Twin Lake Flood-Risk Mitigation Feasibility Study

Prepared for
Ramsey-Washington Metro Watershed District

December 2019

4300 MarketPointe Drive, Suite 200
Minneapolis, MN 55435
952.832.2600
www.barr.com

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Certifications

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.

December 3, 2019

Brandon Barnes
PE #: 49540

Date

Abbreviations

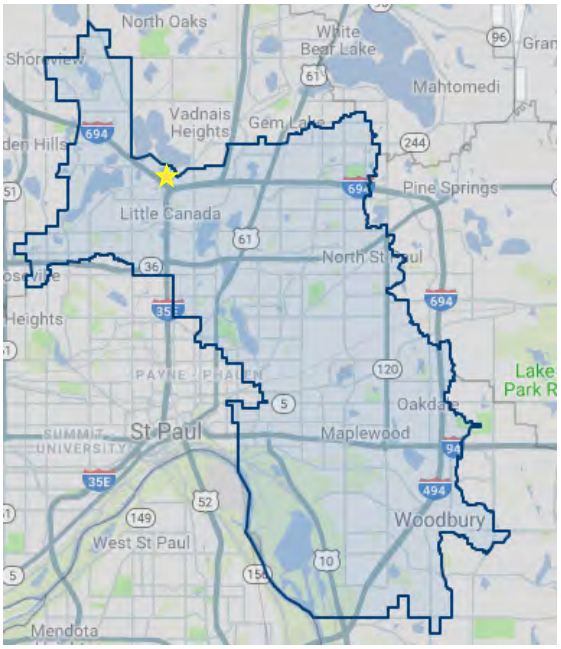
BP	British Petroleum
BWSR	Board of Soil and Water Resources
cfs	Cubic feet per second
ERP	Emergency Response Plan
FEMA	Federal Emergency Management Agency
HEC-SSP	Hydrologic Engineering Center Statistical Software Package
ID	Identification
MDNR	Minnesota Department of Natural Resources
MnDOT	Minnesota Department of Transportation
MnRAM	Minnesota Rapid Assessment Method for Evaluating Wetland Functions
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
MSP	Minneapolis-Saint Paul International Airport
NAVD88	North America Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWL	Normal Water Level
OHW	Ordinary High Water
RWMWD	Ramsey-Washington Metro Watershed District
SP	State Project
SPRWS	Saint Paul Regional Water Services
SWMM	Stormwater Management Model
SWPPP	Stormwater Pollution Prevention Plan
TP40	Technical Paper 40
USACE	United States Army Corps of Engineers

Executive Summary

During the spring and summer of 2019, record high water levels were measured in Twin Lake. Lake levels exceeded the 100-year water level and the low floor elevation of the lowest habitable structure on Twin Lake (154 Twin Lake Boulevard). In response to recent high water levels, the RWMWD Board of Managers authorized the evaluation of alternatives to reduce flood risk to habitable structures.

An evaluation for flood-risk reduction alternatives was completed relative to applicable design criteria and flood-risk mitigation goals. For the context of this feasibility study, design criteria are the minimum requirements each flood-risk alternative must achieve based on the rules and requirements of entities with permitting authority. Flood-risk mitigation goals are objectives that go above and beyond minimum design criteria. The evaluation for each alternative considered floodplain impacts, regulatory approvals, affected property owners, wetland/upland impacts, and cost to construct and maintain. A feasibility evaluation was completed for the following alternatives:

- Alternative 1: Remove flood-prone structure
- Alternative 2: Emergency response plan
- Alternative 3: Gravity outlet at elevation 874.0
- Alternative 4: Gravity outlet at elevation 872.2



Twin Lake location within RWMWD.

In addition, other alternatives were considered and ultimately discarded because they did not meet the minimum design criteria. These included a permanent stormwater lift station and lowering the embankment north of Waldo Pond.

Based on the evaluation, Alternative 4, gravity outlet at elevation 872.2, is recommended as the most feasible flood-risk mitigation alternative. This alternative would include a gravity outlet at elevation 872.2 consisting of a ditch and gravity pipe with a valve through the existing embankment. This alternative would include a detailed operating plan that describes when the valve could be opened and when it should be closed. This recommendation is based on Twin Lake flood-risk mitigation objectives, as well as the assessment of downstream impacts, site and wetland impacts, and flexibility for long-term management. Alternative 4 does discharge additional water downstream and therefore increases the flood risk to properties along Gervais Creek and in the Phalen Chain. However, adherence to an operating plan developed consistent with permitting requirements and hydrologic modeling will reduce the risk for Alternative 4.

Alternative 4 is a feasible project, consistent with the 2019 District Management Plan and based on available information and requirements of permitting entities. This alternative mitigates flood risk while protecting the water quality of Twin Lake.

The engineer's opinion of probable cost for the design, permitting, and construction of Alternative 4 is $226,000, with a potential range of $181,000 to $339,000, based on the current level of design. As plans and specifications for the recommended alternative are prepared, the District should continue to collaborate with City of Little Canada staff about design details and long-term maintenance. If the Board elects to pursue the project, it is recommended that coordination with the City of Little Canada start in the near-term to develop a cooperative agreement in advance of the project implementation, and coordination with the property owners regarding easement acquisition begin prior to final design.

1 Introduction

This report summarizes the feasibility evaluation of proposed modifications that would reduce flood risk to habitable structures in the Twin Lake watershed in Little Canada and Vadnais Heights, Minnesota. Figure 1-1 illustrates the Twin Lake watershed, drainage patterns, and contributing subwatersheds under historically typical conditions. This report is prepared under the direction of the Board of Managers of the Ramsey-Washington Metro Watershed District (RWMWD or District).

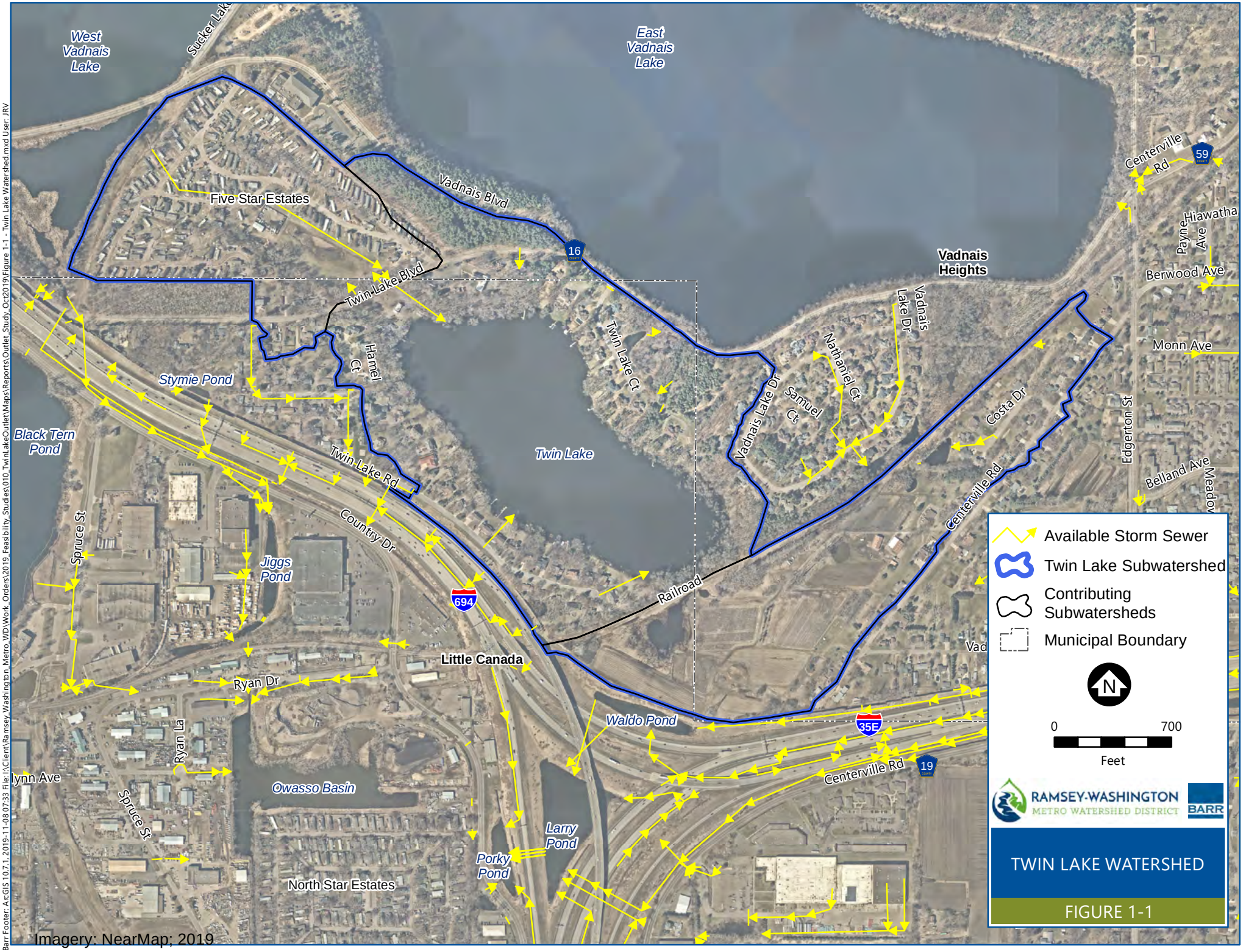
The District was established on February 24, 1975, by the Minnesota Water Resources Board (now the Minnesota Board of Water and Soil Resources, or BWSR), pursuant to the Minnesota Watershed Act, to affect the protection and provident use of water resources. The District is located in eastern Ramsey County and western Washington County, encompassing an area of nearly 65 square miles.

Stormwater management and development were guided by the District's 1977 Overall Plan, which was revised in December 1986, May 1997, June 2007, and April 2017 in accordance with the Metropolitan Surface Water Management Act and Watershed Law (Minnesota Statutes Chapters 103B and 103D). The April 2017 plan is the current guiding document of the District (the Plan) and prioritizes, "flood-mitigation projects to protect habitable structures or major arterial roadways" (reference [1]).

RWMWD defines the term "habitable" as:

> *Any enclosed space usable for living or business purposes, which includes but is not limited to: working, sleeping, eating, cooking, recreation, office, office storage, or any combination thereof. An area used only for storage incidental to a residential use is not included in the definition of Habitable* (reference [2]).

During the spring and summer of 2019, record high water levels were measured in Twin Lake. Lake levels exceeded the 100-year water level and the low floor elevation of the lowest habitable structure on Twin Lake (154 Twin Lake Boulevard). In response to recent high water levels, the RWMWD Board of Managers authorized the evaluation of alternatives to reduce flood risk to habitable structures.



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2 Lake and Watershed Description

Twin Lake is located in the northwest portion of the RWMWD. The drainage area to Twin Lake is approximately 192 acres; historically, the lake has functioned as a landlocked water body. "Landlocked" water bodies or lakes refer to basins where historic water levels have remained below the overflow elevation. Typically, the water balance for Twin Lake has been in a relative state of equilibrium—where the runoff from the subwatershed is generally equal to groundwater seepage and evaporation to the atmosphere.

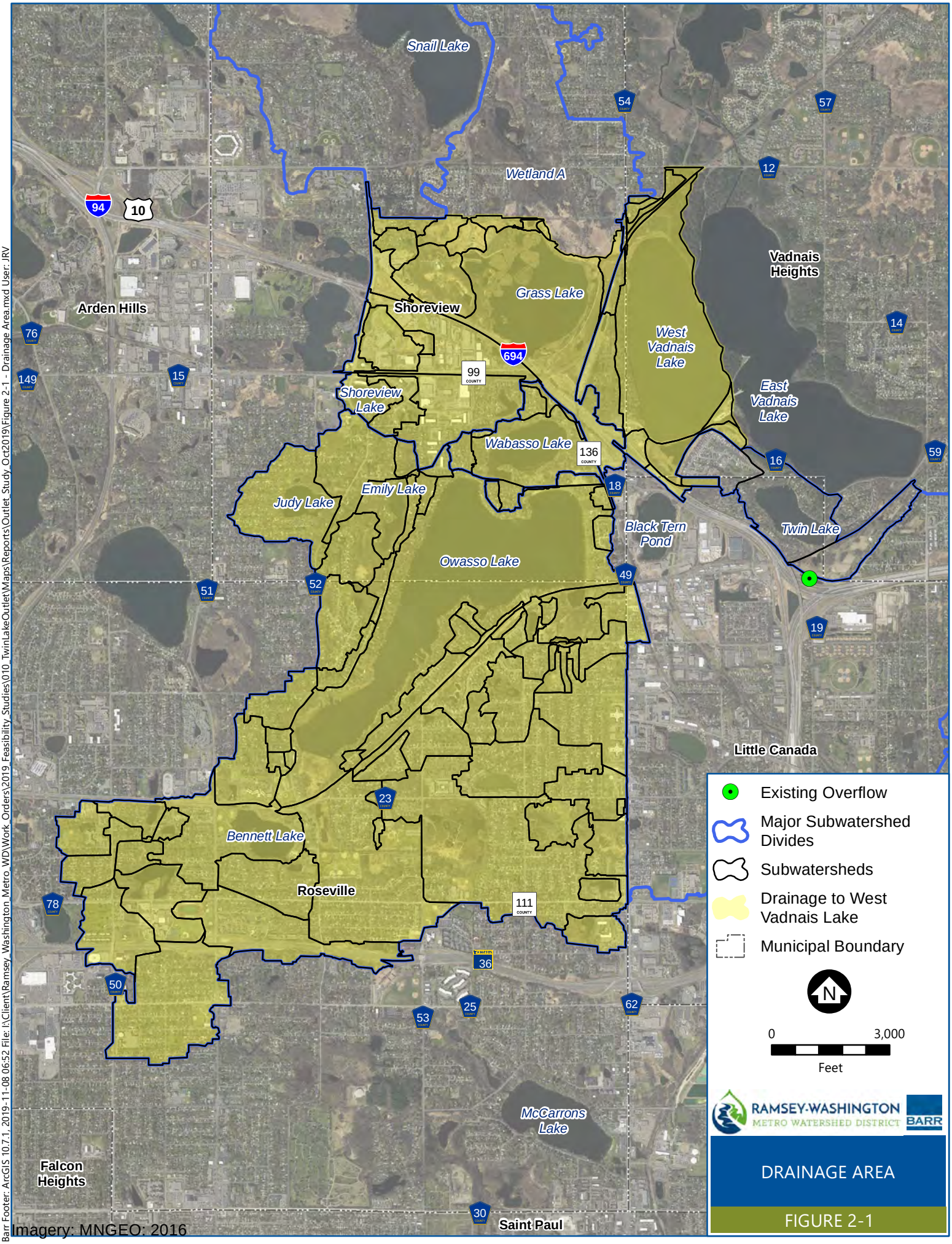
Table 2-1 provides a summary of the physical characteristics for Twin Lake. Twin Lake has an open-water surface area of approximately 33.5 acres and a maximum depth of approximately 33 feet. The lake area, depth, and volume depend on the water level of the lake, which typically varies between an elevation of 869 and 870 feet (reference [3]).

Table 2-1 Twin Lake Physical Parameters

Lake Characteristic	Twin Lake
Minnesota Department of Natural Resources (MDNR) identification (ID)	62-0039-00
MPCA Lake Classification	Deep
MDNR ordinary high water (OHW) elevation	869.9
Water-level-control elevation (feet)	877.0
Surface area (acres)	Approximately 33.5
Maximum depth (feet)	Approximately 33
Littoral area	44%
Volume (at OHW elevation) (acre-feet)	Approximately 565
Total watershed area (acres)	192 (1)
Trophic status based on 2015 growing season average water quality data	Mesotrophic

Note(s):
(1) Watershed area includes surface area of lake and does not consider overflows from West Vadnais Lake.

During the summer of 2019, West Vadnais Lake levels reached record highs causing water to overflow into Twin Lake, increasing the drainage area to Twin Lake to over 5,000 acres. The watershed historically tributary to Twin Lake and the larger watershed tributary to West Vadnais Lake which overflowed to Twin Lake during 2019 are shown in Figure 2-1.



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2.1 Twin Lake and Downstream Drainage System

Historically, Twin Lake has functioned as a landlocked water body. Typically, inflows to the lake have been relatively equal to infiltration and evaporation. However, if the water levels rise, the lake can overflow to the Gervais Creek subwatershed. The following sections describe the current drainage patterns within the Twin Lake subwatershed, and existing flood-prone areas in the Twin Lake and downstream subwatersheds.

2.1.1 Current Drainage Patterns

Historically, the drainage area to Twin Lake has been approximately 192 acres. The drainage area includes approximately 38 acres north of Twin Lake Boulevard and approximately 53 acres south of the railroad tracks.

The area northwest of Twin Lake Boulevard includes the Five Star Estates development. In this area, stormwater is collected in the storm sewer system, which discharges to a culvert below Twin Lake Boulevard and outlets to Twin Lake, as shown on Figure 2-2.

Figure 2-2 Culvert below Twin Lake Boulevard

The culvert below Twin Lake Boulevard conveys stormwater from the Five Star Estates development into Twin lake. Survey completed by Barr Engineering Co., August 2018. The green icon indicates the location of the inset photograph.

On the south side of Twin Lake there is a culvert below the railroad tracks. There are approximately 53 acres south of the railroad tracks that drain to the culvert. During dry periods, some stormwater is stored in the pond and wetland south of the railroad tracks. During wet periods, stormwater from this area flows

north into Twin Lake. Figure 2-3 and Figure 2-4 show the area are upstream (south) and downstream (north) of the culvert below the railroad tracks.

Figure 2-3 Upstream of Culvert below Railroad Tracks

The culvert below the railroad tracks conveys stormwater north into Twin Lake. The green icon indicates the location of the inset photograph. The inset photograph shows the area facing north, towards the inlet of the culvert below the railroad tracks. The PVC pipe in the inset photograph is a field crossing installed by the property owner. Survey completed by Barr Engineering Co., August 2018.

Figure 2-4 Downstream of Culvert below Railroad Tracks

The culvert below the railroad tracks conveys stormwater north into Twin Lake. The green icon indicates the location of the inset photograph. The inset photograph shows the area facing southwest; the railroad tracks are on the left and Twin Lake is to the right. Survey completed by Barr Engineering Co., August 2018.

The overflow outlet from the watershed is to the Minnesota Department of Transportation (MnDOT) stormwater pond in the I-694 right-of-way (named "Waldo Pond"). As shown in Figure 2-5, the low point in the embankment is 877.0. If water were to overtop the embankment, it would flow downstream through the I-694 storm sewer system into Gervais Creek, the Phalen Chain of Lakes, and ultimately the Mississippi River.

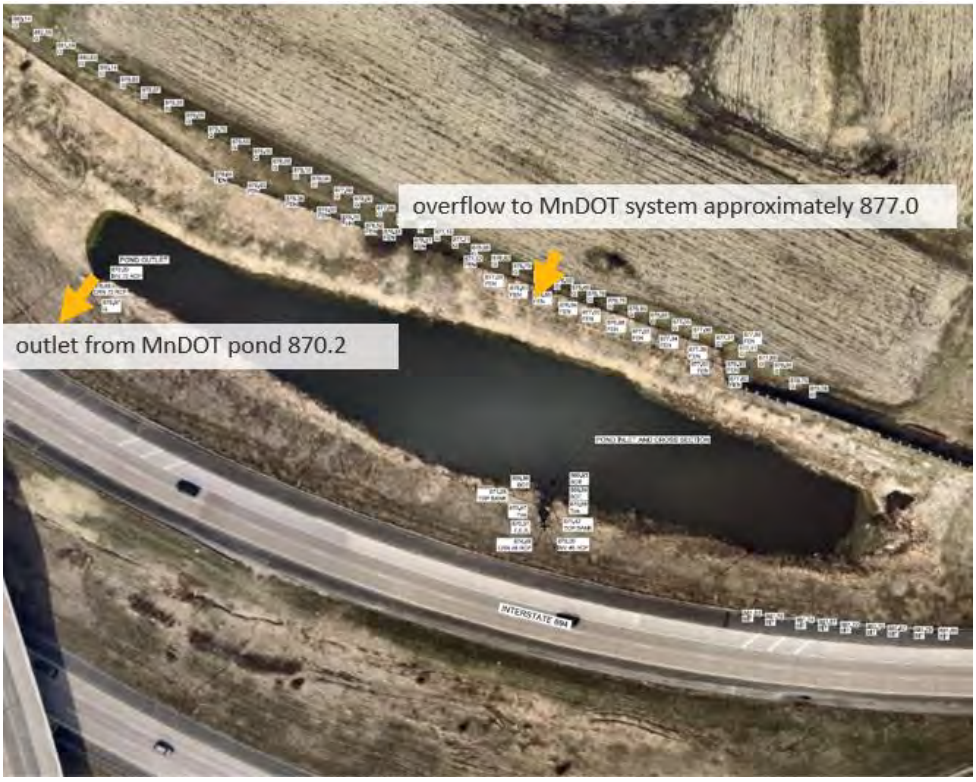


Figure 2-5 Watershed Overflow Location

The overflow from the Twin lake watershed is south into Waldo Pond. Survey completed by Barr Engineering Co., August 2018.

2.1.2 Existing Flood-Prone Areas

Drainage near the Twin Lake watershed was evaluated to define the 100-year floodplain downstream of Twin Lake, the 100-year floodplain on Twin Lake, and the Twin Lake stage-duration curve. A 100-year flood level is the flood level of a waterbody or low-lying area that has a 1-percent chance of occurring or being exceeded in any given year. It is determined by either storm event modeling or a statistical frequency analysis. A 100-year floodplain is the area inundated at the 100-year level elevation.

2.1.2.1 Existing Floodplain Downstream of Twin Lake

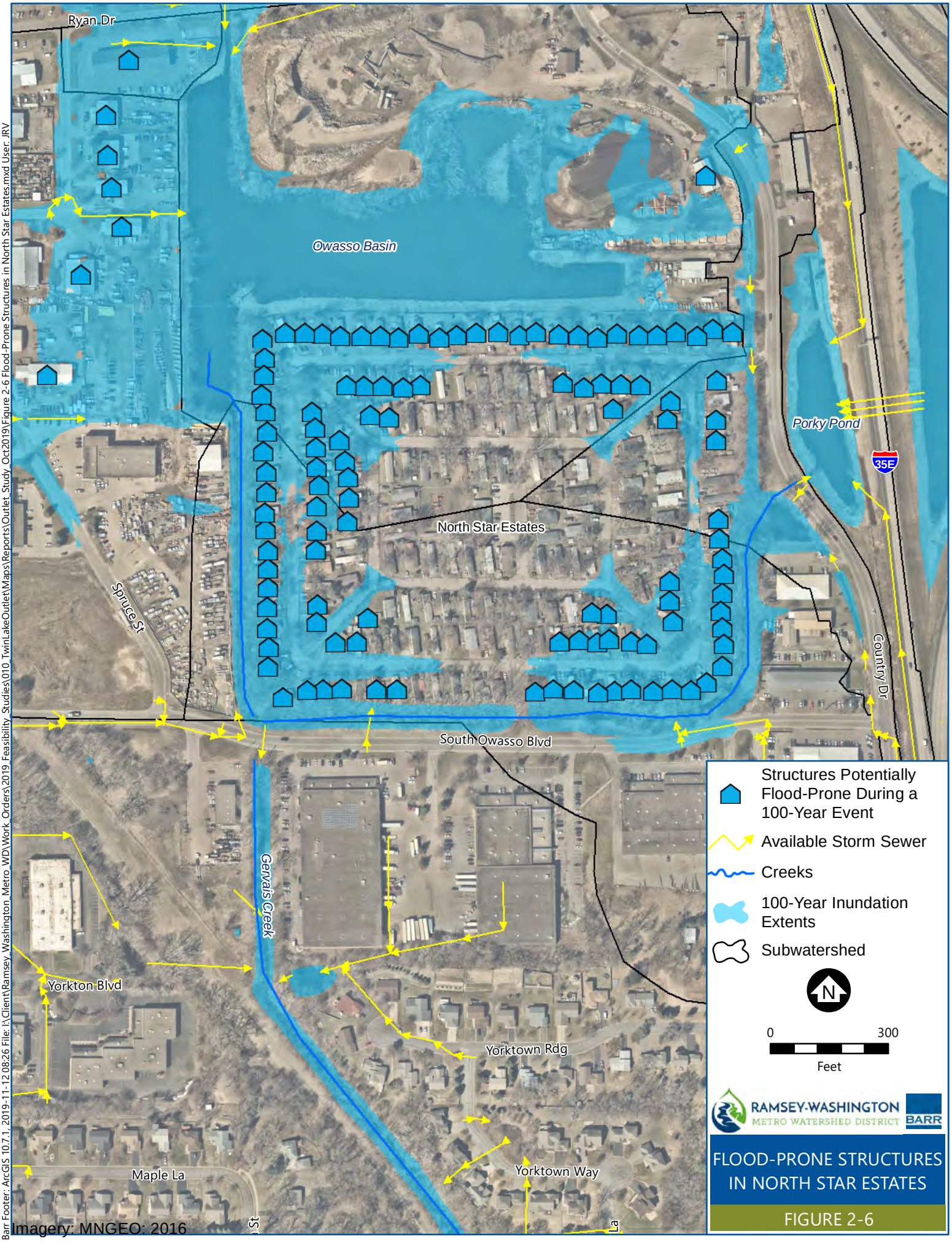
Through the adoption of the District Plan, the District establishes 100-year flood levels for District-managed waterbodies based on hydrologic and hydraulic modeling using Atlas 14 precipitation data (reference [1]). One-hundred-year water surface elevations published in the District Plan or subsequent

studies may differ from Federal Emergency Management Agency (FEMA) base flood elevations published prior to the adoption of Atlas 14.

For the subwatersheds downstream of a potential outlet from Twin Lake, including Gervais Creek, the Phalen Chain of Lakes, and the Saint Paul Beltline, the District stormwater model was used to calculate the 100-year water levels. The District stormwater model was developed using U.S. Environmental Protection Agency's Storm Water Management Model (SWMM) with a computerized graphical interface developed by XP Solutions, now Innovyze (XP-SWMM, version 2014). XP-SWMM simulates both the hydrologic and hydraulic components of watershed modeling. The model uses rainfall and watershed characteristics to generate watershed runoff (hydrology), which is routed simultaneously through pipes and overland flow paths (hydraulics). The model also accounts for detention in ponding areas, backflow in pipes, and tailwater conditions that may exist and affect upstream storage or pipe flows.

Model parameters have been calibrated to measured lake levels throughout the District (reference [4]). The 100-year water levels were simulated using the 100-year, 4-day duration Atlas 14 rainfall depths. Floodplain extents were used to define potentially flood-prone structures in the downstream subwatersheds. The District model assumes that stormwater culverts, sewers, and lake outlets are all free of debris and functioning as designed for calculating floodplain elevations.

North Star Estates, a development located west of the I-35E and I-694 interchange (shown in Figure 2-6), has 114 structures below the 100-year floodplain. Further downstream there are two structures on Gervais Lake, shown in Figure 2-7, whose low entry elevations are below the 100-year floodplain.



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2.1.2.2 Existing Twin Lake Floodplain

Twin Lake is a landlocked lake. Water levels in landlocked lakes fluctuate depending on climatic and groundwater conditions. The two primary outflows from landlocked lakes are evaporation and net groundwater outflow, or seepage. Due to the variability in the water surface elevations, the water level prior to running a design rainfall event can vary. Also, prior to 2018, lake levels were not officially taken or recorded in Twin Lake, leaving no historical record of measured lake levels to evaluate. Therefore, Twin Lake was evaluated using 70 years of historical, continuous rainfall data to generate a time series of historical water levels. Then the water levels were statistically evaluated to calculate the elevation corresponding to a 1-percent-annual-probability of occurrence, which is also referred to as the 100-year water level.

Barr used the District's stormwater model to simulate existing conditions in the Twin Lake watershed. The XP-SWMM model's hydrologic inputs were previously calibrated (reference [4]). The evaluation assumes that future hydrologic conditions will match existing hydrology and that the net seepage rate to groundwater and groundwater elevations remain constant during the 70-year simulation.

Historic, hourly precipitation and temperature data from the Minneapolis-Saint Paul International Airport (MSP) weather station were used to model 70-continuous years from January 1949 through December 2018. Years prior to 1949 were not modeled due to the lack of precipitation data. The Twin Lake continuous modeling results are shown in Figure 2-8.

Twin Lake Ordinary High Water (OHW) elevation is determined by the MDNR in the field. The OHW is defined as the elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence on the landscape, typically at the point were natural vegetation changes from aquatic to terrestrial (reference [5]). The OHW for Twin Lake is 869.9 (reference [3]).

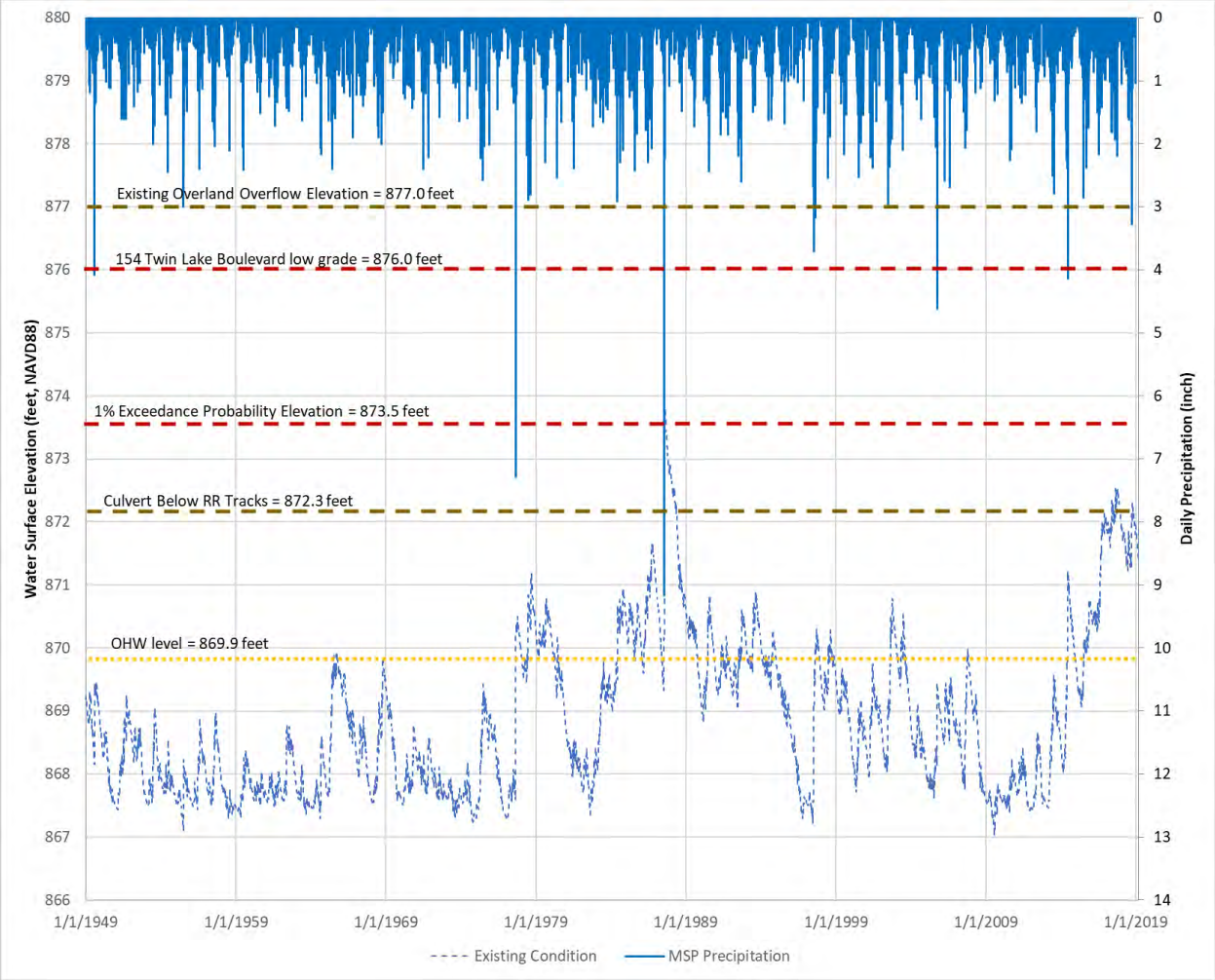


Figure 2-8 **Twin Lake's Simulated Historical Water Levels** under Existing Conditions

The United States Army Corp of Engineers (USACE) Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) was used to estimate the 1-percent-annual-probability lake level (or the elevation defined as the 100-year flood level). The Twin Lake probability curve is shown in Figure 2-9. Using this method, the 100-year flood level for Twin Lake is calculated as 873.5. Figure 2-10 shows the 100-year floodplain on Twin Lake. The floodplain in Waldo Pond would overtop the embankment during a 100-year event, and overflow from Waldo Pond would be conveyed north into Twin Lake. Overflow from Waldo Pond north towards Twin Lake has not occurred in the past but is considered when determining the 100-year floodplain.

The lowest habitable structure on Twin Lake (154 Twin Lake Boulevard) has a low entry elevation of 876.0. The annual water surface "exceedance probability" shown in the figure below shows a range of historical elevations for Twin Lake and the statistical probability that each is exceeded in a given year. For example, there is a 1-percent chance that the lake level will exceed elevation 873.5 in any given year.

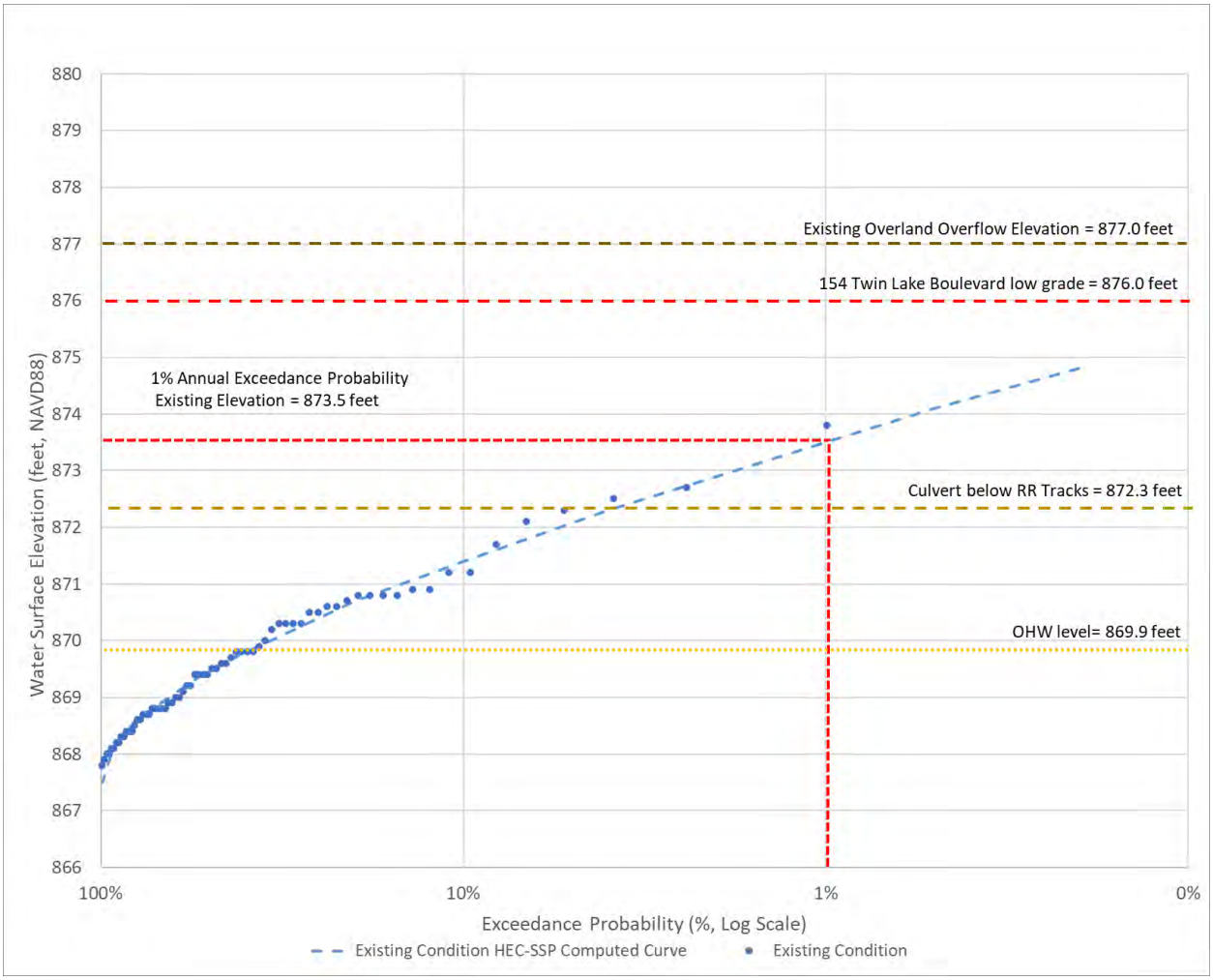
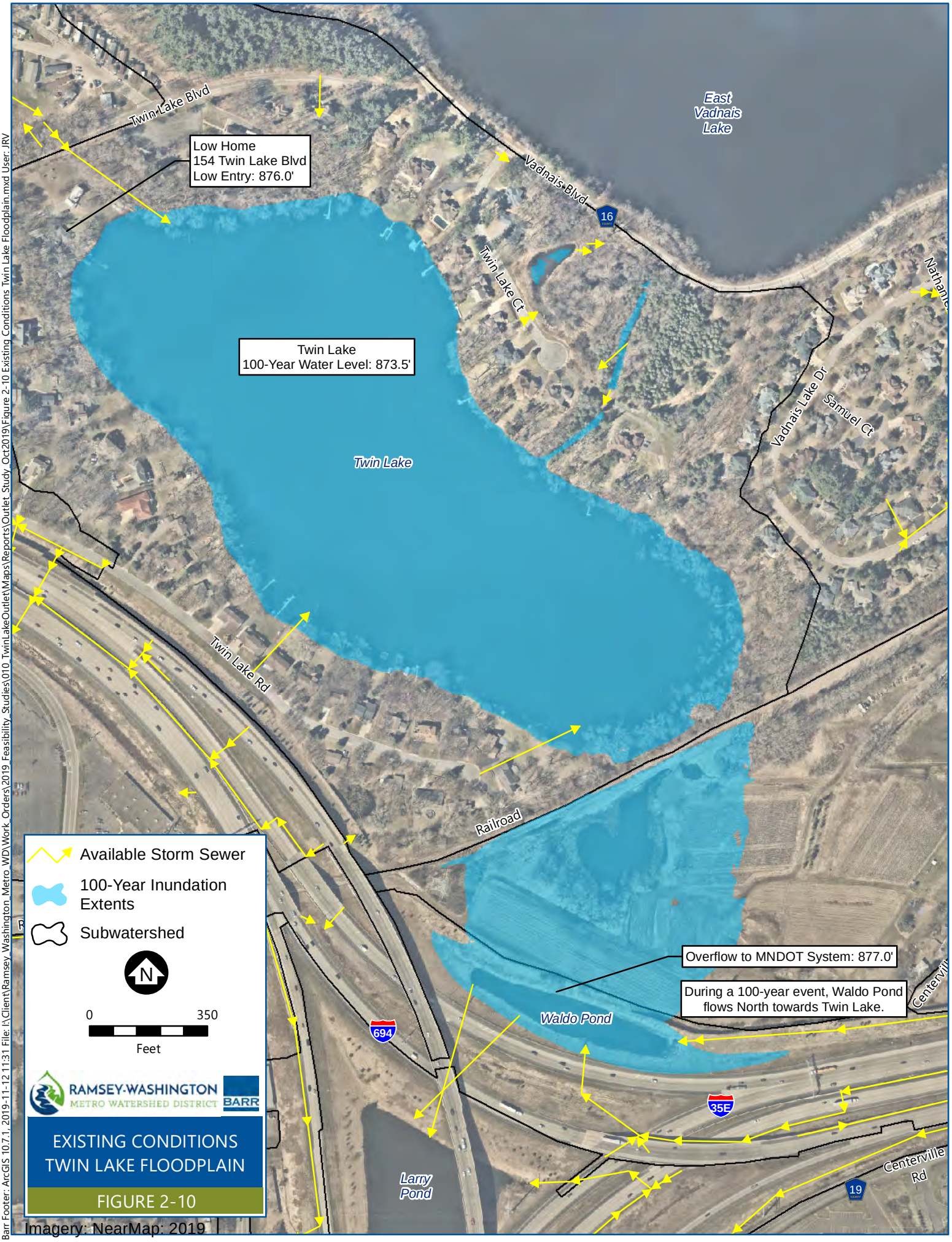


Figure 2-9 Existing Conditions Twin Lake Annual-Exceedance Probability

Existing conditions elevation-frequency curve is based on simulation of 1949 – 2018 rainfall.



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2.1.2.3 Existing Twin Lake Stage-Duration Curve

Outflow from landlocked waterbodies is typically limited to evaporation and seepage. As a result, it can take a long time, in some cases several years, for water levels to return to a perceived "normal" following periods of high rainfall. In landlocked basins, shoreline impacts can result from prolonged periods of inundation. As a result flood-risk reduction projects for landlocked basins, such as Twin Lake, may also consider changes to the stage-duration curve.

A stage-duration curve is a plot of the percentage of time the lake level exceeds a given elevation. Whereas the elevation-frequency curve is the probability that a given elevation will be exceeded. In other words, a frequency curve indicates the likelihood that the lake level will exceed a given elevation, and a duration curve indicates how long the water level has stayed above a given elevation. Water bodies with highly variable elevations often have a steep curve, which indicates a quick return to the outlet elevation. Landlocked water bodies often have a flatter curve, which indicates a slower return to normal elevations.

Because historic continuous water level measurements are not available for Twin Lake, the District's stormwater model was used to generate a continuous time series of historical lake levels, which are shown in Figure 2-8. The continuous simulation results were used to develop the stage-duration curve for Twin Lake, which is shown in Figure 2-11.

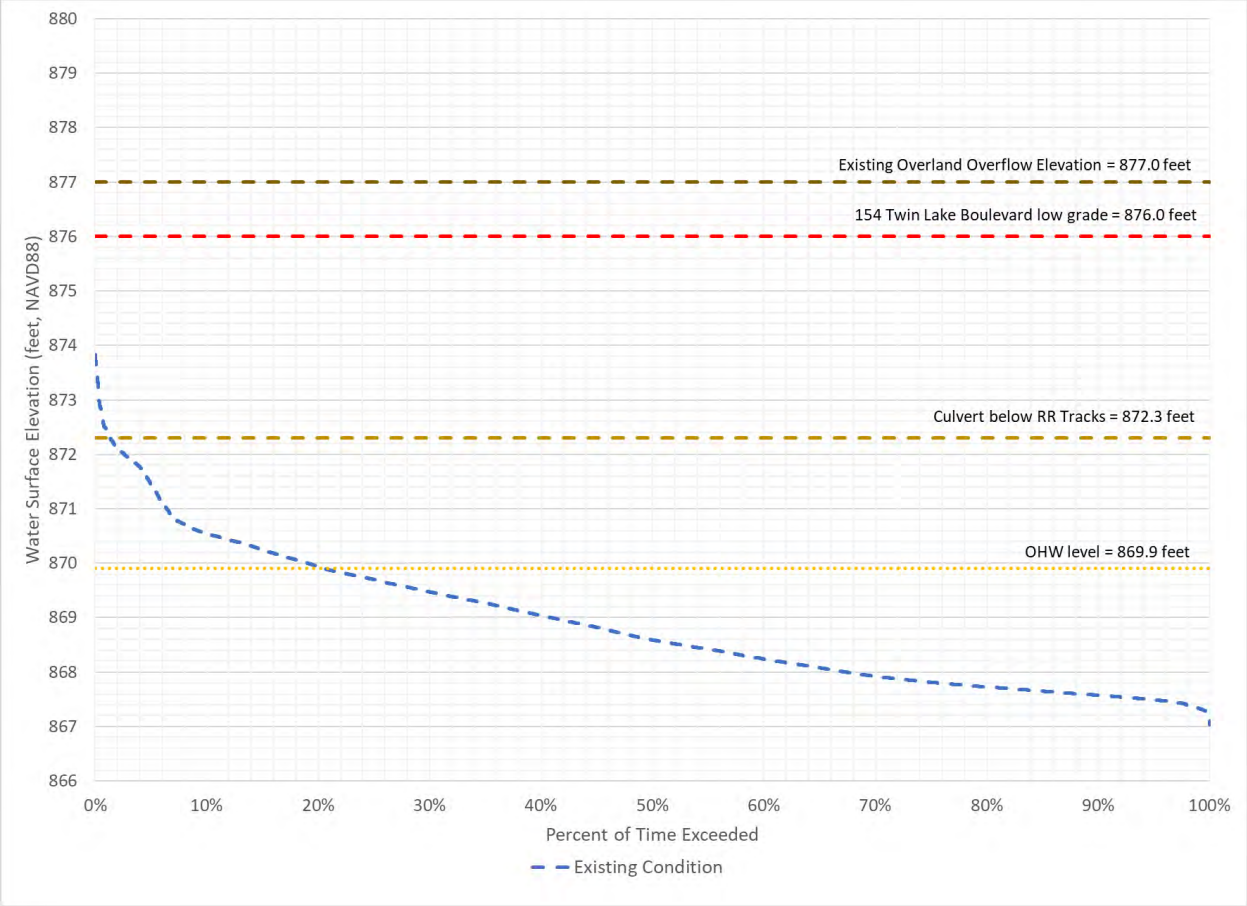


Figure 2-11 Existing Conditions: Twin Lake Elevation-Duration curve

Existing conditions elevation-duration curve is based on simulation of 1949 – 2018 rainfall.

2.2 Historic Drainage Patterns

Twin Lake is located upstream of Gervais Creek (County Ditch 16). The complete history of the Ramsey County ditch system is not clear. Many of the original construction drawings, surveys, descriptions, and many legal documents supporting the construction of the county ditches were destroyed in earlier fires or records lost in moves of the County administration (reference [6]). In 1982, legislation restricted Ramsey County ditch maintenance within watershed districts (reference [7]), and authority for maintenance of county ditches was transferred to RWMWD in 1983 (reference [8]). At that time the District gathered available documents related to County Ditch 16. As requested by the RWMWD Managers, the following is a brief history of County Ditch 16 to provide background on past decisions and guidance on actions going forward.

County Ditch 16 Established

County Ditch 16 was established by the Ramsey County Board on January 3, 1918 (reference [9]). The upstream extent of County Ditch 16 was a point where drainage crosses the Northern Pacific Railroad, continuing southeasterly to the confluence with Gervais Creek at old Centerville Road (reference [9]).

Figure 2-12 shows the December 1917 Ramsey County survey of the County Ditch 16 alignment. County Ditch 16 served as the outlet from Twin Lake if water levels in the lake reached the outlet elevation. The original intent for County Ditch 16 was to improve drainage for agricultural purposes (reference [6]). District does not have original construction drawings that provide information on the profile or ditch geometry.

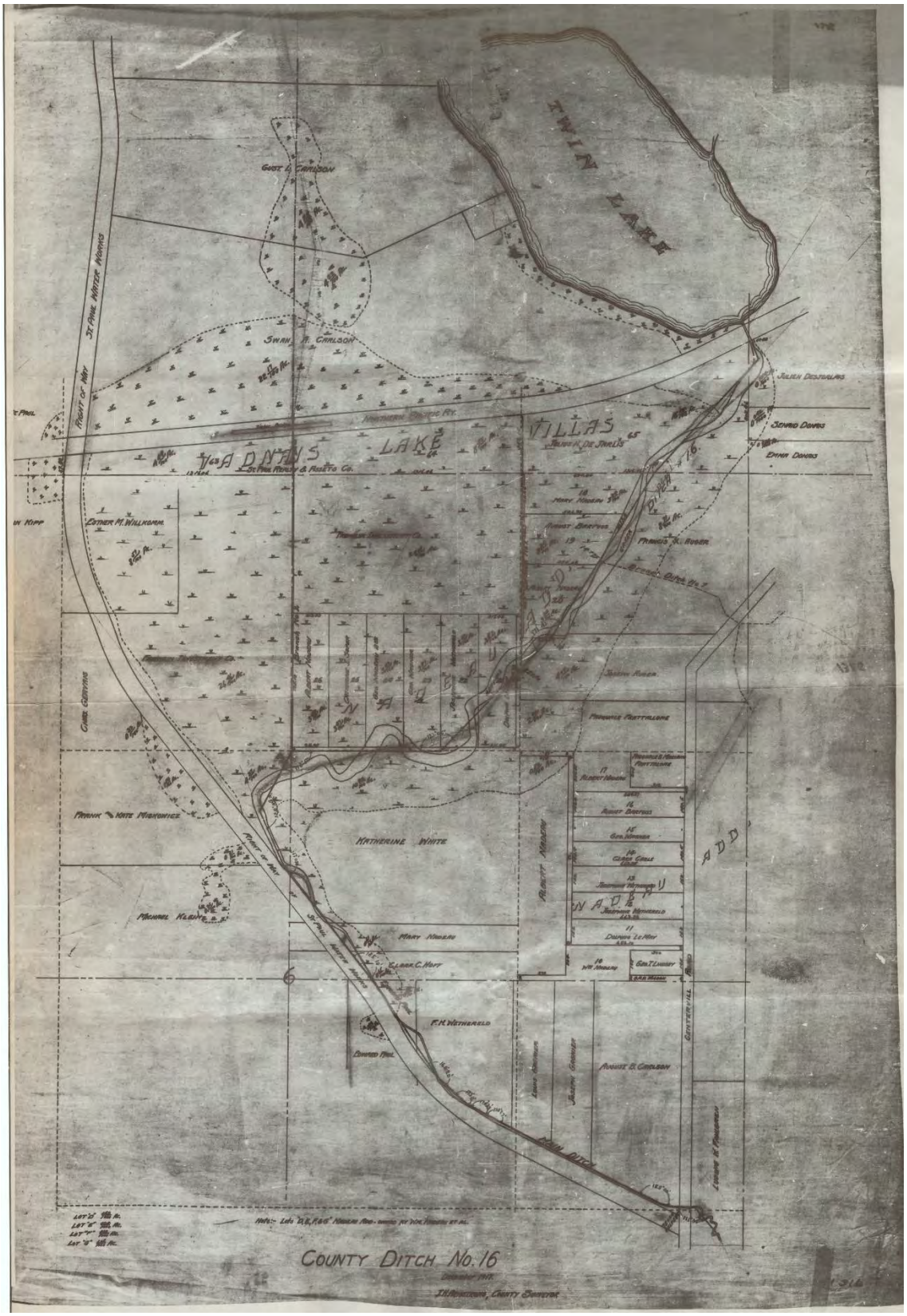


Figure 2-12 Survey of County Ditch 16 Alignment (1917)

CONSTRUCTION OF BP PIPELINE

Standard Oil Company obtained an easement in 1946 for the Dubuque-Twin Cities pipeline (reference [10]), and the pipeline was constructed in 1947 (reference [11]). The pipeline is a 10-inch-steel petroleum pipeline. The approximate alignment is shown on Figure 2-13. In this area, the pipeline is approximately 4 feet deep (reference [11], [12]), which corresponds to an invert elevation of approximately 871.0. Original construction drawings for the pipeline were not available for this study, but current standards require a minimum 2 foot vertical separation for utility crossings, and a minimum 4 foot vertical separation for drainage ditch crossings.

The pipeline is shown on the as-built drawings for I-694 and the recent MnDOT State Project (SP) 6280-304, which improved the I-694 and I-35E interchange, drawings (reference [12], [13]). MnDOT SP 6280-304 is also referred to as "Unweave-the-Weave"

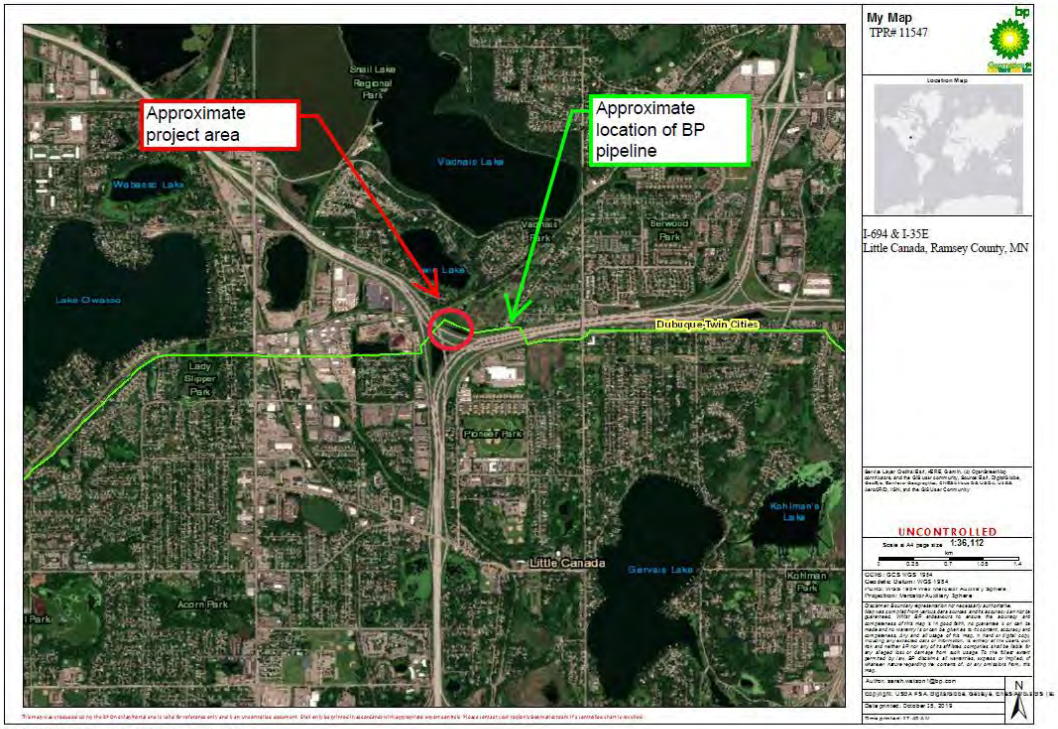


Figure 2-13 Approximate Location of Petroleum Pipeline

The approximate location of the BP pipeline is shown in green. In general, the pipeline is located north of Waldo Pond near the fence along the MnDOT right-of-way. The approximate project area in red shows the general location of the MnDOT berm and Waldo Pond.

CONSTRUCTION OF INTERSTATE SYSTEM

In the late 1960s MnDOT constructed I-694. As a result of the interstate construction, and specifically the interchange between I-694 and I-35E, the portion of County Ditch 16 was modified and realigned, as shown in Figure 2-14. County Ditch 16 was routed through a culvert near the MnDOT right-of-way and directed into the MnDOT drainage system. Within the MnDOT drainage system, County Ditch 16 was

piped through the I-694/I-35E interchange and discharged back into an open ditch west of I-35E (reference [12]). The inlet to the culvert below I-694 was listed as 872.02 (National Geodetic Vertical Datum of 1929 [NGVD29]) on the as-built drawings. The profile for the realigned portion of County Ditch 16 does not show the 10-inch petroleum pipeline, so it is unclear whether the realignment of County Ditch 16 meets current criteria for minimum offset from a petroleum pipeline. The as-built drawings do not include information regarding the profile of County Ditch 16 north of the MnDOT right-of-way.

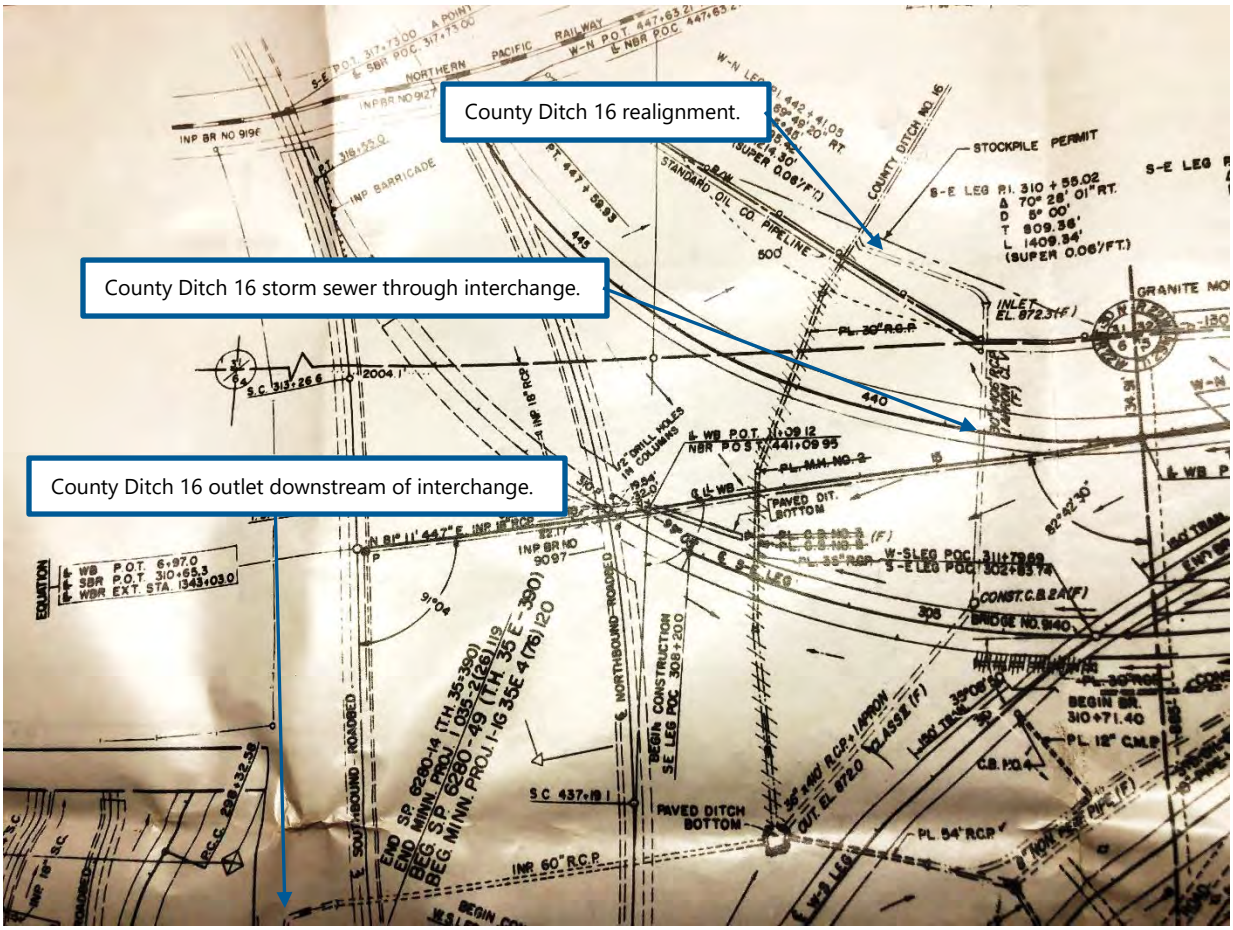


Figure 2-14 I-694 As-Built Drawing (1970)

The 1970 as-built drawing for the I-694/I-35E interchange shows the realignment of County Ditch 16 north of the interchange. Within the interchange the open ditch was replaced with a storm sewer that outlets to the west side of the interchange.

Milner W. Carley & Associates Report on County Ditches 16 and 7

In 1968, Milner W. Carley & Associates completed a report documenting the history of the two county ditches, drainage concerns, and recommendations for modifications to the county ditch system (reference [14]). The study was supporting documentation for proposed modifications to the ditch system to improve drainage. The report noted that the county ditches were constructed in the early 1900's to benefit agricultural lands, but the watershed had been increased due to extension of private ditches and development of property.

The report included figures of profiles for the county ditch system. Figure 2-15 shows the portion of County Ditch 16 from the railroad tracks to I-694. The 1968 profile indicated that there were high points near 874, between the railroad and I-694 that would control when water from Twin Lake would be conveyed downstream. However, the report noted that no maintenance had been performed on County Ditch 16 or 7 since they were constructed, and it is unclear whether the high points in the profile were intended or developed over time following the original ditch construction. The report did not include recommendations for improvements to the section of ditch upstream of I-694.

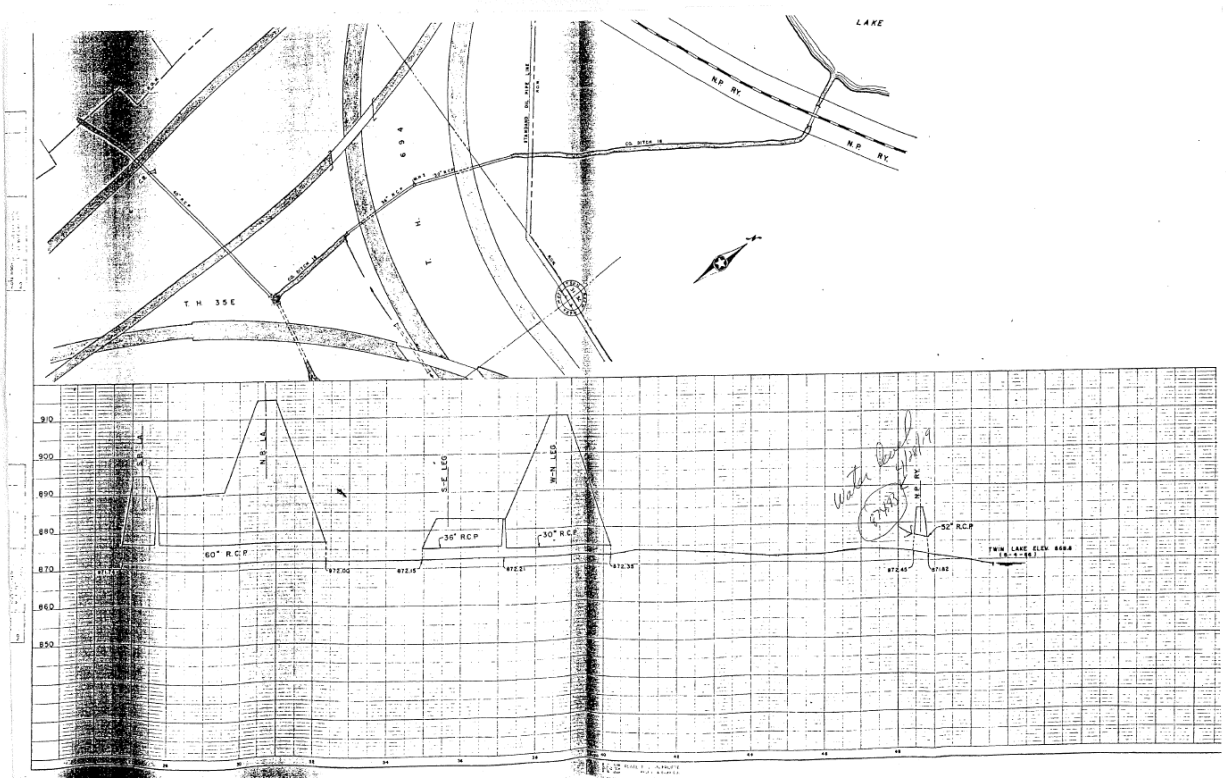


Figure 2-15 Drainage Profile between Twin Lake and I-694 (1968)

Drainage profile between Twin Lake and I-694, from the Milner W. Carley & Associates 1968 Report for County Ditches 16 and 7. The Twin Lake water level in the profile is labeled 1966. The profile indicates there are high points in the County Ditch near approximately 874.0 between the railroad tracks and I-694.

Ramsey County Hydrologic Study

In the early 1970s, open space in Ramsey County was rapidly beginning to be developed. At that time the Ramsey County Commissioners determined that water resource management should be developed around the principle that water is an asset to be enjoyed, utilized, and conserved, and not passed downstream quickly to the nearest river (reference [15]). In support of that principal the Ramsey County Commissioners passed a resolution that:

> *"Now, therefore, be it resolved, that all land development that increases the runoff from any area shall provide for the removal of pollutants and further shall provide ponding so that the rate of flow into lakes, streams or ditches shall not be greater that it was originally."*

In response to the resolution, the Commissioners completed a hydrologic study to develop information needed to enforce the resolution. The study was completed in 1975 and noted that "*the existing control level of Twin lake is at an elevation 874, which is caused by a high point in County Ditch 16 between Twin Lake and Interstate highway 694*" (reference [15]). The study recommended that improvements to the County Ditch 16 system should include lowering the outlet to reduce flood risk to the low home on Twin Lake (reference [15]). However, it is worth noting that this was a planning-level study which did not consider the elevations of downstream culverts through I-694 that would have limited how low the outlet could be and did not consider potential downstream impacts.

Jurisdiction Transferred to RWMWD

In 1983, RWMWD took over jurisdiction of County ditches within the watershed. District staff completed assessments of the ditch system in the fall of 1983 and spring of 1984 (reference [6]). Documentation included a photographic log, depth and width, bank slope, vegetative cover on the bank slope, bottom width, water depth, adjacent land use, identification of ditch bank erosion, and the inventory of outfall structures. The inspection noted that County Ditch 16 was stable and well-vegetated with the exception of the portion north of Owasso Boulevard where some erosion was occurring.

RWMWD Hydrologic Study

In 1993, RWMWD completed a hydrologic study of the Twin Lake subwatershed to evaluate flood risk and identify strategies that would reduce the potential for flooding and degradation of water quality in Twin Lake. As part of the study, drainage profiles were developed between East Vadnais Lake (referred to as Vadnais Lake in the study) and Twin Lake and from Twin Lake to I-694.

The drainage profile between Twin Lake and I-694, shown in Figure 2-16, indicated that the area between the railroad tracks and I-694 drained towards Twin Lake.

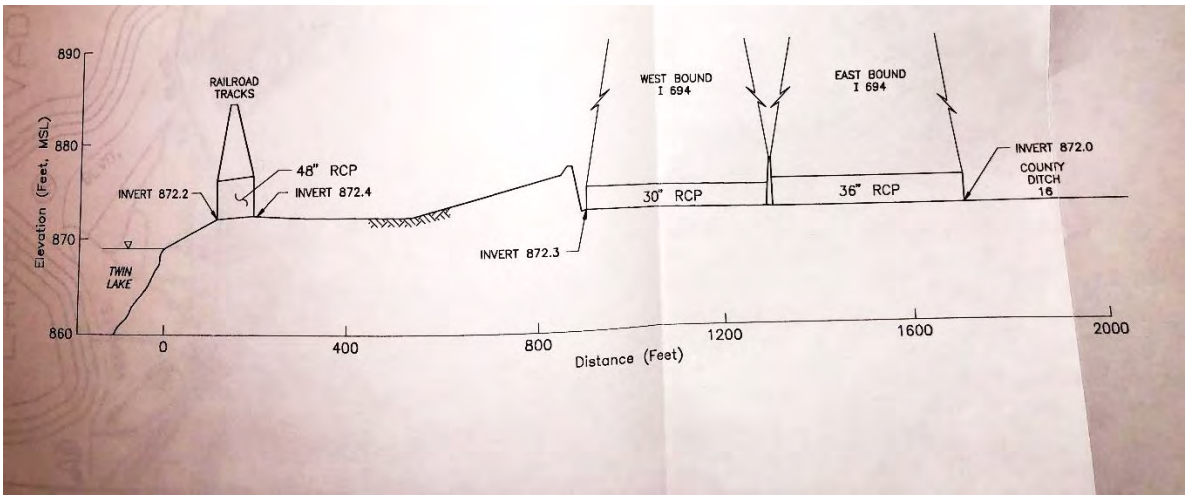


Figure 2-16 Drainage Profile between Twin Lake and I-694 (1993)

Drainage profile between Twin Lake and I-694. In general, the area between the railroad tracks and I-694 is sloped towards Twin Lake. Water levels in Twin Lake would need to exceed the crest of the berm north of westbound I-694 before discharging to the MnDOT drainage system.

The 1993 study also noted that there was potential for Vadnais Lake (East Vadnais Lake) to overflow into Twin Lake. However, Saint Paul Regional Water Services (SPRWS) historically maintained (and still maintains) the East Vadnais Lake level below the overflow to prevent discharge to Twin Lake and avoid adverse water quality impacts to Twin Lake. Because the East Vadnais Lake level was actively managed, the 1993 study assumed there would not be an overflow into Twin Lake (reference [16]). It is important to note that the 1993 study, and previous studies, include general references to Vadnais Lake. The figures in the reports indicate that the discussion is in reference to East Vadnais Lake.

Stormwater modeling developed for the 1993 study estimated a 100-year water level in Twin Lake of 875.1, which was lower than the low home on Twin Lake (low entry of 876.0). Due to the proximity of the 100-year water level to the low home, the 1993 study included a recommendation to construct a pipe to the I-694 drainage system. However, since the calculated flood level was dependent on the starting water level in Twin Lake and the duration of the rainfall event, the recommendation was to defer modifications to the system until water levels in Twin Lake rose above 870.5. If water levels exceeded 870.5, pumping or culvert construction could be selected as a management approach.

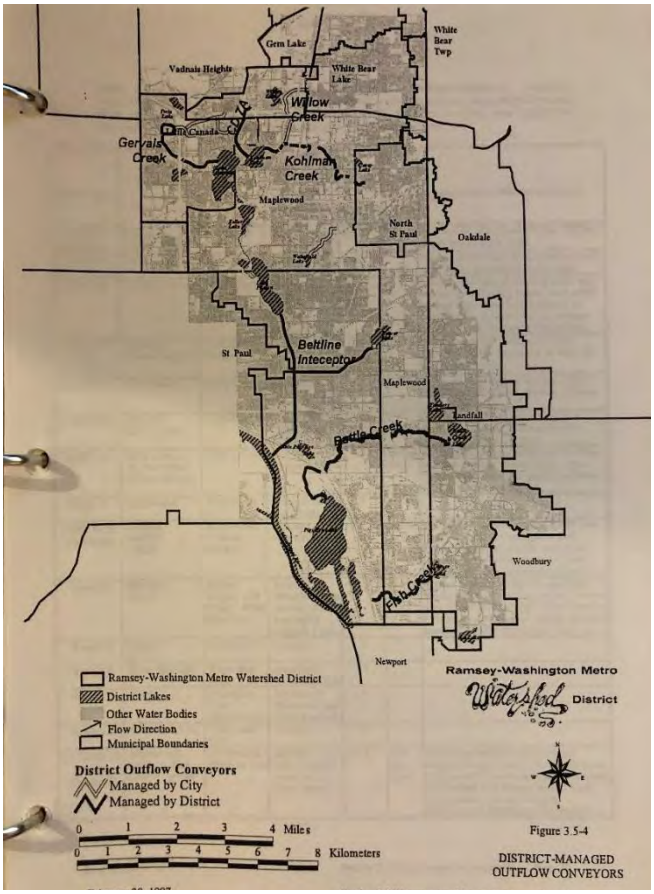
It is important to note that the 1993 study did not recommend removing the embankment near I-694 because doing so could threaten the water quality of Twin Lake. The study noted that because Twin Lake is landlocked it has remained relatively free of pollutants and algal overabundance. Twin Lake is separated from interstate runoff, and this separation is beneficial since it prevents pollutants in highway stormwater runoff from reaching the lake. The study recommended, if possible, to maintain this hydraulic separation.

1997 Watershed Management Plan

The RWMWD 1997 Plan included a County Ditch inventory. The 1997 Plan noted:

> *"County Ditch 16 drains 1,900 acres from portions of Vadnais Heights and Little Canada (including Round and Savage Lakes). The original ditch extended to Twin Lakes. The ditch is now cut off by I-694 and no longer exists north of the freeway. For all practical purposes County Ditch 16 now ends at I-35E, although some improvements were made by the District west of I-35. This plan identifies District responsibility for the flows between I-35E and Gervais Lake; the cities are responsible for the lateral (primary) drainage systems above I-35E."*

The 1997 Plan included the extent County Ditches and streams managed by the District shown on Figure 2-17.



The 1997 Plan indicated that County Ditch 16 ended at I-35E.

Figure 2-17 District Managed County Ditches from 1997 Watershed Management Plan

Unweave the Weave

Figure 2-18 Unweave-the-Weave Stormwater Ponds

In 2005, MnDOT fully reconstructed and improved the I-694 and I-35E interchange. The MnDOT project SP 6280-304, has often been referred to as "Unweave the Weave". As part of the project, MnDOT constructed several stormwater ponds for stormwater detention and treat runoff prior to discharging downstream. Three stormwater ponds, shown in Figure 2-18 as "Waldo," "Larry," and "Porky" were constructed near the interchange. Waldo Pond, constructed on the north side of I-694, was excavated and tied into existing ground north of the MnDOT right-of-way. The improvements to the interchange did not impact the crest elevation of the embankment that separated the MnDOT right-of-way and the agricultural field north of the highway. Downstream of Waldo Pond, MnDOT

drainage is conveyed through Larry and Porky Ponds before discharging to Gervais Creek west of I-694.

2007 RWMWD Watershed Management Plan

The 2007 RWMWD Plan included discussion of the 1993 Hydrologic Study (reference [16]). Future management recommendations for Twin Lake focused on preventing further degradation by keeping Twin Lake segregated from nearby drainage systems including I-694 and East Vadnais Lake. The 1997 Plan, noted that if overflow from East Vadnais Lake was expected, flow should be diverted around Twin Lake to avoid degrading the Twin Lake water quality. The plan also noted that,

> *"Assuming it is not necessary to accommodate periodic flows from Vadnais Lake, it was recommended that alterations to the Twin Lake outlet be considered, and lake levels continue to be monitored. The predicted 100-year flood level for Twin Lake is 875.1 feet, based on hydrologic modeling of the drainage area for the 100-year frequency, 30-day snowmelt event. This flood level is based on a maximum allowable normal water level of 870.7 feet, which is rarely, if ever, reached. When the water level of Twin Lake becomes extremely high, water would flow from the lake to the wetland north of I-694, through the culvert under I-694 and into the Gervais Creek system. If water levels reach 870.5 feet, an additional culvert should be installed through an existing dike that guards the entrance to the I-694 culvert to allow increased capacity from Twin Lake at a lower elevation, or the lake should be pumped to lower the risk of potential flooding. A permit from MNDOT would be required before an additional culvert could be placed. If RWMWD should decide to proceed with installing an additional culvert, the District will discuss the work with MNDOT before applying for a permit."*

At the time of the 2007 plan Twin Lake levels were low and overflows from East Vadnais Lake had not occurred. Following recommendations from previous studies consideration of system modifications was delayed until there was a need (reference [16]).

Atlas 14

In 2013, the National Oceanic and Atmospheric Administration (NOAA) released updated precipitation frequency estimates for the Midwestern states (NOAA Atlas 14, Volume 8). These estimates, which serve as an update to the U.S. Weather Bureau's Technical Paper 40 (TP 40), published in 1961, reflect the results of statistical analyses performed for a much longer period of recorded precipitation data. The results show significant increases in rainfall amounts in the Twin Cities area where the 100-year, 24-hour rainfall depth increased by approximately 25% when compared to TP 40. Following the release of Atlas 14, the District updated the hydrologic and hydraulic model of the stormwater system to incorporate the updated precipitation estimates to calculate the 100-year floodplain. The updated models resulted in identification of several structures downstream of Twin Lake within the 100-year floodplain.

2017 RWMWD Watershed Management Plan

In April 2017, the District revised its Plan in accordance with the Metropolitan Surface Water Management Act and Watershed Law (Minnesota Statutes Chapters 103B and 103D). The 2017 Plan is the current guiding document of the District. Section 2.0 of the Plan includes information regarding the Twin Lake subwatershed, including a general description, past studies, land use, drainage patterns, and District-managed waterbodies.

The Plan includes a discussion regarding managing Twin Lake flood risk if East Vadnais Lake overflows into Twin Lake. If outflow from East Vadnais is necessary, the Plan includes a recommendation that the flow be diverted around Twin Lake to reduce the potential for flooding and protect the water quality of Twin Lake. The Plan also notes that if regular discharge from East Vadnais Lake is anticipated, construction of a culvert through the embankment upstream of I-694 should be evaluated; however, additional coordination with MnDOT would be required prior to construction. In addition, the Plan states,

> *"If an outflow of 63 cfs from Vadnais Lake is necessary, it is recommended that the flow be diverted around Twin Lake to reduce the potential for flooding and protect the water quality of Twin Lake. It was suggested that the potential flow be diverted through wetlands west of Twin Lake, under I-694, and into the Gervais Creek system. Further study of this route would be necessary to assess the impacts on the Gervais Creek system."*

At the time the Plan was published, the District had completed a Districtwide update of the stormwater model to incorporate precipitation depths published in NOAA's Atlas 14, as well as best available topographic information. Since then, site-specific survey information has been collected in the Twin Lake watershed (2019); as such, more accurate outlet and overflow elevations are currently available. The District has continued to update the stormwater model as information has been collected.

City of Little Canada Requests Input from RWMWD

During the summer of 2018, the City of Little Canada requested assistance from the District to respond to residents' concerns related to high water levels. These concerns included discharge into Twin Lake through the culvert below the railroad tracks, dying trees around the perimeter of the lake, and damage to docks, beaches, and landscaping.

In August 2018, District staff met with Little Canada staff to discuss recent survey results for drainage structures within the watershed and review recent precipitation values, stormwater model simulation results, and available groundwater elevation information. Following the meeting, City of Little Canada staff asked District staff to attend a meeting with residents to support City staff and respond to questions.

Barr and the RWMWD attended a public open house facilitated by the City of Little Canada on October 8, 2018. During the meeting, Barr and RWMWD staff explained drainage patterns in the Twin Lake watershed and presented information on the recent survey of critical outlet structures within the subwatershed, recent lake-level information, past water quality data, historic precipitation data, and general groundwater patterns within the region (reference [17]). Residents asked questions related to how the MnDOT Unweave-the-Weave project and East Vadnais Lake affect Twin Lake water surface elevations. Residents also volunteered to provide anecdotal information on lake levels for further validation of the District stormwater model. The City of Little Canada offered to host another public meeting in the spring of 2019 and requested that the RWMWD attend to present responses to additional information provided by residents.

Record Precipitation

Historic water level measurements have not been routinely collected on Twin Lake. The District and County began recording water levels in 2018. Residents indicated that prior to approximately 2014 lake levels remained relatively stable. Following the October 8, 2018, public meeting, residents provided photographs that could be used to estimate historic lake levels. Photographs were compared to aerial images, available topographic information, and landmarks to estimate the lake level at the time the photograph was taken. The photographs provided by residents are consistent with general observations from past studies that lake levels have been relatively consistent (reference [16]). Since approximately 2014, residents have observed a gradual increase in lake levels. Estimated water levels, based on photographs provided by residents and recent measured water levels, are shown on Figure 2-19.

The increase in lake levels corresponds to the wettest period in the historic record. The rainfall record from the Minnesota State Climatology Office extends through 1891—128 complete years of data (Figure 2-20, reference [18]). The rainfall record indicates that:

- 2016 was the wettest year in the historic record (1891 to 2018)
- Three of the 10 wettest years were 2014–2016.
- Seven of the 9 previous years were in the top 30th percentile.
- The past 6 years have been the wettest consecutive 6-year period in the historic records.
- 2019 has the potential to end up as the wettest year on record.

As evident in the photographs provided by residents and water levels simulated using the District's stormwater model, shown in Figure 2-19, the increase in rainfall resulted in higher lake levels.

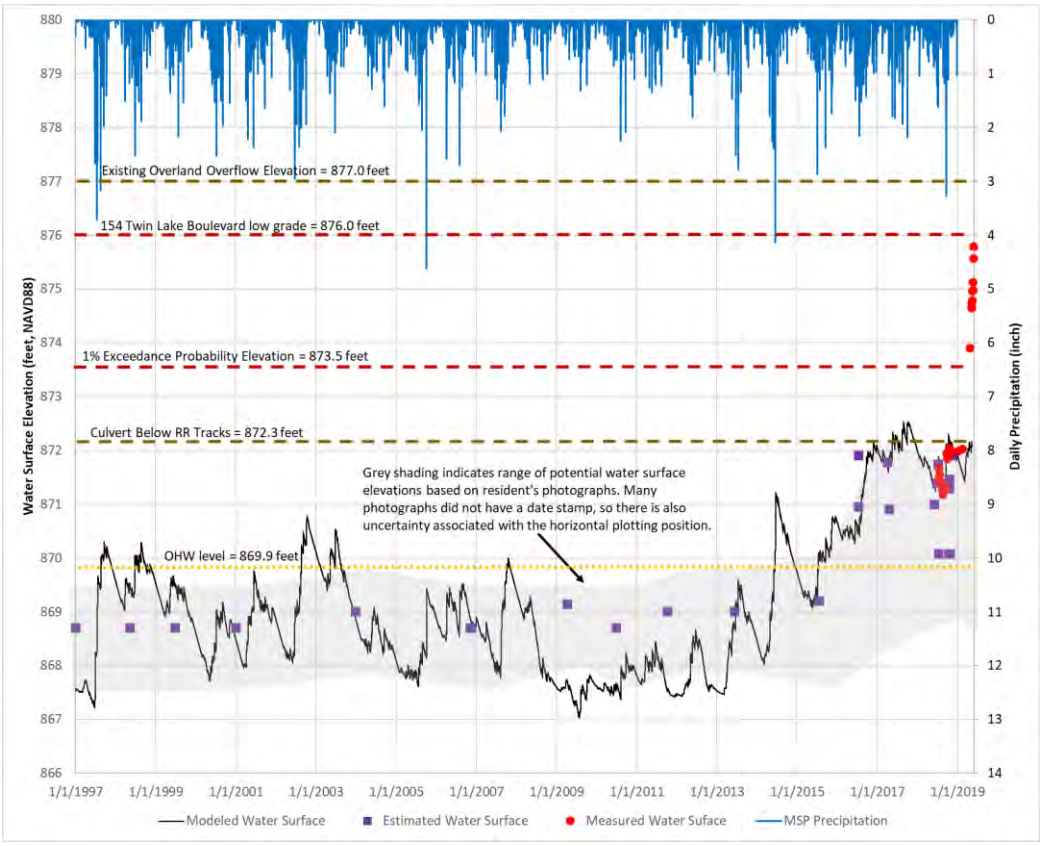
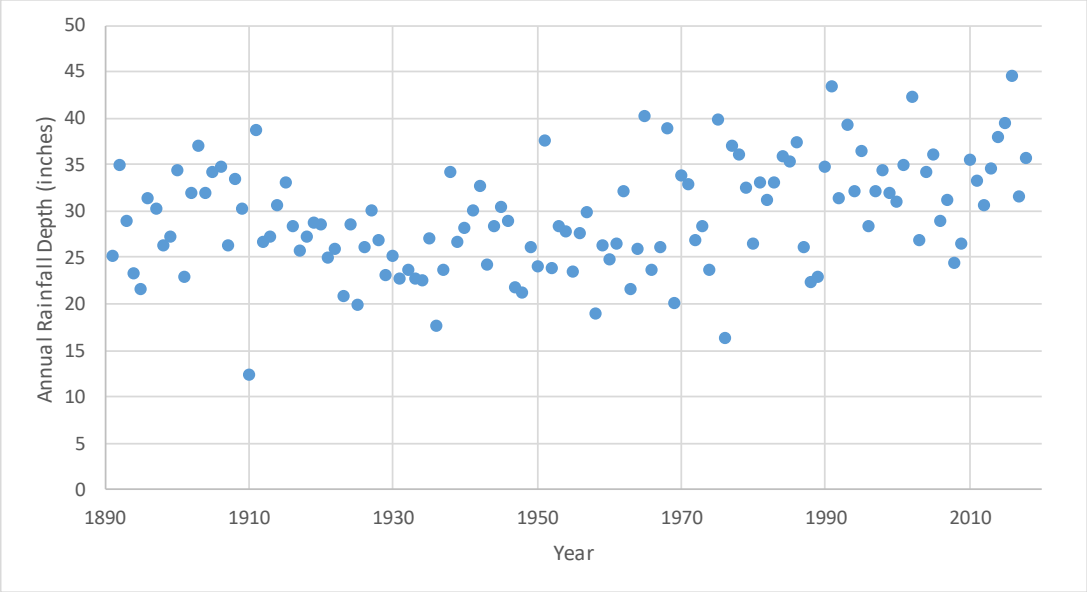


Figure 2-19 Historic Twin Lake Water Levels

This figure shows how the past levels of Twin Lake correspond to the modeled water surface that we estimate for the lake that does not include inflows from West Vadnais Lake. The red dots show measured Twin Lake water surfaces in 2019 that began to sharply increase in April and May 2019 as a result of the inflow from West Vadnais Lake.



Reference [18]

Figure 2-20 Annual Precipitation Record

Public Meetings, Spring of 2019

On March 12, 2019, Barr and the RWMWD attended a follow-up meeting, also facilitated by the City of Little Canada. Barr presented information to address residents' questions from the first public meeting, including how or if the Unweave-the-Weave project affected drainage patterns and historic water levels for East Vadnais Lake and Twin Lake. Following the October meeting, residents provided photographs of lake levels dating back to the mid-1990s, which were used to estimate historic lake levels. Barr used the RWMWD stormwater model to simulate the rise in lake levels prior to March 2019. Simulation results approximated available lake level measurements and estimated water levels, indicating that prior to 2019 the rise in lake levels was due to wetter-than-normal years. During the meeting, several questions were raised about water quality and future lake levels; the RWMWD informed residents that it would continue to monitor both water quality and lake levels (reference [19]).

Following the spring 2019 meeting, Twin Lake water levels were increasing faster than anticipated based on the District's stormwater model. Barr completed a survey of the area north of Five Star Estates on May 17, 2019. During the survey, a 24-inch stormwater inlet was identified west of Star Circle in Vadnais Heights. Barr requested information on the culvert from the City of Vadnais Heights and the City of Little Canada. Neither city had information on the storm sewer inlet or private storm sewer system in the Five Star Estates development. The City of Little Canada requested information from the engineer for the Five Star Estates development and received preliminary utility plans on May 20, 2019. These were dated June 10, 2013 but did not include the storm sewer inlet located in the field (reference [20]). On May 21, 2019, the City of Little Canada received utility information from the Five Star Estates' engineer that was revised on August 20, 2018, and did include the storm sewer inlet identified during the field survey (reference [21]). The revised survey showed that overflow from West Vadnais Lake was being conveyed through the Five Star Estates' private storm sewer into Twin Lake. Information included in the revised survey was communicated to the City of Little Canada City Council and Twin Lake residents during the May 22, 2019, City Council meeting. During this meeting, at the request of City of Little Canada staff, RWMWD also provided the City Council with a summary of information previously presented to residents during public meetings on October 8, 2018, and March 12, 2019 (reference [22]).

Overflow from West Vadnais Lake

As a result of the record precipitation, water levels in many waterbodies within the District were higher than normal during the spring and summer of 2019, including West Vadnais Lake. During the summer of 2019, West Vadnais Lake levels reached record highs and water overtopped along the southeast side of the lake. Overflow followed existing topography and drained to the 24-inch inlet west of Five Star Estates, which ultimately discharged to Twin Lake. This increased the drainage area to Twin Lake to over 5,000 acres. The additional inflow volume resulted in a continued rise in Twin Lake levels. Barr has not found documentation of an overflow from West Vadnais to Twin Lake prior to 2019.

In response to rising water levels, residents placed sandbags around the entry to the low home at 154 Twin Lake Boulevard (Figure 2-21). Other lake residents (with homes whose low entries are above the overflow elevation of 877.0) were concerned about the prolonged high water levels and water entering basements from waves, and some placed sandbags around low entries and sheds.

Figure 2-21 Sandbags at 154 Twin Lake Boulevard

Photo showing where residents and City staff placed approximately 1,900 sandbags at 154 Twin Lake Boulevard and 253 Twin Lake Trail on Saturday, May 25, 2019, and Tuesday, May 28, 2019. On Friday, May 24, 2019, 154 Twin Lake Boulevard was surveyed by RWMWD staff as the home on Twin Lake with the lowest entry elevation (876.0, 1 foot below the overflow in the MnDOT berm at 877.0). The City of Little Canada provided the sandbag materials and placement guidance to the residents.

The District estimated that Twin Lake would overtop the MnDOT embankment due to the continued inflows and rising water levels in Twin Lake. During the June 5, 2019, RWMWD meeting, Managers decided to support pumping from Twin Lake to the MnDOT storm sewer system. The decision was made acknowledging that pumping would mitigate flood risk on Twin Lake, while increasing flood risk to habitable structures downstream. During the meeting, District Managers also directed Barr and District staff to aid City of Little Canada staff in obtaining permits from MnDOT and the Minnesota Department of Natural Resources (MDNR) for temporary pumping.

Following the RWMWD Managers' decision to support temporary pumping from Twin Lake, the City of Little Canada City Council called an emergency meeting on June 6, 2019, to discuss emergency pumping (reference [23]). The City Council decided to authorize temporary pumping. Barr, RWMWD, and City of Little Canada staff obtained permits from MnDOT and the MDNR to lower Twin Lake water levels to 873.5, following an operational plan that was approved by MnDOT (reference [24]). Temporary pumping was started on June 11, 2019, and water levels were lowered to 873.5 by June 28, 2019. After June 28, 2019, water levels in Twin Lake continued to gradually decline through mid-July.

On July 1, 2019, conditions were conducive for placement of temporary sandbags where overflows had eroded areas along the southeast side of West Vadnais Lake. To a great degree, this contained the water

to its intended elevation based on the top of the eroded sections in the overflow areas. This resulted in a reduction of overflow from West Vadnais Lake to Twin Lake.

On July 10, 2019, the City of Little Canada City Council passed a motion to amend the permits the City had with MnDOT and the MDNR to lower Twin Lake to elevation 871.0. City of Little Canada staff requested assistance from Barr and RWMWD staff in revising the permits. To further lower the water level in Twin Lake, the pump intake was moved north of the railroad tracks. Pumping resumed on July 31, 2019. Twin Lake water levels were lowered, and City staff modified the sanitary sewer manhole to reduce the potential for inflow from the lake to the sanitary system. On September 11, 2019, the City council decided to leave the pump in Twin Lake because West Vadnais Lake levels were close to overtopping the temporary berm. All pumping operations were closely monitored and operated consistent with permitting requirements and monitoring of Owasso Basin and Phalen Chain water levels.

Rainfall in September and October resulted in West Vadnais overtopping once again. The City resumed pumping from Twin Lake on October 7, 2019, to prevent a rapid rise in lake levels. At the same time, RWMWD staff members were implementing a temporary bypass to route West Vadnais Lake overflow around Twin Lake. Water levels in the lake were managed effectively by the pumping.

Following the high water levels in 2019, the RWMWD Board of Managers authorized this feasibility study to evaluate alternatives to mitigate flood risk to habitable structures on Twin Lake.

3 Design Criteria

Modifying the outlet from Twin Lake will require approval from multiple entities with permitting authority. The following is a list of entities with permitting authority and minimum design criteria for an outlet modification.

3.1 Ramsey-Washington Metro Watershed District

RWMWD seeks to protect the public health and welfare and the natural resources of the District by providing reasonable regulation of the District's lands and waters to reduce the severity and frequency of flooding and high water; preserve floodplain and wetland storage capacity; improve chemical, physical, and biological quality of surface water; reduce sedimentation; preserve waterbodies' hydraulic and navigational capacity; preserve natural wetland and shore land features; and minimize future public expenditures to avoid or correct these problems.

An outlet from Twin Lake must meet the requirements of Rule C, Stormwater Management, which supports several Board policies including, "…to protect and maintain downstream drainage systems to provide permanent and safe conveyance of stormwater. Reduce the frequency and/or duration of potential downstream flooding." To comply with Rule C a proposed modification must demonstrate that runoff rates for the proposed activity shall not exceed existing runoff rates for the 2-year, 10-year, and 100-year critical storm events using Atlas 14 precipitation depths and MSE3 storm distributions, or as provided by the District. Runoff rates may be restricted to less than the existing rates when the capacity of downstream conveyance systems is limited.

We do not anticipate that proposed modifications will increase or disturb impervious surface; therefore, the runoff volume, or onsite retention, requirement in rule C may not apply.

An outlet from Twin Lake must also meet requirements in Rule D, Flood Control, which supports several Board policies including to "Encourage water quantity controls to ensure no net increase in the impacts or potential for flood on or off the site and encourage, where practical, controls to address existing flooding problems." To comply with Rule D a proposed modification must demonstrate that there would be no increase in the potential for flooding downstream of the modification.

An outlet from Twin Lake may also trigger requirements of Rule E, Wetland Management, which governs impacts to wetlands and wetland buffers. This rule applies whether or not the District is the Wetland Conservation Act local government unit in the municipality where the wetland is located.

An outlet from Twin Lake must meet the requirements in Rule F Erosion and Sediment Control. The project must implement erosion and sediment controls to limit the export of sediment off site, which impacts surface water quality.

3.2 Minnesota Department of Transportation

MnDOT regulates activities that impact the state drainage systems and activities within the MnDOT MS4-regulated area. A MnDOT Drainage Permit must be obtained when systems modify or connect to the state drainage system. The purpose of the Drainage Permit is to protect Minnesota's investment in infrastructure, including stormwater treatment basins, ditches, and storm sewer systems. As part of the Drainage Permit application the applicant must demonstrate that the peak discharge rate conveyed to the MnDOT drainage system does not increase for the 100-year event.

For permanent connections to the state drainage system, MnDOT requires permanent easement for proposed infrastructure and an operations and maintenance plan. Where modifications would reestablish a historic drainage connection, MnDOT would require the outlet type and configuration to be consistent with what was previously approved.

3.3 City of Little Canada

The City of Little Canada regulates grading within the city. Modifications may require a Fill Permit, which is required for all filling/grading work when over 100 cubic yards of material is placed.

3.4 Minnesota Department of Natural Resources

The MDNR regulates work below the ordinary high water (OHW) level of public waters. The OHW level for Twin Lake is 869.9 feet (North American Vertical Datum of 1988, NAVD88). If the outlet modification includes work below the OHW level a Public Water Work Permit must be obtained from the MDNR.

The MNDR requires an Appropriation Permit for actively managing the conveyance of stormwater. An Appropriation Permit would be required for outlet modifications that include pumping or a gate.

3.5 Minnesota Pollution Control Agency

The MPCA regulates the National Pollutant Discharge Elimination System (NPDES) stormwater permitting program. An NPDES permit is required for construction projects that disturb more than 1 acre of soil. An NPDES permit may be required depending on the area of disturbance. The MPCA will also require a stormwater pollution prevention plan (SWPPP).

3.6 BP Pipelines (North America)

Construction or excavation work performed near pipelines, or within a pipeline right-of-way is regulated by the United States Department of Transportation and the Office of Pipeline Safety. A proposed project that is located near a BP pipeline must be reviewed to ensure there are no adverse impacts to the operation and integrity of the pipeline. Work within the BP right-of-way must be reviewed by BP for conformance with applicable requirements. Typically, proposed modifications must comply with BP's General Design and Construction standards. Below is a summary of applicable standards and design criteria that applies to a utility crossing:

- No utility structures (manholes or catch basins) shall be located over the pipeline.

- Minimum vertical separation of 2 feet between the pipeline and underground utilities.
- Grading should not remove cover or add fill over the pipeline.
- A minimum of 4 feet of cover is required for all drainage ditches.
- Design plans must show the location and depth of the pipeline.

3.7 Summary of Design Criteria

Mitigating flood risk will require approval from multiple entities with permitting authority. Table 3-1 summarizes minimum design criteria. Additional requirements may be identified during final design of the selected alternative if the configuration, operation, or function changes when additional information is available.

Table 3-1 Design Criteria Summary

Design Criteria	Permitting Authority
No increase in peak runoff rate during 2-year, 10-year, or 100-year event	RWMWD – Rule C MnDOT
No increase in downstream flood elevations	RWMWD – Rule D
Implement erosion and sediment controls	RWMWD – Rule E City of Little Canada – Fill Permit MPCA – NPDES Permit
Avoid, minimize, and mitigate wetland impacts	RWMWD – Rule F
Minimum 2-foot vertical offset from pipeline for pipes	BP
Minimum 4-foot vertical offset from pipeline for drainage ditches	BP
Pump or actively manage discharge	MDNR

4 Flood-Risk Mitigation Goals

In the context of this feasibility study, flood-risk mitigation goals are considered objectives that go above and beyond the minimum criteria discussed in Section 3. For example, a goal for a system modification may be to provide additional freeboard for the low home or reduce the frequency with which lake levels extend onto residential property. These are potential benefits that system modifications could provide but are not necessarily a requirement. For the context of this evaluation, flood-risk mitigation goals that will be considered are the following:

- Provides additional freeboard between the 100-year water level and the entry of the low home
- Minimizes the frequency and duration that lake levels extend onto residential property or encroach upon auxiliary structures that were built below the floodplain (e.g., sheds or docks)
- Minimizes impacts to upland area including trees
- Provides flexibility for future operation and management of lake levels

Table 4-1 summarizes design goals for modifications to mitigate flood risk to habitable structures. Additional goals maybe identified following stakeholder input during the next phase of design.

Table 4-1 Summary of Design Goals

Design Goal	Notes
Maximize freeboard board between low home and 100-year water level.	Design goals are secondary objectives that a system modification should achieve after meeting the minimum design criteria summarized in Section 3.
Minimize the frequency and duration of inundation on residential property	
Minimize impacts to upland area	
Provide flexibility for future optimization	

5 Flood-Risk Mitigation Alternatives

Several flood-risk mitigation alternatives were considered for Twin Lake. Alternatives that did not meet the minimum design criteria were not evaluated in detail. Section 5.1 includes a brief summary of alternatives that were considered but were not evaluated in detail. Section 5.2 includes a discussion of the five alternatives that were evaluated in detail.

5.1 High-Level Screening of Alternatives

Selection of feasible flood-risk mitigation alternatives occurs by considering a holistic approach that accounts for unique site constraints, operation and maintenance, environmental concerns, effectiveness, downstream impacts, and overall cost. System modifications, at a minimum, should meet the design criteria summarized in Section 3 and preferably achieve the goals summarized in Section 4. As part of this feasibility study several types of system modifications were considered and ultimately discarded because they did not meet the minimum design criteria. A few of these alternatives are briefly described in the following sections.

5.1.1 Lowering Overflow Elevation to MnDOT Pond

Twin Lake is landlocked and the watershed has historically been separated from the I-694 drainage area. In general, this separation has prevented highway runoff, and the pollutants it carries, from discharging to Twin Lake, helping to preserve the historically good water quality in the lake. Lowering the overflow elevation from Twin Lake will allow water to discharge from the lake. However, that also would increase the potential for highway runoff to flow into Twin Lake during large or intense storm events. Maintaining the hydraulic separation between the interstate runoff and Twin Lake has been studied by the District in the past, and findings have led to the recommendation that the embankment should not be lowered (reference [16]). If any hydraulic connection was provided, it should include a backflow preventer to minimize the risk of the highway runoff draining toward the lake.

In addition, the 100-year water surface elevation in Waldo Pond calculated for Unweave the Weave project was originally calculated to be Elevation 876.7, which was based on rainfall depths published in TP40, the industry standard at the time of the design in 2005. Since then, the design rainfall depths for a given return period were revised (per Atlas 14) and, based on the District stormwater model, using the revised data the 100-year water surface elevation in Waldo Pond was updated to be Elevation 881.1. Lowering the overflow elevation would provide a hydraulic connection for more stormwater from Waldo Pond to discharge to Twin Lake and increase the flood elevation. Because lowering the overflow elevation would have adverse impacts on the water quality and increase the risk of flooding of Twin Lake, this alternative was not evaluated in detail.

5.1.2 Permanent Lift Station

MnDOT guidance for reestablishing a permanent connection to the state drainage system is to match the previously approved outlet type and outlet elevation. In the case of Twin Lake, this elevation would be considered as elevation 872.2 through the embankment north of Waldo Pond. The 1970 as-constructed

drawing shows an invert of 872.02 (reference [25]), which was converted to NAVD88 by adding 0.14 feet. Typically, permanent lift stations cost significantly more to construct and maintain than gravity drainage systems. Therefore, a permanent lift station was not evaluated in detail, since gravity flow options are under consideration.

5.2 Flood-Risk Mitigation Alternatives

Four alternatives to reduce flood risk were considered:

- Alternative 1 – Remove Flood-Prone Structure
- Alternative 2 – Emergency Response Plan
- Alternative 3 – Gravity Outlet at Elevation 874.0 through the embankment north of Waldo Pond
- Alternative 4 – Gravity Outlet at Elevation 872.2 through the embankment north of Waldo Pond

Each alternative is discussed in more detail below. The intent of each alternative is to reduce flood risk for habitable structures, meet the design criteria summarized in Section 3, and flood-risk mitigation goals summarized in Section 4.

5.2.1 Alternative 1: Remove Flood-Prone Structure

Alternative 1 includes the evaluation of the purchase of one home in the flood zone (154 Twin Lake Boulevard) and removal of it and all auxiliary structures, driveway, utilities, and abatement of hazardous materials such as asbestos, lead, or mercury, should they exist. When a property is within the floodplain or experiences flooding, costs for the property owner and community to respond can be high. When flood waters eventually recede repairs and cleanup may continue long after the flood risk as passed. Removal of flood-prone structures is the most permanent form of flood-hazard mitigation.

Typically, removal of flood-prone structures is most common when structures are located in the floodplain. Often voluntary buyouts to homeowners are offered to those who are subject to a continued risk of flooding. In the case of Twin Lake, the low home is located above the 100-year floodplain elevation of 873.5. However, because the home is located below the overflow from Twin Lake (elevation 877.0), this home has a higher risk of flooding and potential for prolonged periods of high water levels.

Alternative 1 is shown on Figure 5-1. This alternative does not include modifications to the drainage system or removal of other auxiliary structures that have been constructed below the overflow elevation of 877.0.

5.2.1.1 Floodplain Impacts

This alternative includes removal of the low home and designating the property as open space. This alternative does not change the storage volume within the floodplain or significantly change the volume of runoff that reaches Twin Lake. Therefore, this alternative does not result in changes to the 100-year water level in Twin Lake, discussed in Section 2.1.2.2; the Twin Lake elevation-duration curve, discussed in Section 2.1.2.3; or 100-year water levels downstream of Twin Lake, discussed in Section 2.1.2.1.

5.2.1.2 Regulatory Approvals

A fill permit will be required by the City of Little Canada. If the structure will not be relocated, a demolition permit will also be required by the city. The City of Little Canada provides guidance on pre-demolition procedures including inspection, which requires completion of a hazard substance assessment. Additional permits may be required if hazard substances are present.

The MPCA regulates the NPDES stormwater permitting program. An NPDES permit is required for construction projects that disturb 1 acre. The MPCA will also require a SWPPP.

The MDNR regulates work below the OHW level of public waters. The OHW level for Twin Lake is 869.9 feet (NAVD88). Because work would not occur below the OHW level, a Public Water Work Permit is not required.

RWMWD regulates the control of floodwater to ensure the preservation of floodplains and flood storage areas, improve water quality, preserve vegetation, alleviate identified erosion problems, ensure the preservation of wetland and creek buffers, and prevent erosion of shorelines and stream banks. A RWMWD permit will be required for Rule F – Erosion and Sediment Control.

5.2.1.3 Affected Property Owners

Site disturbance would be limited to the property at 154 Twin Lake Boulevard. Access to the site would be via a construction entrance constructed off Twin Lake Boulevard to the north of the site. Access may affect the shared driveway with 174 Twin Lake Boulevard, and permission would be required from the property owner to access the driveway.

5.2.1.4 Wetland/Upland Impacts

Based on the District's wetland inventory there do not appear to be any wetlands on the property. No temporary or permanent wetlands are anticipated for this modification.

5.2.1.5 Engineer's Opinion of Probable Cost

The engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. The planning-level opinion of cost was developed by estimating the cost of land and property acquisition. Costs associated with property acquisition were obtained from the Ramsey County Property Records and Revenue department. This evaluation assumed an estimated acquisition cost of 125% of the estimated market value. The additional is intended to account for the cost of appraisals, and adjustments for market value.

Operation and maintenance costs were assumed to include routine vegetation management over a 30-year period. This equates to an estimated total project cost of $1,097,000 over a 30-year period, with an accuracy range of ($878,000 to $1,646,000). Appendix A includes a detailed discussion of Alternative 1, including assumptions used to develop the engineer's opinion of probable cost.

This alternative does not reduce the risk of lake shore and lawn damage or social impacts due to extended periods of high lake levels.

5.2.2 Alternative 2: Emergency Response Plan

The purpose of an Emergency Response Plan (ERP) is to describe the responsibilities for operation and emergency procedures to provide flood-risk reduction. Typically, an ERP defines responsible parties, contact information, and actions to be completed to mitigate flood damage for low homes or roadways adjacent to the lakes. The District's role is to develop these plans in coordination with the cities. The District may provide assistance with identifying conditions that pose a flood risk, or implement system modifications that facilitate emergency responses, such as furnishing sumps or constructing access to a site. The final ERP is adopted by the city responsible for implementing emergency responses defined in the plan.

Alternative 2 includes an evaluation of the development of a formal ERP for Twin Lake. This feasibility evaluation assumes that the ERP includes mobilization of temporary pumps, similar to the temporary measures implemented during the summer of 2019. The essence of the plan would formalize many of those actions taken.

The ERP includes temporary pumping from south of the railroad tracks into Waldo Pond, as shown on Figure 5-2. Temporary pumping would lower the water level in Twin Lake to elevation 872.3, which is the elevation of the controlled by the culvert below the railroad tracks. The railroad culvert was in place prior to Ramsey County establishing County Ditch 16 in 1918 (reference [14]).

The temporary pumping would discharge at maximum rate of 10 cubic feet per second (cfs) to until the water level is lowered and maintained at an elevation of 872.3. Pumping operations would follow an operating plan to reduce the added risk of impacts to structures downstream near Owasso Bain and on the Phalen Chain of Lakes. The operating plan would include conditions when pumping could occur when the increased risk of flooding downstream is minimized. This operating plan would require that the pumping be shut down, regardless of water levels in Twin Lake, should downstream flood levels be increased significantly. The operating plan would likely reflect the actions and permit requirements of the summer of 2019.

Figure 5-2 shows the location of the temporary pump, pump intake, pump discharge, and access easements required to implement the ERP. Emergency responses shown are subject to a right-of-entry agreement between the City of Little Canada and property owners for parcels shown on Figure 5-2.

LEGEND

- EXISTING 5' CONTOUR — 880
- EXISTING 1' CONTOUR — 881
- EXISTING 10" PETROLEUM PIPELINE — P — P
- EXISTING EASEMENTS
- RIGHT-OF-WAY
- PARCELS
- WETLAND — WT / WT

872.30
INV 42 PEP

872.51
INV 18 PVC

871.71
INV 18 PVC

RAILROAD

PARCEL ID:
313022440018

DRAINAGE EASEMENT

PARCEL ID:
313022440019

EDGE OF DELINEATED WETLAND

PUMP INTAKE

INTAKE LINE

TEMPORARY PUMP LOCATION

ACCESS EASEMENT

DISCHARGE LINE

FENCE

10" STEEL PETROLEUM PIPELINE APPROX. EL. 871.0'

870.20
INV 72 RCP

PUMP DISCHARGE

WALDO POND
NWL = 870.2
BOTTOM = 866.0

870.20
INV 48 RCP

PARCEL ID:
32302233004

3157 CENTERVILLE ROAD

3151 CENTERVILLE ROAD

PARCEL ID:
323022330028

3143 CENTERVILLE ROAD

PARCEL LINES

3135 CENTERVILLE ROAD

CENTERVILLE ROAD

SITE ACCESS

EASEMENT LINES

INTERSTATE 694 SOUND BARRIER

WESTBOUND INTERSTATE 694

EASTBOUND INTERSTATE 694

GOPHER STATE ONE CALL

GOPHER STATE ONE CALL:
CALL BEFORE YOU DIG.
1-800-252-1166

CONTRACTOR SHALL BE RESPONSIBLE FOR FIELD-LOCATING ALL SITE UTILITIES, PRIVATE AND PUBLIC, PRIOR TO STARTING THE WORK. ALL UTILITIES SHOWN ON THE PLANS ARE APPROXIMATE. ANY UTILITIES DAMAGED BY CONTRACTOR SHALL BE REPAIRED BY CONTRACTOR TO THE SATISFACTION OF THE UTILITY OWNER.

1 - PLAN: ALTERNATIVE 2 - EMERGENCY RESPONSE PLAN

N

0 60 120
SCALE IN FEET

NOTE:

LOCATIONS FOR ACCESS, TEMPORARAY PUMP, AND TEMPORARY PIPE TO BE COORDINATED WITH OWNERS.

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION

CLIENT
BID
CONSTRUCTION

RELEASED TO/FOR

A	B	C	0	1	2	3
DATE RELEASED						

BARR
Corporate Headquarters:
Minneapolis, Minnesota
Ph: 1-800-632-2277

Project Office:
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
Suite 200
MINNEAPOLIS, MN 55435
Ph: 1-800-632-2277
Fax: (952) 832-2601
www.barr.com

Scale	AS SHOWN
Date	11/11/2019
Drawn	GWB
Checked	BJB
Designed	BJB
Approved	-

RAMSEY-WASHINGTON METRO WATERSHED DISTRICT

TWIN LAKE FLOOD-RISK MITIGATION FEASIBILITY STUDY

ALTERNATIVE 2
EMERGENCY RESPONSE PLAN

BARR PROJECT No.	
23621200.19	
CLIENT PROJECT No.	
DWG. No.	REV. No.
FIGURE 5-2	A

5.2.2.1 Floodplain Impacts

The District's stormwater model was used to evaluate the floodplain impacts on Twin Lake and downstream of the proposed temporary discharge location. Since Twin Lake is currently landlocked, discharge out of the lake would need to be controlled to prevent increases to downstream water bodies and minimize the increased risk of flooding downstream. For this evaluation, the following operating plan was assumed for the temporary pumps in an ERP:

1. Temporary pumps would be turned on if the water level in Twin Lake exceeds elevation 873.5.
2. The temporary pumps would be operated to convey a maximum of 10 cfs into Waldo Pond.
3. The temporary pumps would be shut off 12 hours prior to a forecasted rainfall event greater than 2 inches. The temporary pumps could be restarted after the water level in Waldo Pond begins to recede.
4. The temporary pumps would be operated to lower the lake level to 872.3, which is the invert elevation of the culvert below the railroad tracks.

A temporary connection to the MnDOT drainage system should be operated such that the additional discharge does not reduce the capacity of the interstate drainage system during a rainfall event. In addition, there are habitable structures downstream of the gravity outlet that are below the 100-year floodplain, as discussed in Section 2.1.2.1, even without additional proposed flow from Twin Lake. The District stormwater model indicates that the lowest homes at North Star Estates could be impacted by a 4-inch, 4-day rainfall event. Therefore, the operation of the temporary pumps must minimize the increased risk to habitable structures downstream.

The District's stormwater model indicates that the travel time from the proposed gravity outlet through the MnDOT system is approximately 6 hours. The water level in Gervais Creek will draw down to within 0.4 feet of the channel bottom at Owasso Boulevard approximately 12 hours after the pumping is stopped during dry weather conditions. Therefore, to prevent increased risk of flooding for North Star Estates or a reduction in the capacity of the I-694 storm sewer system, pumps would be turned off 12 hours prior to a forecasted 2-inch rainfall event. Pumps would be turned on after water levels in Waldo Pond begin to recede following the event. This proposed operation is consistent with the plan approved by MnDOT during the summer of 2019 (reference [24]), but does result in an increase to flood risk on the Phalen Chain.

The floodplain impacts, following the operation plan described above, were evaluated using the District's stormwater model. Three types of impacts were evaluated:

1. Impacts to the 100-year floodplain in Twin Lake
2. Impacts to the 100-year floodplain downstream of Twin Lake
3. Impacts to inundation duration in Twin Lake.

Twin Lake Elevation

The District's stormwater model was used to simulate Alternative 2 conditions in the Twin Lake watershed following the same methodology used to evaluate existing conditions discussed in Section 2.1.2.2. The District stormwater model was used to simulate rainfall from 1949 to 2018, assuming that the ERP was implemented when the water level reached elevation 873.5. The Twin Lake continuous modeling results for Alternative 2 are shown in Figure 5-3. As shown in Figure 5-3, the water level in Twin Lake would have triggered the ERP once. As a result, the 100-year water level (or 1-percent-annual-exceedance probability) is slightly lower, as shown in Figure 5-4.

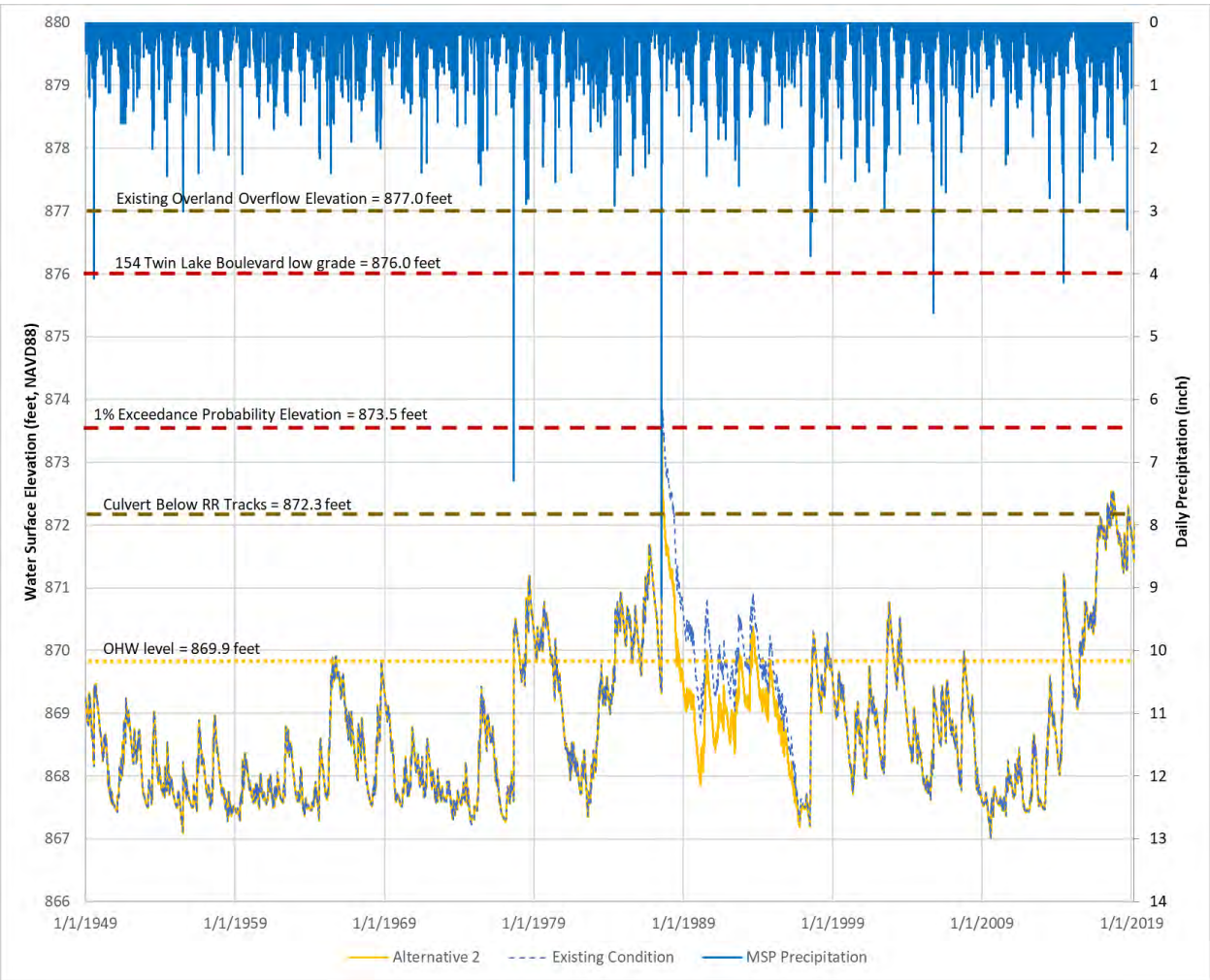


Figure 5-3 Alternative 2 Twin Lake Water Levels

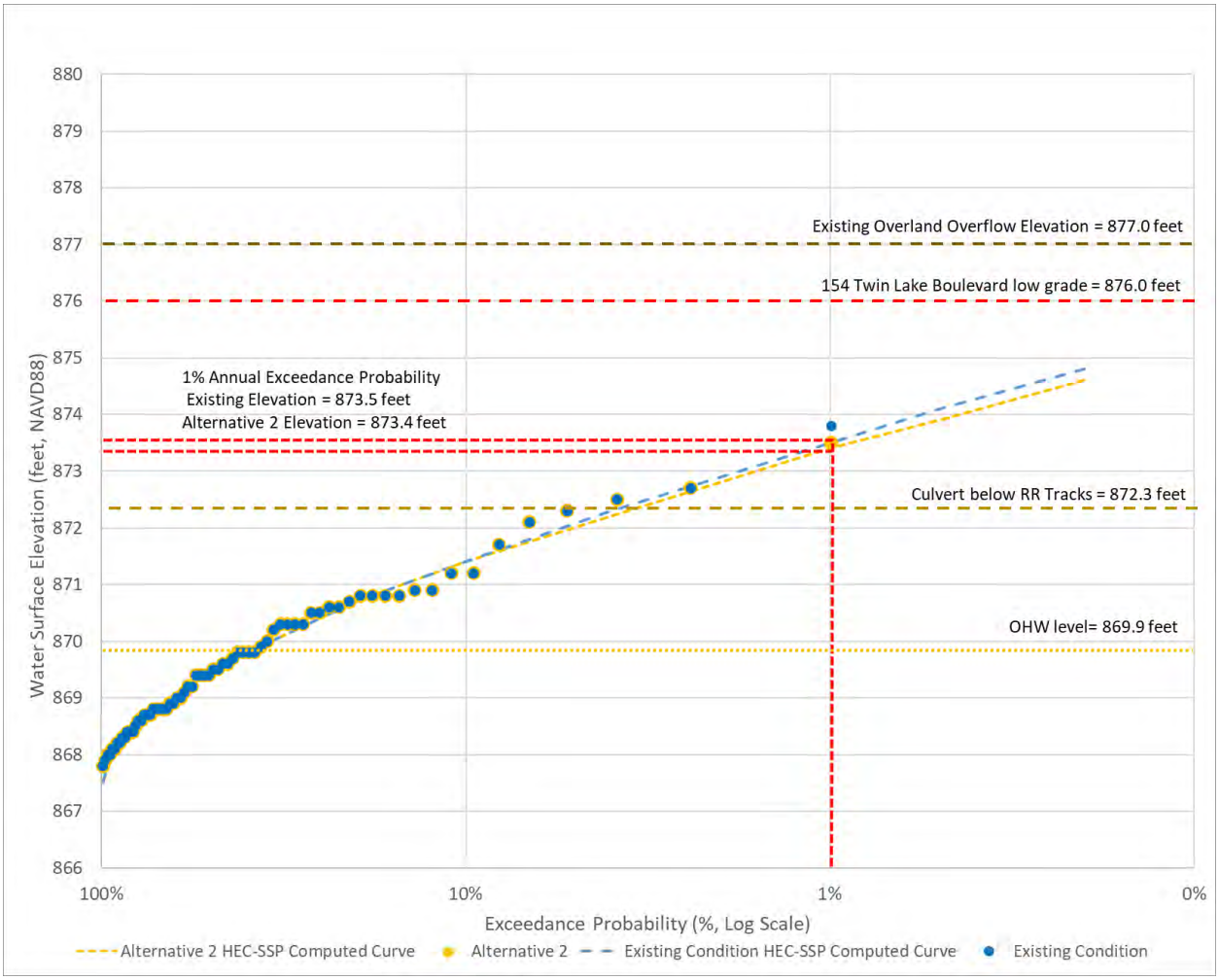


Figure 5-4 Alternative 2 Twin Lake Annual Exceedance

Twin Lake Inundation Duration

A stage-duration curve is a plot of the percentage of time the lake level exceeds a given elevation. Water bodies with highly variable elevations often have a steep curve, which indicates a quick return to the outlet elevation. Landlocked water bodies often have a flatter curve, which indicates a slower return to normal elevations.

Because historic continuous water-level measurements are not available for Twin Lake, the District stormwater model was used to generate a continuous time series of lake levels for the Alternative 2 condition. These are shown in Figure 5-3. The continuous simulation results were used to develop the stage-duration curve for Twin Lake, similar to the methodology followed for existing conditions described in Section 2.1.2.3. Simulation results indicate that the Alternative 2 outlet would reduce the duration (or percentage of time) that the lake level exceeds elevations above 872.3.

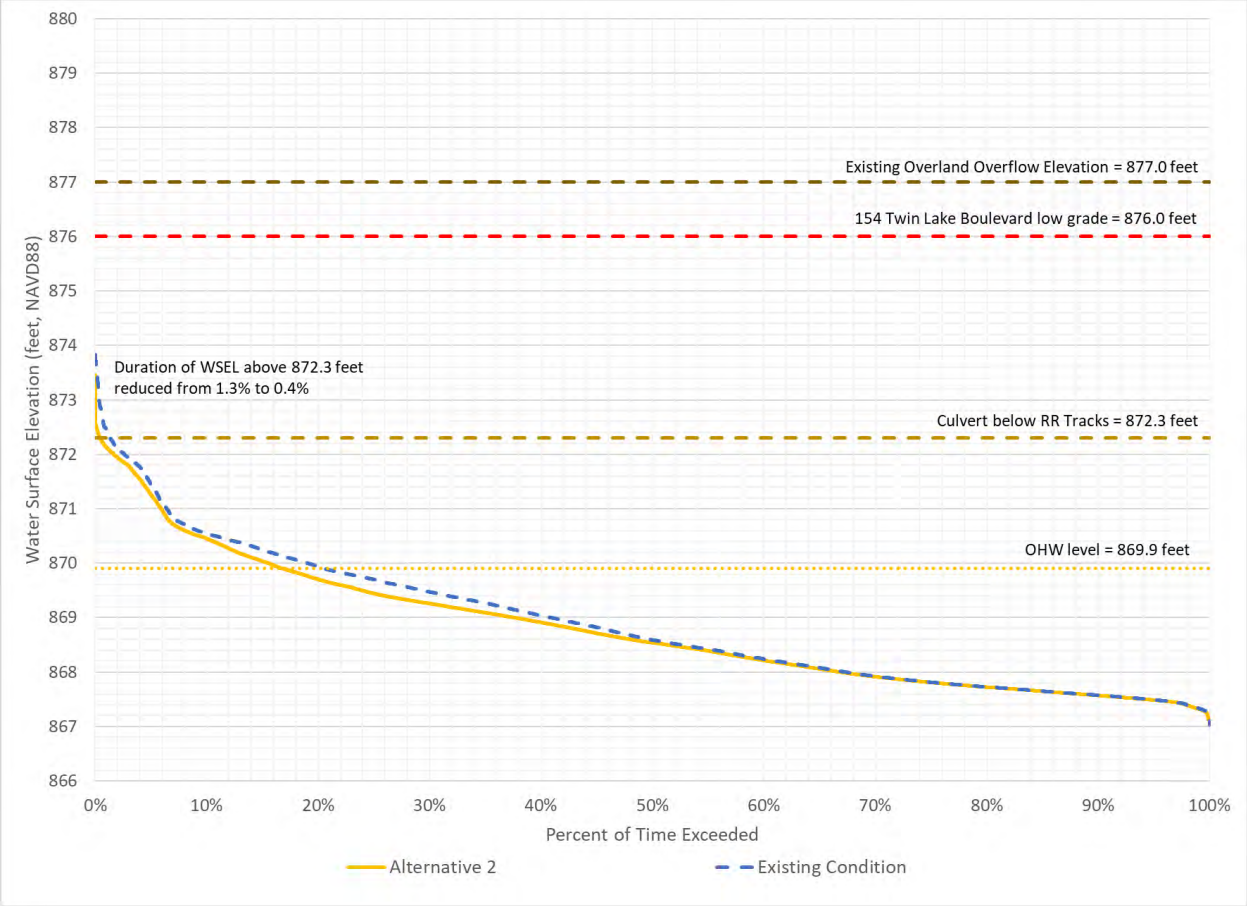


Figure 5-5 Alternative 2 Twin Lake Elevation-Duration Curve

Impacts to the Downstream Floodplain

Downstream impacts at Gervais Lake are summarized in Table 5-1. Following the proposed operational plan would mitigate impacts to the 100-year floodplain downstream of Twin Lake near North Star Estates. However, the operation plan would not mitigate change to the 100-year water level in the Phalen Chain of Lakes, and additional system modifications would be required to mitigate flood risk in the Phalen Chain of Lakes.

Table 5-1 Alternative 2 Floodplain Impacts

Location	Change in the 100-Year Water Surface Elevation (feet)
Twin Lake	(0.1)
Gervais Lake	0.01

Note(s):
(1) Additional system modifications on the Lake Phalen Chain would be required to mitigate increases to the 100-year floodplain.

5.2.2.2 Regulatory Approvals

The City of Little Canada would need to approve the final ERP for Twin Lake.

A drainage permit for a temporary connection to the state drainage system would be required by MnDOT. The drainage permit would include an operation and maintenance plan, pre-pumping and post-pumping photographs documenting the condition of the state drainage system, and a commitment to restore the MnDOT drainage system to pre-pumping conditions. MnDOT also requires an evaluation of impacts to floodplain elevations during the 100-year event.

The MDNR regulates pumping or actively managing discharge from a basin by operating gates or valves and will require an appropriation permit. The ERP is not anticipated to include work below the OHW level, and a project-specific Public Water Work Permit would not be required.

5.2.2.3 Affected Property Owners

Proposed ERP modifications would be located on the MnDOT right-of-way and parcel ID 313022440018, owned by Highpoint Ridge LLC and Frattalone Companies (reference [26]). Modifications in the ERP would also cross BP and Xcel utility easements.

Implementation of emergency responses would be subject to obtaining a right-of-entry agreement from Frattalone Companies and MnDOT. Coordination with property owners would be required to determine whether permanent site access could be constructed or whether a temporary access road would need to be constructed as part of emergency response actions.

5.2.2.4 Wetland/Upland Impacts

The total area of temporary disturbance for the emergency response modifications is approximately 0.8 acres. This area includes the footprint of the access road, temporary pump, pump intake, discharge line, and access easements. Based on the wetland delineation report (reference [27]) it is estimated that there would be 0.1 acres of temporary wetland impact. The total area of wetland impacts may change during the next phase of design and coordination with property owners regarding locations for temporary emergency response modifications.

Alternative 2 may result in impacts to the existing agricultural drainage or agricultural use of fields, which would need to be addressed in an agreement with the property owner. Due to the existing land use, it is not anticipated that Alternative 2 would result in removal of significant trees.

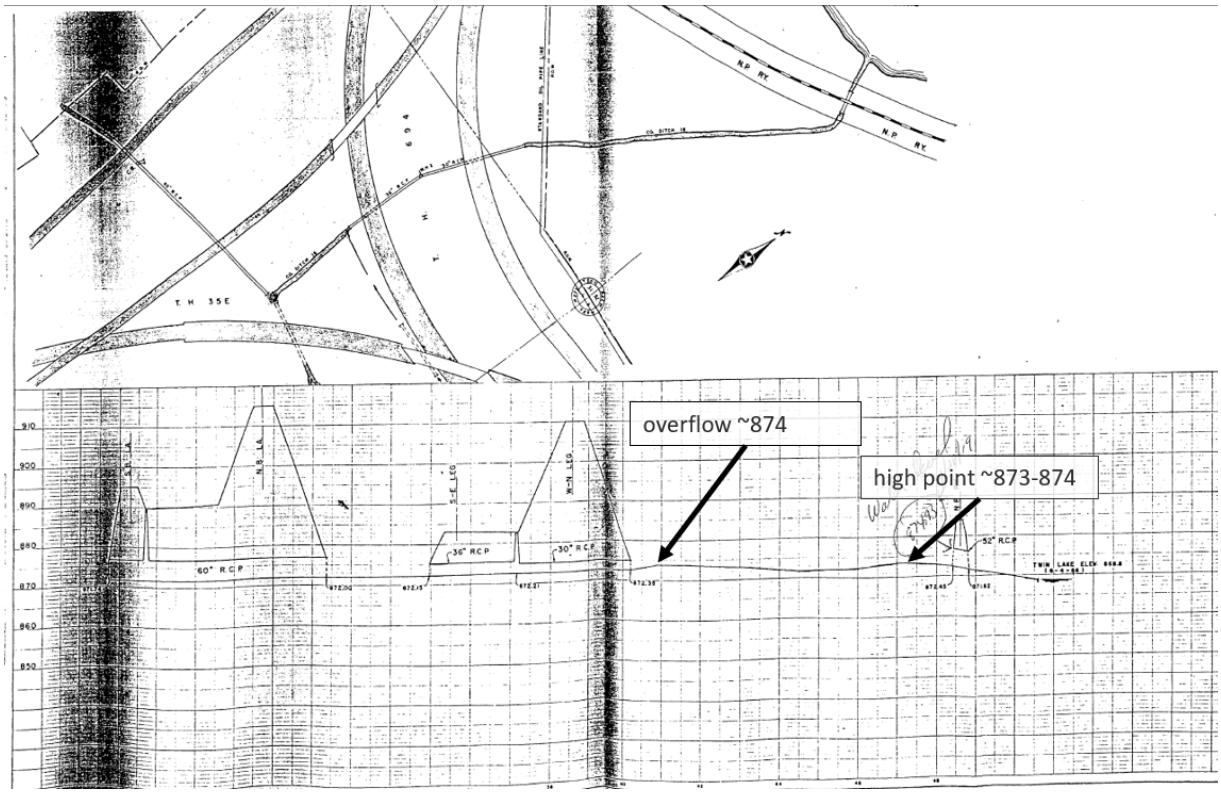
5.2.2.5 Engineer's Opinion of Probable Cost

The engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. The opinion of probable cost assumes that an emergency response would be required three times within the next 30-year period. However, the frequency of implementation is dependent on changing climate conditions and rainfall patterns, which may result in mobilizing emergency measures more than three times.

Appendix A includes a detailed discussion of Alternative 2, including assumptions used to develop the engineer's opinion of probable cost. This equates to an estimated total project cost of $430,000 over a 30-year period, with an accuracy range of ($344,000 to $646,000).

5.2.3 Alternative 3: Gravity Outlet at Elevation 874.0

Alternative 3 is shown on Figure 5-7. The proposed outlet consists of grading a ditch from the wetland south of the railroad to the gravity outlet to Waldo Pond. An inlet elevation at 874.0 is located above the 100-year floodplain for Twin Lake, as described in Section 2.1.2.2. The location of the ditch would minimize impacts to the wetland and wetland buffer. An outlet elevation of 874.0 is also consistent with the available documentation for the county ditch system, which shows a highpoint in the ditch between the railroad tracks and I-694, as shown in Figure 5-6 (reference [14]).



Reference [14]

Figure 5-6 1966 Highpoint between I-694 and Railroad

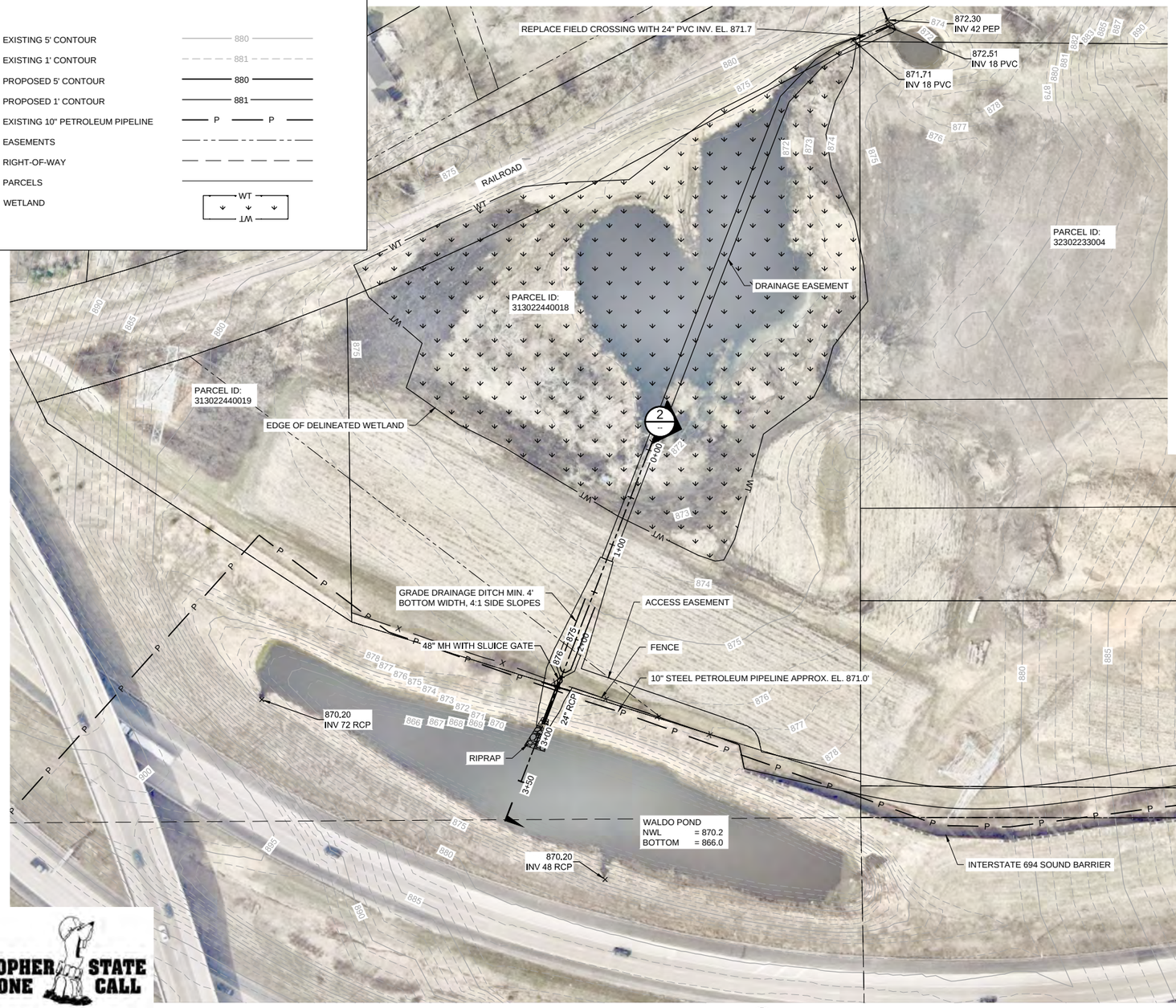
The Alternative 3 outlet to Waldo Pond consists of a minimum 24-inch pipe with a backflow preventer and gatewell. The location of the gatewell would be determined during final design, but MnDOT indicated that operable structures should be located within a permanent drainage easement outside of the MnDOT right-of-way. The outlet consists of a valve to control discharge through the connection. The ability to control the timing of discharge into the MnDOT system is necessary to minimize the increased risk of flooding downstream. Similarly, the alignment could change during final design based on discussions with the property owner and efforts to minimize wetland impacts and avoid utility conflicts. The alignment

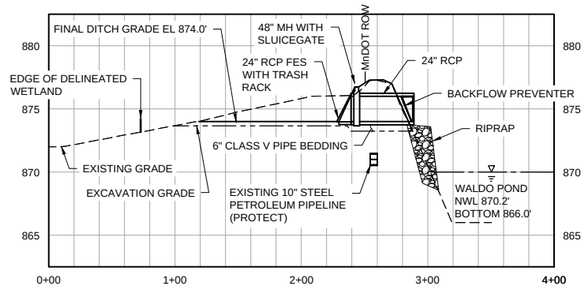
shown on Figure 5-7 generally follows the alignment shown on the original I-694 as-built drawings (reference [12]).

A backflow prevention device is included because if a large rainfall event occurred when the gate was open water could potentially flow from Waldo Pond into Twin Lake. Discharge from the highway drainage system into Twin Lake may have adverse water quality impacts and increase water levels in the lake. To mitigate the potential for discharge from the interstate drainage system back to Twin Lake, both a backflow prevention device and gate valve are recommended if this gravity outlet alternative is pursued. The system would require an operating plan with highlights of the plan discussed later in this section.

LEGEND

- EXISTING 5' CONTOUR — 880
- EXISTING 1' CONTOUR — 881
- PROPOSED 5' CONTOUR — 880
- PROPOSED 1' CONTOUR — 881
- EXISTING 10" PETROLEUM PIPELINE — P — P
- EASEMENTS
- RIGHT-OF-WAY
- PARCELS
- WETLAND — WT / WT





2 — PROFILE: ALTERNATIVE 3 - GRAVITY OUTLET AT ELEVATION 874.0'
1H:10V

0 60 120
SCALE IN FEET

1 — PLAN: ALTERNATIVE 3 - GRAVITY OUTLET AT ELEVATION 874.0'

N
0 60 120
SCALE IN FEET

NOTE:

LOCATIONS FOR ACCESS, TEMPORARAY PUMP, AND TEMPORARY PIPE TO BE COORDINATED WITH OWNERS.

GOPHER STATE ONE CALL

GOPHER STATE ONE CALL:
CALL BEFORE YOU DIG.
1-800-252-1166

CONTRACTOR SHALL BE RESPONSIBLE FOR FIELD-LOCATING ALL SITE UTILITIES, PRIVATE AND PUBLIC, PRIOR TO STARTING THE WORK. ALL UTILITIES SHOWN ON THE PLANS ARE APPROXIMATE. ANY UTILITIES DAMAGED BY CONTRACTOR SHALL BE REPAIRED BY CONTRACTOR TO THE SATISFACTION OF THE UTILITY OWNER.

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION
					CLIENT
					BID
					CONSTRUCTION
					RELEASED TO/FOR
A	B	C	0	1	2	3	DATE RELEASED

BARR
Corporate Headquarters:
Minneapolis, Minnesota
Ph: 1-800-632-2277

Project Office:
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
Suite 200
MINNEAPOLIS, MN 55435
Ph: 1-800-632-2277
Fax: (952) 832-2601
www.barr.com

Scale	AS SHOWN
Date	11/11/2019
Drawn	GWB
Checked	BJB
Designed	BJB
Approved	-

RAMSEY-WASHINGTON METRO WATERSHED DISTRICT

TWIN LAKE FLOOD-RISK MITIGATION FEASIBILITY STUDY

ALTERNATIVE 3
GRAVITY OUTLET AT ELEVATION 874.0'

BARR PROJECT No.	23621200.19
CLIENT PROJECT No.	
DWG. No.	FIGURE 5-7
REV. No.	A

5.2.3.1 Floodplain Impacts

The District's calibrated stormwater model, developed in XP-SWMM, was used to evaluate the floodplain impacts in Twin Lake and downstream of the proposed outlet. Since Twin Lake is currently landlocked, flow through the gravity outlet would need to be controlled to prevent increases to downstream water bodies. For this evaluation the following operational plan was assumed:

1. The gravity outlet would be opened if water levels in Twin Lake reach elevation 874.0.
2. The outlet would be closed 12 hours prior to a forecasted rainfall event greater than 2 inches. The outlet could be reopened after the water level in Waldo Pond begins to recede.
3. The gravity outlet would be closed the remainder of the year.

A connection to the MnDOT system should be operated such that the additional discharge does not reduce the capacity of the interstate drainage system during a rainfall event. In addition, as discussed in Section 2.1.2.1, there are habitable structures downstream of the gravity outlet that are below the 100-year floodplain even without additional flow from Twin Lake. The District stormwater model indicates that the lowest homes at North Star Estates could be impacted by a 4-inch, 4-day rainfall event. Therefore, the operation of the outlet must mitigate the risk to downstream habitable structures.

The District's stormwater model indicates that the travel time from the proposed gravity outlet through the MnDOT system is approximately 6 hours. During dry weather conditions, the water level in Gervais Creek will draw down to within 0.4 feet of the channel bottom at Owasso Boulevard approximately 12 hours after the pumping is stopped. Therefore, to prevent increased flood risk for North Star Estates or a reduction in the capacity of the I-694 storm sewer system, the gate valve would be closed 12 hours prior to a forecasted 2-inch rainfall event. The gate valve would be opened after water levels in Waldo pond begin to recede following the event.

Following the operation plan described above, three types of floodplain impacts were evaluated using the District's stormwater model:

1. Impacts to the 100-year floodplain in Twin Lake
2. Impacts to the 100-year floodplain downstream of Twin Lake
3. Impacts to the duration of inundation in Twin Lake

Twin Lake Elevation

The District's stormwater model was used to simulate Alternative 3 conditions in the Twin Lake watershed following the same methodology used to evaluate existing conditions discussed in Section 2.1.2.2. The District stormwater model was used to simulate rainfall from 1949 to 2018, assuming that stormwater was conveyed to Waldo pond when the water level reached elevation 874.0. The Twin Lake continuous modeling results for Alternative 3 are shown in Figure 5-8. As shown in Figure 5-8, the water level in Twin Lake would not have exceeded the outlet elevation between 1949 and 2018. As a result, the 100-year

water level (or 1-percent annual-exceedance probability) is the same as existing conditions, as shown in Figure 5-11.

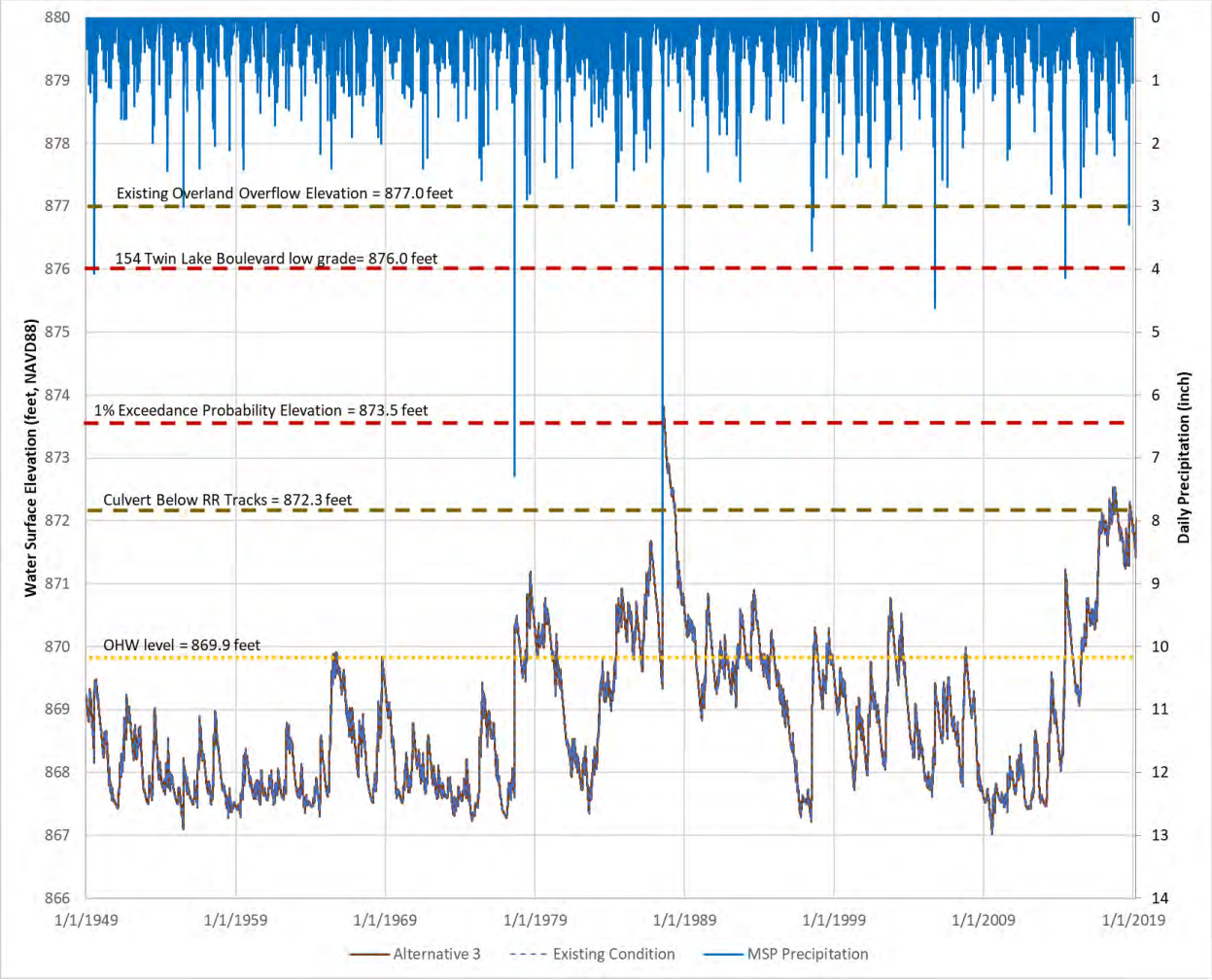


Figure 5-8 Alternative 3 Twin Lake Water Levels

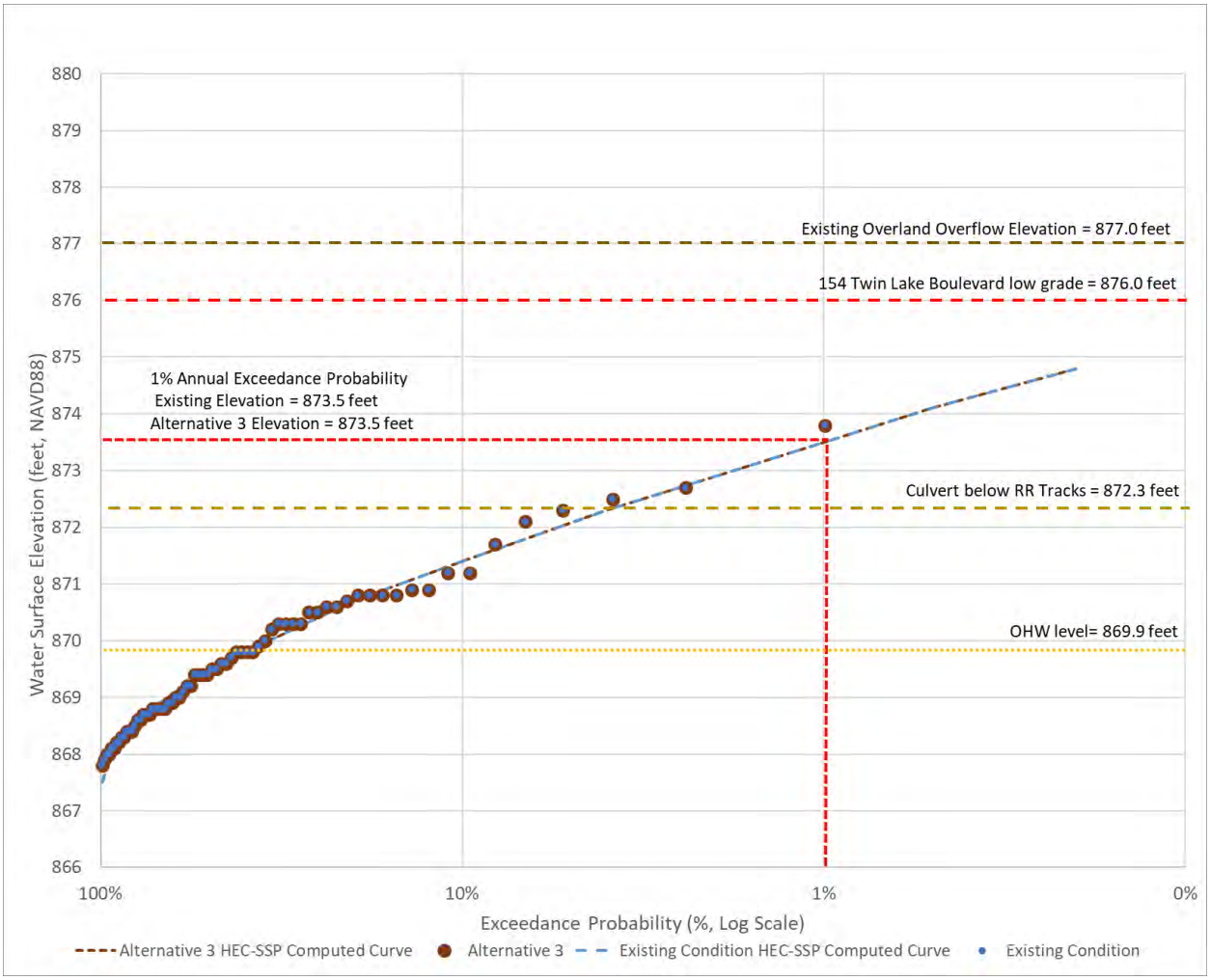


Figure 5-9 Alternative 3 Twin Lake Annual Exceedance

Twin Lake Inundation Duration

A stage-duration curve is a plot of the percentage of time the lake level exceeds a given elevation. Water bodies with highly variable elevations often have a steep curve, which indicates a quick return to the outlet elevation. Landlocked water bodies often have a flatter curve, which indicates a slower return to normal elevations.

The District stormwater model was used to generate a continuous time series of lake levels for the Alternative 3 condition; these are shown in Figure 5-8. The continuous simulation results were used to develop the stage-duration curve for Twin Lake, similar to the methodology followed for existing conditions described in Section 2.1.2.3.

Simulation results indicate that the Alternative 3 outlet would not change the duration (or percentage of time) that the lake level exceeds a given elevation during the period evaluated (1949–2018).

During the summer of 2019, the water level in Twin Lake exceeded 874.0, and the Alternative 3 outlet would have reduced the period that lake levels exceeded the proposed outlet elevation.

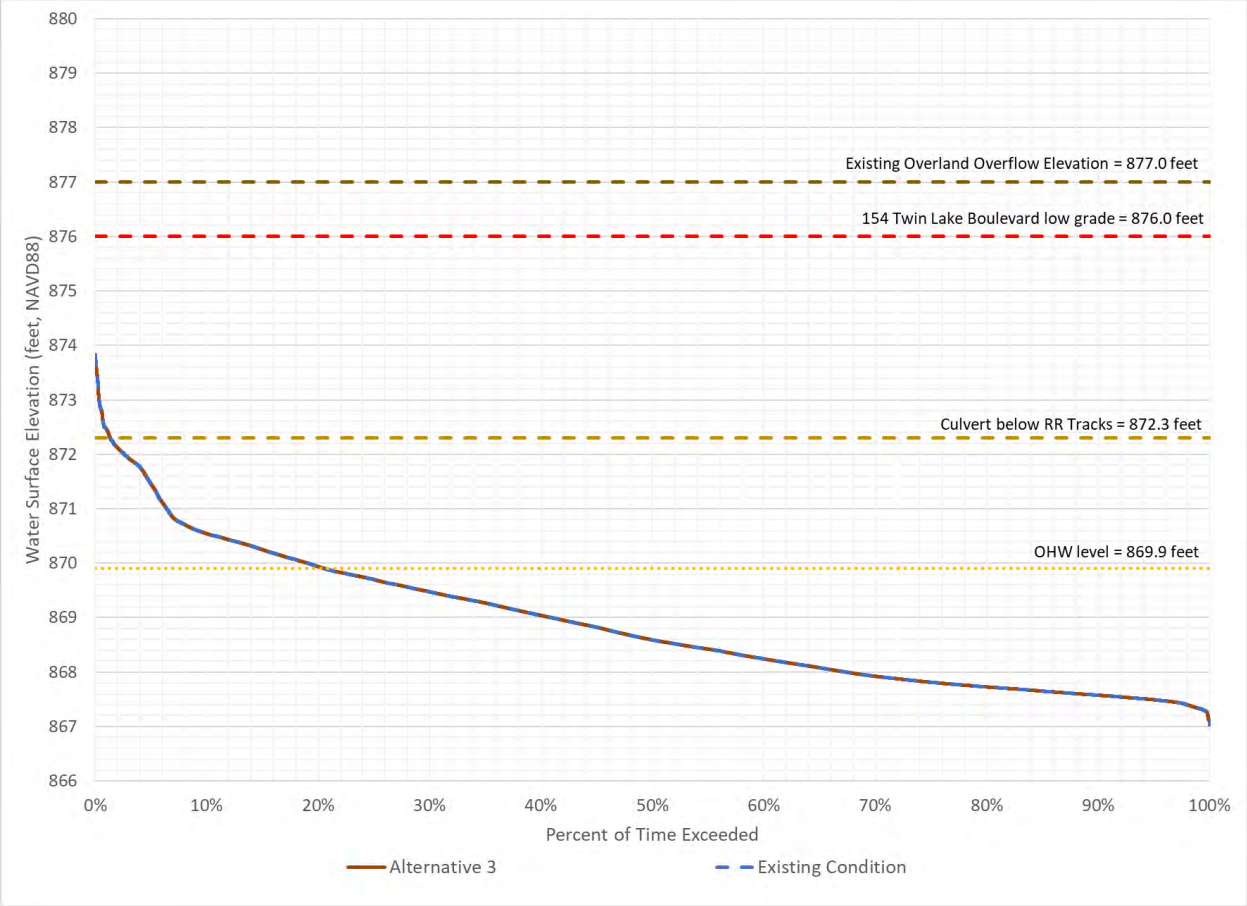


Figure 5-10 Alternative 3 Twin Lake Elevation-Duration Curve

Because the Alternative 3 outlet elevation is higher than the culvert below the railroad tracks, modifications to the outlet elevation, temporary pumping, or other methods would be required if water levels in Twin Lake needed to be lowered further.

Impacts to the Downstream Floodplain

The District stormwater model was used to calculate the 100-year floodplain impacts downstream of a new gravity outlet following the same methodology used to evaluate existing conditions described in Section 2.1.2.1. Downstream impacts at Gervais Lake are summarized in Table 5-2. Following the proposed operational plan would mitigate impacts to the 100-year floodplain downstream of Twin Lake. If discharge is required during the spring or summer months, there is potential for increase to the 100-year floodplain on the Phalen Chain of Lakes that would require additional mitigation.

Table 5-2 Alternative 3 Floodplain Impacts

Location	Change in the 100-Year Water Surface Elevation (Feet)
Twin Lake	0.00
Gervais Lake	0.01 [1]

Note(s):
(1) Additional system modifications on the Lake Phalen Chain would be required to mitigate increases to the 100-year floodplain.

5.2.3.2 Regulatory Approvals

A fill permit will be required by the City of Little Canada.

The MPCA regulates the NPDES stormwater permitting program. An NPDES permit is required for construction projects that disturb 1 acre. The MPCA will also require a SWPPP.

The MDNR regulates work below the OHW level of public waters. The OHW level for Twin Lake is 869.9 feet (NAVD88). Because work would not occur below the OHW level, a Public Water Work Permit is not required.

MDNR requires an appropriation permit for active management of a gravity outlet. If operation of gates or valves is not included in the final design, an appropriation permit would not be required. However, an appropriation permit would be needed if temporary pumping was done to lower the water level below 874.0

MnDOT regulates activities that impact the state drainage system. Reestablishing a connection to the MnDOT stormwater system would require a drainage permit from MnDOT. MnDOT would also require documentation of permanent easements for upstream infrastructure and an operations and maintenance plan. MnDOT would request that a gravity outlet be provided at the same elevation previously approved for the 1970 County Ditch 16 realignment. If an alternate elevation is proposed, supporting documentation for the deviation would also be required.

RWMWD regulates the control of floodwater to ensure the preservation of floodplains and flood storage areas, improve water quality, preserve vegetation, alleviate identified erosion problems, ensure the preservation of wetland and creek buffers, and prevent erosion of shorelines and stream banks. A RWMWD permit will be required for Rule C – Stormwater Management, Rule D – Flood Control, Rule E – Wetland Management, and Rule F – Erosion and Sediment Control.

5.2.3.3 Affected Property Owners

Proposed modifications would be located on MnDOT right-of-way and parcel ID 313022440018, which is owned by Highpoint Ridge LLC and Frattalone Companies. Modifications also include drainage improvements on BP and Xcel utility easements.

Construction of a drainage ditch on parcel ID 313022440018 is subject to obtaining a permanent drainage easement from the property owner. The proposed drainage ditch would be through existing agricultural land and result in a reduction of area that could be used for farming.

Site access would likely occur from Centerville Avenue. There is an existing access road to the Xcel transmission line that could be used for access. A permanent access road would be needed along the MnDOT right-of-way to access the gatewell.

5.2.3.4 Wetland/Upland Impacts

The total area of disturbance and drainage and access easements for the proposed outlet is approximately 0.8 acres. This area includes the footprint of the grading extents for the drainage ditch, gatewell, gravity pipe, and drainage and access easements. Based on the wetland delineation report (reference [27]), it is estimated that this alternative will not result in wetland impacts.

The District is the wetland permitting authority for this project and has a no-net-loss policy for wetlands within the District. If wetland impacts are identified during the next phase of design, a wetland replacement and mitigation plan would need to be developed during the next phase of design. It is possible that some wetland mitigation could occur adjacent to the existing wetland ditch pending coordination with the property owner.

Alternative 3 will result in permanent modifications to the area between the railroad tracks and Waldo Pond. It is anticipated that in reestablishing the ditch, permanent wetland impacts will be avoided or minimized. Alternative 3 will also result in permanent impacts to the existing agricultural drainage. Construction of the outlet and ditch would remove approximately 0.1 acres of existing agricultural area. Due to the existing land use, it is not anticipated that Alternative 3 would result in removal of significant trees.

5.2.3.5 Engineer's Opinion of Probable Cost

The engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. The opinion of probable cost includes costs for construction, planning engineering and design, permitting, construction management, contingency, and operation and maintenance costs over a 30-year period. Maintenance requirements for Alternative 3 include yearly site inspections of the ditch and piped outlet through the embankment, vegetation maintenance, and inspections during periods when water is flowing through the outlet. The opinion of probable cost assumes that monitoring of discharge through the outlet would be required three times within the next 30-year period. However, the frequency of monitoring is dependent on changing climate conditions and rainfall patterns, which may result in monitoring more than three times.

Appendix A includes a detailed discussion of Alternative 3, including assumptions used to develop the engineer's opinion of probable cost. This equates to an estimated total project cost of $190,000 over a 30-year period, with an accuracy range of ($153,000 to $285,000).

5.2.4 Alternative 4: Gravity Outlet at Elevation 872.2

Alternative 4 is shown on Figure 5-11. The proposed outlet would consist of grading a ditch from the culvert below the railroad tracks to a new gravity outlet through the MnDOT berm to Waldo Pond. The location of the ditch would be selected to minimize impacts to the wetland and wetland buffer. The outlet to Waldo Pond would be 24-inch diameter pipe with a backflow preventer and gatewell. An outlet elevation of 872.2 is lower than the control elevations listed in available documentation for the county ditch system (references [14], [16]), which indicated there was a high point in the ditch between the railroad and I-694 at approximately elevation 874 as shown on Figure 5-6. However, elevation 872.2 is consistent with the inlet to the I-694 drainage system that was constructed in 1970 (reference [25]). The lower inlet elevation would provide the ability to lower water levels, relative to Alternative 3. It is important to note that placement of an outlet through the embankment any lower than this elevation would not appreciably lower the levels in Twin Lake, as the culvert under the railroad is at an elevation of 872.3. This elevation was established prior to establishment of the county ditch and serves as the water level control of the lake.

The piped connection through the embankment would consist of a valve to control discharge through the connection. The ability to control the timing of discharge into the MnDOT system is necessary to meet the project design criteria of not increasing discharge during the 2-, 10-, or 100-year events. In addition, North Star Estates, shown in Figure 2-6, has a history of flooding during intense rainfall events, and controlling the timing of when flow is discharged is necessary to minimize the increased risk of downstream impacts.

If the valve was open during large rainfall events, there would be potential for water to flow from Waldo Pond into Twin Lake. Discharge from the highway drainage system into Twin Lake may have adverse water quality impacts. Therefore, a backflow prevention device would be required on the downstream end of the outlet.

LEGEND

- EXISTING 5' CONTOUR — 880
- EXISTING 1' CONTOUR — 881
- PROPOSED 5' CONTOUR — 880
- PROPOSED 1' CONTOUR — 881
- EXISTING 10" PETROLEUM PIPELINE — P — P
- EASEMENTS
- RIGHT-OF-WAY
- PARCELS
- WETLAND — WT

REPLACE FIELD CROSSING WITH 24" PVC INV. EL. 871.7

872.30
INV 42 PEP

872.51
INV 18 PVC

871.71
INV 18 PVC

RAILROAD

DRAINAGE EASEMENT

PARCEL ID:
313022440018

PARCEL ID:
32302233004

PARCEL ID:
313022440019

EDGE OF DELINEATED WETLAND

GRADE DRAINAGE DITCH MIN. 4'
BOTTOM WIDTH, 4:1 SIDE SLOPES

48" MH WITH
SLUICEGATE

ACCESS EASEMENT

FENCE

10" STEEL PETROLEUM PIPELINE APPROX. EL. 871.0'

870.20
INV 72 RCP

24" RCP
L=100'

870.20
INV 48 RCP

WALDO POND
NWL = 870.2
BOTTOM = 866.0

INTERSTATE 694 SOUND BARRIER

PARCEL LINES

PARCEL ID:
323022330028

3151 CENTERVILLE ROAD

3143 CENTERVILLE ROAD

3135 CENTERVILLE ROAD

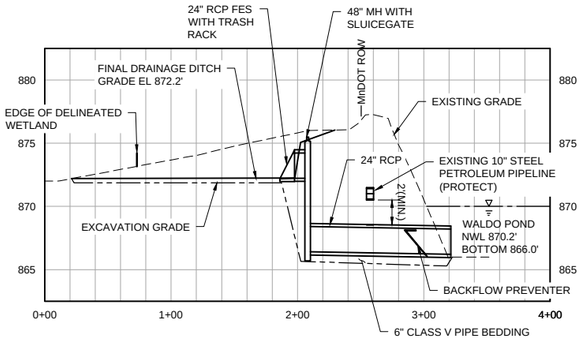
CENTERVILLE ROAD

SITE ACCESS

EASEMENT LINES

WESTBOUND INTERSTATE 694

EASTBOUND INTERSTATE 694



2 - PROFILE: OPTION 4 - GRAVITY OUTLET AT ELEVATION 872.2'
1H:10V

0 60 120
SCALE IN FEET

1 - PLAN: ALTERNATIVE 4 - GRAVITY OUTLET AT ELEVATION 872.2'

N

0 60 120
SCALE IN FEET

NOTE:

LOCATIONS FOR ACCESS, TEMPORARAY PUMP, AND TEMPORARY PIPE TO BE COORDINATED WITH OWNERS.

GOPHER STATE ONE CALL

GOPHER STATE ONE CALL:
CALL BEFORE YOU DIG.
1-800-252-1166

CONTRACTOR SHALL BE RESPONSIBLE FOR FIELD-LOCATING ALL SITE UTILITIES, PRIVATE AND PUBLIC, PRIOR TO STARTING THE WORK. ALL UTILITIES SHOWN ON THE PLANS ARE APPROXIMATE. ANY UTILITIES DAMAGED BY CONTRACTOR SHALL BE REPAIRED BY CONTRACTOR TO THE SATISFACTION OF THE UTILITY OWNER.

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION

CLIENT
BID
CONSTRUCTION

RELEASED TO/FOR

A	B	C	0	1	2	3
DATE RELEASED						

BARR
Corporate Headquarters:
Minneapolis, Minnesota
Ph: 1-800-632-2277

Project Office:
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
Suite 200
MINNEAPOLIS, MN 55435
Ph: 1-800-632-2277
Fax: (952) 832-2601
www.barr.com

Scale	AS SHOWN
Date	11/11/2019
Drawn	GWB
Checked	BJB
Designed	BJB
Approved	-

RAMSEY-WASHINGTON METRO WATERSHED DISTRICT

TWIN LAKE FLOOD-RISK MITIGATION FEASIBILITY STUDY

ALTERNATIVE 4
GRAVITY OUTLET AT ELEVATION 872.2'

BARR PROJECT No. 23621200.19
CLIENT PROJECT No.
DWG. No. FIGURE 5-11
REV. No. A

5.2.4.1 Floodplain Impacts

The District's calibrated stormwater model, developed in XP-SWMM, was used to evaluate the floodplain impacts in Twin Lake and downstream of the proposed outlet. Since Twin Lake is currently landlocked, flow through the gravity outlet would need to be controlled to prevent increases to downstream water bodies.

The probability of large rainfall events in the late fall is less than during the spring and summer months. The period-of-record summary statistics for rainfall from the MDNR indicate that the average total monthly rainfall in November is 1.5 inches (reference [18]). In addition, Atlas 14 publishes a seasonality analysis, shown on Figure 5-12. The seasonality plot shows the percentage of rainfall events that exceed a given annual exceedance probability. The plot shows that during November, less than 1 percent of precipitation events exceeded the 24-hour duration 2-year event, which is 2.8-inches. While the Atlas 14 seasonality analysis is not a seasonal precipitation frequency estimate, it does illustrate that the risk of rainfall events that would result in flooding within North Star Estates is lower during the later fall months compared to the spring and summer months.

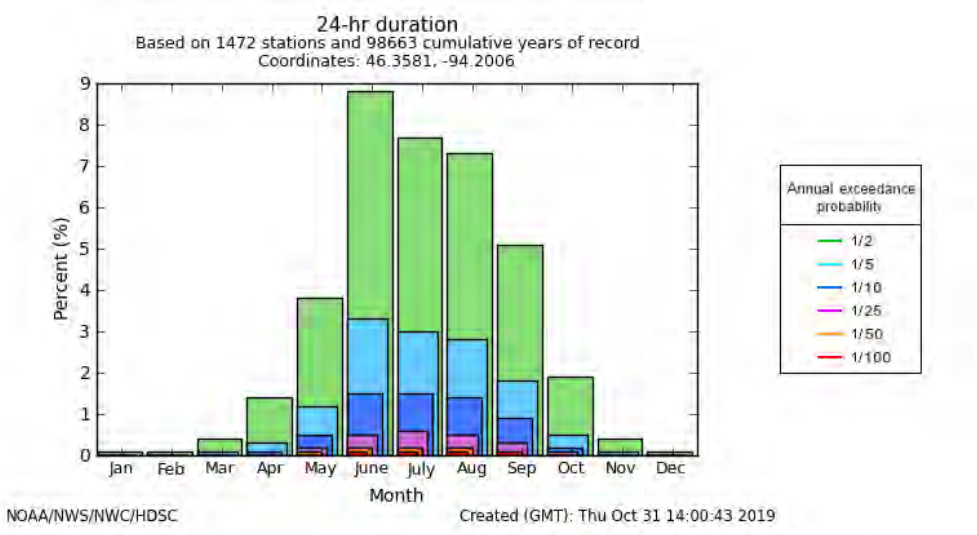


Figure 5-12 Seasonality Analysis

Seasonality analysis figure from Atlas 14. The figure shows the percentage of precipitation totals for a given duration that exceed the precipitation frequency estimate (reference [28]).

For this evaluation the following operational plan was assumed:

1. The gravity outlet would be opened from November 15–February 15 to allow a maximum of 10 cfs out of the system to lower the water level to 872.3 (the invert of the culvert below the railroad tracks).

2. The gravity outlet would be closed the remainder of the year under most normal rainfall and flooding conditions.

3. The outlet would be closed 12 hours prior to a forecasted rainfall event greater than 2 inches. The outlet could be reopened after the water level in Waldo Pond begins to recede.

4. The gravity outlet would be opened between February 16 and November 14 if any of the following occur:

    a. The water level in Twin Lake reaches 873.5

    b. The water level in Waldo Pond exceeds 877.0 and water is conveyed north into Twin Lake

    If the gravity outlet is opened during this period, it is assumed that it would be closed 12 hours prior to a forecasted rainfall event greater than 2 inches, and would remain closed until the water level in Waldo Pond begins to recede, the water level in Owasso Basin is within 0.4-feet of the outlet, and downstream water levels have receded.

If this alternative is selected, a detailed operating plan would need to be developed during the next phase of design to include the above mentioned in more detail. Continuous monitoring and adaptive control, such as the Opti-CMAC system, maybe incorporated into the design to automate operation of the gate based on the time of year and weather forecasts.

A connection to the MnDOT system should be operated such that the additional discharge does not reduce the capacity of the interstate drainage system during a rainfall event. In addition, as discussed in Section 2.1.2.1, there are habitable structures downstream of the gravity outlet that are below the 100-year floodplain even without additional proposed flow from Twin Lake. The District stormwater model indicates that the lowest homes at North Star Estates could be impacted by a 4-inch, 4-day rainfall event. Therefore, the operation of the outlet must mitigate the risk to downstream habitable structures.

The District's stormwater model indicates that during dry weather conditions the travel time from the proposed gravity outlet through the MnDOT system is approximately 6 hours and that the water level in Gervais Creek will draw down to within 0.4 feet of the channel bottom at Owasso Boulevard approximately 12 hours after the pumping is stopped. Therefore, to prevent increased risk of flooding for North Star Estates or a reduction in the capacity of the I-694 storm sewer system, the outlet would be closed 12 hours prior to a forecasted 2-inch rainfall event. The outlet could be opened after water levels in Waldo Pond begin to recede following the event. This proposed operation is consistent with the plan approved by MnDOT during the summer of 2019 (reference [24]).

Twin Lake Elevation

The District's stormwater model was used to simulate Alternative 4 conditions in the Twin Lake watershed, following the same methodology used to evaluate existing conditions discussed in Section 2.1.2.2. The District stormwater model was used to simulate rainfall from 1949 to 2018, assuming that the operation plan for the outlet was implemented. The Twin Lake continuous modeling results for Alternative 4 (Figure 5-13) show the water level in Twin Lake would have exceeded the outlet elevation between 1949 and 2018. As a result, the 100-year water level (or 1-percent-annual-exceedance probability) is lower than existing conditions, as shown in Figure 5-14.

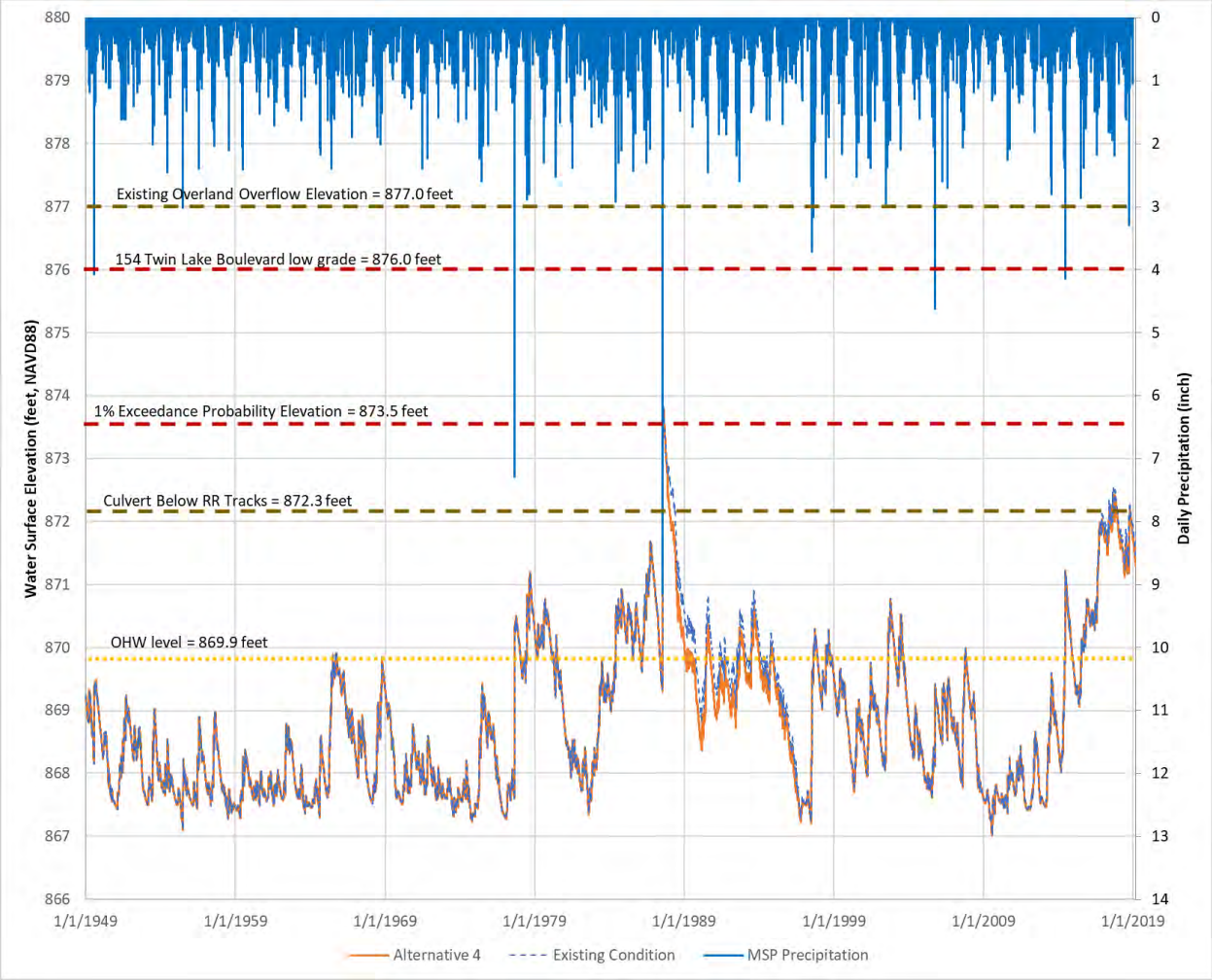


Figure 5-13 Alternative 4 Twin Lake Water Levels

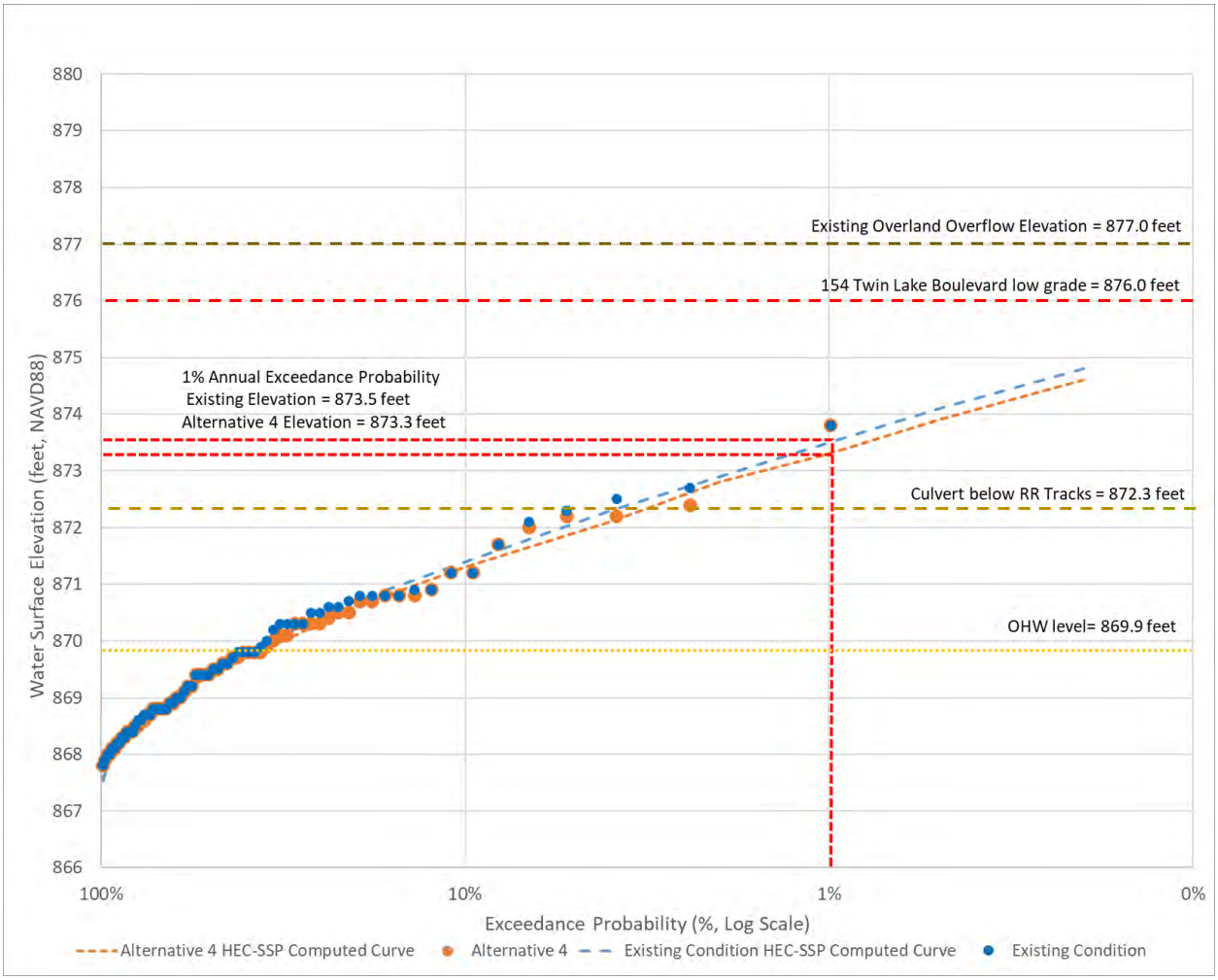


Figure 5-14 Alternative 4 Twin Lake Annual Exceedance

Twin Lake Inundation Duration

Similar to previous alternatives, the District stormwater model was used to generate a continuous time series of lake levels for the Alternative 4 condition, shown in Figure 5-13. The continuous simulation results were used to develop the stage-duration curve for Twin Lake, shown in Figure 5-15, similar to the methodology followed for existing conditions described in Section 2.1.2.3.

Simulation results indicate that the Alternative 4 outlet would reduce the duration (or percentage of time) that the lake level exceeds elevation 872.2 from 1.7-percent to 1.1-percent of the time during the period evaluated (1949–2018).

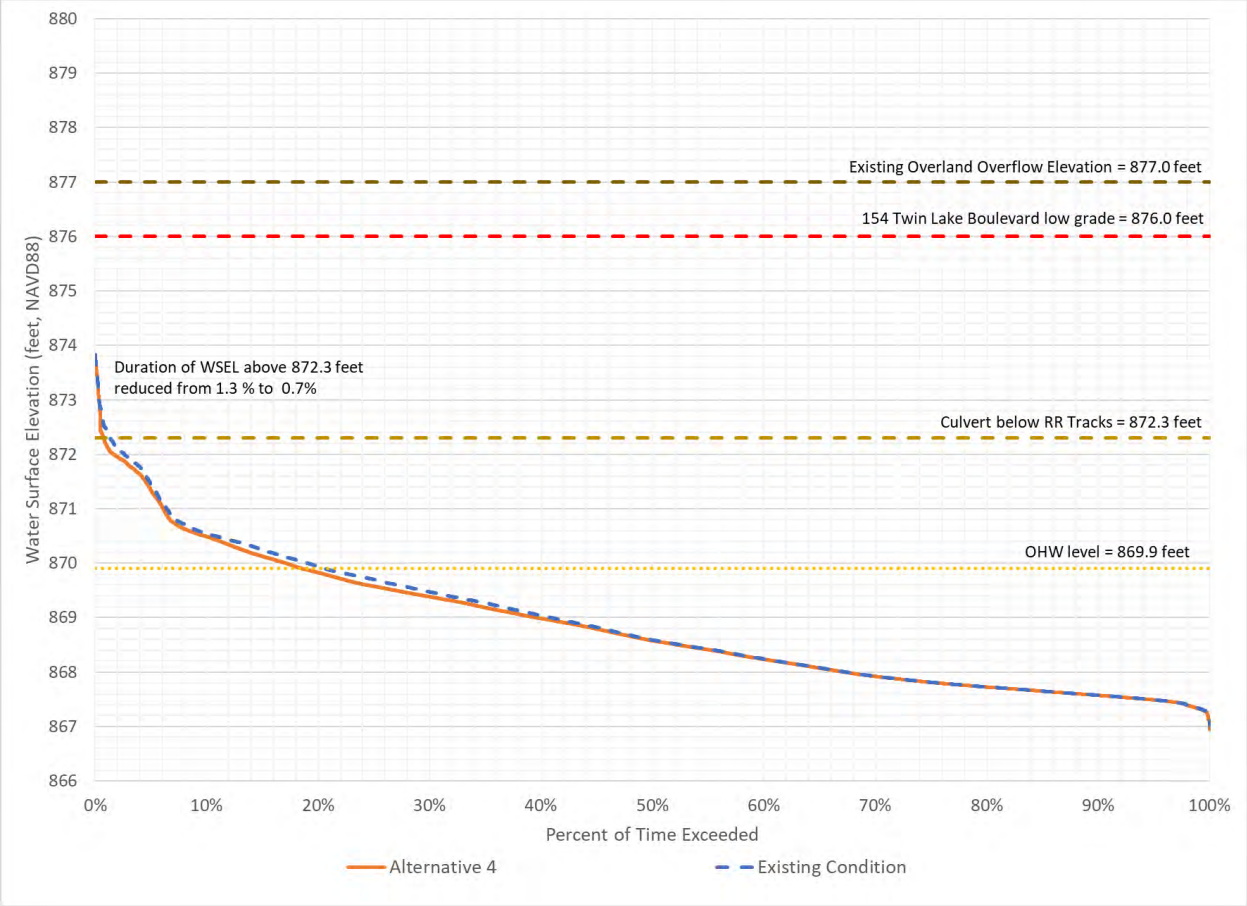


Figure 5-15 Alternative 4 Twin Lake Elevation-Duration Curve

Impacts to the Downstream Floodplain

The District stormwater model was used to calculate the 100-year floodplain impacts downstream of a new gravity outlet following the same methodology used to evaluate existing conditions described in Section 2.1.2.1. Downstream impacts at Gervais Lake are summarized in Table 5-3. Following the proposed operational plan would minimize increased risk to the 100-year floodplain of areas downstream of Twin Lake. If discharge is required during the spring or summer months, there is the potential for increase to the 100-year floodplain on the Phalen Chain of Lakes that would require additional attention during those operations.

Table 5-3 Alternative 4 Floodplain Impacts

Location	Change in the 100-Year Water Surface Elevation (feet)
Twin Lake	(0.2)
Gervais Lake	0.00 [1]

Note(s):
There would be an increase to the 100-year water surface elevation if discharge is required during the spring or summer months.

5.2.4.2 Regulatory Approvals

The permits required for Alternative 4 will be similar to the permits required for Alternative 3, discussed in Section 5.2.3.2.

5.2.4.3 Affected Property Owners

The affected property owners for Alternative 4 will be similar to the property owners affected by Alternative 3, discussed in Section 5.2.3.3.

5.2.4.4 Wetland/Upland Impacts

The total area of disturbance and drainage and access easements for the proposed outlet is approximately 0.8 acres. This area includes the footprint of the grading extents for the drainage ditch, gatewell, gravity pipe, and drainage and access easements. Based on the wetland delineation report (reference [27]), it is estimated that approximately 0.1 acres of the existing wetland could be impacted by the proposed improvements. The total area of wetland impacts may change during the next phase of design as grading extents are optimized.

The District is the wetland permitting authority for this project and has a no-net-loss policy for wetlands within the District. Wetland replacement and mitigation plans would need to be developed during the next phase of design. It is possible that some wetland mitigation could occur adjacent to the existing wetland ditch pending coordination with the property owner.

Alternative 4 will result in permanent modifications to the area between the railroad tracks and Waldo Pond. It is anticipated that the design to reestablish the ditch will avoid or minimize permanent wetland impacts. Alternative 4 will also result in permanent impacts to the existing agricultural drainage. Construction of the outlet and ditch would remove approximately 0.2-acres of existing agricultural area. Due to the existing land use, it is not anticipated that Alternative 4 would result in removal of significant trees.

5.2.4.5 Engineer's Opinion of Probable Cost

The engineer's opinion of probable cost is reported as a range of probable costs. The range reflects the level of uncertainty, unknowns, and risk associated with the level of design completed. The opinion of probable cost includes costs for construction, planning engineering and design, permitting, construction

management, contingency, and operation and maintenance costs over a 30-year period. Maintenance requirements for Alternative 4 include yearly site inspections of the ditch and piped outlet through the embankment, vegetation maintenance, and operation of the gated outlet. The opinion of probable cost assumes that operation of the gatewell would be required three times within the next 30-year period. However, the frequency of operation is dependent on changing climate conditions and rainfall patterns, which may result in operation more than three times.

Appendix A includes a detailed discussion of Alternative 4, including assumptions used to develop the engineer's opinion of probable cost. This equates to an estimated total project cost of $267,000 over a 30-year period, with an accuracy range of ($214,000 to $401,000).

5.3 Conceptual Design Summary

Table 5-4 summarizes the design criteria (Section 3) and design goals (Section 4) for each of the four alternatives considered.

Table 5-4 Conceptual Design Summary

	Alternative 1: Remove Flood-Prone Structure	Alternative 2: Emergency Response Plan	Alternative 3: Gravity Outlet at Elevation 874.0	Alternative 4: Gravity Outlet at Elevation 872.2
Design Criteria				
No increase in peak runoff rate during 2-year, 10-year, or 100-year event	✓	✓ See Note 1	✓ See Note 1	✓ See Note 1
No increase in downstream 100-year elevations	✓ See Note 2	✗ See Note 2	✗ See Note 2	✓ See Note 2
Implement erosion and sediment controls	✓	✓	✓	✓
Avoid, minimize, and mitigate wetland impacts	✓ No impacts	✓ No impacts	✓ No impacts. See Note 3	✓ See Note 3
Minimum 2-foot vertical offset from petroleum pipeline	NA	✓	✓	✓
Pump or actively manage discharge will require MDNR appropriation permit	NA	✓ See Note 4	✓ See Note 4	✓ See Note 4
Flood-Risk Mitigation Goals				
Maximize freeboard between low home and 100-year water level	✗ See Note 5	✓	✗	✓
Minimize duration that inundation extends onto residential property	✗ See Note 6	✗ See Note 6	✗ See Note 6	✓
Minimize impacts to upland area	✗ See Note 7	✓	✓	✓
Provide flexibility for future optimization	✗ See Note 8	✗ See Note 8	✗ See Note 8	✓
Engineer's opinion of probable cost over a 30-year period	$878,000 - $1,646,000 $1,097,000	$344,000 - $646,000 $430,000	$153,000 - $285,000 $190,000	$214,000 - $401,000 $267,000

Note(s):

(1) If operation plan is developed for when temporary pump can be operated or gate can be opened. There may be periods when the pump is turned off or gate is closed to avoid increases to the peak discharge rate.

(2) Discharging any additional flow downstream changes flood-risk. Alternative 1 is the only alternative that does not change downstream flood-risk. Alternatives 2 and 3 result in increases to the 100-year floodplain in the Phalen Chain and would require downstream modifications to mitigate impacts to the 100-year flood elevation. Alternative 4 includes an operating plan to reduce the potential to downstream impacts to the 100-year floodplain. Adherence to the operating plan that is consistent with permitting requirements and hydrologic modeling will reduce that risk.

(3) Wetland impacts must be minimized during final design. Alternative 3 and Alternative 4 may have opportunity for wetland enhancement and ecosystem restoration for a wetland adjacent to agricultural field.

(4) MDNR appropriation permit is required prior to activating Alternative 2 temporary pump. An appropriation permit may not be required for Alternative 3 if operable gates are removed from the design. A long-term appropriation permit may be obtained for permanent outlet included in Alternative 4.

(5) Alternative 1 removes the low home.

(6) Alternative 1 does not reduce inundation duration. Alternative 2 only reduces the duration that inundation extends onto residential property when the water levels trigger implementation of emergency response measures. Alternative 3 does not reduce inundation duration for water levels below 874.0.

(7) Alternative 1 disturbs the most upland area, including relocation of existing home.

(8) Alternatives 1, 2, and 3 do not include permanent modifications that allow for flexibility to modify future management of lake levels. Alternative 4 would allow the outlet elevation to be increased in the future.

Alternatives 1 and 4 meet the minimum design criteria for approval from entities with permitting authority discussed in Section 3. Alternative 4 is the only alternative that also meets each of the flood-risk mitigation goals listed in Section 4.

Of the alternatives evaluated, a gravity outlet at elevation 872.2 (Alternative 4) reduces flood risk within Twin Lake, and, along with the operating plan, minimizes the increased risk of flooding downstream. Alternative 4 has a lower lifecycle cost compared to Alternatives 1 and 2 and a similar cost to Alternative 3.

If a gravity outlet at 872.2 is selected (i.e., Alternative 4), design optimizations to minimize impacts to the existing wetland and agricultural fields should be considered. During final design a detailed operational plan would need to be developed and approved by the City of Little Canada, MnDOT, and the MDNR. During final design of the selected alternative, ongoing coordination would be required with the City of Little Canada, MnDOT, MDNR, and the property owner of parcel ID 313022440018.

6 Recommendation

Alternative 4, gravity outlet at elevation 872.2, is recommended as the most feasible flood-risk mitigation alternative. This alternative would include a detailed operating plan that would describe when the valve associated with this alternative could be opened and when it should be closed. This recommendation is based on Twin Lake flood-risk mitigation objectives, as well as the assessment of downstream impacts, site and wetland impacts, and flexibility for long-term management. Alternatives 2, 3, and 4 all discharge additional water downstream and therefore increase the flood risk to properties along Gervais Creek and in the Phalen Chain. However, adherence to an operating plan developed consistent with permitting requirements and hydrologic modeling will reduce the risk for Alternative 4. The engineering assessment was based on information collected during a review of available data and preliminary site characterization.

Alternative 4 is a feasible project, consistent with the 2019 District Management Plan and based on available information and requirements of permitting jurisdictions. This BMP combination mitigates flood risk while protecting the water quality of Twin Lake.

The engineer's opinion of probable cost for the design, permitting, and construction of Alternative 4 is $226,000, with a potential range of $181,000 to $339,000, based on the current level of design. As plans and specifications for the recommended alternative are prepared, the District should continue to collaborate with City of Little Canada staff about design details and long-term maintenance. If the Board elects to pursue the project, it is recommended that coordination with the City of Little Canada start in the near-term to develop a cooperative agreement in advance of the project implementation. Over a 30-year period, necessary long-term maintenance is anticipated to be between $33,000 and $62,000.

7 References

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[21] Cornerstone Land Surveying Inc, *Five Star Estates Existing Conditions Survey,* Vadnais Heights, 2018.

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Appendix A

Engineer's Opinion of Probable Cost

1 Cost Estimate

Engineer's opinions of probable costs for design, permitting, and construction were developed for each flood-risk mitigation alternative. These opinions of costs, project reserves, contingency, documentation and discussion are intended to provide background information for feasibility alternatives assessment, analysis purposes and budget authorization by RWMWD. The cost of time escalation is not included in the opinions of probable cost. All costs are presented in 2019 US dollars.

Quantities were estimated with calculations based on available information. Dimensions, areas, and volumes for construction were estimated using Excel, GIS, CAD, and information from 2019 temporary pumping.

Unit costs are based on recent bid prices, published construction cost index resources, and similar stormwater projects. Unit process were developed and compared to similar project prices. Costs associated with Base Planning Engineering and Design (PED) are based on percentages of estimated construction cost and are within a range similar to those used in past projects designed by Barr. Costs associated with Construction Management (CM) are based on estimated costs to manage the construction process, based on Barr's experience with similar projects, but may change depending on the services that are provided during construction. The estimates also include Permitting and Regulatory Approvals, which is intended to account for additional planning, coordination, and mitigation costs that are likely to be incurred as the project is permitted with environmental agencies.

The opinions of cost include tasks and items related to engineering and design, permitting, and constructing each conceptual design. The opinions of cost do not include other tasks following construction of each alternative presented such as operations and maintenance, or monitoring.

Contingency used in these opinions of probable cost are intended to help identify an estimated construction cost amount for the minor items included in the current Project scope but have not yet been quantified or estimated directly during the feasibility evaluation. Stated another way, contingency is the resultant of the pluses and minuses that cannot be estimated at the level of project definition that exists. The contingency includes the cost of ancillary items not currently itemized in the quantity summaries but commonly identified in more detailed design and required for completeness of the work. A 35% contingency is applied to the estimated construction cost to account for the costs of these items.

Industry resources for cost estimating (*AACE International Recommended Practice No. 18R-97, and ASTM E2516-06 Standard Classification for Cost Estimate Classification System*) provide guidance on cost uncertainty, depending on the level of project design developed. The opinion of probable cost for the alternatives evaluated generally corresponds to a Class 4 estimate characterized by completion of limited engineering and use of deterministic estimating methods. As the level of design detail increases, the level of uncertainty is reduced. Figure A-1 provides a graphic representation of how uncertainty (or accuracy) of cost estimates can be expected to improve as more detailed design is developed.

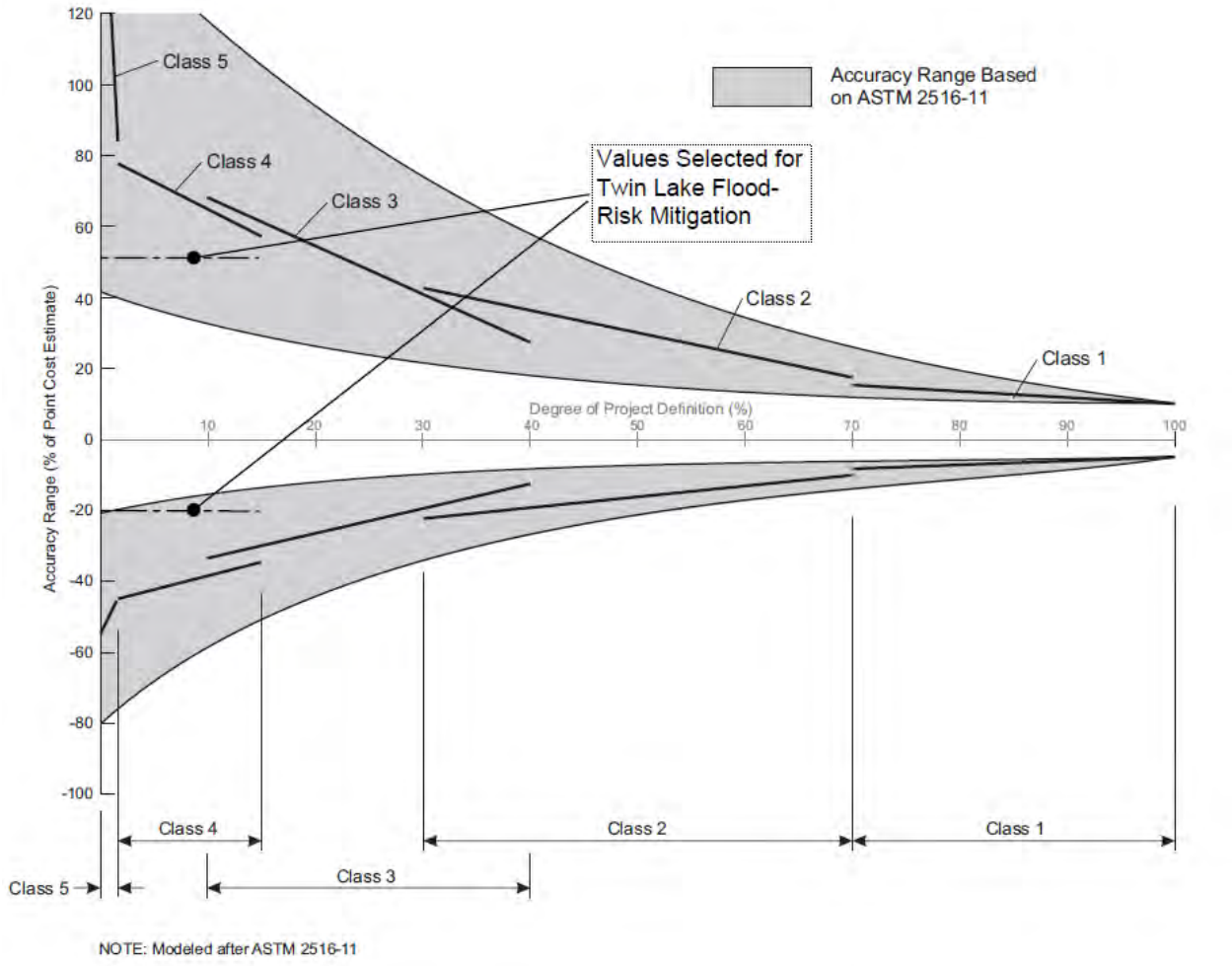

Figure A-1 Relationship between Cost Accuracy and Degree of Project Definition

At this early stage of design, the range of uncertainty of total project cost is high. Due to the early stage of design, it is standard practice to place a broad accuracy range around the point cost estimate.

The accuracy range is based on professional judgment considering the level of design completed, the complexity of the project, and the uncertainties in the project scope; the accuracy range does not include costs for future scope changes that are not part of the project as currently defined or risk contingency. The estimated accuracy range for this point estimate is -20% to +50%.

The opinion of probable cost provided is made on the basis of Barr Engineering's experience and qualifications and represents our best judgment as experienced and qualified professionals familiar with the project. It is acknowledged that additional investigations and additional site specific information that becomes available in the next stage of design may result in changes to the proposed configuration, cost and functioning of project features. This opinion is based on project-related information available to Barr Engineering at this time and includes a conceptual-level feasibility design of the project. The opinion of cost may change as more information becomes available and further design is completed. In addition, because we have no control over the eventual 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, Barr Engineering cannot and does not guarantee that proposals, bids, or actual costs will not vary from the opinions of probable cost presented. If RWMWD wishes greater assurance as to the probable project cost, the RWMWD should authorize further investigation and design of a selected alternative.

Table A-1 provides a comparison of the opinion of costs for each of the five alternatives. Table A-2 through Table A-5 include opinion of cost for each design alternative, and Table A-6 includes opinion of cost for operation and maintenance over a 30-year period.

Table A-1 **Engineer's Opinion of Probable** Cost **–** Feasibility Estimate Summary

Flood-Risk Mitigation Alternative	Engineer's Opinion of Probable Cost ($)[1,3]	Engineer's Opinion of Probable Maintenance Cost Over a 30 Year Lifecycle ($)[2,3]	Total Project Cost ($)[3]
Alternative 1 Purchase Flood-Prone Structure	$874,000 - $1,638,000 $1,092,000	$4,000 - $8,000 $5,000	$878,000 - $1,646,000 $1,097,000
Alternative 2 Emergency Response Plan	$52,000 - $98,000 $65,000	$292,000 - $548,000 $365,000	$344,000 - $646,000 $430,000
Alternative 3 Gravity outlet at elevation 874.0	$132,000 - $246,000 $164,000	$21,000 - $39,000 $26,000	$153,000 - $285,000 $190,000
Alternative 4 Gravity outlet at elevation 872.2	$181,000 - $339,000 $226,000	$33,000 - $62,000 $41,000	$214,000 - $401,000 $267,000

Note(s):

(1) Approximate values based on available information. Costs are for construction costs for Alternatives 1, 3, and 4 and initial cost to develop ERP for Alternative 2. Estimated easement acquisition costs are included for all Alternatives based on information available. See Tables A-2 through A-5 for additional details.

(2) Operation and maintenance costs include vegetation maintenance for Alternatives 1, 3, and 4. Implementation of emergency response measures for Alternative 2. Gatewell operation and monitoring for Alternatives 3 and 4. See Table A-6 for additional details.

(3) The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%.

2 References

American Society for Testing and Materials. 2006. ASTM E2516-06 Standard Classification for Cost Estimate Classification System. ASTM International, West Conshohocken, PA, DOI: 10.1520/E2516-06

Association for the Advancement of Cost Estimating. 2005. *AACE International Recommended Practice NO. 18R-97*, February 2, 2005

Table A-2 Engineer's Opinion of Probable Project Cost: Alternative 1 - Removal of Flood-Prone Structure

PREPARED BY: BARR ENGINEERING COMPANY

REV 1 SHEET: 1 OF 5

TWIN LAKE FLOOD-RISK MITIGATION FEASIBILITY STUDY
ENGINEER'S OPINION OF PROBABLE PROJECT COST
PROJECT: TWIN LAKE FLOOD-RISK MITIGATION
LOCATION: City of Little Canada, MN
PROJECT #: 23/62-1200.19-010

Engineer's Opinion of Probable Project Cost
Alternative 1 – Remove Flood-Prone Structure
Twin Lake Flood-Risk Mitigation

	Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
	A	Mobilization/Demobilization	L.S.	1	$ 3,300	$3,300.00	1,2,3,4,5
	B	Property acquisition	L.S.	1	$ 722,750	$722,750.00	1,2,3,4,5, 9
	C	Hazardous substance abatement, demolition, and utility	L.S.	1	$ 10,000	$10,000.00	1,2,3,4,5, 10
	D	Silt fence	L.F.	100	$ 3.50	$350.00	1,2,3,4,5
	E	Site restoration (seed)	Acre	1	$ 5,000.00	$6,000.00	1,2,3,4,5
		CONSTRUCTION SUBTOTAL				$742,000.00	1,2,3,4,5,8, 9, 10
		CONSTRUCTION CONTINGENCY (35%)				$260,000.00	1,5,8, 9, 10
		ESTIMATED CONSTRUCTION COST				$1,002,000.00	1,2,3,4,5,8, 9, 10
		PLANNING, ENGINEERING & DESIGN				$40,000.00	1,2,3,4,5,8, 9, 10
		PERMITTING & REGULATORY APPROVALS				$10,000.00	1,5,6,8, 9, 10
		CONSTRUCTION MANAGEMENT				$40,000.00	1,5,8, 9, 10
		ESTIMATED TOTAL PROJECT COST				$1,092,000.00	1,2,3,4,5,7,8, 9 ,10
		ESTIMATED ACCURACY RANGE	**-20%**			**$874,000.00**	5,7,8
			50%			**$1,638,000.00**	5,7,8

Notes

[1] Limited design work completed (10 - 15%).

[2] Quantities based on design work completed.

[3] Unit prices based on information available at this time.

[4] No soil borings collected. No wetland delineation completed in the field.

[5] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that wetland mitigation/replacement is not required. Included are the cost for agency communication and application preparation for a permit . If replacement/mitigation is required, the total cost may increase to approximately $10,000 plus an additional $100,000/acre of wetland disturbed.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are reported to nearest thousand dollars.

[9] Property value obtained from the Ramsey County Property Records and Revenue department. Property value multiplied by 1.25 to account for cost of appraisal and adjustment to market value.

[10] Hazard substance assessment and abatement investigation has not been completed. Presence of potential hazardous substances is not included in the estimate.

Table A-3 Engineer's Opinion of Probable Project Cost: Alternative 2 - Emergency Response

PREPARED BY: BARR ENGINEERING COMPANY

REV 1 SHEET: 2 OF 5

TWIN LAKE FLOOD-RISK MITIGATION FEASIBILITY STUDY
ENGINEER'S OPINION OF PROBABLE PROJECT COST
PROJECT: TWIN LAKE FLOOD-RISK MITIGATION
LOCATION: City of Little Canada, MN
PROJECT #: 23/62-1200.19-010

Engineer's Opinion of Probable Project Cost
Alternative 2 – Emergency Response Plan
Twin Lake Flood-Risk Mitigation

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Develop ERP	L.S.	1	$ 15,000.00	$15,000.00	1,2
B	Easement Acquisition	Acre	0.8	$ 35,000.00	$28,000.00	1,2, 6
C	Agency coordination	L.S.	1	$ 5,000.00	$5,000.00	1,2, 7
	EMERGENCY RESPONSE PLAN SUBTOTAL				$48,000.00	1,2, 3, 4, 5
	EMERGENCY RESPONSE PLAN CONTINGENCY (35%)				$17,000.00	1,2, 3, 4, 5
	ESTIMATED EMERGENCY RESPONSE PLAN COST				$65,000.00	1,2,3,4,5, 6, 7
	ESTIMATED TOTAL PROJECT COST				$65,000.00	1,2,3,4,5, 6, 7
	ESTIMATED ACCURACY RANGE	**-20%**			**$52,000.00**	1,2,3,4,5, 6, 7
		50%			**$98,000.00**	1,2,3,4,5, 6, 7

Notes

[1] Limited design work completed (10 - 15%).

[2] Quantities based on design work completed.

[3] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[4] The estimated costs do not include maintenance, monitoring or additional tasks following emergency response.

[5] Estimate costs are reported to nearest thousand dollars.

[6] Property value obtained from the Ramsey County Property Records and Revenue department. Property value multiplied by 1.25 to account for cost of appraisal and adjustment to market value. Easesment assessment was not completed as part of this evaluation.

[7] Coordination with MnDOT, MDNR, and City of Little Canada while developing Emergency Response Plan. Does not include obtaining permits required to implement temporary emergency response items. Cost does not include wetland permitting mitigation/replacement. If wetland replacement/mitigation is required, the total cost may increase to approximately $10,000 plus an additional $100,000/acre of wetland disturbed.

Table A-4 Engineer's Opinion of Probable Project Cost: Alternative 3 – Gravity Outlet (874.0)

PREPARED BY: BARR ENGINEERING COMPANY

REV 1 SHEET: 3 OF 5

TWIN LAKE FLOOD-RISK MITIGATION FEASIBILITY STUDY
ENGINEER'S OPINION OF PROBABLE PROJECT COST
PROJECT: TWIN LAKE FLOOD-RISK MITIGATION
LOCATION: City of Little Canada, MN
PROJECT #: 23/62-1200.19-010

Engineer's Opinion of Probable Project Cost
Alternative 3– Gravity Outlet (874.0)
Twin Lake Flood-Risk Mitigation

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/Demobilization	L.S.	1	$ 9,900.00	$9,900.00	1,2,3,4,5
B	Remove & replace chain link fence	L.F.	20	$ 15.00	$300.00	1,2,3,4,5
C	Rock erosion control construction entrance	Each	1	$ 1,500.00	$1,500.00	1,2,3,4,5
D	Erosion control silt fence	L.F.	100	$ 3.50	$350.00	1,2,3,4,5
E	Erosoion control blanket	S.Y.	700	$ 2.50	$1,750.00	1,2,3,4,5
F	Common excavation - embankment	C.Y.	40	$ 20.00	$800.00	1,2,3,4,5
G	Common excavation - ditch	C.Y.	60	$ 10.00	$600.00	1,2,3,4,5
H	Bedding	C.Y.	3	$ 35.00	$105.00	1,2,3,4,5
I	Backfill	C.Y.	37	$ 4.00	$148.00	1,2,3,4,5
J	Compaction	C.Y.	37	$ 3.50	$129.50	1,2,3,4,5
K	24-inch RCP	L.F.	45	$ 75.00	$3,375.00	1,2,3,4,5
L	Sluice gate	Each	1	$ 25,000.00	$25,000.00	1,2,3,4,5
M	48-inch manhole	L.F.	4	$ 375.00	$1,500.00	1,2,3,4,5
N	Inline backflow preventer	Each	1	$ 12,000.00	$12,000.00	1,2,3,4,5
O	Riprap	Ton	15	$ 95.00	$1,425.00	
P	Floating silt curtain	L.F.	100	$ 10.50	$1,050.00	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				$60,000.00	1,2,3,4,5,8
	CONSTRUCTION CONTINGENCY (35%)				$21,000.00	1,5,8
	ESTIMATED CONSTRUCTION COST				$81,000.00	1,2,3,4,5,8
	PLANNING, ENGINEERING & DESIGN				$36,500.00	1,2,3,4,5,8
	PERMITTING & REGULATORY APPROVALS				$10,000.00	1,5,6,8
	EASEMENT ACQUISITION	Acre	0.8	$35,000.00	$28,000.00	9
	CONSTRUCTION MANAGEMENT				$8,000.00	1,5,8
	ESTIMATED TOTAL PROJECT COST				$164,000.00	1,2,3,4,5,7,8
	ESTIMATED ACCURACY RANGE	**-20%**			**$132,000.00**	5,7,8
		50%			**$246,000.00**	5,7,8

Notes

[1] Limited design work completed (10 - 15%).

[2] Quantities based on design work completed.

[3] Unit prices based on information available at this time.

[4] No soil borings collected.

[5] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that wetland mitigation/replacement is not required. Included are the cost for agency communication and application preparation for a permit . If replacement/mitigation is required, the total cost may increase to approximately $10,000 plus an additional $100,000/acre of wetland disturbed.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are reported to nearest thousand dollars.

[9] Property value obtained from the Ramsey County Property Records and Revenue department. Property value multiplied by 1.25 to account for cost of appraisal and adjustment to market value.

Table A-5 Engineer's Opinion of Probable Project Cost: Alternative 4 – Gravity Outlet (872.2)

PREPARED BY: BARR ENGINEERING COMPANY

REV 1 SHEET: 4 OF 5

TWIN LAKE FLOOD-RISK MITIGATION FEASIBILITY STUDY
ENGINEER'S OPINION OF PROBABLE PROJECT COST
PROJECT: TWIN LAKE FLOOD-RISK MITIGATION
LOCATION: City of Little Canada, MN
PROJECT #: 23/62-1200.19-010

Engineer's Opinion of Probable Project Cost
Alternative 4– Gravity Outlet (872.2)
Twin Lake Flood-Risk Mitigation

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/Demobilization	L.S.	1	$ 14,100.00	$14,100.00	1,2,3,4,5
B	Manage Water	L.S.	1	$ 10,000.00	$10,000.00	1,2,3,4,5
C	Remove & replace chain link fence	L.F.	20	$ 15.00	$300.00	1,2,3,4,5
D	Rock erosion control construction entrance	Each	1	$ 1,500.00	$1,500.00	1,2,3,4,5
E	Erosion control silt fence	L.F.	100	$ 3.50	$350.00	1,2,3,4,5
F	Erosoion control blanket	S.Y.	750	$ 2.50	$1,875.00	1,2,3,4,5
G	Common excavation - embankment	C.Y.	580	$ 20.00	$11,600.00	1,2,3,4,5
H	Common excavation - ditch	C.Y.	150	$ 10.00	$1,500.00	1,2,3,4,5
I	Bedding	C.Y.	7	$ 35.00	$245.00	1,2,3,4,5
J	Backfill	C.Y.	573	$ 4.00	$2,292.00	1,2,3,4,5
K	Compaction	C.Y.	573	$ 3.50	$2,005.50	1,2,3,4,5
L	24-inch RCP	L.F.	110	$ 75.00	$8,250.00	1,2,3,4,5
M	Sluice gate	Each	1	$ 25,000.00	$25,000.00	1,2,3,4,5
N	48-inch manhole	L.F.	8	$ 375.00	$3,000.00	1,2,3,4,5
O	Inline backflow preventer	Each	1	$ 12,000.00	$12,000.00	1,2,3,4,5
P	Floating silt curtain	L.F.	100	$ 10.50	$1,050.00	1,2,3,4,5
	CONSTRUCTION SUBTOTAL				$95,000.00	1,2,3,4,5,8
	CONSTRUCTION CONTINGENCY (35%)				$33,000.00	1,5,8
	ESTIMATED CONSTRUCTION COST				$128,000.00	1,2,3,4,5,8
	PLANNING, ENGINEERING & DESIGN				$46,500.00	1,2,3,4,5,8
	PERMITTING & REGULATORY APPROVALS				$10,000.00	1,5,6,8
	EASEMENT ACQUISITION	Acre	0.8	$35,000.00	$28,000.00	9
	CONSTRUCTION MANAGEMENT				$13,000.00	1,5,8
	ESTIMATED TOTAL PROJECT COST				$226,000.00	1,2,3,4,5,7,8
	ESTIMATED ACCURACY RANGE	**-20%**			**$181,000.00**	5,7,8
		50%			**$339,000.00**	5,7,8

Notes

[1] Limited design work completed (10 - 15%).

[2] Quantities based on design work completed.

[3] Unit prices based on information available at this time.

[4] No soil borings collected.

[5] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that wetland mitigation/replacement is not required. Included are the cost for agency communication and application preparation for a permit . If replacement/mitigation is required, the total cost may increase to approximately $10,000 plus an additional $100,000/acre of wetland disturbed.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are reported to nearest thousand dollars.

[9] Property value obtained from the Ramsey County Property Records and Revenue department. Property value multiplied by 1.25 to account for cost of appraisal and adjustment to market value.

Table A-6 Engineer's Opinion of Probable Project Cost: 30-Year Operation and Maintenance

PREPARED BY: BARR ENGINEERING COMPANY

SHEET: 5 OF 5

TWIN LAKE FLOOD-RISK MITIGATION FEASIBILITY STUDY
ENGINEER'S OPINION OF PROBABLE PROJECT COST
PROJECT: TWIN LAKE FLOOD-RISK MITIGATION
LOCATION: City of Little Canada, MN
PROJECT #: 23/62-1200.19-010

Engineer's Opinion of Probable Project Cost
30-Year Operation and Maintenance Costs
Twin Lake Flood-Risk Mitigation

	Cat. No.	ITEM DESCRIPTION	Conversion	Alt. 1	Alt.2	Alt. 3	Alt. 4	NOTES
	A	Vegetation Maintenance ($40/hr)	2-4 hrs/yr	$ 3,600				1, 2, 3, 4
	B	Implement emergency response plan	once every 10 years		$ 270,000			1, 2, 3, 4
	C	Vegetation maintenance ($40/hr)	8-16 hrs/yr			$ 14,400		1, 2, 3, 4
	D	Vegetation maintenance ($40/hr)	16 - 24 hrs/yr				$ 24,000	1, 2, 3, 4
	E	Gatewell operation	once every 10-years			$ 4,800	$ 6,000	1, 2, 3, 4
		O&M SUBTOTAL		$ 4,000	$ 270,000	$ 19,000	$ 30,000	1, 2, 3, 4, 5
		O&M CONTINGENCY (35%)		$ 1,000	$ 95,000	$ 7,000	$ 11,000	1, 2, 3, 4, 5
		ESTIMATED O&M COST		$ 5,000	$ 365,000	$ 26,000	$ 41,000	1, 2, 3, 4, 5
		ESTIMATED ACCURACY RANGE		**$ 4,000**	**$ 292,000**	**$ 21,000**	**$ 33,000**	4, 5
		(-20% to 50%)		**$ 8,000**	**$ 548,000**	**$ 39,000**	**$ 62,000**	4, 5

Notes

[1] Limited design work completed (10 - 15%).

[2] Prices based on information available at this time.

[3] Vegetation maintenance of Alternative 1 is less than Alternatives 3 and 4 as surface footprint is smaller. Vegetation maintence for Alternative 3 is less than Alternative 4 because ditch section is smaller.

[4] This feasibility-level (Class 4, 10-15% design completion per ASTM E 2516-06) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. Contingency is an allowance for the net sum of costs that will be in the Final O&M Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Operation and Maintenance Cost as the project is defined is -20% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency.

[5] Estimate costs are reported to nearest thousand dollars.