Southwest Light Rail Transit: Kenilworth Shallow LRT Tunnels Water Resources Evaluation

DRAFT

Metropolitan Council

Project No. 76701

Revision 0
January 30, 2013

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prepared for

Metropolitan Council

St. Paul, Minnesota

Project No. 76701

Revision 0
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prepared by

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EXECUTIVE SUMMARY

The Metropolitan Council (Council) has developed preliminary plans and designs for the Southwest Light Rail Transit (SWLRT) Green Line Extension project. The planned Green Line Extension project is approximately 16 miles long and runs southwest from downtown Minneapolis through the cities of St. Louis Park, Hopkins, Minnetonka, and Eden Prairie. Within the Green Line Extension project, the Council is exploring the option of installing two shallow tunnel segments (north and south) between the proposed West Lake and Penn Stations, both of which would be located within the city limits of Minneapolis, MN. The area where the shallow tunnels would be located is known as the Kenilworth Corridor.

As part of the design exploration process, the Council has developed a draft Basis of Design report (BODR) and draft Water Resources Monitoring Program (WMP), which together present an approach to constructing the shallow tunnels, and a means for controlling seepage groundwater into the tunnels and mitigating impacts to water resources in the area during construction and operation of the light rail transit (LRT) system.

Burns & McDonnell Engineering Company (Burns & McDonnell) was retained by the Council to conduct an independent engineering evaluation and technical review (evaluation) of these six documents:

1. Kenilworth Shallow LRT Tunnel BODR (Metropolitan Council, 2013)
2. SWLRT Project Office (SPO) letter to Minnehaha Creek Watershed District (MCWD)dated September 4, 2013 (Alexander, 2013)
3. MCWD response letter to SPO dated September 10, 2013 (Wisker, 2013)
4. Wenck Associates(Wenck), Inc., letter to MCWD dated September 9, 2013 (Panzer, 2013)
5. Kenilworth Shallow LRT Tunnel draft Water Resources Monitoring Program (Metropolitan Council, 2013)
6. Modified Phase I Environmental Site Assessment (SEH, Inc., 2013)

The evaluation focused on addressing the following issues identified in the September 4, 2013 SPO letter to MCWD:

- *Potential impacts to the groundwater elevation in the vicinity of the proposed tunnel.*
- *Potential impacts to the Chain of Lakes "water budget" due to water that is anticipated to be collected in the proposed tunnel and routed to the sanitary sewer.*
- *Potential for the proposed tunnel to cause a groundwater flow blockage related to groundwater flow between Cedar Lake and Lake of the Isles. SPO presented materials that indicated that the water elevations of Cedar Lake and Lake of the Isles are uniform and rise and fall together.*
- *Reasonability of the design criteria provided in the BODR for leakage rates for both permanent sheet piling and waterproofing systems surrounding the proposed concrete tunnel. The leakage rate design criteria provided by the SPO is related to the quantity and flow rate of water that would be collected by storm or sanitary sewer systems.*

- *Reasonability of methods presented to address construction dewatering and to minimize the amount of temporary dewatering required. SPO presented information regarding tunnel construction temporary dewatering as well as a step-by-step potential construction methodology that was the basis for determining flow rates and quantities of temporary dewatering.*
- *Reasonability of the 50-year design recommended by the SPO for stormwater infiltration and whether this approach will address concerns related to discharging warmer water back into the storm sewers or lakes during winter months.*
- *Any other potential impacts to water resources in the area.*

Burns & McDonnell's evaluation was accomplished by gathering information at project meetings, and reviewing the project documents mentioned above. The project meetings consisted of two technical project meetings on December 10 and 19, 2013 and town hall/community meetings that were held in Minneapolis and St. Louis Park on January 7, 2014 and January 9, 2014, respectively. Project documents were systematically reviewed in a charrette setting by an interdisciplinary team of water resources professionals using the following steps:

1. Identify specific statements and conclusions made in relation to water resources and the issues identified in the SPO September 4, 2013 letter to MCWD.
2. List the specific data and assumptions these in which statements are based.
3. Review the data and assumptions for potential sources of uncertainty, seasonal fluctuations, safety factors, sensitivity to change, etc.
4. As appropriate, suggest alternative lines of evidence (data, methodology, etc.) that may provide additional clarification or support of the statements/conclusions.

A summary of conclusions and recommendations, incorporating topics provided by project stakeholder and town hall/community meeting participants are provided below.

1.1 Potential Impacts to Groundwater Elevation in the Vicinity of the Proposed Tunnels

1.1.1 Kenilworth Corridor Hydrogeology

The near-surface geology in the Kenilworth Corridor primarily consists of fluvial deposits of sands and gravels with some silty sand to silt layers and underlain by a coarse sand aquifer extending to a depth of greater than 120 feet, a buried swamp deposit and areas with man-placed fill have also been identified. The water table generally ranges in depth from 15 to 25 feet below grade along the proposed route. Perched groundwater may be encountered above the water table in areas with silty layers and swamp deposits.

Cedar Lake and Lake of the Isles are within the Minnehaha Creek watershed and generally drain sequentially through the chain of lakes to the south toward Minnehaha Creek. Cedar Lake and Lake of the Isles are connected by an open channel that equalizes the lake levels in Cedar Lake, the channel and Lake of the Isles. The piezometer data indicate that the lake level elevation in the channel is higher than most of the groundwater elevations. This suggests that groundwater in the corridor does not discharge to the channel and lakes in the corridor and that the lakes may be recharging the aquifer. This is counter to a more typical groundwater-surface water relationship in this climate where groundwater flows toward and discharges to surface water.

Since piezometers are installed only along the proposed route in the Kenilworth Corridor, they only provide a one dimensional view of the groundwater elevations and it is difficult to conclusively determine the groundwater flow pattern. Additional piezometers lateral to the proposed route are needed to better characterize the groundwater flow system in two dimensions, and a few nested piezometers completed at a greater depth would help to evaluate potential downward flow. Also, the water levels presented are only from October and November 2013. Seasonal water level data are needed to better understand ground water elevations during wet periods and in response to rain events.

1.1.2 Potential Impacts to Groundwater Elevation due to Pumping or Leakage into Tunnel

The BODR presents a construction method that intends to isolate the tunnels from the groundwater system with minimal leakage. As a result, there should be little impact on groundwater levels because traditional dewatering methods will not be used provided the construction can achieve the stated leakage rates. The proposed north and south tunnels system is not analogous to the dewatering occurring at 1800 Lake Street. We recommend removing the term "dewatering" from the BODR because it may imply pumping to lower the water table during construction and/or operation of the shallow tunnels option.

1.1.3 Potential Impacts to Groundwater Elevation due to Blockage of Groundwater Flow

The considerable thickness and overall transmissivity of the alluvial aquifer should be able to easily transmit groundwater under the sheet piling without a significant increase in water levels. The only foreseeable situation where a significant rise in water levels could occur would be if there were some areas where a confining silt layer separated a portion of the upper aquifer from the lower aquifer and the sheet piling extended all the way or nearly all the way through the upper aquifer and the tunnel was somewhat perpendicular to horizontal groundwater flow. This appears to be unlikely to occur, however, as stated above; more characterization of groundwater flow is needed to be certain that this would not be an issue.

1.2 Potential Impacts to the Chain of Lakes 'Water Budget'

According to the information in the BODR, only about 34 acre-feet (11 million gallons) would be redirected to the sanitary sewer system annually. This volume of water represents a relatively small portion of the overall water budget of the chain of lakes system. However, sanitary sewer systems are designed to convey sanitary waste and are typically sized for much smaller flows. A comprehensive capacity analysis and range of scenarios to adequately understand the implications of routing water to these systems and city approval is required.

1.3 Potential for the proposed tunnel to cause a groundwater flow blockage related to groundwater flow between Cedar Lake and Lake of the Isles

Cedar Lake and Lake of the Isles are connected by an open channel that equalizes the water level elevation both lakes and the channel. Therefore, there is not a hydraulic driver for groundwater flow from one lake to another across the Kenilworth Corridor. However, the groundwater flow system has not been adequately characterized to conclusively describe groundwater flow in the Kenilworth Corridor.

1.4 Reasonability of methods presented to address construction dewatering and to minimize the amount of temporary dewatering required

In summary, it appears that the some of the pumping rates presented in the BODR for the construction and operation of the tunnel system are in error. It does not appear that these are serious issues that would represent major flaws in the basis of design.

It is recommended that these rates be thoroughly re-evaluated with clearly stated assumptions, input values, and ranges of calculated values. Additionally, the anticipated long-term performance of the waterproofing system should be evaluated considering its durability and other projects where this system has been used in similar settings.

1.5 Reasonability of the 50-year design recommended by the SPO for stormwater infiltration and whether this approach will address concerns related to discharging warmer water back into the storm sewers or lakes during winter months.

During winter, contributions from stormwater and snow melt are assumed to be minimal because of below freezing air temperatures. As a result, the water removed is expected to be mostly groundwater with a temperature of about 55 °F. This water will not be discharged directly into surface water bodies. But will be discharged to underground infiltration chambers that will return this water to the groundwater system. As such, no impacts on the ice cover of the water bodies are expected assuming: the chambers are located below the frost line and are sufficiently large enough to infiltrate the maximum volume of water. The chambers should be designed for the 100-year design storm and a comprehensive capacity analysis and range of scenarios to adequately understand the implications of routing water to these systems and city approval is obtained.

1.6 Other Potential Impacts to Water Resources in the Area

Surface water runoff that enters the portals (entrance/ exits of the tunnels) and tunnels has the potential to contain sediment, oil and grease and chlorides from ice melting chemicals. Stormwater pre-treatment devices, such as grit chambers, should be included in the design to remove sediment, oil and grease which could clog chamber pore space and degrade the functionality of the system. This potential for groundwater contamination, however, could be largely prevented by investigating snow and ice control best management practices, such as blowing or shoveling snow. In the Phase I report, several areas were noted as “high risk” for environmental impacts, many of these are former railroad operations areas. A Phase II investigation is needed in the Kenilworth Corridor to determine if contaminated soil or groundwater may be encountered during the construction.

1.7 Water Resources Monitoring Program Assessment

1.7.1 Groundwater

The groundwater monitoring plan is preliminary and does not go into sufficient detail on key locations to monitor groundwater levels or specific threshold criteria that could indicate an issue with groundwater levels or flow. We recommend revising this document after additional characterization of the groundwater flow system has been completed, as recommended. The revision should include sufficient and specific monitoring locations, parameters, threshold criteria, as well as a monitoring schedule and a course of action should a threshold criteria be exceeded.

1.7.2 Water Quality

Groundwater should be sampled and analyzed for hydrocarbons, chlorides, and other potential contaminants attributable to the project. Beginning before construction, samples should be collected in late spring and fall from sites near underground infiltration chambers (chambers) and from sites in the track corridor away from the chambers.

2 RECOMMENDATIONS

In conclusion, recommended actions are as follows:

- Additional piezometers lateral to the planned route both north and the south of the channel are needed to better characterize the groundwater flow system in two dimensions. Also some sets of nested piezometers should be installed to evaluate vertical groundwater flow in the Kenilworth Corridor. This will help to better characterize and understand the direction and gradient of groundwater flow and the interaction between groundwater and surface water.
- Revise the BODR, removing the term "dewatering" and providing a comprehensive section on water resources.
- A comprehensive capacity analysis and range of scenarios to adequately understand the implications of routing water to sanitary and storm sewer systems is needed for final design.
- Design the underground infiltration chambers for the 100-year design storm event.
- Incorporate stormwater pre-treatment devices in the design.
- A Phase II investigation is needed in the Kenilworth Corridor to determine if contaminated soil or groundwater may be encountered during the construction or operation of the shallow tunnel system.
- Revise the WMP document after additional characterization of the groundwater flow system has been completed sufficiently and specific monitoring locations, parameters, threshold criteria, as well as a monitoring schedule and course of action should a threshold criteria be exceeded.
- Sample and analyze groundwater for hydrocarbons, chlorides, other potential contaminants attributable to the project near the infiltration chambers.

TABLE OF CONTENTS

Page No.

LIST OF FIGURES

1 BACKGROUND

The Metropolitan Council (Council) has developed preliminary plans and designs for the Southwest Light Rail Transit (SWLRT) Green Line Extension project. The planned Green Line Extension project is approximately 16 miles long and runs southwest from downtown Minneapolis through the cities of St. Louis Park, Hopkins, Minnetonka, and Eden Prairie. Within the Green Line Extension project, the Council is exploring the option of installing two shallow tunnel segments (north and south) between the proposed West Lake and Penn Stations, both of which would be located within the city limits of Minneapolis, MN. The section of the overall project route where the shallow tunnels would be located is known as the Kenilworth Corridor. The proposed 2,500-foot long north tunnel segment begins roughly 600 feet north of Lake of the Isles-Cedar Lake channel (Channel) and ends approximately 1,000 feet north of West 21st Street (Metropolitan Council, 2013). The proposed 2, 200-foot south tunnel segment begins roughly 500 feet north of West Lake Street Bridge and ends approximately 400 feet south of the Channel (Metropolitan Council, 2013). As part of the exploration process, the Council has developed a draft Basis of Design report (BODR) and draft Water Resources Monitoring Program (WMP), which together present an approach to constructing the shallow tunnels, and a means for controlling groundwater and mitigating impacts to water resources in the area during construction and operation of the light rail transit (LRT) system.

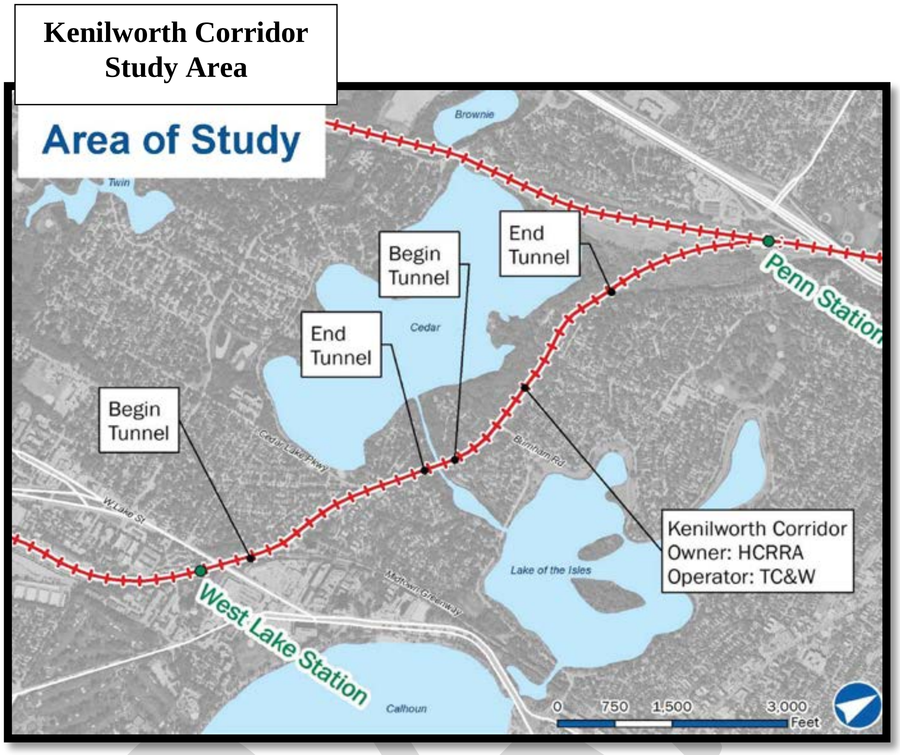

Figure 1: Kenilworth Corridor Study Area (SPO Map)

Burns & McDonnell Engineering Company (Burns & McDonnell) was retained by the Council to conduct an independent engineering evaluation and technical review (evaluation) of the materials provided in BODR. This evaluation was to specifically address the seven issues identified in the SWLRT Project Office's (SPO) letter to Minnehaha Creek Watershed District (MCWD) dated September 4, 2013, and to review and evaluate the WMP.

1.1 Scope

Burns & McDonnell was provided copies of six documents that were to form the basis for its evaluation of potential impacts to water resources in the Kenilworth Corridor due to the proposed construction and operation of the shallow tunnel option. The six documents reviewed were:

1. Kenilworth Shallow LRT Tunnel BODR (Metropolitan Council, 2013)
2. September 4, 2013 SPO letter to Minnehaha Creek Watershed District (MCWD) (Alexander, 2013)
3. September 10, 2013 MCWD response letter to SPO (Wisker, 2013)
4. September 9, 2013 Wenck Associates(Wenck), Inc., letter to MCWD (Panzer, 2013)
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The evaluation focused on addressing the following issues identified in the September 4, 2013 SPO letter to MCWD (Alexander, 2013):

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- *Reasonability of the 50-year design recommended by the SPO for stormwater infiltration and whether this approach will address concerns related to discharging warmer water back into the storm sewers or lakes during winter months.*
- *Any other potential impacts to water resources in the area.*

In addition to reviewing the provided documents to address the specific issues cited above, Burns & McDonnell participated in meetings with the SPO project stakeholders City of Minneapolis, Hennepin County and Minneapolis Park and Recreation Board (MPRB); a project technical meeting with the City of Minneapolis, MPRB and Barr Engineering Company (Barr); and the Minneapolis and St. Louis Park town hall meetings.

No data collection or analytical modeling were included as part of the Burns & McDonnell's evaluation.

1.2 Project Understanding

As part of assessing the shallow tunnels option for the Kenilworth Corridor, the Council developed the BODR, which presents an approach to constructing the shallow tunnels, and a means for mitigating potential impacts to water resources in the area during construction and operations of the LRT system. Our understanding of the proposed tunnel construction and operation process and how water resources will be handled during construction and operation phases is presented below.

1.2.1 Water Management during Construction

The tunnel construction method presented in the BODR is intended to eliminate the need for active dewatering by isolating the tunnels from groundwater. Beginning at each end of the north and south tunnels the construction will be segmented into roughly 150-foot long by 37-foot wide cells.

Prior to any excavation, each section will be isolated from any adjacent groundwater by driving sheet piling around its perimeter. Next, the soil within each section will be excavated to the proposed depth. In areas where the proposed depth is below the water table, a clam shell bucket will be used to wet-excavate the soils without any pumping of groundwater. After, the soil is excavated to the proposed depth; a concrete slab will be poured to seal the base of the tunnel from the underlying groundwater. In areas where the base of the excavation is below the water table, the concrete will be tremmied into place below the water level to create a seal. After the concrete has cured and the seal has been established, any water remaining in the now-sealed excavation will be pumped out (Figure 2). For the segments beneath the water table, there will likely be some leakage through the sheet piling and concrete slab as stated in the BODR and discussed in Section 2.4.

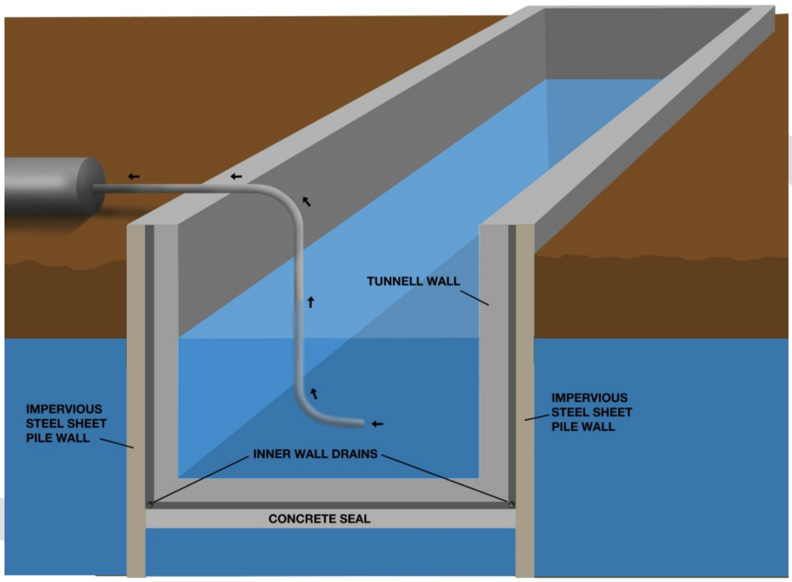

Figure 2: Construction Sheet Pile Cell

With this approach, the water removed during construction would be limited to the amount of precipitation that falls into the cell, the volume of groundwater in the cell when the sheet piling is installed, and leakage through the sheet piling and basal concrete slab. During warm weather months, the water pumped from the cells would be discharged to temporary onsite treatment facilities to remove sediment (filtration basins, portable baffle tanks, etc.) then discharged to the storm sewer system which would then discharge to the chain of lakes. To address temperature differences between water in the cells and in the lake during winter months, water from the cells would be discharged to constructed underground infiltration chambers (chambers), the sanitary sewer, or storage tanks that would be hauled offsite.

1.2.2 Water Management during Operation

When the tunnel system is operating, water would be collected and managed from three different areas: the portals, inner walls and the tunnel. The portals, or entrances/exits of the tunnel, are uncovered and open to rain and snow. Stormwater and snowmelt from the portals would be collected in drains at the base of the portals that are designed to capture a 100-year design storm event. Water captured would be pumped into chambers and infiltrated to groundwater (Figure 3:

Portal Water Control System). Runoff volumes in excess of the chambers' 50-year design storm event volume will overflow from the chambers and discharge into the storm sewer system before the chain of lakes. All design storm events are based on National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfalls (Metropolitan Council, 2013).

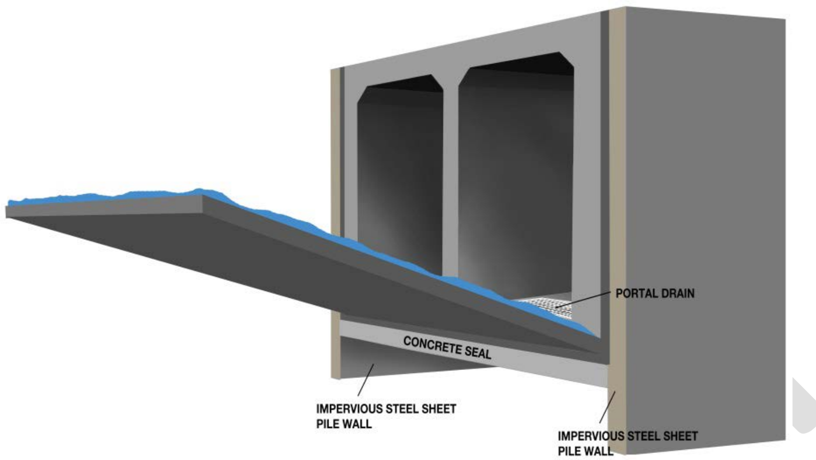

Figure 3: Portal Water Control System

The inner wall (external shallow LRT Tunnel Water Control System) drainage collection area is located between the outside of the tunnel walls and floor of the tunnel and the initial sheet pile walls and concrete seal (Figure 4). This area would collect any groundwater that seeps through the sheet piling and concrete seal. That water would be routed to a chamber and returned to the groundwater system.

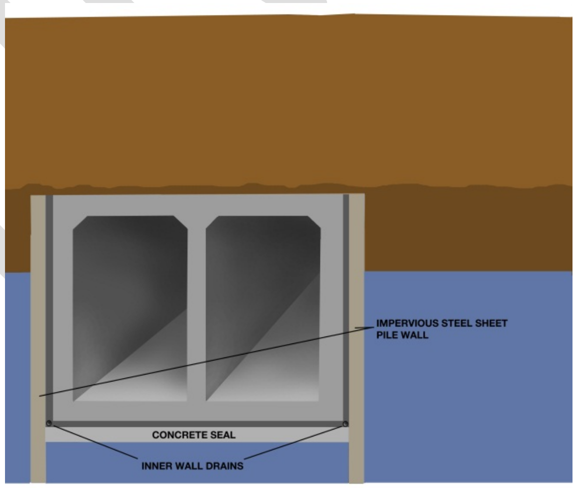

Figure 4: Inner Wall Water Control System

And finally, any water collected inside the tunnel from stormwater, snowmelt and groundwater seepage would be collected in storm drains. That water, which may come in contact with potential contaminants, would be pumped to the City of Minneapolis or Metropolitan Council Environmental Service (MCES) sanitary sewer system (Figure 5).

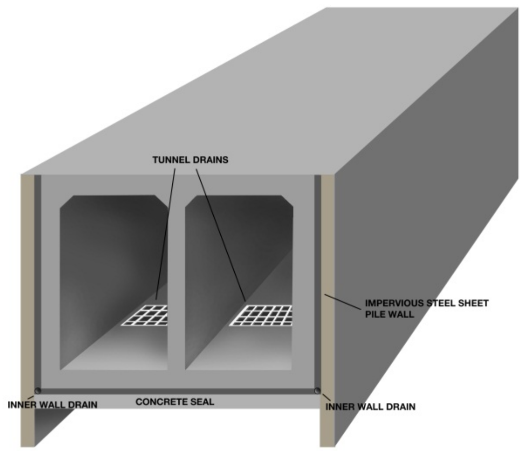

Figure 5: Tunnel Water Control System

1.2.3 Water Resource Monitoring Program

As presented in the draft WMP, the purpose of the document is to satisfy applicable regulatory requirements of the Minnesota Department of Natural Resources (DNR), Minnesota Pollution Control Agency (MPCA) and MCWD and present a means to monitor surface water and groundwater before and during construction, and during operation. The procedures documented in the draft WMP report present a means for establishing baseline conditions, detecting changes and setting criteria that would trigger the development of appropriate corrective actions, if necessary.

2 APPROACH

Burns & McDonnell's evaluation was accomplished by gathering information at project meetings, and review of project documents identified in the Scope (Section 1.1). The project meetings consisted of a kick-off meeting, one stakeholder meeting and two town hall meetings (Minneapolis and St. Louis Park). The meetings provided supplementary background information about the project, identified areas of public concern and allowed for the scope of the evaluation to be amended by comments received from project stakeholders and the public-at-large.

The kick-off meeting, which was held December 10, 2013, provided an opportunity for Burns & McDonnell team and project stakeholder introductions; provided an overview of the shallow tunnels option; and allowed the project stakeholders to share data. The project stakeholders also voiced concerns about potential groundwater contamination and the capacity of sanitary and stormwater sewer systems to handle proposed flows.

The City of Minneapolis, MPRB, Hennepin County, Barr, the SPO and Burns & McDonnell held a project technical meeting on December 19, 2013. The meeting provided a platform for the City of Minneapolis, MPRB and their consultant Barr to present questions for consideration during the evaluation and in the future, should the option progress. Specific to this evaluation were the following topics: groundwater and surface water monitoring, risk analysis of safety factors considering the range of lake and groundwater elevations, and lake water quality and temperature issues.

Town hall/community meetings were held in Minneapolis and St. Louis Park on January 7, 2014 and January 9, 2014, respectively. The professionally facilitated meetings gave participants the opportunity to refine the scope of the evaluation and to specify concerns to be addressed as part of this evaluation. Below are topics generated specific to this evaluation at those meetings:

- Dewatering impact: thermal, biological and groundwater
- Contamination from disrupted soils
- Climate change and design storms
- Decision criteria: water quality and groundwater and surface water levels
- 1800 West Lake Street apartment complex dewatering impacts and challenges

Project documents listed in the scope were systematically reviewed in a charrette setting by an interdisciplinary team of water resources professional using the following steps:

1. Identify specific statements and conclusions made in relation to water resources and the issues identified in the SPO September 4, 2013 letter to MCWD.
2. List the specific data and assumptions these statements are based on.
3. Review the data and assumptions for potential sources of uncertainty, seasonal fluctuations, safety factors, sensitivity to change, etc.
4. As appropriate, suggest alternative lines of evidence (data, methodology, etc.) that may provide additional clarification or support of the statements/conclusions.

A summary of conclusions and recommendations, incorporating topics provided by project stakeholder and town hall/community meeting participants are provided in the following sections.

3 EVALUATION

3.1 Potential Impacts to Groundwater Elevation in the Vicinity of the Proposed Tunnels

3.1.1 Kenilworth Corridor Hydrogeology

The near-surface geology in the Kenilworth Corridor primarily consists of fluvial deposits of sands and gravels with some silty sand to silt layers and a coarse sand aquifer extending to a depth of greater than 120 feet, based on the information presented in the American Engineering Testing (AET) memorandum dated August 26, 2013, that was included as Appendix C of the BODR and a revised AET memorandum date December 13, 2013. AET also identified a buried swamp deposit near West 21st street and areas with man-placed fill near the surface. The water table generally ranges in depth from 15 to 25 feet below grade along the proposed route based on the piezometers installed by AET (2013). Perched groundwater may be encountered in areas of silty layers and the buried swamp deposits above the water table, but these would be expected to be limited in extent and seasonal duration.

Water level data provided by MPRB for a nested set of monitoring wells installed at depths of 30 and 100 feet located near the Kenilworth Corridor at the north end of Lake of the Isles indicate that there has been a downward gradient (MPRB email with attached files, dated January 2, 2014). The period of record for MPRB's water level data is 1982 through the end of 2013, so these data provide some historical context to the variation of water levels both seasonally and year to year. The water level in the 30-foot monitoring well has ranged over approximately six feet during the monitoring period with seasonal fluctuations of up to three feet. The water levels also show a slight upward trend indicating that water levels have risen approximately 1.5 feet during the monitoring period.

Cedar Lake and Lake of the Isles are within the Minnehaha Creek watershed and generally drain sequentially through the chain of lakes to the south toward Minnehaha Creek. Cedar Lake and Lake of the Isles are connected by an open channel that equalizes the lake levels in Cedar Lake, the channel and Lake of the Isles. The AET piezometer data indicate that the lake level elevation in the channel is higher than most of the groundwater elevations **(**Figure 6**).** This suggests that ground water in the corridor does not discharge to the channel and lakes and that the lakes may be recharging the aquifer. This is counter to a more typical groundwater-surface water relationship in this climate where groundwater flows toward and discharges to surface water.

The AET memo states that the overall groundwater gradient is to the northeast, toward discharge in the Bassett Creek watershed. This would be another anomaly from a "typical" groundwater-surface water relationship where shallow groundwater flow would generally be in the same direction as surface water and flow would not leave the watershed. There is a low topographic divide 500 to 1000 feet northeast of Cedar Lake that separates the Minnehaha Creek and Bassett Creek watersheds. In addition, there is a buried bedrock valley filled with course sands beneath this area that could provide a connection for groundwater flow to the northeast. The MPRB wells near Lake of the Isles indicate a downward gradient, so that the primary flow direction may be downward to a more transmissive aquifer at depth.

Since the AET piezometers are installed only along the proposed route in the Kenilworth Corridor, they only provide a one dimensional view of the groundwater elevations and it is difficult to conclusively determine the groundwater flow pattern. Additional piezometers lateral to the proposed route are needed to better characterize the groundwater flow system in two dimensions, and a few nested piezometers completed at a greater depth would help to evaluate potential downward flow. Also, the water levels presented are only from October and November 2014. Seasonal water level data are needed to better understand ground water elevations during wet periods and in response to rain events.

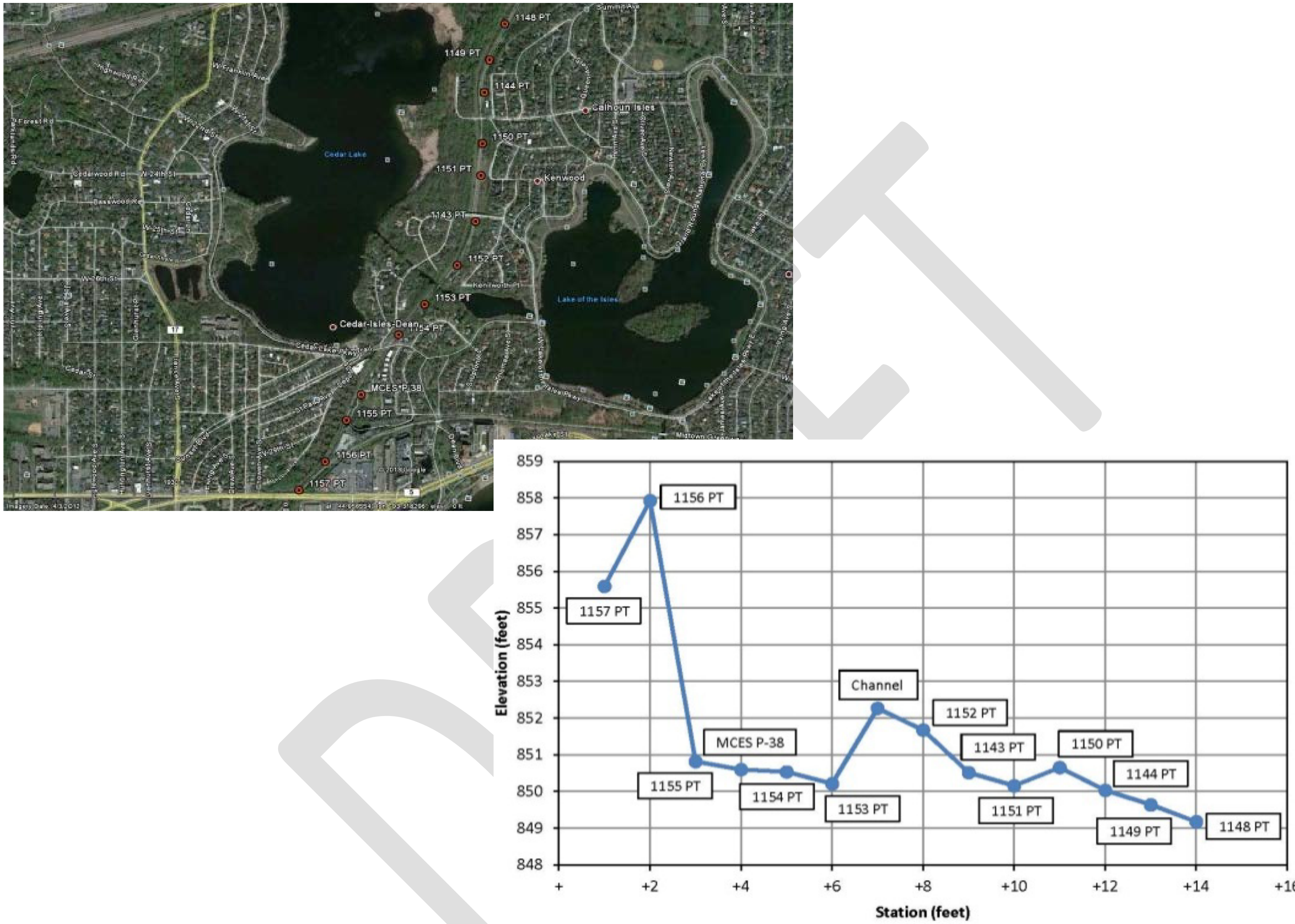

Figure 6: Groundwater Piezometer Data (Vayen, 2013)

3.1.2 Potential Impacts to Groundwater Elevation due to Pumping or Leakage into Tunnel

The proposed method of the tunnel construction, as described in the BODR and summarized in Section 1.2.1 should have little impact on groundwater levels because traditional dewatering methods will not be used during construction or during operation of the tunnel. Rather, the BODR presents a construction method in which the tunnel will be isolated from the groundwater system with minimal leakage into the tunnel. If the leakage rates presented in the BODR are met, there should be little to no drawdown of the adjacent water table due to leakage into the tunnel.

As heard at several meetings, there is public concern about "dewatering" from the tunnel resulting in lowered groundwater levels as has recently been reported with the 1800 Lake Street building near the southeast shore of Lake of the Isles. It is understood, based on the Barr Report (2013), that traditional dewatering at the 1800 Lake Street building is occurring to lower the water table to stop groundwater leakage into the basement of the building (Barr Engineering, 2013).

The use of the term "dewatering" in the BODR may imply that groundwater extraction (pumping) will occur to lower the water table outside of the 150-foot by 37-foot cell to keep the bottom of the excavation dry during construction and operation of the tunnel system. However, as discussed above, the proposed construction method described in the BODR does not include any traditional dewatering because the construction method relies on isolating the cell with sheet piling and concrete seals from the adjacent groundwater with minimal groundwater leakage into the excavations or the finished tunnel system. For these reasons, the proposed north and south tunnels system is not analogous to the dewatering occurring at 1800 Lake Street. We recommend removing the term "dewatering" from the BODR because it may imply pumping to lower the water table during construction and/or operation of the tunnel system.

3.1.3 Potential Impacts to Groundwater Elevation due to Blockage of Groundwater Flow

The depth of the sheet piling is not specified in the BODR, however, it appears that it will extend ten or more feet beneath the water table in some areas and, therefore, has the potential to block horizontal groundwater flow and potentially result in an increase in water levels on the up-gradient side of the sheet piling/tunnel. However, the considerable thickness and overall transmissivity of the alluvial aquifer should be able to easily transmit groundwater under the sheet piling without a significant increase in water levels. AET developed a two dimensional hypothetical groundwater model to illustrate that the permeability of the aquifer is great enough that even if it were much thinner, the rise in water level would not be significant (Vayen, 2013). The only foreseeable situation where a significant rise in water levels could occur would be if there were some areas where a confining silt layer separated a portion of the upper aquifer from the lower aquifer and the sheet piling extended all the way or nearly all the way through the upper aquifer and the tunnel was somewhat perpendicular to horizontal groundwater flow. This appears to be unlikely to occur, however, as stated above; more characterization of groundwater flow is needed to be certain that this would not be an issue.

3.2 Potential Impacts to the Chain of Lakes 'Water Budget' due to water that is anticipated to be collected in the proposed tunnel and routed to the sanitary sewer

Along the Kenilworth Corridor, rain and snow have the potential to saturate the soil, recharge the underlying groundwater system or concentrate on the surface, runoff into the storm sewer system and recharge the surrounding lake system. The proposed water collection, treatment, and management system described in section 1.2 and the BODR would re-direct water from the chain of lakes and groundwater systems to the sanitary sewer.

According to the information in the BODR, only about 34 acre-feet (11 million gallons) would be redirected to the sanitary sewer system (Metropolitan Council, 2013). This volume of water represents a relatively small portion of the overall water budget of the chain of lakes system. In reviewing the information, a calculation error was identified. Once corrected, the water volume estimate in the tunnel directed to the sanitary sewer system is expected to be even smaller. Section 3.4 has additional seepage discussion.

Although the amount of water that would be re-directed is relatively small for a lake water budget perspective, sanitary sewer systems are designed to convey sanitary waste and are typically sized for much smaller flows and, therefore, may not be able to convey the added groundwater and stormwater. Overtaxing the sanitary sewer system could cause problems for residential and businesses users, as well as maintenance issues. A comprehensive capacity analysis and range of scenarios is required to adequately understand the implications of routing water to these systems. City approval should be obtained prior to the moving forward with discharging to the sanitary sewer system.

3.3 Potential for the proposed tunnel to cause a groundwater flow blockage related to groundwater flow between Cedar Lake and Lake of the Isles

Cedar Lake and Lake of the Isles are connected by an open channel that equalizes the water level elevation both lakes and the channel. Therefore, there is not a hydraulic driver for groundwater flow from one lake to another across the Kenilworth Corridor. However, that does not mean that there is not groundwater flow in the Kenilworth Corridor. As discussed in section 3.1, the groundwater flow system has not been adequately characterized to conclusively describe groundwater flow in the Kenilworth Corridor.

3.4 Reasonability of the design criteria provided in the BODR for leakage rates for both permanent sheet piling and waterproofing systems surrounding the proposed concrete tunnel.

The BODR describes two permanent systems to limit and collect groundwater seepage. These systems consist of a sheet piling system outside the tunnel walls and a waterproof coating on the tunnel walls. The sheet piling would consist of interlocking pieces with sealed joints (either a bituminous or water-swelling product), and would be set in a concrete seal at the base. A drainage layer would be installed between the sheet piling system and the tunnel walls to collect any seepage through the sheet piling system. The tunnel walls would be sealed with unspecified waterproofing materials.

According to the BODR, the seepage rates through the sheet piles were derived from *The Impervious Steel Sheet Pile Wall (ArcelorMittal, 2009).* Seepage rates through the coated tunnel walls were derived from Federal Highway Administration Publication No. FHWA-NHI-10-034 *Technical Manual for Design and Construction of Road Tunnels – Civil Elements (2009)* as the source for the seepage calculation through the coated tunnel walls.

The water removal rates stated in the BODR are as follows:

Temporary Water Control Rates:

Cell 1 Pumping Rate (15 DAYS): 10.0 GPM (Excavation)
Cell 2 Pumping Rate (45 DAYS): 2.4 GPM (Construction)

Permanent Water Control Rates:

External Concrete Tunnel (Storm Sewer) – Estimated Discharge Rates & Volumes
South Portal South Tunnel Pumping Rate: 0.4 GPM
North Portal South Tunnel Pumping Rate: 2.3 GPM
South Portal North Tunnel Pumping Rate: 7.4 GPM
North Portal North Tunnel Pumping Rate: 2.3 GPM
Total Pumping Rate: 12.4 GPM

Internal Concrete Tunnel (Sanitary Sewer) – Estimated Discharge Rates & Volumes
South Portal South Tunnel Pumping Rate: 2.7 GPM
North Portal South Tunnel Pumping Rate: 7.3 GPM
South Portal North Tunnel Pumping Rate: 6.4 GPM
North Portal North Tunnel Pumping Rate: 4.7 GPM
Total Pumping Rate: 21.1 GPM

The amount of groundwater seepage anticipated through these systems is presented in the BODR, and a spreadsheet containing these calculations was provided for Burns & McDonnell's review.

Groundwater Seepage Calculations

The spreadsheet provided for review contained calculations (in separate sections, or tabs) for permanent and water control and temporary water control. The section for permanent water control consisted of tables containing calculations for seepage or drainage into various components of the tunnel. Table 1 presented the calculation for Internal Tunnel Drainage, representing groundwater that seeps through the tunnel walls to be collected from the internal drainage system and discharged to the sanitary sewer. Table 2 presented the calculations for External Tunnel Drainage, representing groundwater that seeps through the sheet piling into the external drainage system and ultimately discharged to the storm sewer. Table 3 relates to surface drainage into the portal area and is not addressed in this section.

Temporary Water Control

The section for temporary water control consisted of two tables addressing water control in excavation cells and in construction cells. Based on our review of the spreadsheet, the methodology used for calculating the estimated groundwater seepage rates to the external tunnel appears to be reasonable. However, some errors were apparent with the actual calculations, as discussed below.

- Based on our understanding of the proposed construction method, the Cell 1 (Excavation) dewatering calculation would not apply because no pumping of groundwater would occur until after the excavation is complete and the concrete seal is in place. At that point the Cell 2 (Construction) scenario would apply.
- Although sealed sheet piling joints are proposed in the BODR, the analysis for groundwater control during construction of the excavation cells appears to assume open joints as stated in the BODR construction sequence.
- The calculation for groundwater removal in the excavation cell factors in the seepage rate for each sheet piling joint, the total number of joints, and the maximum precipitation anticipated to occur during the 15-day construction period. Additionally, this calculation factors in the volume of the cell that is below lake level during the 15-day period. However, when this volume is factored into the calculated pumping rate for the excavation cell a 45-day period is assumed. Groundwater removal from the excavation cell will occur in 15 days as that is the length of time the cell will be under construction. If the 15-day excavation cell period is substituted in place of the 45-day period, the resultant pumping rate is 24.6 gpm, rather than the 10 gpm reported in the BODR.
- For the Cell 2 (Construction) calculation (in which the sheet pile joints will be sealed) a joint resistance of 1.0×10^{-7} m/s is used. A joint resistance of 3×10^{-10} m/s should be used (according to the referenced sheet pile manual). When this factor is applied in the spreadsheet calculation, a pumping rate of 0.6 gpm is the result, rather than 2.4 gpm presented in the BODR.
- The source of the presumed rainfall amounts (6 inches for the excavation scenario and 12 inches for the construction scenario) was not stated. This would be a significant amount of rainfall and, therefore, would likely represent a near-worst case scenario for precipitation. It is recommended that the source of the precipitation amounts used in the calculations be stated.

Permanent Water Control

External Concrete Tunnel

Based on review of the submitted calculation spreadsheet, the methodology used for the seepage rates to the external tunnel appears to be reasonable. However, some errors were apparent with the actual calculations, as discussed below.

The joint resistance used in the calculation is appropriate for open (unsealed) sheet pile joints (per the referenced sheet pile manual), yet the installation process described in the BODR states that the joints will be sealed. The sheet pile manual suggests using a minimum joint resistance of 3×10^{-10} m/s for sealed joints. If this value is substituted into the spreadsheet equation the infiltration rate is much less than 1 gpm for each tunnel section.

Internal tunnel drainage:

The shallow LRT tunnels will have a second waterproofing system, applied to the outside faces of the concrete tunnels inside the sheet piling. The material to be applied was not specified and may include "external and/or internal membranes and coatings, specialized concrete designs, and water stop joint treatments".

The calculation for seepage into the tunnels through the tunnel walls assumes an infiltration rate of 0.002 gallons/square foot/day. This is the allowable infiltration rate permitted as stated on page 1-14 of the *Technical Manual for Design and Construction of Road Tunnels – Civil Elements (2009).*

Based on review of the calculations in the spreadsheet, the methodology used for calculating the estimated groundwater seepage rates to the external tunnel appears to be reasonable. However, an error is apparent with the actual calculations, as discussed below.

- The calculation for the tunnel surface area appears to be in error. The surface area of each tunnel side and the surface area of the floor slab should be summed to arrive at the total area available for infiltration. This results in a total area of 50,820 square feet. The area calculation in the spreadsheet appears to have multiplied the surface areas of the tunnel sides by the surface are of the floor slab, resulting in total volume of the tunnel segment. Using the permitted infiltration rate of 0.002 gal/sq ft/day, inflows to the tunnel through the tunnel walls and bottom slab are expected to be much lower than presented in the report. For example, the revised calculation indicates an inflow to the south tunnel's south portal to be more on the order of 0.07 gpm and 37,099 gallons annually, not 2.7 gpm and 1.4 million gallons annually as stated in the BODR. Similarly reduced inflows are indicated for the other portals.

In summary, it appears that the some of the pumping rates presented in the BODR for the construction and operation of the tunnel system are in error. It does not appear that these are serious issues that would represent major flaws in the basis of design.

It is recommended that these rates be thoroughly re-evaluated with clearly stated assumptions, input values, and ranges of calculated values. Additionally, the anticipated long-term performance of the waterproofing system should be evaluated considering its durability and other projects where this system has been used in similar settings.

3.5 Reasonability of methods presented to address construction dewatering and to minimize the amount of temporary dewatering required

Projects of this type frequently utilize active dewatering methods for groundwater control throughout construction that utilize one or more wells or a well point system. Pumping of the wells or well point system lowers the groundwater table in the vicinity of the excavation and maintains it at a certain level so that construction activities can proceed in a relatively dry excavation. Once construction is complete, dewatering pumps are turned off and groundwater returns to its normal elevation.

The BODR proposes a unique method for groundwater control. Once initial excavation and clamshell excavation is complete the initial dewatering commences, with water and remaining sediment pumped out to leave a relatively dry cell into which groundwater seeps. Once the initial volume of water is removed the sheet piling in place will severely limit the amount of infiltration into the work area. This approach seems reasonable.

3.6 Reasonability of the 50-year design recommended by the SPO for stormwater infiltration and whether this approach will address concerns related to discharging warmer water back into the storm sewers or lakes during winter months.

Water from the following sources will be removed and sent to chambers:

- sheet pile cells during construction
- stormwater and snow melt from the tunnel portals
- groundwater that seeps into the drainage system between the sheet pile, the concrete seal, and the concrete tunnel walls and floors

During the winter, contributions from stormwater and snow melt are assumed to be minimal because of below freezing air temperatures. The water removed in winter, therefore, is expected to be mostly groundwater (from construction dewatering or seepage) with a temperature of about 55 °F. Concerns exists that discharge of this relatively warm water into one of the nearby surface water bodies in winter could lead to thinning or loss of ice cover resulting in hazardous conditions and a loss of recreational opportunities. Such an occurrence has occurred nearby were the winter discharge of groundwater from the foundation of a large building into a storm sewer that leads directly to a pond has adversely impacted the thickness of ice on the receiving water body (Barr Engineering, 2013).

The water removed in winter, however, will not be discharged directly into surface water bodies. This water instead will instead be discharged to chambers that will return this water to its source. Because the water in winter is expected to be mostly groundwater, returning this water to the aquifer will result in little net change in the volume of water in the aquifer. Although local groundwater gradients may be affected in areas immediately around the tunnels and chambers, the current exchange of water between the lakes and the aquifer is expected to remain the same. As such, no impacts on the ice cover of the water bodies around the proposed shallow LRT tunnels are expected assuming:

- The chambers are located below the frost line so that ice will not form in the pore spaces around the chambers and prevent infiltration.
- The chambers are sufficiently large to infiltrate the maximum volume of water expected to be removed from the tunnels in winter so that no overflow from the chambers will occur to storm sewers that discharge into surface water bodies.

Stormwater volumes provided in the BODR for the 50-year and 100-year design storm events were 0.26 acre-feet and 0.30 acre-feet, respectively for the South Portal. Using appropriate significant figures for this level of design and the relatively insignificant change from one design storm event to the other, the chambers should be designed for the 100-year design storm with an overflow for greater storm events. Also, stormwater runoff from storms greater than the 50-year design storm event for the portal areas would be directed to the City of Minneapolis or MCES storm sewer system. Storm sewer infrastructure is typically designed for storm events much less that the 50-year event. As recommended for sanitary sewer connections; city of Minneapolis approval and a comprehensive capacity analysis and range of scenarios should also be completed for storm sewer connections to adequately understand potential implications.

Climate variability was a topic of concern expressed during the town hall meetings. As noted in the BODR, portal water control systems were designed NOAA Atlas 14. NOAA Atlas provides engineers precipitation frequency at average recurrence intervals of 1-year through 1,000-year for the Minnesota and 10 Midwestern states (USDC & NOAA, 2013). Importantly, it includes information on temporal distributions for heavy precipitation amounts for selected durations and seasonal information for annual maxima data used in the frequency analysis and examines the potential effects of climate change as trends in historic annual maximum series (USDC & NOAA, 2013). Using NOAA Atlas 14 rainfall, incorporates climate variability into the proposed design.

3.7 Other Potential Impacts to Water Resources in the Area

Surface water runoff that enters the portals and tunnels has the potential to contain sediment, oil and grease and chlorides from ice melting chemicals. Stormwater pre-treatment devices, such as grit chambers, should be included in the design to remove sediment, oil and grease which could clog chamber pore space and degrade the functionality of the system. Chlorides in the runoff pumped out of the portals and tunnels would not be removed by the stormwater pre-treatment systems designed to remove oil, grease, and solids, and would pass through the chambers into the groundwater. This potential for groundwater contamination, however, could be largely prevented by implementing snow and ice control best management practices, such as blowing or shoveling snow.

A Phase I Environmental Assessment was completed for properties along the entire proposed shallow tunnels option (SEH, Inc., 2013). In the Kenilworth Corridor, several areas were noted as "high risk" for environmental impacts, many of these are former railroad operations areas. A phase II investigation is needed in the Kenilworth Corridor to determine if contaminated soil or groundwater may be encountered during the construction. In addition, the potential for contaminated groundwater leaking into the tunnel system and potential vapor intrusion into the tunnel by any volatile organic compounds that are found to be present should be evaluated.

3.8 Water Resources Monitoring Program Assessment

3.8.1 Groundwater Levels

The groundwater monitoring program proposed in the draft WMP report is a preliminary outline of monitoring water levels. It is divided into three phases: Pre-Construction, Construction, and In-

Service Operations. Pre-construction monitoring would consist of measuring monthly water levels in the existing piezometers and at the Channel. Construction monitoring would consist of weekly monitoring of the existing piezometers (and additional or replacement piezometers due to construction activities) with a to-be-determined threshold criteria that would lead to more frequent monitoring and/or corrective action. The In-Service monitoring phase consists of measuring baseline water levels in the piezometers and subsequent monthly measurements with to-be-determined threshold criteria that would lead to more frequent monitoring and/or corrective action similar to the construction monitoring.

The groundwater monitoring plan is preliminary and does not go into much detail on key locations to monitor groundwater levels or specific threshold criteria that could indicate an issue with groundwater levels or flow. This is likely because it is a preliminary plan, and the groundwater flow system has not be fully characterized to determine key locations or criteria that would indicate that the tunnel system is not performing as designed with regard to groundwater resources. We recommend revising this document after additional characterization of the groundwater flow system has been completed. The revision should include sufficient and specific monitoring locations, parameters, threshold criteria, as well as the monitoring schedule and course of action should a threshold criteria be exceeded.

3.8.2 Water Quality

Groundwater should be sampled and analyzed for hydrocarbons, chlorides, other potential contaminants attributable to the project. Samples should be collected from sites near chambers and from sites in the track corridor but away from the chambers. Sampling should occur in late spring to assess the impact of snowmelt and in fall to assess the impacts of warm season runoff. Sampling should begin pre-construction to establish a baseline and continue through construction and operation.

4 RECOMMENDATIONS

In conclusion, recommended actions are as follows:

- Additional piezometers lateral to the planned route both north and the south of the channel are needed to better characterize the groundwater flow system in two dimensions. Also some sets of nested piezometers should be installed to evaluate vertical groundwater flow in the Kenilworth Corridor. This will help to better characterize and understand the direction and gradient of groundwater flow and the interaction between groundwater and surface water. Also, seasonal water level data are needed to better understand ground water elevations during wet periods and in response to rainfall events.

- Revise the BODR, removing the term "dewatering" and providing a comprehensive section on water resources.
- A comprehensive capacity analysis and range of scenarios to adequately understand the implications of routing water to sanitary and storm sewer systems is needed for final design.
- Design the underground infiltration chambers for the 100-year design storm event.
- Incorporate stormwater pre-treatment devices in the design.
- A Phase II investigation is needed in the Kenilworth Corridor to determine if contaminated soil or groundwater may be encountered during the construction or operation of the shallow tunnel system.
- Revise the WMP document after additional characterization of the groundwater flow system has been completed sufficiently and specific monitoring locations, parameters, threshold criteria, as well as a monitoring schedule and course of action should a threshold criteria be exceeded.
- Sample and analyze groundwater for hydrocarbons, chlorides, other potential contaminants attributable to the project near the infiltration chambers.

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