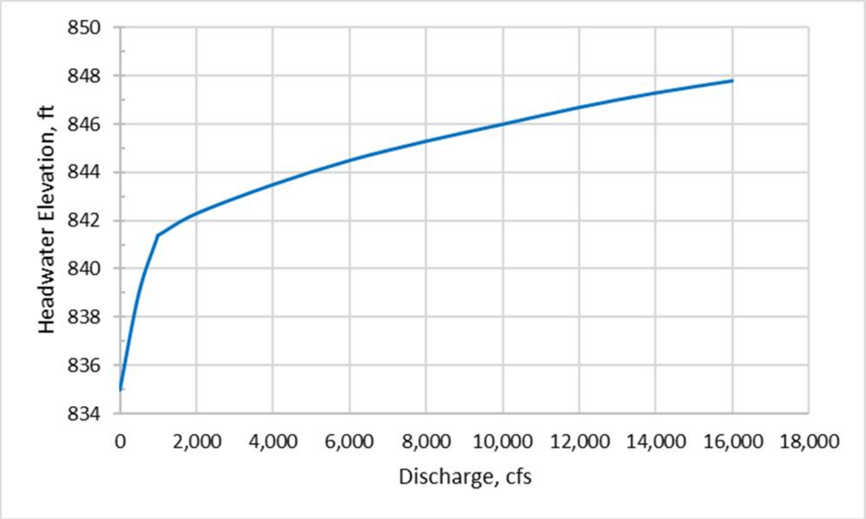
9. River Surfing

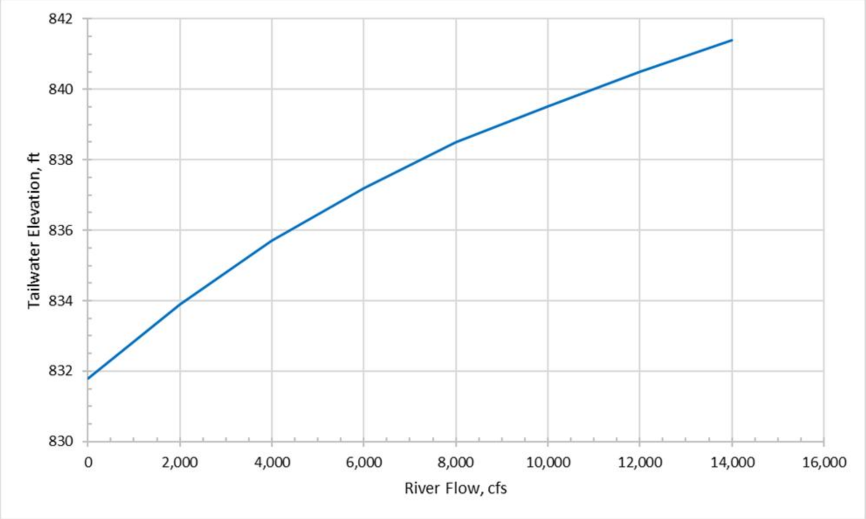
USGS Gage 05286000 - Rum River near St. Francis:

Period	River Flow, cfs		
	Min	Max	Mean
Jan	144	1,439	356
Feb	134	2,669	329
Mar	121	6,787	873
Apr	256	10,335	2,061
May	390	8,369	1,835
Jun	190	7,600	1,379
Jul	112	5,810	842
Aug	100	3,833	700
Sep	132	4,712	711
Oct	182	6,348	916
Nov	208	3,778	716
Dec	144	3,031	467
Annual	100	10,335	934

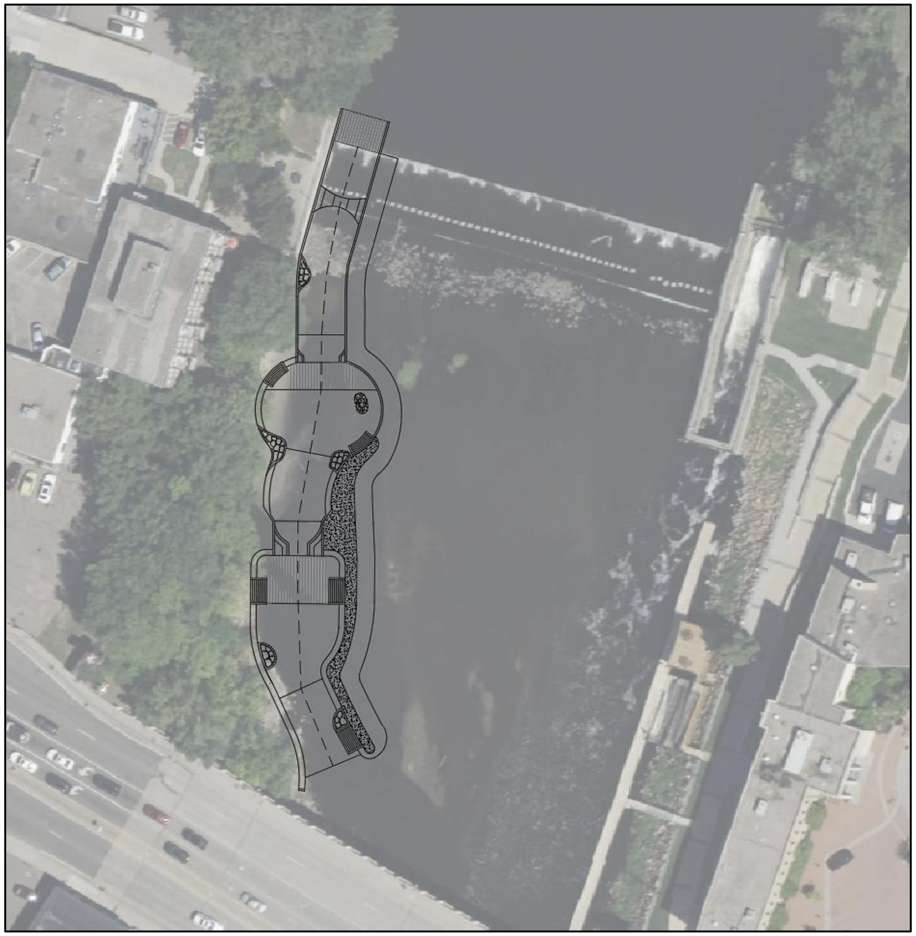
26ft wide channel (8m) – typical section, 300cfs target flow (excluding fish passage)

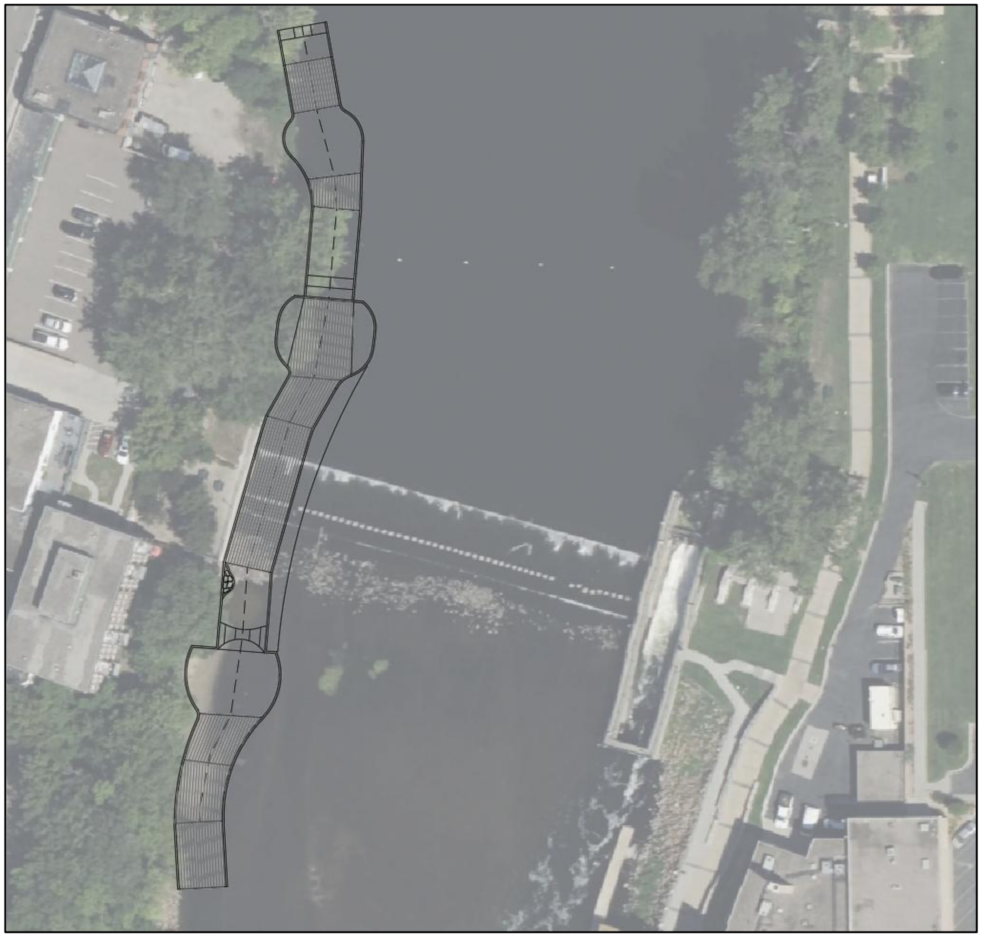
Existing conditions: 11.35ft grade change from crest of dam to bottom of pool, headwater-tailwater surface varies.





9. River Surfing



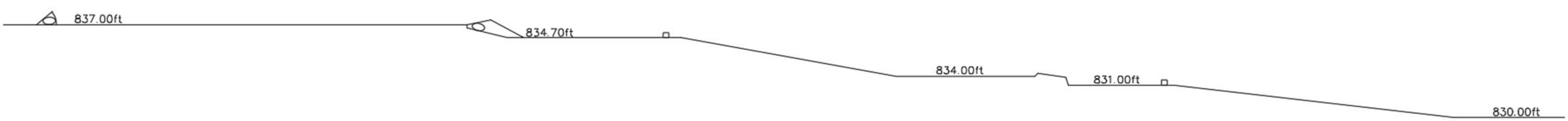


9. River Surfing

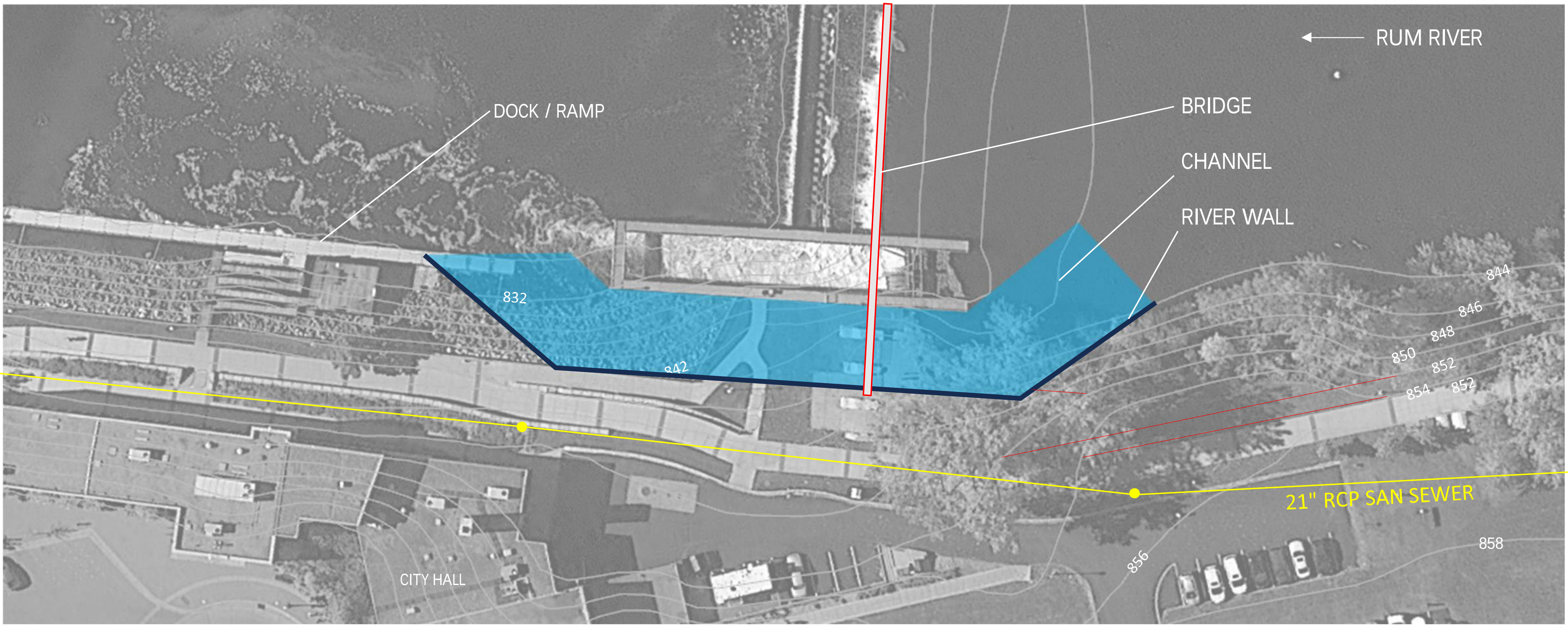
2000cfs – Headwater EL +/– 842.50
– Tailwater EL +/– 834.00

1000cfs – Headwater EL +/– 841.50
– Tailwater EL +/– 833.00

500cfs – Headwater EL +/– 838.00
– Tailwater EL +/– 832.10



10. Supplemental Channel



HDR ANOKA REAL. CLASSIC. Kimley»Horn

SUPPLEMENTAL SLIDES

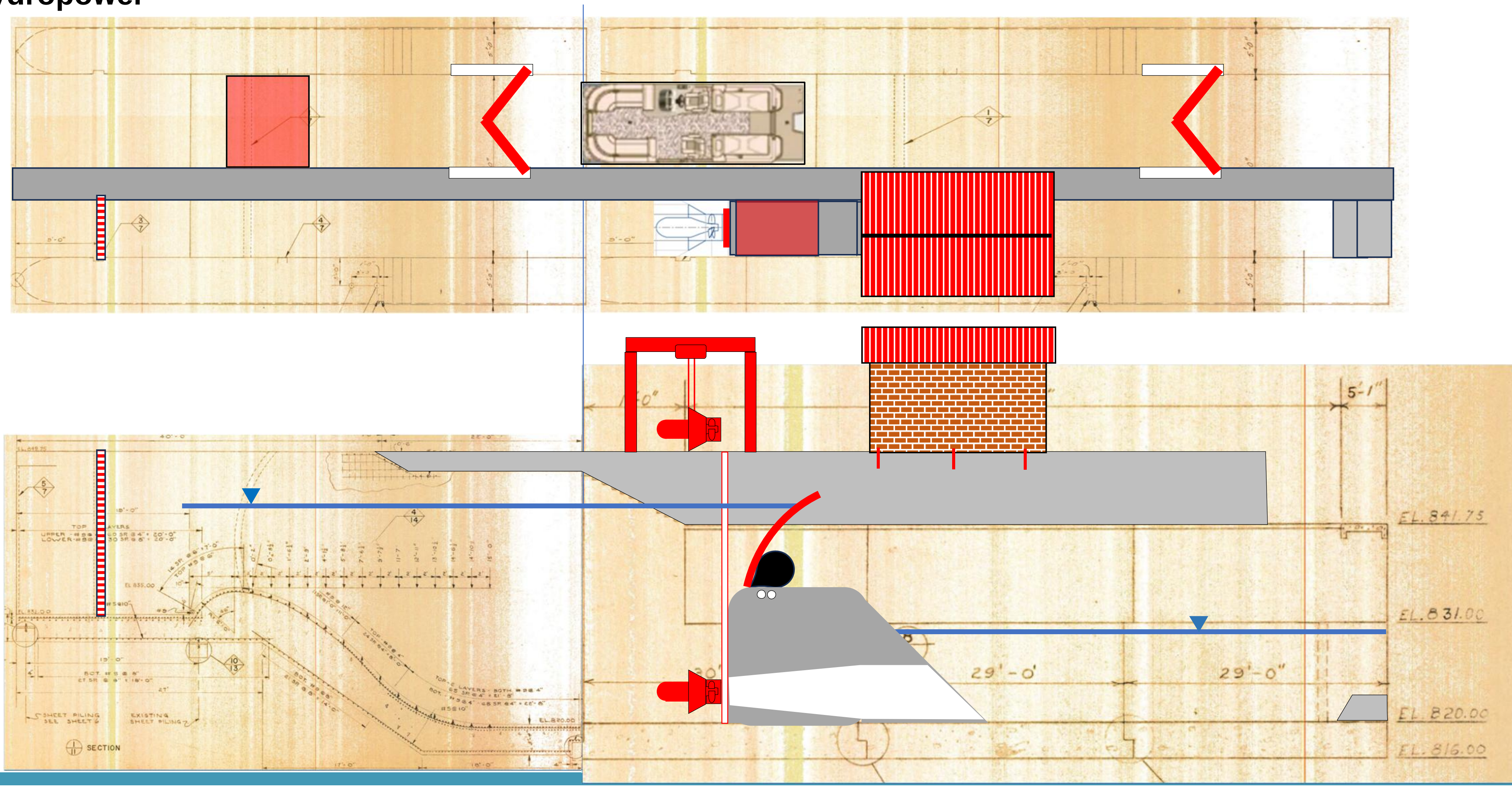
Funding Sources

MINNESOTA'S LEGACY
TRACK THE PROGRESS

Outdoor Heritage Fund

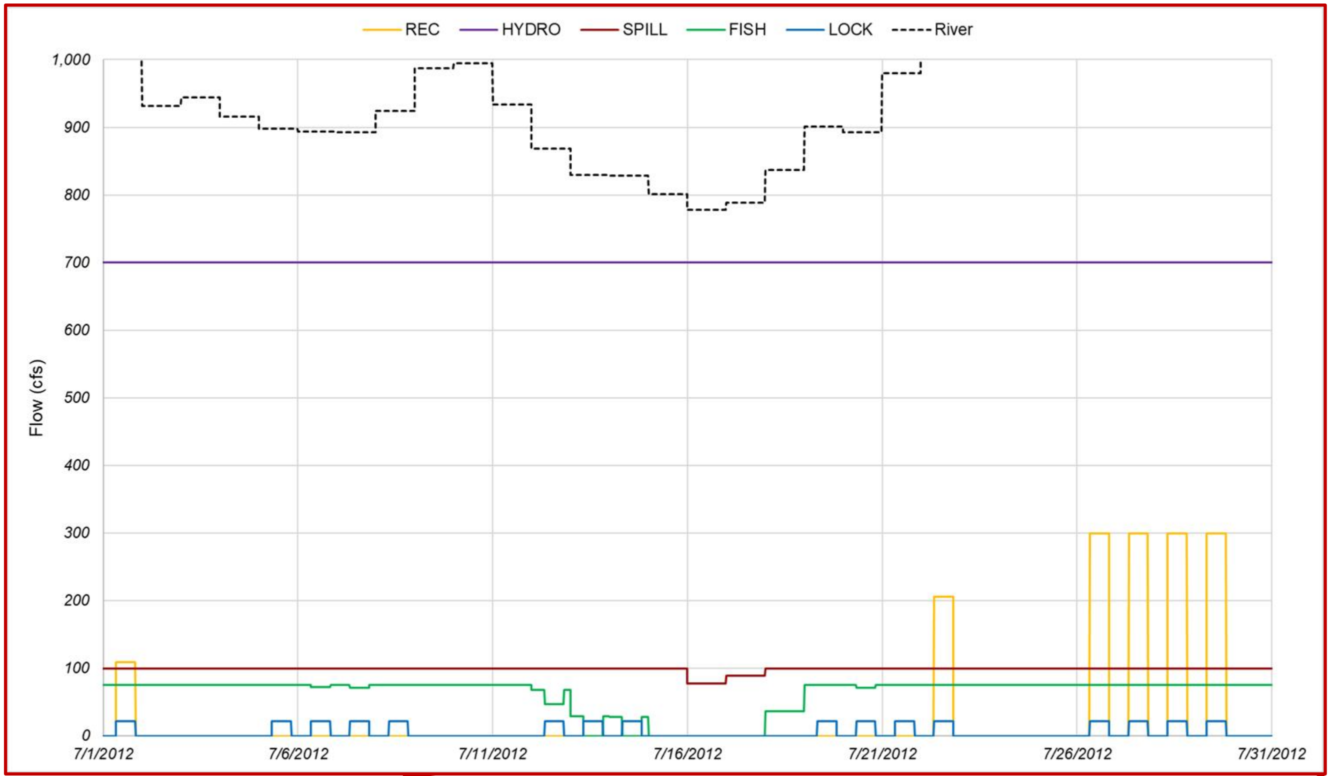
Funding Opportunity	Objective(s)	Linkage to RRD	Details
DE-FOA-0003139C, Distributed Energy Systems Demonstrations Program	*prove out the operations and the financial value of connected energy systems with high amounts of renewable generation, (megawatts and various assets like electric vehicles), commercial and industrial facilities, and smart buildings and homes*	RRD with forecasting, controls, and complementary storage could provide services within distribution grid.	$10M to $25M, very competitive
DE-FOA-0003123: Pilot-Scale Operational Validation	*rapid operational validation of pilot-scale components, subsystems, or systems for clean energy technologies*	RRD could anchor a distribution-scale testbed for hydropower components, power control systems, energy storage, and renewables.	DOE has requested input, timeline for funding opportunity TBD
DE-FOA-0003195: Grid Resilience and Innovation Partnerships (GRIP) Topic 3	*behind the meter asset operations, aggregation, and coordination to provide demand response and grid services, including building systems, distributed generation, energy storage, electric vehicle fleets and others*	RRD with forecasting, controls, and complementary storage could provide services within distribution grid.	Application window closed, awaiting further info on future application windows
Corps Water Infrastructure Financing Program	*financing for safety projects to maintain, upgrade, and repair dams identified in the National Inventory of Dams with a primary owner type of State, Tribal government, local government, public utility, or private*	Improve resiliency and safety of RRD	
USF&WS Fish Passage Technical and Planning Assistance	*financial and technical assistance for projects that improve the ability of fish or other aquatic species to migrate by reconnecting habitat that has been fragmented by a barrier such as a dam or culvert..*		On average the program contributes about $70,000 per project. There is no upper limit to project funding

7. Hydropower



1. Rum River Hydrology

Example 1: Hydropower Priority

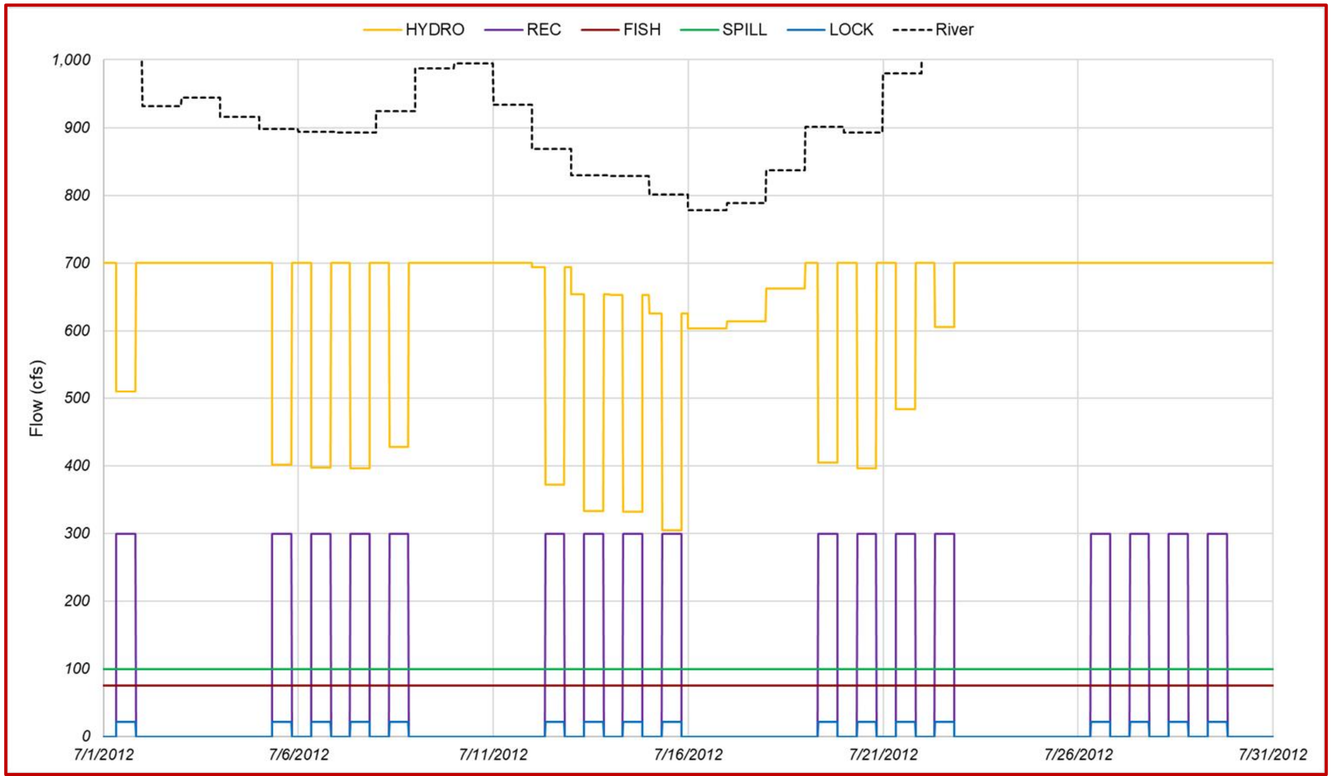


SUMMARY												
Priority	Feature	Operating?	Required Flow	Start Month	End Month	Start D.O.W.	End D.O.W.	Start T.O.D.	End T.O.D.	Dry Availability	Ave Availability	Wet Availability
1	HYDRO	Yes	140.0	24/7	24/7	24/7	24/7	24/7	24/7	41%	67%	91%
2	SPILL	Yes	100.0	1	12	1	7	0:00	23:59	30%	34%	58%
3	LOCK	Yes	21.7	5	10	5	1	8:00	20:00	8%	47%	82%
4	FISH	Yes	75.0	24/7	24/7	24/7	24/7	24/7	24/7	9%	30%	55%
5	REC	Yes	300.0	5	10	5	1	8:00	20:00	0%	32%	60%

HDR ANOKA REAL. CLASSIC. Kimley»Horn

1. Rum River Hydrology

Example 2: Recreation Priority
(Note Legend Change)



SUMMARY

Priority	Feature	Operating?	Required Flow	Start Month	End Month	Start D.O.W.	End D.O.W.	Start T.O.D.	End T.O.D.	Dry Availability	Ave Availability	Wet Availability
1	REC	Yes	300.0	5	10	5	1	8:00	20:00	75%	93%	82%
2	FISH	Yes	75.0	24/7	24/7	24/7	24/7	24/7	24/7	91%	93%	84%
3	LOCK	Yes	21.7	5	10	5	1	8:00	20:00	24%	64%	82%
4	SPILL	Yes	100.0	1	12	1	7	0:00	23:59	75%	92%	84%
5	HYDRO	Yes	140.0	24/7	24/7	24/7	24/7	24/7	24/7	20%	43%	83%

CITY OF ANOKA
RUM RIVER DAM CONCEPT DEVELOPMENT AND FEASIBILITY ANALYSIS
PMT MEETING #1 – KICKOFF MEETING
FEBRUARY 22, 2024 at 10:00 AM

SUMMARY

1) INTRODUCTIONS

Lisa LaCasse - City	***Marty Weber - HDR***	***Paul Berkshire - HDR***
Ben Nelson - City	***Dan Kvasnicka - HDR***	***Scott Shipley - Calibre***
Mark Anderson - City	***Faith Powell - HDR***	***Riley Adams - Calibre***
Jon Holmes - City	***Joe Dvorak - HDR***	***Mike Lynn - DOC***
Del Vancura - City	***Don Pereira - HDR***	***Dan Coyle - KH***
Warren Magnus - City	***Matt Redington - HDR***	

2) PROJECT SCOPE

Highest priority items are identified below. Not all elements of the project are compatible with each other.

A. Repairs and Safety Improvements
B. Automated Crest Gate System or Modifications – ***Priority #2***
C. Maintenance Platform / Walkway
D. New Boat Passage/Portage System; Lock, Trolley, Etc…
E. New Fish Passage System
F. New Electricity Generation System – ***Priority #1***
G. New Standing Surfing Wave
H. Environmental and Flood Control
I. Enhanced and Decorative Lighting

3) PROJECT PROCESS

A. Identify Regulatory Requirements
B. Generate Ideas – ***Brainstorm and think big first before narrowing down options***
C. Evaluate Alternatives and Costs ***- Biggest constraints are impact on space and availability of water. HDR has a detailed 20-year hydrologic model.***
D. Select Preferred Alternative– ***No public engagement planned during feasibility process. Possibly some select stakeholder engagement to determine preferred alternative. Depending on preferred alternative, environmental and regulatory process will require a formal public engagement and public hearing process.***
E. Develop Feasibility Report

4) PROJECT BUDGET – ***Working project budget is $12M. City would like possible project cost ranges as soon as possible. A project cost is needed by mid-summer for state capital bonding bill.***

5) DISCUSSION

A. Existing Dam– <u>***ACTION ITEM: City provide copy of documents for existing dam***</u>
    - Original design report ***- Original design report is required for feasibility analysis. Report should include stability analyses, geotechnical***

information, spillway hydraulic design, etc. If City or DNR does not have report, City to reach out to Barr Engineering.
- Geotechnical information
- Construction photos
- Existing utilities & available power – ***See attachment***

B. Hydraulics
- ***HDR is developing "model" that will distribute available river flow (based on historic data) to the various dam features to determine if and how often desired flows can be achieved.***
- Tailwater rating curve – ***Included in current O&M Manual but will need to be verified in subsequent design phases.***
- Hazard classification/spillway design flood ***- NDI classifies dam as low hazard as of May 23, 2023***
- DNR operating permit – ***No DNR operating permit. City is ok with HDR contacting DNR. Jason Boyle from DNR inspects dam twice per year. <u>ACTION ITEM: City summarize annual operation and maintenance activities.</u>***
- ***HDR recommended that existing spillway capacity be maintained (or increased) new facility.***
-

C. Recreational Boat Passage
- ***Anticipated that lock will be required as opposed to "lift" or "ramp" which are much more cumbersome and come with safety concerns.***
- Design vessel dimensions – ***Start with same design vessel as 1993 report; 28-foot vessel length.***
- Anticipated season / days / hours – ***Need navigable upper pool in summer months***
- Anticipated passage logistics – ***Most likely a lock that requires staff to serve as "lock master", i.e., automated locking using key cards or similar is not recommended.***

D. Fish Passage
- Target species – ***Does ACD have a fish management plan? Channel catfish are native and habitat is moving north as average temps are rising. Concern that channel catfish might ultimately arrive in Mille Lacs.***
- Operating season – ***TBD***.
- Coordination with Anoka Conservation District / DNR Fisheries – ***City is ok with HDR contacting ACD. <u>ACTION ITEM: City provide HDR with contact info for ACD.</u> Some discussion about possibility of endangered mussels in Rum River.***

E. Hydropower
- Coordination with Anoka Municipal Utilities – ***300 – 500kW generating potential. Need a control building for hydro electrical and control equipment. Same building could be used for spillway gate actuators and controls. Gates would most likely be automatically controlled to keep pool elevation relatively constant.***
- Anticipated use of power
- Value of power / energy (including Clean Energy Choice Program) ***- $0.04 /kWh Minnesota Municipal Power Agency buy back cost.***
- Economic analysis & parameters – ***St. Anthony Falls has a modular turbine system. <u>ACTION ITEM: HDR setup a site visit to St. Anthony Falls.</u>***

- AMU responsible for transmitting power from facility to grid, with intertie likely near City Hall.
- Federal Energy Regulatory Commission (FERC) – ***Non-federal projects require license or exemption which can be time consuming. Consider deferring FERC process to after other dam improvements are made.***

F. River Surfing

- Anticipated season / days / hours – ***TBD.***
- Anticipated user logistics – ***Need to isolate river recreation from hydropower infrastructure. Likely a separate side channel with multiple drops to address 12' elevation change. Avoid "washing" surfers into boats downstream. Standing wave(s) is goal. <u>ACTION ITEM: City to research record drawings for river wall and provide plans to HDR.</u>***

G. Spillway Bridge

- Public Access – ***Long term goal is to design the Anoka Riverwalk trail to cross the Rum River at the dam. Need to determine if the functional spillway access needed for the dam can also be used as a public trail.***
- Security
- Preliminary concept – ***HDR will develop concept for functional spillway access. KH will develop Anoka Riverwalk bridge concepts and tie-ins on each side of the river.***

H. Site Design, Riverwalk, Lighting and Placemaking

- Downtown Context – ***Downtown Anoka hosts many annual (Riverfest, Halloween Parade) and weekly events (Farmers Market, Classic Car Show), in addition to a vibrant downtown shopping and dining district. The river is used for snowmobiling and a snowmobile parking area is setup each winter in downtown.***
- Future Riverwalk Trail – ***The City has planned a Riverwalk Trail on both sides of the Rum River, from the dam south to Peninsula Park. Portions of the trail are in place or are in design.***

I. General

- Property / Easement Boundaries – ***Available on line***.
- Hydro remnants disposition – ***City indicated that area east of dam (including old hydro remnants) is available for dam works***.
- Sanitary sewer line exists beneath sidewalk on river side of City Hall.

6) TENTATIVE SCHEDULE

PMT #2 – Design Charrette to Generate Alternatives	***March 27, 2024 from 10-2p***
PMT #3 – Select Alternatives for Council Worksession	***June 12, 2024***
Council Worksession – Select Preferred Alternative	July 22, 2024
PMT #4 - Finalize Feasibility Report	November 6, 2024
Council Meeting – Present Feasibility Report	December 9, 2024

7) NEXT MEETING

8) OTHER DISCUSSION

Appendix F

MnDNR Comments & Responses

MNDNR COMMENTS AND RESPONSES			
Topic	**No.**	**Comment**	**Design Team Response**
General	1	To fully evalute each project element, there needs to be a shared understanding of the impacts of dams on river functions. The interuption of natural processes of sediment transport impacts ecological function and water quality over time. As water is dammed, the water energy slope is lowered, decreasing the rivers ability to transport sediment. As a result, sediment builds up (aggrades) upstream of the structure filling in the reservoir and eventually decreasing its size and capacity. This diminishes the benefits provided by a reservoir (loss of recreational use and flood attenuation). The rate at which this process occurs depends on the health of the watershed, specifically the excess sediment load typically generated by overland sources and/or in-channel (bed and streambanks). At the same time, sediment-deprived water below a dam can lead to increased bank erosion rates.	It is recommended that future phases of design/planning include continued conversations with the DNR and other regulatory agencies to identify additional studies that may be required to further vett the proposed project. In this case, sediment transport modeling may be appropriate. On an annual basis, the City of Anoka performed maintenance dredging of navigation channel downstream
	2	Dams can also have an impact on water quality. Reserviors tend to be wider than the typical river width which can lead to more stagnant water, increased temperatures and accelerated eutrophication. As a result, dissolved oxygen can decrease during the summer months, impacting aquatic life. In addition, the aggraded sediments contain excess nutrients and can be both a sink and/or source depending on how the sediment is managed. As a reservoir becomes more eutrophied, there are increases in algae blooms and typically a decline in recreational use.	Again, it is recommended that future phases of design/planning include continued conversations with the DNR and other regulatory agencies to identify additional studies that may be required to further vett the proposed project. In this case, water quality modeling may be appropriate. Since 1996, Metropolitan Council performs annual water quality monitoring of the Rum River upstream and downstream of the dam. Dissolved oxygen remains above the state standard and reducing phosphorus levels in the
	3	Moving forward, we strongly recommend any information prepared for anticipated environmental review as well as regulatory process address and demonstrate the least impactful alternative(s).	Understood.
	3a	Justifications for the project concepts are based on the least impactful option for the resource, not on whether its perceived as more desireable than the current conditions.	Understood.
	3b	A range of feasible alternatives should be contemplated including: no dam present (full aquatic organism passage, unimpeded sediment transport); full fish passage (e.g. rock arch rapids – maintains existing reservoir); and, partial fish passage (nature-like fish way).	Understood.
	4	There is a significant amount of concrete and artificial material envisioned for placement within the Rum River watercourse. Any proposed new structure in public waters must be consistent with Minnesota 3 Rules 6115.0210 and 6115.0211. In particular, a project must represent the minimal impact solution to a specific need with respect to all other reasonable (i.e. feasible) alternatives.	Understood.
	5	Additional details are needed on current dam operations, including the need to raise water in the spring and lower water levels in the fall.	Understood.
	6	Additional details are needed on the hydrology and hydraulic capacity of the current and proposed dam, including how the Mississippi River tailwater will affect the hydraulics of the features and the ability of the lock to safely pass flood flows.	Concur. Verification of tailwater rating including effects of Mississippi River backwater effects are planned for the next phase of design.
	7	If funding is limited, what will the city's priorities be among the different elements of the retrofit? Would the city move ahead with only a partial retrofit?	The City would consider any retrofit improvements for the operation and safety of the dam.
Recreational Vessel Passage	1	Recreational Vessel Passage (i.e. lock) 1. Significant operations and additional maintenance are required for the recreation feature and lock. Is the City willing to commit to those features long term?	The City would undertake the operations and long term maintenance of a recreational vessel passage. The same commitment the City has for the existing dam.
	2	Is there a demonstrated need to include the lock alternative? Public boat launches are located immediately upstream and downstream of the dam?	Agree that the public boat launches provide good access to the Rum River upstream and downstream of the dam, but providing direct accessibility to the upper Rum from the Mississippi would be a significant improvement to recreational opportunities. The dam is a major asset to the region with the recreational pool extending over 6-miles upstream, thus benefiting multiple communities. Recreational opportunities will be further enhanced through the lock feature as it will re-establish the connection to the Mississippi River.

MNDNR COMMENTS AND RESPONSES			
Topic	**No.**	**Comment**	**Design Team Response**
Water Recreation	1	Please address the potential for fish to be trapped within the water recreational feature pools.	The entire channel is designed to positively drain. Primarily the channel is flat or sloping downward, with the exception of the exit of the pool immediately upstream of the beginner wave (the lowest wave structure). In this structure, a notch will be cut in the low flow to ensure drainage of the upstream pool when the water is turned off (see attached images). In areas where rapidblocs span the entire channel width, a gap can be left in the blocks to allow for water drainage and fish egress. We are happy to also submit a preliminary Rapidbloc layout for DNR to review prior to finalizing the design, should the project progress past the feasibility stage. Finally, we can discuss a plan with the City to complete a quick inspection when the recreation channel
	2	Ideally the DNR would like to see full aquatic organism passage and sediment transport utilizing natural stream processes.	Understood.
	3	Whitewater recreational features provide an opportunity to increase connectivity when sited at a dam, however, their efficacy in providing fish passage is variable depending on the design used. Artificial features that include high velocities preferred by whitewater recreationalists do not favor fish passage due to physical and behavioral limitations of fish.	Understood. While fish passage incorporated into recreational structures is possible and has been used successfully at other sites, it is not necessarily ideal at this site due to the large amount of drop at the dam. This is the reason that a separate fish passage channel is included in the design. The fish passage channel runs parralel to the recreation channel and will provides slopes, velocity limits and roughness elements aimed specifically at fish passage. The lower recreation channel could be designed to provide fish passage, however the geometry and velocities required to produce the upper standing surf wave would not be ideal for fish passage. When not in use for recreation (i.e. at night), this channel could be reconfigured for additional fish passage by adjusting the pneumatic gates. Note that the current fish passage detail shows a V-shape concrete channel, with embedded roughness elements (cobble, small boulders,
	4	If fish passage and sediment transport is part of the water recreational feature, there is a list of data, modeling and analysis required to demonstrate and quantify passage across seasons, flow regimes and within the constructed channel/structures.	Understood.
	5	What are the likely operational and maintenance costs and issues with the water recreational features?	Likely similar to a conventional dam. Actual O&M costs would be investigated in subsequent stages of design.
Fish Passage	--	Dams impede the migration, diversity, and abundance of aquatic organisms. A review of fish survey data from “Fish Mapper” shows 93 fish species present above the Coon Rapids dam on the Mississippi River and 65 species above the Anoka Dam on the Rum River or a 35% decrease in diversity. Fish passage structures should be designed to pass all Minnesota native fish species and associated life-stages at a variety of flows. There are different methods for achieving fish passage and the ones which represent natural hydraulic conditions, structures and dimensions are likely to be more successful at increasing connectivity. Additional modeling and analysis may be required depending on what is	Understood.
	1	Is there any control for the fish passage channel? Does the ability to pass fish go away during winter drawdown?	The current plan is to have flow control at the upstream end of the fish passage channel and it would continue to pass water during the winter drawdown.
	2a	It is unknown whether the fish passage structure would function as intended. 4 a. Fish are attracted to flow. In order to adequately pass fish, a significant number of them must be able to find the entrance to the fishway. There are other locations at the whitewater feature and along the face of the dam that will also have flow to attract fish and divert them away from the fishway. With the fishway entrance not associated with the face of the dam where much of the flow will pass the dam, fish will be unlikely to find the entrance to the fishway	Modifications to enhance the fish passage feature will be investigated in subsequent phases of design.
	2b	The fishway appears to be an artificial concrete channel. How have such structures been demonstrated to pass the species of fish found in the Rum River? What design elements for the fishway will increase its likelihood of passing fish?	As currently conceived, the fish passage feature requires concrete or other structural elements to allow it to fit in with the existing dam and other prospective dam features. The intent is to combine natural rock with the concrete to make the channel as natural as practicable.
	3	How will flow be prioritized for operation of the various elements of the dam? During low flow periods, will the fishway be prioritized, or will some flow still be used for the recreational features?	Although this has not yet been fully vetted, it is anticipated that the higher priorities would be fish passage and aesthetic spillway flow. Navigation would likely be next (in season), followed by the recreation

Appendix G

Project Flyer

ANOKA RUM RIVER DAM

The City is working to reimagine the Rum River Dam for the next 100 years.

Our vision for the future – result of the 2024 feasibility study

BENEFITS

Infrastructure improvements

Modernize dam function

Replace antiquated, manually installed timber flashboards with automated crest gates.

- Improve **safety** with automated gates
- Year-round debris removal
- Predictive and adaptable water level management

Recreational features

NEW

Pedestrian and maintenance bridge

Create a river crossing for the expanding regional trail system.

- Provide access to remove debris from the dam
- Provide overlooks for respite, fishing, and taking in nature and historic downtown views
- Provide access to the river surfing feature

NEW

River surfing

A new sport growing in popularity in the United States where surfers, paddleboarders, and kayakers ride a standing wave and tubers can take a leisurely float in a new recreational channel.

- Make Anoka a unique river recreation tourism destination
- The first river surfing location in Minnesota
- More predictable and safer water in a purpose-built channel than in an uncontrolled river
- Ability to turn off the water to the channel in case of an emergency

NEW

Navigation lock

Conversion of an existing structure to allow pontoons and other watercraft to navigate the dam.

- Allow boats to travel between the Upper and Lower Rum and Mississippi Rivers
- Assist with the release of flood waters
- Aid in the passage of native fish species for spawning
- Allow water draw down for dam inspection and maintenance

A lock is the most cost effective recreational vessel passage to construct, maintain, and operate with best boating experience for multiple boats at a time.

BENEFITS

Regional impacts

NEW

Fish passage

Allows fish to swim along and leap a variety of low steps to travel from one side of the dam to the other.

- Create an educational feature and integrate with the landscape using nature-inspired design
- Support spawning and bolster the fishery by increasing access to preferred habitat
- Easy closure of the passage for maintenance and seaonal flood releases through use of an integrated gate system

NEW

First responder training

- Create a regional water rescue training venue
- Simulation of real-life emergency scenarios, providing hands-on experience in a controlled environment
- Improved proficiency in swift water rescue techniques

NEW

Create a new midwest tourist attraction

- Bring a focus to the river as a regional amenity
- Market the community as an outdoor destination
- Generate direct profits for businesses within the region

Improve the environment

- Enhance the fishery by connecting the Mississippi River and Mille Lacs Lake to support spawning of native fish
- Reduce spring flooding and therefore upstream riverbank erosion, impacts to infrastructure, and damage to aquatic habitat

NEW

Navigation Lock

- Re-establish the connection from the Rum River to the Mississippi River
- Regional recreation benefit to river patrons in multiple communities

Whitewater park venues have seen economic impacts as high as $9M per year.

Profits are generated through vendor operations (watercraft and gear rentals, raft trips, lessons) and patronage of regional businesses (restaurants, shops, hotels) by visitors attending river-based events.

FUNDING

Previous allocation:

$500,000

Feasibility study completed

***Current request:* $5.6M**

Preliminary design, survey, public engagement/communication, environmental documents for the proposed improvements

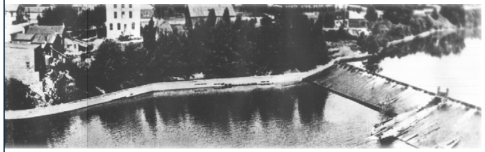
Estimated total project cost:

$51M

In addition to state funding, the City of Anoka is pursuing available federal and state grants.

TIMELINE

1853 — First Rum River Dam built



1935 — City of Anoka begins owning and operating the Rum River Dam

1969 — Rum River Dam reconstructed; the structure in place today

2023 — $500,000 secured to conduct a feasibility study including design, engineering, and environmental analysis of the proposed dam modifications

2024 — Feasibility study

We are here

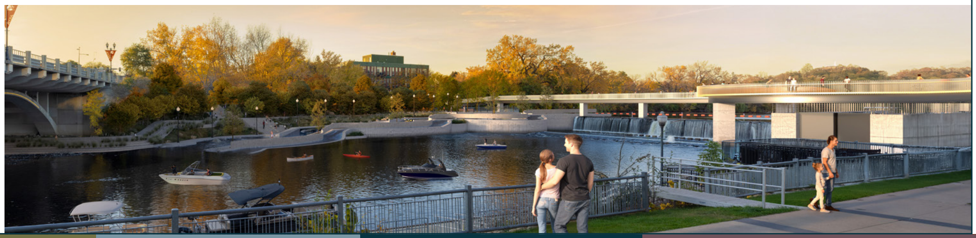
2025 — Preliminary design, survey, public engagement/communication, environmental documents

2026 — Final design, geotechnical, complete public engagement/communication, complete grant applications, and solicit non-state funding

2027 — Apply for permits, utility infrastructure/relocation

2028 — Begin construction

2030 — Construction substantially complete



CONTACT THE PROJECT TEAM

Greg Lee, City Manager	**763-576-2711**	**GLee@ci.anoka.mn.us**
Lisa LaCasse, Public Services Administrator	**763-576-2984**	**LLaCasse@ci.anoka.mn.us**
Ben Nelson, Assistant City Engineer	**763-576-2785**	**BNelson@ci.anoka.mn.us**

anokaminnesota.com

Appendix H

Scope of Work

05 | Work Plan and Approach

Approach

Our team's approach is defined by technical excellence, an effective process to identify, thoroughly develop and evaluate design concepts, and a commitment to collaboration. The technical work will not be done in a vacuum, rather we will constructively communicate with the City throughout the study to keep the Project Management Team (PMT) educated on key findings and factors guiding project development. **Our team, led by Marty Weber,** will work closely with the City's project manager consultant to coordinate the design concepts with adjacent placemaking features such as community access, trails, landscaping, and lighting, and will participate in the PMT to help identify, advance, and eventually select the preferred dam configuration.

HDR's proposed work plan consists of the following tasks.

Task 1 – Project Management

The purpose of this task is to monitor the scope, schedule, and budget and provide monthly status reporting, accounting, and management of the project team including subconsultants. This task will include HDR's standard activities such as project setup, monitoring, and coordination with subconsultants. Bi-weekly remote progress meetings with the City Project Manager are also included. Lastly, HDR will also provide information to the City necessary for compliance with the Department of Energy grant contract reporting requirements.

HDR has developed a Quality Management System (QMS) based on the principles and guidelines set forth by the ISO 9001:2015 international standard for quality management. HDR's QMS requires and monitors quality control plans and procedures from subconsultants on all of our projects. HDR will tailor a project-specific quality control plan for the Rum River Dam Project and will share this plan with the City if desired.

Task 2 – Meetings

HDR will participate in the formal meetings identified in the RFP. Assumed meeting durations and HDR participation are presented below. Participation is assumed for budgeting purposes but can be modified as desired.

MEETING	DATE	HRS	HDR PARTICIPATION: IN PERSON	HDR PARTICIPATION: REMOTE
PMT1 Kickoff	1/19/24	2 hr	PM + River Surfing, Lock, & Fish Passage Leads	Hydropower, Hydraulics, Structural, Permitting, & Funding Leads
PMT2 Design Charrette	1/30/24	2 hr	PM + Hydraulics, Lock, & Fish Passage Leads	River Surfing, Hydropower, & Structural Leads
PMT3 - Alts Selection	4/22/24	2 hr	PM + Hydraulics Lead	Lock, Fish Passage, River Surfing, Hydropower, & Structural Leads
Council Work Session	5/28/24	2 hr	PM	--
PMT4 Report Review	7/31/24	2 hr	PM	--
Council Meeting	9/16/24	2 hr	PM	--

HDR will assist in the preparation of agendas and meeting notes.

Task 3 - Information Gathering and Review

HDR will gather and review background information from the City, MnDNR Dam Safety Office, and publicly available sources. Information may include Rum River flow data, area topographic and bathymetric data, property ownership and dam construction documentation, geological/geotechnical data, and GIS datasets. With acceptance from the City, HDR will also meet with other stakeholders (e.g., DNR Fisheries and Anoka Conservation District) to discuss the status of fisheries management plans, aquatic biodiversity concerns, and potential water quality impacts. The HDR design team will review background information to support subsequent tasks.

HDR will also visit the dam site to make observations including physically accessible features including but not limited to the spillway, abutments, Tainter gate bay, recreational features, and adjacent properties. The site visit will be documented through photographs and written notes.

The schedule does not allow sufficient time to plan and execute a geotechnical investigation program after selection of the preferred alternative. The feasibility report will however include a preliminary geotechnical investigation plan (and associated cost opinion) that would be executed in subsequent design phases.

Task 4 – Alternatives Preparation

The purpose of this task is to prepare for the PMT design charrette. HDR will prepare high-level, conceptual designs for the prospective dam facilities:

- ***Spillway Crest Gates –*** New crest gates assumed to be mounted on spillway and same height as current flashboards. Concept would include required operating system, i.e., air piping, compressed air system, pool monitoring equipment, and pool operating system.
- ***Boat Passage –*** Preliminary sizing of lock (or other lift system) based on vessel size established during kickoff meeting with consideration to past and planned Rum River boat channel dredging projects.

HDR agrees with the recommendation made in the 1993 navigation assessment to perform a survey of area boat owners to gain more insight into the size and drafts of vessels that would use the lock. HDR's Strategic Communications Group could assist with this and other public outreach efforts as a value added service.

- ***Fish Passage –*** In lieu of more elaborate computational fluid dynamic (CFD) modeling which would be conducted in subsequent phases of design, HDR will perform a preliminary evaluation of rock rapids type fish passage system based on DNR guidelines[1]. Said guidelines consider target species swimming abilities, rapids' slopes, and rapids' stone sizing applied to the Rum River Dam configuration and river flow characteristics. Should a rock rapids type system be deemed infeasible, i.e., due to space limitations, HDR will transition to the more compact, structural type fishway such as the "Standard Denil" or others as described by the U.S. Fish and Wildlife Service[2].
- ***Hydropower –*** Preliminary concept based on capacity (kilowatts) established during kickoff meeting. This would include preliminary turbine selection (type, dimensions, vertical setting) based on available flow and head conditions.
- ***River Surfing -*** Determination of optimal flow range, factors that may affect feature usage, river access points and portage routes. Evaluation of available head and the appropriate number, size and style of river surfing features to safely meet the City's goals within the constraints of the site.
- ***Sketches*** illustrating concepts for the above dam discharge facilities. Sketches will be prepared using effective visuals with aerial images or existing drawings as background.

HDR will develop a water allocation model, potentially using HDR's propriatary Computer Hydroelectric Opertions and Planning Software (CHEOPS™) if appropriate. The model will determine each feature's average operating times on seasonal and annual bases and can be adapted in real time to support work session discussions.

HDR will assist the City with development of a permitting matrix that covers both the dam improvements alone (i.e., excluding the FERC) and the addition of hydropower (i.e., including the FERC). Lastly, HDR will develop a multi-criteria decision analysis (MCDA) framework to facilitate the alternatives selection process. The MCDA criteria (e.g., cost, operability, dam/public safety) and scoring would be established in consultation with the PMT.

Task 5 – Alternatives Development

The purpose of this task is to prepare for the alternatives' selection processes, i.e., PMT Meeting and Council Work Session. Decisions and direction discussed during the design charrette will be key in executing this task.

- Sketches illustrating refined concepts for the various dam features. Sketches will again be prepared using Microsoft PowerPoint® or similar software with aerial images or existing drawings as background.
- Updates to water allocation model and permitting matrix | Hydropower concept refinement including energy generation analysis | life-cycle economic analysis | turbine/generator OEM outreach
- River surfing feature refinement: Develop three concepts which may differ by number, style, shape, material, configuration, and

1 - "Reconnecting Rivers: Natural Channel Design in Dam Removals and Fish Passage, Chapter 2 – Nature-like Fishways", 2010.
2 - USFWS, "Fish Passage Engineering Design Criteria" June 2019.

location. Prepare narrative on potential (direct and indirect) revenue generation.

- Fish passage system refinement (either rock rapids or structural type)
- Identification of pool level monitoring and control system
- Preliminary cost opinion
- Preliminary funding source summary
- Refined MCDA
- Preliminary development schedule

Results of the above-described work will be captured in narratives, figures, and tabulations to support development of the feasibility report and meeting presentations by the City's Project Manager. HDR will participate in the April 22, 2024 alternatives selection meeting and May 28, 2024 Council meeting.

Task 6 – Feasibility Report

It is HDR's understanding that the City Council work session on May 28, 2024, will result in clear direction on the dam features that are to be carried into the feasibility study. HDR will apply this direction to support preparation of the feasibility report:

- Narratives that describe the alternatives identification, alternatives development, and alternatives refinement processes.
- Updates to water allocation model | permitting matrix | hydropower concept including life cycle analyses| cost opinion | funding sources | final MCDA | development schedule
- Preliminary dam safety computations/evaluations for new or modified structures: structural stability analyses of existing dam, existing lock walls, and proposed new structures | qualitative design of seepage control measures for new structures | hydraulic analyses of new or modified spillway features.
- Narrative on path forward including additional field (technical and environmental) investigations, studies, designs, etc. This will include the preliminary geotechnical investigation program.
- Updated sketches showing the existing dam, adjacent lands, proposed new dam safety improvements, dam lighting, new discharge features, and control of water plan.
- Report supplements, i.e. figures, tables, and appended computations.

HDR will submit a draft feasibility report to the PMT approximately two weeks in advance of the July 31, 2024, meeting.

Following the meeting, HDR will incorporate agreed upon changes to the report. Salient results will be put into presentation format.

HDR will then assist the PMT with presentation to the Anoka City Council on September 16, 2024.

City/City Project Manager Responsibilities

- Provide project background documentation.
- Facilitate formal meetings, i.e., PMT and Council meetings.
- Participate in bi-weekly coordination meetings.
- Provide access for site visit.
- Provide insight into desired function of dam features including as applicable, seasons for river surfing and boat passage, size of boats for passage, minimum spillway flow (for aesthetics or otherwise), planned river dredging projects, etc.
- Input regarding site-civil works, trails, landscaping, and lighting.
- Value of electricity ($/kWh & $/kW/month).
- Value associated with Anoka Municipal Utility's Clean Energy Choice Program.
- Produce concept layouts based on input from HDR.
- Merge HDR-prepared documentation with City-prepared documentation and produce final documents for regulatory requirements, cost opinions, and reports

Deliverables

- Documents (meeting agendas/notes, report narratives, safety plan) in .pdf format
- Sketches in .pdf or .pptx formats
- Tables and computations in .xlsx format

Assumptions

- Meeting durations and participation as described in Task 2.
- Existing .pdf drawings or publicly available aerial photographs will be used as backgrounds for HDR sketches, i.e., new AutoCAD (or similar) drawings (if desired) will be produced by others.
- Other than the site visit, services exclude any supplemental field work required to obtain additional information, i.e., surveys, utilities, geotechnical investigations, or otherwise.
- Original (ca 1968) design report (or similar) is available to inform and support preliminary designs, i.e., structural stability analyses, seepage analyses, and spillway hydraulic analyses.
- The hydropower concept would extend from the turbine(s) through the step-up transformer. Concept and cost development beyond that point (e.g., distribution lines and interconnect facilities) would be by Anoka Municipal Utility or others.
- The hydropower life cycle analysis is not to be construed as a "bankable document".
- Due to industry workload, HDR cannot guarantee timeliness of turbine-generator Original Equipment Manufacturer (OEM) responses.
- Cost opinions will be developed according to AACE International, "Practice No. 69R-12 - Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Hydropower Industry", January 25, 2015. Class 5 for Task 5 and Class 4 for Task 6.