Hiawatha Golf Course – Stormwater, Surface Water, and Groundwater Analysis Summary*

Prepared for
Minneapolis Park and Recreation Board &
City of Minneapolis

2/28/2017

*Note: This memo represents a summary of data and work completed through February 2017 and is not a complete record of the work done to date. Additional data has been collected and additional stormwater and groundwater pumping analyses have been completed since this memo was prepared and will be summarized in subsequent memos.

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Technical Memorandum

To: Michael Schroeder, MPRB & Katrina Kessler, City of Minneapolis
From: Jen Koehler, Kurt Leuthold, Ray Wuolo, & Adam Janzen, Barr Engineering
Subject: Hiawatha Golf Course – Stormwater, Surface Watefr, and Groundwater Analysis Summary
Date: 2/28/2017
Project: 23/27-1466.01
c: Della Young, Paul Hudalla, City of Minneapolis

Barr Engineering Company (Barr) has been assisting the Minneapolis Park and Recreation Board (MPRB) and the City of Minneapolis (City) on the evaluation of the surface, storm, and groundwater management issues related to the Hiawatha Golf Course area since 2013. The initial work was in relation to stormwater management in the Golf Course for the City of Minneapolis. However, beginning in late 2015, Barr was hired to help the MPRB begin understanding the groundwater impacts to the golf course area. This memorandum summarizes all the information compiled and work completed to date as it relates to the water management at the Hiawatha Golf Course.

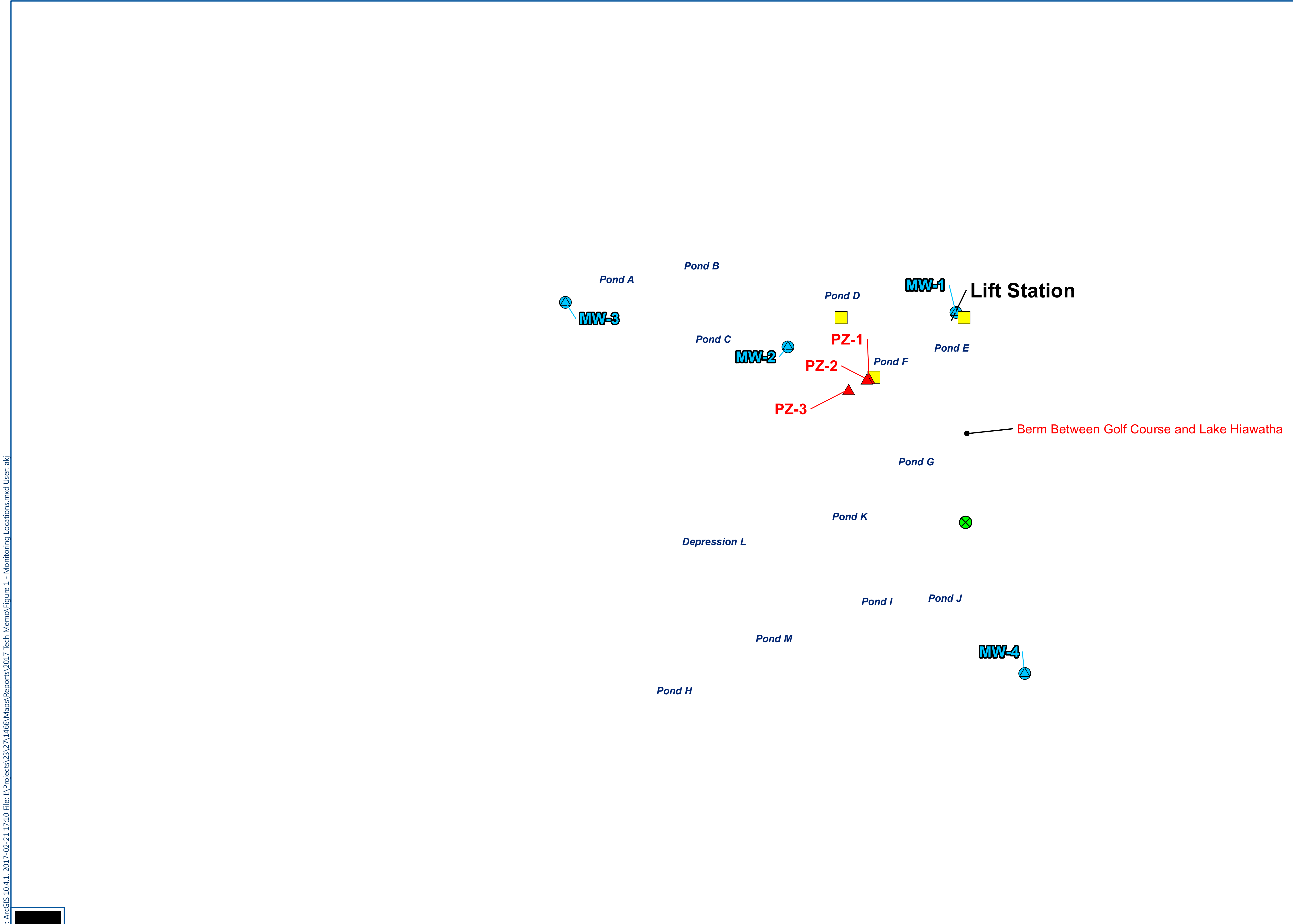
1.0 Project Background

The Hiawatha Golf Course area was historically a wetland, with the existing 18-hole golf course being created by the MPRB in the late 1920s with dredged spoils from the bottom of Lake Hiawatha. In the winter, the park provides space used for cross-county skiing. This area is also part of the larger Nokomis-Hiawatha Regional Park, one of the most visited parks in the MPRB system.

An existing berm with an overtopping elevation of 815.7 feet above NGVD29 (ft NGVD29) as of June 2014 separates Lake Hiawatha from the golf course, and much of the golf course area is below the lake OHW of 812.8. To maintain a playable golf course, the course is heavily drain-tiled to address wet conditions and pumped to maintain water levels in a series of interconnected ponds around elevation 808.5/809.0 ft NGVD29. There are two existing pumps in a lift station near Pond E, originally installed in 1993, with the primary pump operating nearly continuously to pump regional groundwater flows and maintain the playable golf course.

In 2011 and 2012, the City of Minneapolis completed a stormwater improvement project. The project diverted stormwater from a 71-acre watershed to the west of the golf course to Pond A in order to provide water quality treatment in Ponds A through F and increase discharge capacity to reduce flooding in the upstream neighborhood. This stormwater runoff along with groundwater inflow to the ponds is pumped to Lake Hiawatha by the existing pumps near Pond E.

Figure 1 shows the Hiawatha Golf Course area, including the golf course watershed, storm sewer, golf course ponds, connections, monitoring locations, etc.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Golf Course Watershed
Storm Sewer
Irrigation Well
Monitoring Well
Piezometer
Staff Gage

0 200 400
Feet

WATERSHED & MONITORING LOCATIONS
Hiawatha Golf Course
Minneapolis Park & Recreation Board

FIGURE 1

2.0 2014 Monitoring

Barr initially conducted water level monitoring at the Hiawatha Golf Course in December 2014. Staff gauges and pressure transducer/data loggers (In-Situ LevelTroll) were installed in Ponds C, D, and F on December 8, 2014. Water levels were monitored at 1-minute intervals until December 15, 2014. During this time the ponds were pumped down as low as possible and then allowed to recover in order to collect information to calibrate a groundwater model; see Sections 3.3.1 and 10.1 below for more information on the aquifer testing and groundwater modeling, respectively.

3.0 2015-2017 Monitoring

Barr has monitored groundwater levels, Lake Hiawatha levels, and pumping rates at the Hiawatha Golf Course from the fall of 2015 through the present in order to understand the magnitude of pumping at the course and the groundwater impacts. Additional monitoring of groundwater and pond levels was conducted in the fall-winter 2015-2016 as part of aquifer testing of the ponds and the deep irrigation well; see Section 3.3 below for information on the aquifer testing. Water quality monitoring was also conducted in early 2016.

3.1 Water Level Monitoring

The following sections discuss the water level monitoring conducted by Barr from late 2015 through January 2017. Figure 1 shows the location of the surface and groundwater level monitoring locations within the Hiawatha Golf Course area. Groundwater and surface water data were collected to better inform the degree of hydraulic connection between the golf course ponds, Lake Hiawatha, and the water table aquifer than using only pond water level data, as was done previously in 2014.

3.1.1 Groundwater Levels

Monitoring wells and temporary piezometers were installed across the golf course to collect groundwater table elevation data. Four shallow monitoring wells, named MW-1 through MW-4, were installed by Stevens Drilling & Environmental from October 26-29, 2015. Table 1 below summarizes construction information for these wells and Attachment A includes well construction records. An elevation survey of the monitoring wells and piezometers was completed by Barr on December 9, 2015.

Table 1 Monitoring Well Construction Information

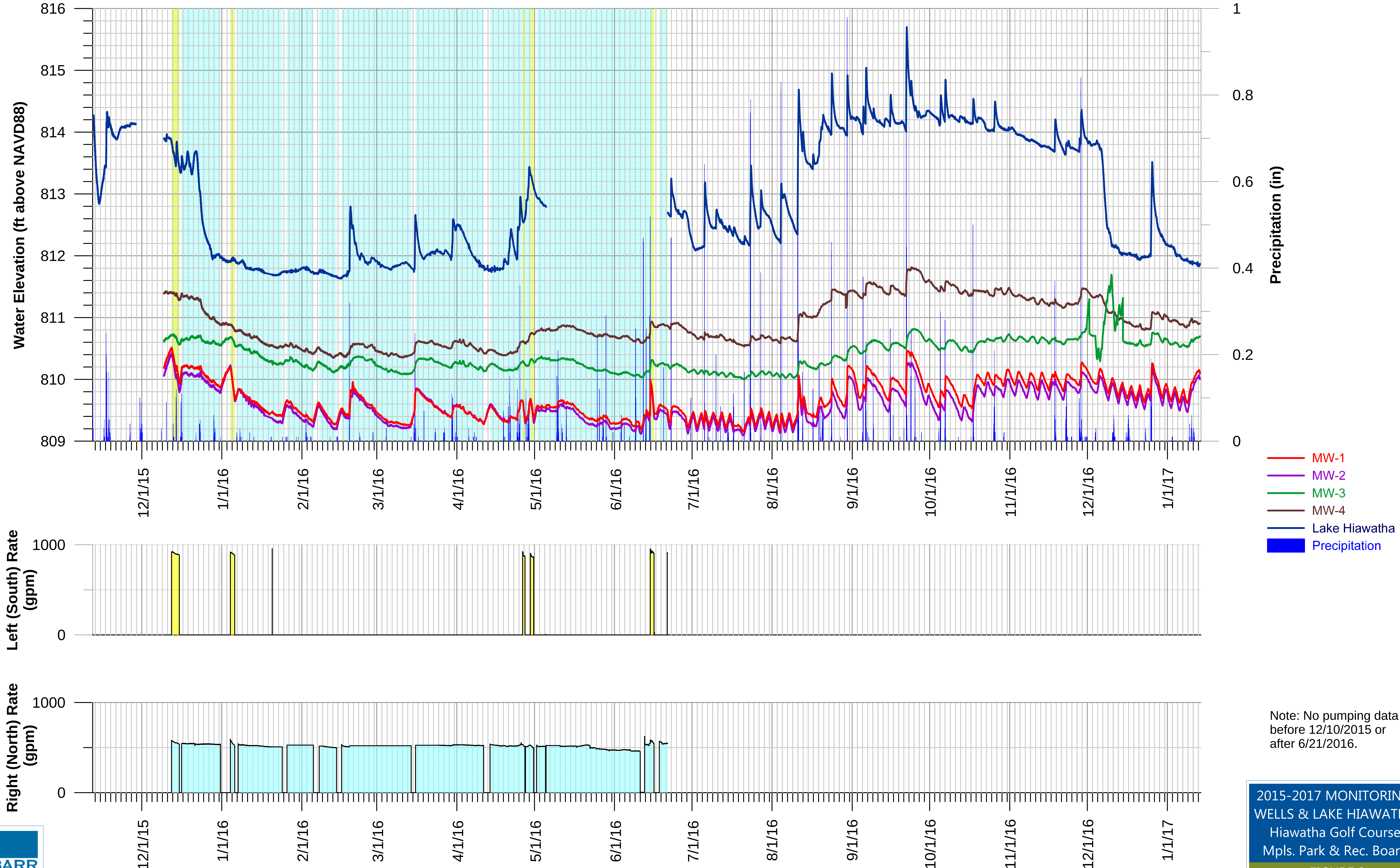
Well	Unique Number	Ground Surface Elevation[1] (ft NAVD88)	Top of Riser Elevation[1] (ft NAVD88)	Well Depth (ft below grade)	Screened Interval (ft below grade)
MW-1	804420	815.2	817.0	30	20-30
MW-2	804421	813.4	815.6	20	10-20
MW-3	804422	816.7	818.5	25	15-25
MW-4	804423	816.9	818.9	35	25-35

[1] Measured using GPS unit with 0.1′ accuracy

Three temporary piezometers, PZ-1, PZ-2, and PZ-3, were installed by Barr near Pond F on November 12, 2015. These piezometers were each approximately 5 feet deep and were constructed by inserting 2″-diameter PVC well screen into hand-augured holes. The piezometers were intended to provide additional water level monitoring locations during the recovery testing and then to be removed at the conclusion of the testing. The piezometers were frozen in place at the conclusion of the recovery testing and were removed by Barr on May 5, 2016, by which point the ground had thawed sufficiently.

Pressure transducer/data loggers (In-Situ LevelTroll) were installed in MW-1, MW-2, MW-3, MW-4, PZ-1, PZ-2, and PZ-3 on November 12, 2015 and programmed to record water levels at 1-minute intervals. Starting on January 17, 2016, several transducers stopped recording due to full memory. The transducers in PZ-1, PZ-2, and PZ-3 were removed on January 20, 2016. For the transducers that remained active in the golf course after January 20, 2016 (MW-1, MW-2, MW-3, MW-4), the memory was cleared after downloading the data and the transducers were reprogrammed to log data at 15-minute intervals. Data were collected at 30-second intervals at MW-1, MW-2, MW-3, and MW-4 during the deep well aquifer test (see Section 3.3.4) from February 16, 2016 to February 19, 2016. The logging interval was increased to 1 hour in all four wells following a data download on February 19, 2016. Since that time, the hourly long-term groundwater monitoring data from these monitoring wells have been downloaded by Barr on May 5, 2016, June 21, 2016, and January 13, 2017.

Figure 2 shows a hydrograph of all water level data collected at MW-1, MW-2, MW-3, and MW-4 from November 12, 2015 through January 13, 2017. Lake Hiawatha water levels, precipitation, and lift station pumping rates are also shown on this figure. Figure 3 shows water levels collected at PZ-1, PZ-2, and PZ-3 from November 12, 2016 through January 20, 2016. Changes in lift station pumping were quite apparent in the data from monitoring wells MW-1 and MW-2, both located adjacent to the pond system, and less apparent but still noticeable at distant monitoring wells MW-3 and MW-4. Water levels in piezometers PZ-1, PZ-2, and PZ-3 readily responded to rain events. PZ-1 and PZ-2 tracked closely with water level changes in Pond F, while PZ-3 showed no response to pumping changes. PZ-3 was screened entirely in peat soil, whereas sand seams with apparently good hydraulic connection to the water table aquifer were encountered at PZ-1 and PZ-2.

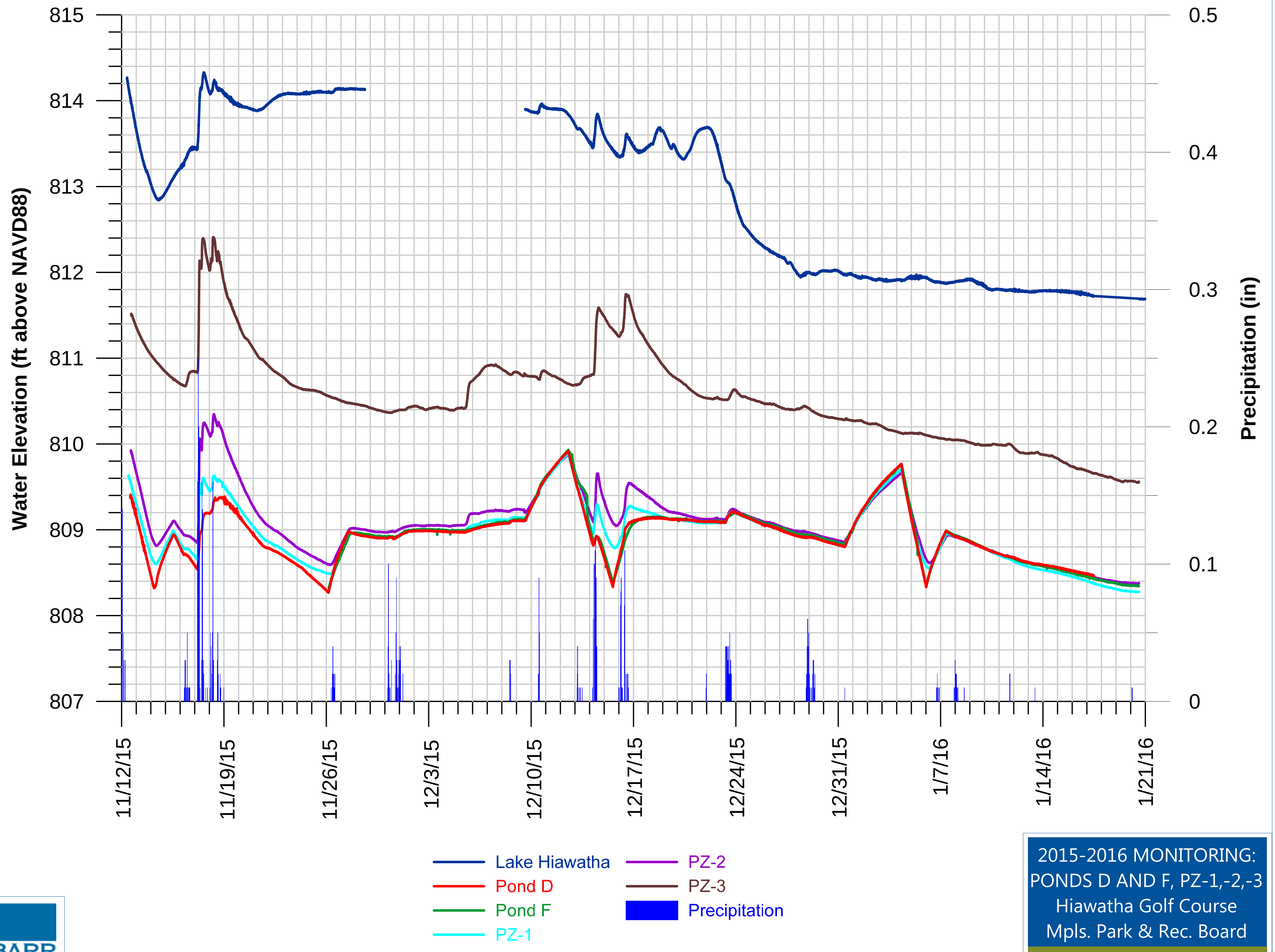


2015-2017 MONITORING:
WELLS & LAKE HIAWATHA
Hiawatha Golf Course
Mpls. Park & Rec. Board

FIGURE 2

BARR

P:\Mpls\23 MN\27\23271466 Hiawatha Golf Course Analyses\WorkFiles\2017Scope\TechnicalMemo\Figures\Draft\grapher\Figure 3 - Monitoring Well Hydrograph.grf



P:\Mpls\23 MN\27\23271466 Hiawatha Golf Course Analyses\WorkFiles\2017Scope\TechnicalMemo\Figures\Draft\grapher\Figure 4 - 2015 Ponds PZ Hydrograph.grf

BARR

2015-2016 MONITORING:
PONDS D AND F, PZ-1,-2,-3
Hiawatha Golf Course
Mpls. Park & Rec. Board

FIGURE 3

3.1.2 Surface Water Levels

Staff gages were installed in Lake Hiawatha, Pond D, and Pond F on November 12, 2015. These staff gauges were surveyed by Barr on December 9, 2015 and the elevations are presented below in Table 2.

Table 2 Staff Gage Survey Elevations

Location	Water Surface Elevation[1] (ft NAVD88)	Reference Staff Gage Reading (ft)	Elevation of Zero Reading on Staff Gage (ft NAVD88)
Lake Hiawatha	813.9	2.65	811.3
Pond D	809.1	2.64	806.5
Pond F	809.1	2.64	806.5

[1] Measured using GPS unit with 0.1' accuracy

Pressure transducer/data loggers (In-Situ LevelTroll) were installed in Lake Hiawatha, Pond D, and Pond F on November 12, 2015 and programmed to record water levels at 1-minute intervals. The transducers in Lake Hiawatha and Pond D stopped recording on January 17, 2016 due to full memory. The memory was cleared on the Lake Hiawatha transducer after downloading the data on January 20, 2016 and the transducer was reprogrammed to log data at hourly intervals. Long-term monitoring data from Lake Hiawatha have been downloaded by Barr on May 5, 2016, June 21, 2016, and January 13, 2017.

The transducer in Lake Hiawatha has been disturbed by passerby on several occasions since its installation. These disturbances are typically apparent in the data record as sudden jumps in the water level readings and, as long as the transducer remained submerged, can easily be corrected in the final data record by applying an appropriate offset to the disturbed data. Disturbances have been noted on November 28, 2015, December 15, 2015, March 21, 2016, April 24, 2016, and May 29, 2016.

All usable water level data collected at Lake Hiawatha are shown on Figure 2. There is a gap from November 28, 2015 to December 9, 2015 when the disturbed transducer was not continuously submerged and therefore the data could not be corrected. There is also a gap from May 5, 2016 to June 21, 2016 during which the data record could not be corrected to match manual staff gauge readings. The Lake Hiawatha water elevations collected from June 21, 2016 to January 13, 2017 are shown on Figure 2 and appear reasonable, though no manual staff gauge readings were taken during this time to confirm the accuracy of the data.

The transducer in Pond D was removed on January 20, 2016. Data logging was stopped on the Pond F transducer on January 20, 2016 but the transducer could not be removed at that time due to ice. The Pond F transducer was removed by Barr on May 5, 2016. Figure 3 shows water levels collected at Pond D, Pond F, and Lake Hiawatha from November 12, 2016 through January 20, 2016.

3.1.3 Flow Monitoring (Pumps)

The golf course lift station located near Pond E includes two pumps that are activated by float switches. One pump acts as a primary pump that operates nearly continuously to maintain pond water levels around 808.5 ft MSL NGVD1929. The second pump is utilized when water levels in the ponds increase to elevation 809.3 ft MSL NGVD1929. A high water alarm will sound at elevation 812.1 ft MSL NGVD 1929. Historic pumping estimates utilized the designed pump capacities (each pump rated to 1,200 gallons per minute) based on information provided by the City of Minneapolis.

Flow meters were installed to explicitly measure volumes of water pumped from the golf course ponds to Lake Hiawatha. Badger Meter M2000 flow meters were installed on each pump in the lift station by Shank Constructors on November 30, 2015. The meter readouts are located in a new box mounted on the back side of the existing lift station control panel. The meter readouts are labeled "Left Pump" and "Right Pump"; the "Left Pump" is the southern pump (labeled "Pump No. 2" in the lift station control panel) and the "Right Pump" is the northern pump (labeled "Pump No. 1" in the lift station control panel).

The data logging capabilities of the flow meters were activated on December 10, 2015. Since that time, each meter has logged its totalized flow volume every 15 minutes. When operational, the southern pump (i.e, "Right Pump" on meter panel, "Pump No. 2" on lift station panel), produces approximately 900 gallons per minute (gpm). The northern pump (i.e., "Right Pump" on the meter panel, "Pump No. 1" on the lift station panel), which appears to operate constantly, produces approximately 530 gpm. The total pumping capacity of the golf course lift station is therefore 1,430 gpm (about 60% of the designed capacity).

The memory on the flow meters fills up in less than 2 months when logging at 15-minute intervals. The meters were downloaded regularly during the aquifer testing period when this resolution of pumping information was necessary. The pumping data record is incomplete after June 21, 2016. All available 15-minute pumping data are shown on Figure 2.

Totalizer readings taken at 1:27 pm on January 13, 2017 were 15,091,785 gallons for the south pump and 320,088,123 gallons for the north pump. These volumes account for all water pumped by the lift station since December 10, 2015; i.e., a combination of stormwater and groundwater. The average lift station pumping rate (accounting for both pumps) calculated from 1:10 pm on December 12, 2015 (when the pumps were turned back on during the first 2015 recovery test) to 1:27 pm on January 13, 2017 is 585 gpm.

3.2 Water Quality Monitoring

Barr collected water quality samples from each of the four monitoring wells, Pond E on the golf course, and Lake Hiawatha for one (1) sampling event. These samples were collected on January 20, 2016 and were tested for the following parameters:

- Alkalinity
- Chlorides

- E. coli
- Nitrate+Nitrite
- Silica
- Soluble Reactive Phosphorus (SRP)
- Sulfate
- Total Kjeldahl Nitrogen
- Total Phosphorus
- Diesel Range Organics
- Gasoline Range Organics
- Volatile Organic Carbon (VOCs)
- Aluminum
- Calcium
- Iron
- Magnesium
- Potassium
- Stable isotopes of hydrogen and oxygen

These parameters were selected in order to determine origin of the water being pumped. Isotope testing was completed by Isotech Laboratories, Inc. The remaining parameters were analyzed by Legend Technical Services. Laboratory results were reviewed by Barr.

Table 3 summarizes the results of the January 2016 water quality sampling.

Table 3 Water Quality Monitoring Summary – January 2016

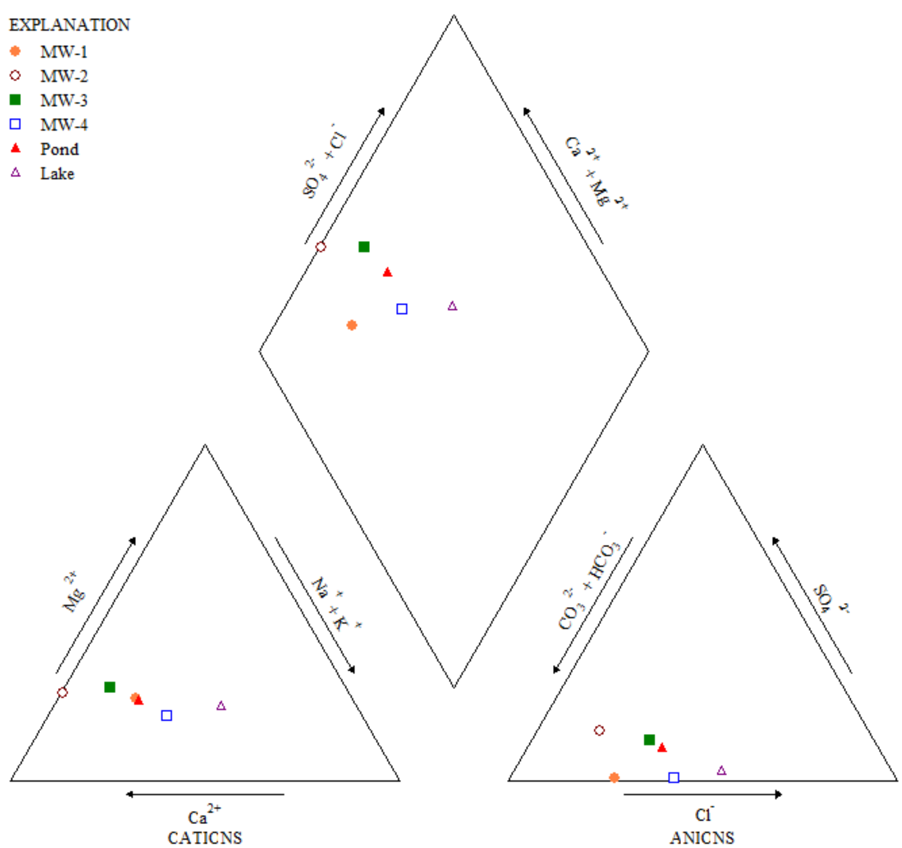
Water Quality Parameter	MW-1	MW-2	MW-3	MW-4	Pond E	Lake Hiawatha
Bicarbonate Alkalinity, as Ca, in mg/L	310	380	310	222	306	179
Chloride, in mg/L	82.7	63.6	116	116	135	154
E. Coli, in MPN/100ml	<1	<1	<1	<1	5	2
Nitrate and Nitrite as N, in mg/L	0.058	2.42	0.045	0.045	0.479	0.259
Silica, in mg/L	36.3	16.1	28.5	30.7	29.3	6.02
Soluble Reactive Phosphorus, mg/L	0.005	0.006	0.004	0.004	0.004	0.005
Sulfate, in mg/L	<5	79.6	63.3	<5	50.5	10.3
Total Kjeldahl Nitrogen (TKN), in mg/L	23.1	1.19	<0.5	1.86	2.18	0.991
Total Phosphorus, in mg/L	0.342	0.011	0.021	0.118	0.076	0.028
Diesel Range Organics (DRO), in ug/L	110	<100	<100	<93	<93	<93
Aluminum, in mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Calcium, in mg/L	90	210	130	77	120	57
Iron, in mg/L	8.8	0.081	1.3	2	3	0.23
Magnesium, in mg/L	24	45	36	18	31	22
Potassium, in mg/L	2.7	2.9	4.3	3.6	4.8	4
δ^2H of water, % relative to VSMOW	48.1	55.6	61.9	38.7	55.5	45.9
$\delta^{18}O$ of water, % relative to VSMOW	6.14	8	8.98	4.11	7.55	5.7

3.2.1 Piper Plot

Piper plots are used to compare the major ion chemistry of water samples by converting concentrations to percent milliequivalents (milliequivalent is equal to the concentration in milligrams/liter multiplied by the molecular mass and charge valence state). The major ions are: calcium, magnesium, sodium, potassium, chloride, sulfate and carbonate/bicarbonate. These dissolved ions typically make up over 90% of the total dissolved solids in natural waters (i.e., groundwater and surface water). The conversion to percent milliequivalents allows for factoring out the actual concentration and focusing on the relative percentages of the major ions in solution. These data are plotted on three trilinear diagrams, collectively referred to as "Piper plots". In general, water samples that have a similar history and originate from a similar source will tend to have similar major ion percentages and will plot next to each other on the Piper plots, making for convenient visual comparisons. If waters are mixtures of two different sources, they typically plot between the two sources on the Piper plots. In general, older groundwater tends to become more enriched in potassium, sodium, sulfate, and chloride compared to recently recharged groundwater and surface water.

Results of major ion analyses for water samples from the four monitoring wells, Lake Hiawatha, and Pond E were converted to percent milliequivalents and plotted on a Piper plot. Major ions from monitoring wells MW-1 and MW-3 are very similar and also similar to the pond water. However, none of the water samples have major ion chemistries that are significantly different and all have compositions that are typical of "young water" that has not spent many decades flowing through aquifers.

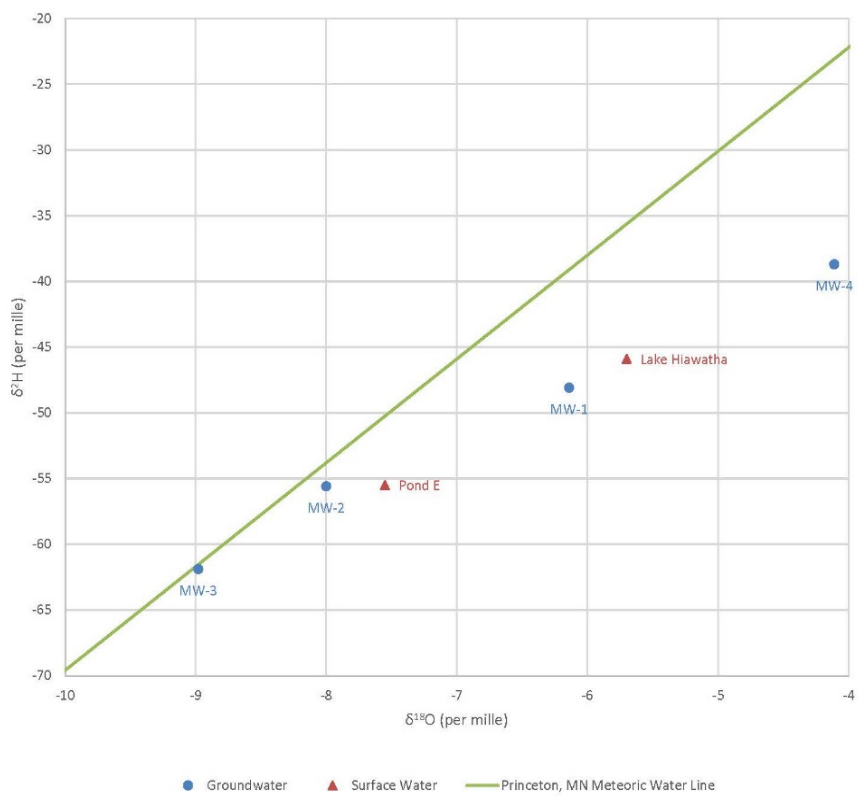
Figure 4 Piper Plot



3.2.2 Isotope Analysis

Figure 5 shows the comparison of the ratios of the stable isotopes of hydrogen and oxygen in the samples. The reference line represents the ratios of stable isotopes in rainwater in this part of the world (Princeton, MN). When rainwater evaporates, the lighter isotopes are evaporated preferentially compared to the heavier isotopes and the surface water tends to become enriched in heavier isotopes – the ratios of water that has undergone evaporation lie below the line. This is reflected in the isotopic ratios for the sample collected from Lake Hiawatha, which is located below the reference line. The isotopic ratios for monitoring wells MW-4 and MW-1 are also located below the reference line. Due to its proximity to Lake Hiawatha, MW-1 shows an isotopic ratio similar to Lake Hiawatha water. MW-4 is also affected by surface waters, potentially Minnehaha Creek, Lake Hiawatha, or Lake Nokomis. The isotopic ratios for MW-2 and MW-3 look like rainwater that has infiltrated into the aquifer; i.e., the water sampled from these wells is representative of the regional groundwater flow. The isotopic ratio for Pond E appears to be a mixture of the regional groundwater and Lake Hiawatha water.

Figure 5 Stable Isotopic Ratio Plots (Deuturium-O18)



3.2.3 Nutrient Summary

Results from water quality samples collected in January 2016 were compared to the most recent 6-years (2010-2015) of water quality data for Lake Hiawatha as provided by the MPRB. It should be noted that water quality samples in 2010 to 2015 were taken mostly during summer months (July and August) and results will vary with time of year. Table 4 summarizes the nutrient comparisons.

Lake Hiawatha TMDL has a total annual phosphorus inflow of 6,463 pounds. The annual total phosphorus (TP) being pumped into Lake Hiawatha from Pond E is calculated at 165 pounds. This is based on pumping 263,000,000 MGY at a concentration of 0.076 mg/L.

Table 4 Lake Hiawatha and Hiawatha Golf Course Nutrient Summary

Water Quality Parameter	Pond E on 1/20/2016	Lake Hiawatha Average (6 Yr)	Lake Hiawatha on 1/20/2016
NOx (Nitrate and Nitrite as N, mg/L)	0.479	0.176	0.259
SRP (Soluble Reactive Phosphorus, mg/L)	0.004	0.018	0.005
TKN (Total Kjeldahl Nitrogen, mg/L)	2.18	0.985	0.991
TP (Total Phosphorus, mg/L)	0.076	0.07	0.028

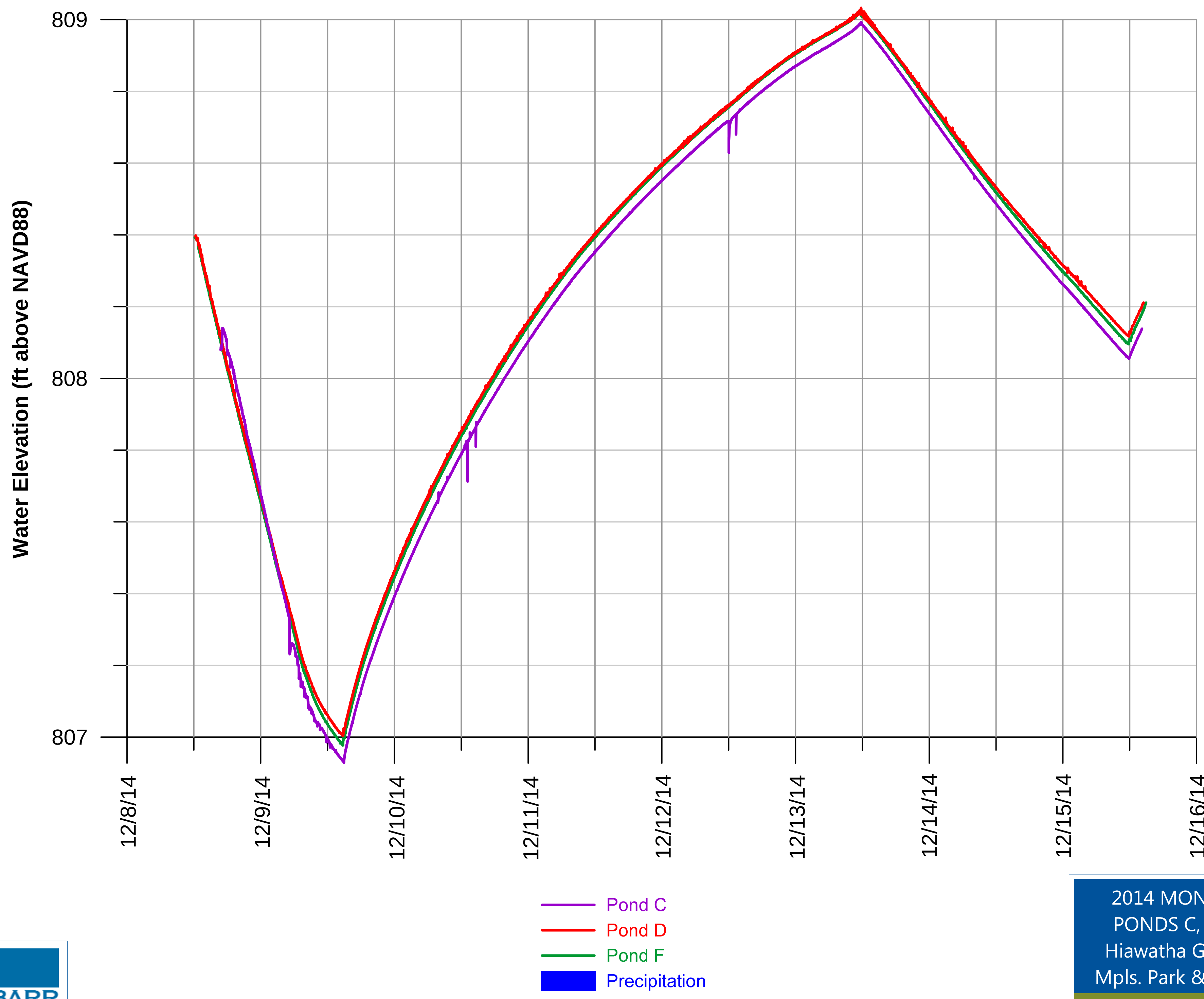
3.3 Aquifer Testing

In order to inform the groundwater model calibration, data was needed to demonstrate how the groundwater system responds to a change in pumping conditions. Barr has conducted three "recovery tests" on the golf course ponds during which the pumps have been shut off and the water level recovery in the ponds and the monitoring wells has been monitored.

An additional aquifer test on the golf course's deep irrigation well was conducted in February 2016. The results from this test were used to evaluate the degree of connection between shallow and deep aquifers in order to assess whether shallow pumping at the golf course impacts deeper aquifers.

3.3.1 2014 Recovery Test

The 2014 recovery test began at 12:42 pm on December 8, 2014 when both pumps were turned on (one had been running prior to the test) in order to lower pond levels as much as possible. Pumping continued until the afternoon of December 9, when golf course staff reported that low water levels in the sump were causing the pumps to draw air. Both pumps were shut off at approximately 2:45 pm on December 9. Pond water levels were then allowed to recover in the absence of pumping for several days. By December 13 the staff gauges in Ponds D and F were completely submerged. One pump was activated at 11:45 am on December 13. Data collection ended with the removal of the transducers from the ponds on the afternoon of December 15, 2014. See Figure 6.



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BARR

2014 MONITORING:
PONDS C, D, AND F
Hiawatha Golf Course
Mpls. Park & Rec. Board

FIGURE 6

3.3.2 First 2015 Recovery Test

Following the installation of the monitoring wells, piezometers, and flow meters in the fall of 2015, a recovery test was conducted in early December 2015. The lift station pumps were turned off at 2:56 pm on December 9, 2015. Water levels in the ponds were allowed to rise in the absence of pumping until 1:10 pm on December 12, 2015, when both pumps were turned back on. Unfortunately, rain events during the testing period, especially on December 14, 2015, resulted in significant surface water inflow to the ponds. Because the purpose of the recovery test was to collect information about groundwater inflow to the ponds, the additional surface water inflow adversely affected the data collected during the test.

3.3.3 Second 2015 Recovery Test

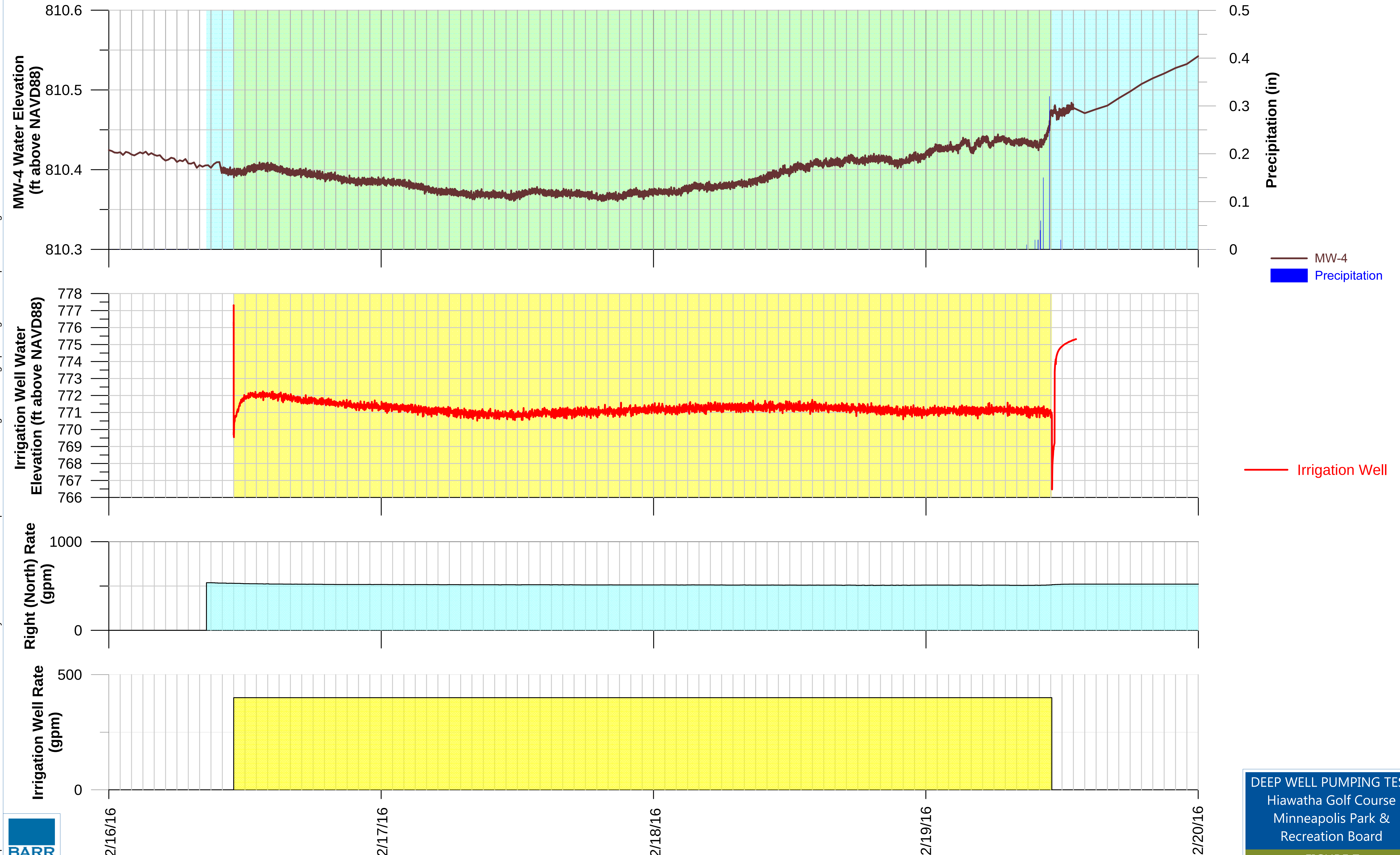
A second recovery test was conducted approximately 3 weeks after the first December 2015 recovery test. In the interim between tests, average temperatures dropped significantly, several inches of snow accumulated, and surface water bodies including Lake Hiawatha and the golf course ponds partially or completely froze over. With no precipitation in the forecast for several days, the pumps were shut off at 11:25 am on December 31, 2015, and pond water levels were allowed to rise in the absence of pumping until 7:40 am on January 4, 2016 when both pumps were turned back on. Both pumps ran until approximately 12:22 am on January 6, 2016, when they both shut off automatically due to the water level in the lift station sump falling below the lower float switch elevation of 808.4 ft NGVD29. The northern pump resumed pumping at approximately 9:00 am on January 7, 2016 when the sump water level reached 809.0 ft NGVD29.

3.3.4 Deep Well Aquifer Test

A deep pumping well, Minnesota unique number 482891, was installed on the golf course in 1992. The open interval of this well intersects the Prairie du Chien Group aquifer from 218 to 260 feet below grade. The location of this well is shown on Figure 1, labeled irrigation well. This well was intended to provide water to augment the golf course irrigation system during dry periods. According to golf course staff, there has always been sufficient water for irrigation and additional water from the deep well has never been needed.

On February 15, 2016, E.H. Renner and Sons temporarily re-plumbed the well to discharge to Lake Hiawatha instead of the pond that supplies the irrigation system. A transducer was installed in the pumping well and programmed to record data in true logarithmic mode, which collects data initially at 4 Hertz (i.e., 4 readings per second) and then increases the recording frequency on a logarithmic scale up to a user-specified maximum interval (1 minute in this case). The transducers in monitoring wells MW-1, MW-2, MW-3, and MW-4 were reprogrammed to record data at 30-second intervals during the test. Pumping of the deep well began at 11:00 am on February 16, 2016. The pumping rate was approximately 400 gpm. Pumping was stopped at approximately 11:25 am on February 19, 2016.

Figure 7 shows a hydrograph of the data collected from the deep well, MW-4, and the lift station flow meters during the pumping test. Water levels in MW-4 decreased around the start of pumping at the deep well, but the timing appears to correlate with the lift station pumps turning on, not the deep well. Similarly, water levels in MW-4 increased near the end of the deep well pumping but the timing appears to correlate with precipitation, not the end of deep well pumping. It was concluded from the test results that there is no connection between the shallow water table aquifer and the deep Prairie du Chien Group aquifer at the golf course. Therefore, pumping from the lift station is not affecting deeper aquifers.



DEEP WELL PUMPING TEST
Hiawatha Golf Course
Minneapolis Park & Recreation Board

FIGURE 7

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4.0 Lake Hiawatha Water Level Analysis

Barr compiled water elevation data for Lake Hiawatha to create a long-term water level record for Lake Hiawatha (1926 to 2017 (present)). The water elevation data was compiled from a variety of sources including information provided by MPRB staff, the Minnesota Department of Natural Resources (MnDNR), and as collected by Barr from 2015 through 2017. Figure 8 shows the long-term water elevations for Lake Hiawatha. Figure 9 shows the average water elevations in Lake Hiawatha by decade for the available data.

Additionally, Barr also utilized flow and stage data from the United States Geological Survey (USGS) monitoring station for Minnehaha Creek at Hiawatha Avenue (station 05289800) to develop a regression equation between the daily average flows in Minnehaha Creek and water levels in Lake Hiawatha (November 2005 through 2017 (present)). There is a strong correlation between creek flows and lake levels. Figure 10 shows the regression equation and correlation coefficient between the USGS gage flow and the Lake Hiawatha elevation.

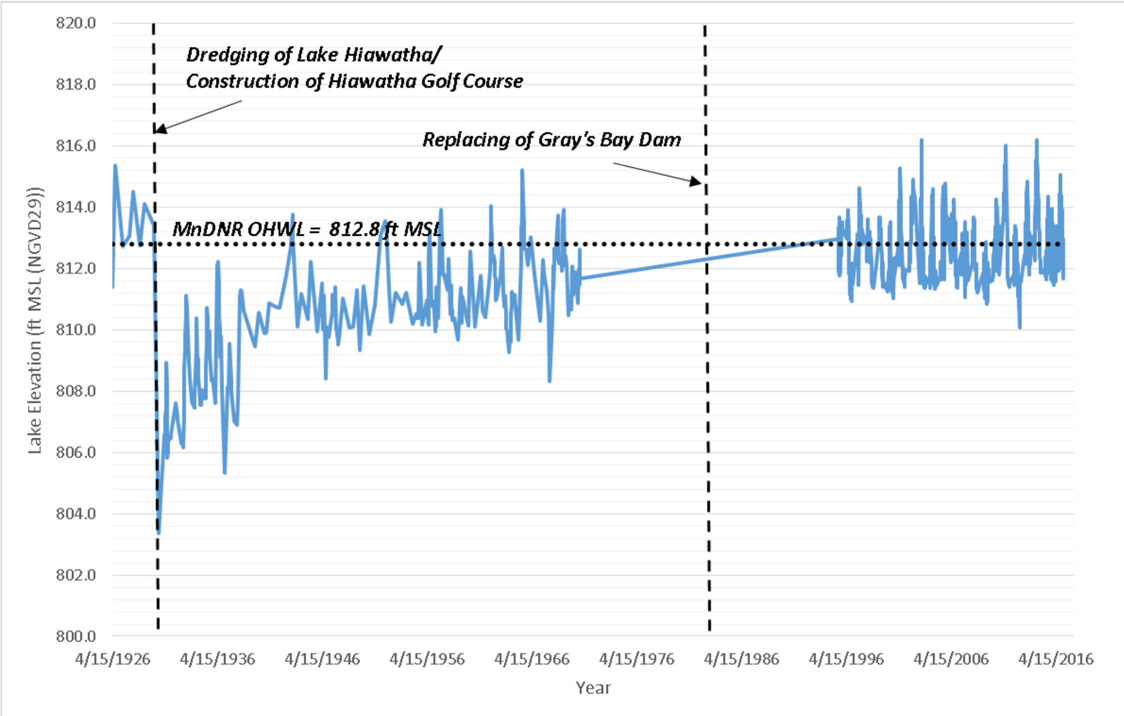


Figure 8 Lake Hiawatha Water Elevations

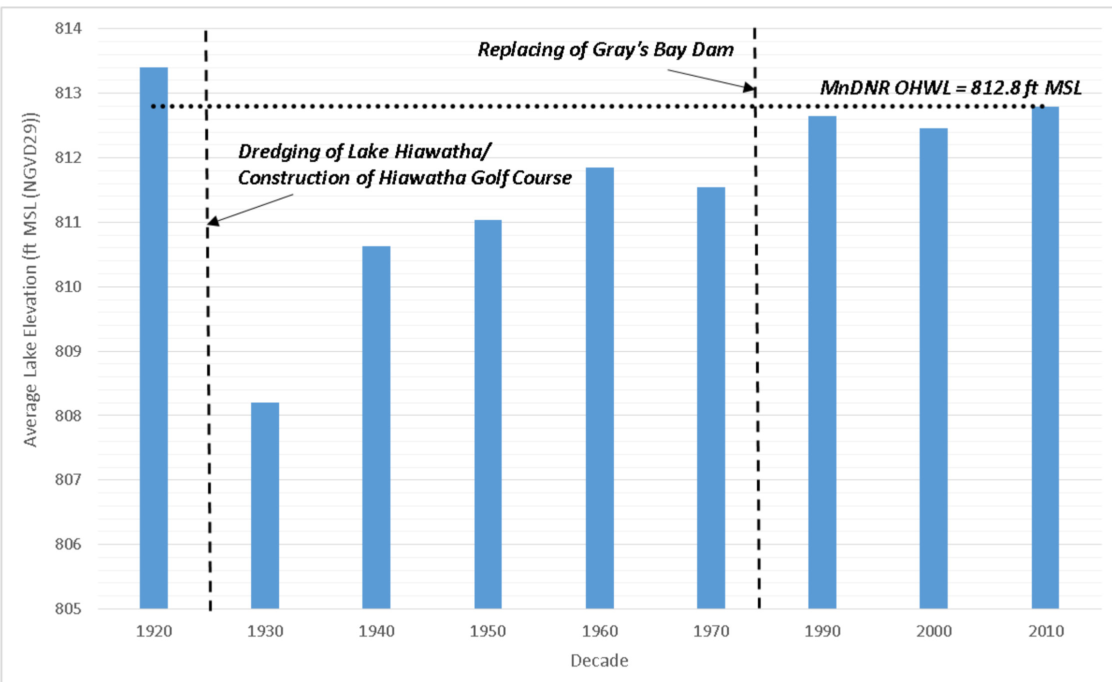


Figure 9 Lake Hiawatha Water Elevations By Decade

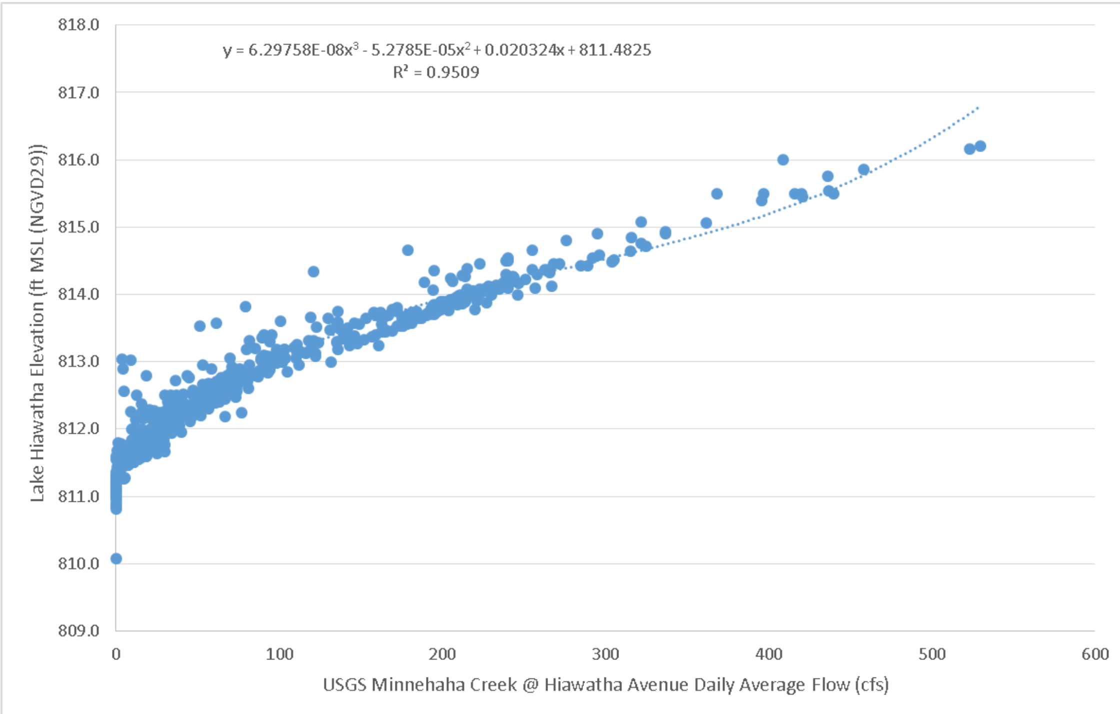


Figure 10 Regression between USGS Gage on Minnehaha Creek and Lake Hiawatha Elevations

Additionally, water elevation statistics are summarized in Table 5 using the entire lake level record, the record between when the golf course was built but before Gray's Bay Dam was replaced, and the record after the replacement of the Gray's Bay Dam at Lake Minnetonka in 1979. Also included in this table are the MnDNR Ordinary High Water Level (OHWL) for Lake Hiawatha and the effective FEMA flood elevation.

Table 5 Lake Hiawatha Water Elevation Summary

Parameter	Entire Record (1926-2017) (ft NGVD29)	Record After Golf Course but Before Gray's Bay Dam Replacement (1930-1970) (ft NGVD29)	Record After Gray's Bay Dam Replacement (1995-2017) (ft NGVD29)
Maximum	816.2	815.2	816.2
Average	812.1	810.3	812.7
Minimum	803.4	803.4	810.1
Standard Deviation	1.7	2.1	1.0
25th Percentile	811.5	809.1	811.8
50th Percentile (Median)	812.2	810.5	812.5
75th Percentile	813.2	811.8	813.5
90th Percentile	814.0	812.7	814.1
OHWL (MnDNR)	812.8	812.8	812.8
Effective FEMA Flood Elevation	817.0	817.0	817.0

Increasing water levels in Lake Hiawatha have likely exacerbated the need for additional volume pumped from the Hiawatha Golf Course, especially in the past several decades. Water levels in Lake Hiawatha have increased due to a variety of reasons including:

- The golf course was constructed in the late 1920s to early 1930s during a dry climatic period in the Twin Cities,
- The Minnehaha Creek watershed has developed significantly since the golf course construction,
- Installation of utilities under Minnehaha Creek downstream of Lake Hiawatha have created high points in the channel that control the water levels in the lake (with the existing outlet weir being submerged), and
- The replacement of the dam at Lake Minnetonka in 1979 has modified the flow regime in the creek, resulting in more constant flows throughout the year when historically flows would stop in Minnehaha Creek during dry periods. Additionally, there are periods of sustained high flows (~250-300 cfs) along Minnehaha Creek when Lake Minnetonka is being drawn down in the fall that can result in elevated water levels in Lake Hiawatha.

5.0 Lake Hiawatha Water Quality & Residence Time

Lake Hiawatha is listed as impaired for excess nutrients by the Minnesota Pollution Control Agency (MPCA). A Total Maximum Daily Load (TMDL) study (Tetra Tech, 2013) was completed and approved on February 24, 2014. Site-specific standards were established for Lake Hiawatha including the following water quality goals for the growing season (June-September):

- Total Phosphorus < 50ug/L
- Chlorophyll a < 14 ug/L
- Secchi Depth > 1.4 m

Through the TMDL process, the seasonal (June – September) flow volumes, phosphorus loads, and lake residence time were summarized from 2001 through 2011 (11 years). The average seasonal inflow to the lake is 1,053 million cubic feet with 77% of the inflow from Minnehaha Creek and 23% coming from stormflow. The seasonal total phosphorus load to Lake Hiawatha is 6,463 pounds. A 30-percent reduction in the total phosphorus load would be needed to achieve the TMDL. The estimated average residence time for Lake Hiawatha is 4.4 days (ranging from 1.8 to 47.4 days).

Based the estimated seasonal volume pumped from the golf course to Lake Hiawatha using the monitored pumping rate, the estimated volume pumped from the golf course to the lake could range from 0.3% (wet conditions) to 7.6% (dry conditions) of the total seasonal inflow volume. Using the water quality data collected in the golf course ponds and the seasonal volume to the lake, the estimated seasonal phosphorus load from the golf course is only less than 1.0 percent of the total seasonal phosphorus load to Lake Hiawatha.

Additionally, residents from the larger Hiawatha community have expressed concerns about trash accumulating in the lake, and a current University of Minnesota civil engineering student is doing a capstone project on the trash problem in the area.

6.0 Golf Course Settlement

The Hiawatha Golf Course area was historically a wetland, and the existing 18-hole golf course was created by the MPRB in the late 1920s with dredged spoils from the bottom of Lake Hiawatha. It is likely the dredged organic material used to create the golf course was placed on top of existing organic material. As a result, settlement may be an issue at the Hiawatha Golf Course. Anecdotal evidence also indicates that settlement has been observed at homes in the neighborhood to the west of the golf course.

The historic or current rates of settlement in the golf course are unknown. However, there are several options the MPRB may consider to quantify the historic or current settlement rates in the golf course area. Attachment B summarizes the potential settlement monitoring options and planning level costs.

7.0 Basement Surveys

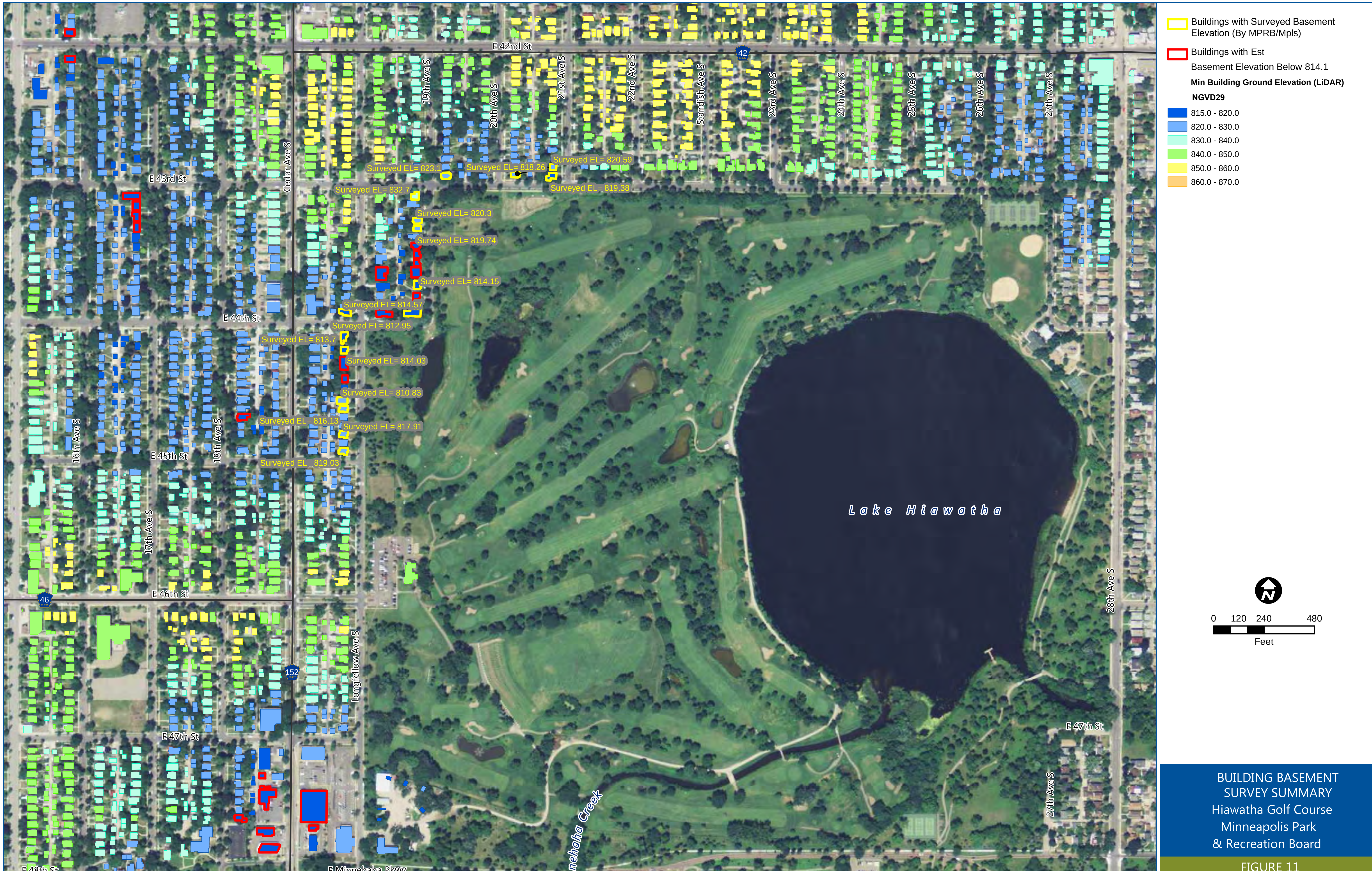
The groundwater monitoring and modeling indicate that the pumping in the golf course is protecting the low basements in the adjacent neighborhood from flooding. Many of the homes near the Hiawatha Golf Course also have sump pumps, and the homes with the lowest basements have sump pumps that run frequently.

In late 2015, a cursory analysis to estimate potential basement floor elevations was performed using building data provided by the City of Minneapolis and the MnDNR LiDAR ground surface elevation data.

MPRB and the City agreed that official surveys should be completed to determine the basement floor elevations as they move forward with the evaluation of the reduced pumping requirements for the Hiawatha Golf Course.

Since the summer of 2016, MPRB and City of Minneapolis staff have surveyed basement floor elevations for 16 homes. These homes and basement elevations are shown on Figure 11. There are several other homes with low basements near the golf course, and MPRB and City of Minneapolis staff will be continuing to survey the basement floor elevations for these homes in 2017.

The MPRB and the City have acknowledged that pumping at some level will need to continue to protect the basements of the adjacent homes. However, there is one home (4432 Longfellow Avenue) that has a complete sport court in the basement and is more than 2 feet lower than the next lowest basement. Under existing conditions, this home operates sump pumps to keep its basement dry.



BUILDING BASEMENT SURVEY SUMMARY
Hiawatha Golf Course
Minneapolis Park & Recreation Board

FIGURE 11

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8.0 Lake Hiawatha Outlet & Minnehaha Creek Surveys

There is a concrete weir at the outlet of Lake Hiawatha with a 2-foot notch into which wooden planks or stop logs could be inserted to raise the lake elevation. However, this structure does not ultimately control the water levels in Lake Hiawatha. There are several high points in the Minnehaha Creek channel downstream of the lake that control the water levels. Upstream of the creek crossing at 28th Avenue South is a high point in the channel resulting from a utility crossing under the creek bed. There are also several other high points in the channel downstream of Lake Hiawatha based on the FEMA Flood Insurance Study creek profile and the Minnehaha Creek Watershed District (MCWD) XPSWMM model.

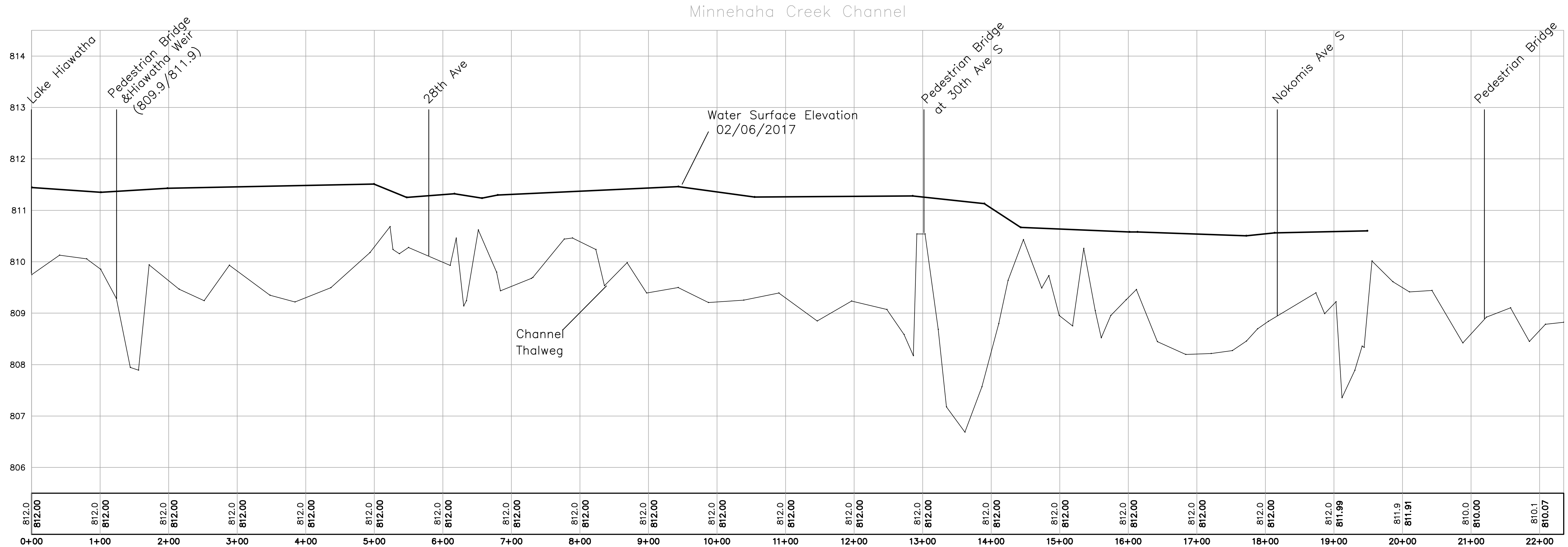
A GPS survey was conducted by Barr along Minnehaha Creek downstream of Lake Hiawatha in January and February 2017. The goal of this survey was to better understand the existing control points in the creek downstream of the lake and to determine if it would be feasible to lower the normal water level of Lake Hiawatha to help reduce pumping from the Hiawatha Golf Course area and to help address known flooding issues in the larger Hiawatha watershed area.

The survey captured elevation shots of the Minnehaha Creek channel thalweg (the lowest point in the channel cross section) approximately every 50 feet from the outlet of Lake Hiawatha to a distance approximately 2,000 feet downstream (to the pedestrian bridge downstream of Nokomis Avenue South). Survey shots were also collected for the existing concrete weir and cross sections upstream and downstream of the road crossing. Survey and manual measurements at the rock weir at the pedestrian bridge at 30th Avenue South were also collected.

Figure 12 shows the thalweg and water surface elevation shots of the Minnehaha Creek channel in plan and profile view. The elevation of the existing concrete weir notch is 809.9 ft NGVD29. The existing control of water levels in Lake Hiawatha is either the high point in the channel upstream of 28th Avenue South or the rock weir under the pedestrian bridge at 30th Avenue South. The high point at 28th Avenue South appears to be caused by a gas main crossing the creek. The weir at 30th Avenue South appears to be manmade and its function is unknown. Both high point elevations are approximately 810.7 ft NGVD29. There are several other high points in the creek channel that are downstream of these crossings that may also affect the water level in Lake Hiawatha.

The lowest channel elevation at the downstream end of the surveyed section of the creek was approximately elevation 809.0 ft NGVD29. Lowering the control for the water levels in Lake Hiawatha to this elevation (~1.5 feet lower than the existing control) would require excavation of approximately 2,000 feet of creek channel, replacement/lowering of utility crossings under the creek bed, and the associated permitting for these activities.

Based on this survey, we have estimated that the potential lowering of Lake Hiawatha control would result in a water surface of 811.8 ft NGVD29, which is approximately one (1) foot lower than that the OHWL and approximate average water elevation (812.8 ft NGVD29) that we have been using for our groundwater and stormwater evaluations.



PRELIMINARY DRAFT

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR 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.

PRINTED NAME

SIGNATURE

DATE LICENSE #

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CONSTRUCTION
RELEASED TO/FOR

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DATE RELEASED

BARR

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Fax: (952) 832-2601
www.barr.com

Scale	AS SHOWN
Date	02/06/2017
Drawn	
Checked	
Designed	
Approved	

MINNEAPOLIS PARK & RECREATION BOARD

HIAWATHA GOLF COURSE
MINNEAPOLIS, MN

MINNEHAHA CREEK CHANNEL SURVEY – DOWNSTREAM OF LAKE HIAWATHA

BARR PROJECT No.

CLIENT PROJECT No.

DWG. No. FIGURE 12

REV. No.

9.0 Stormwater Modeling

9.1 Design Storm Event (XPSWMM)

The City of Minneapolis originally provided two XPSWMM models for the larger Hiawatha watershed and a smaller model of the watershed to the west of the Hiawatha Golf Course that was diverted to the golf course in 2011. Barr combined these models into a single model and updated the following information:

- Updates were made to the golf course ponds including revisions to storage based on the MnDNR 2011 LiDAR ground surface data, updates to pond surface overflows in the model (based on surveys completely by Barr), and incorporation of other areas of the golf course not originally included in the modeling.
- The XPSWM model was run for the Atlas 14 100-year, 24-hour design storm event and water was fully captured.
- The golf course pumping capacity was updated based on the actual pumping/flow monitoring data.
- The regional groundwater inflow was incorporated based on the groundwater modeling (see Section 10.0) and tailwater condition at Lake Hiawatha.

In early 2016, the XPSWMM model was used to begin understanding the existing flood elevations based on the current operations of the golf course pumps. Additionally the model was used to quantify impacts to flood elevations, storm sewer infrastructure, and potentially low homes in the watershed to the west of the golf course.

The preliminary XPSWMM model runs included the following scenarios:

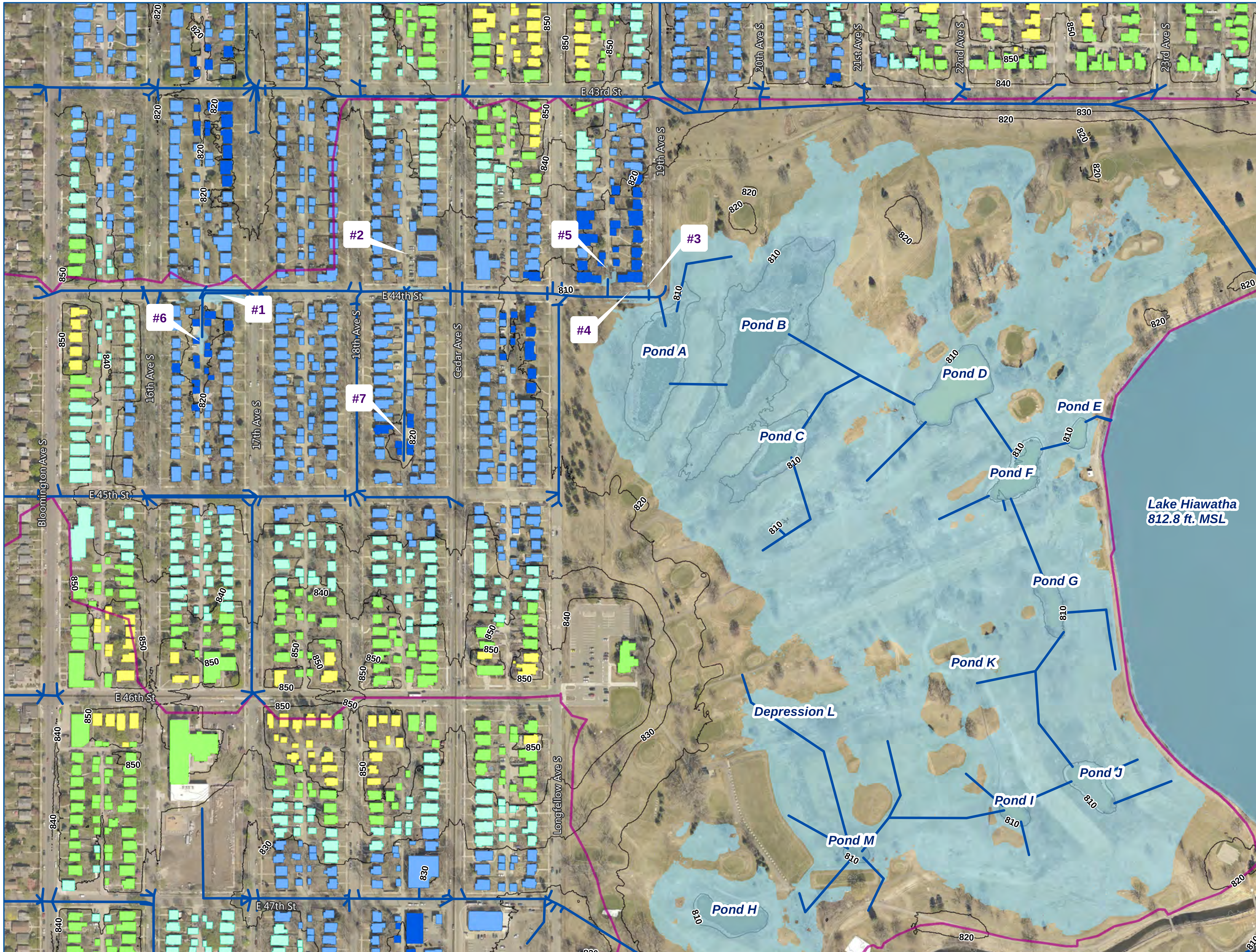
- Scenario 1: Existing conditions model with current pumping information (golf course ponds at 808.5 ft NGVD29) with Lake Hiawatha tailwater at OHWL (812.8 ft NGVD29) for Atlas 14 100-year, 24-hr design storm event
- Scenario 2: Proposed conditions model with gravity connection to lake and golf course ponds and Lake Hiawatha tailwater at OHWL (812.8 ft NGVD29) for Atlas 14 100-year, 24-hr design storm event
- Scenario 3: Proposed conditions model with gravity connection to lake and golf course ponds and Lake Hiawatha tailwater at High Flow conditions (814.1 ft NGVD29) for Atlas 14 10-year, 24-hr design storm event
- Scenario 4: Proposed conditions model with gravity connection to lake and golf course ponds and Lake Hiawatha tailwater at top of berm conditions (815.7 ft NGVD29) for Atlas 14 10-year, 24-hr design storm event

Scenario 5: Proposed conditions model with gravity connection to lake and golf course ponds and Lake Hiawatha tailwater at top of berm conditions (815.7 ft NGVD29) for Atlas 14 100-year, 24-hr design storm event

Table 6 summarizes the flood elevations at key locations within the golf course watershed. Figure to Figure 47 show the estimated extents of inundation in the watershed based on the modeled peak elevation and the MnDNR LiDAR data for each of the five (5) scenarios above.

Table 6 Hiawatha Golf Course and Watershed Flood Elevations and Expected Change in Elevation

Area ID	Node Name	Node Description	Surface Elevation (per storage entered in XPSWMM model from Mpls)	Scenario 1: Existing Conditions Model. Golf Course at 808.5 and Lake Hiawatha at 812.8. Pumping with 100YR Storm	Depth of Flooding at Surface (ft)	Scenario 2: Proposed Conditions Model. Golf Course and Lake Hiawatha at 812.8. No Pumping with 100YR Storm	Elevation Difference from Scenario 1 (negative is decrease)	Scenario 3: Proposed Conditions Model. Golf Course and Lake Hiawatha at 814.1. No Pumping with 10YR Storm	Elevation Difference from Scenario 1 (negative is decrease)	Scenario 4: Proposed Conditions Model. Golf Course and Lake Hiawatha at 815.7. No Pumping with 10YR Storm	Elevation Difference from Scenario 1 (negative is decrease)	Scenario 5: Proposed Conditions Model. Golf Course and Lake Hiawatha at 815.7. No Pumping with 100YR Storm	Elevation Difference from Scenario 1 (negative is decrease)
WATERSHED WEST OF DIVERSION													
#1	1644B	Low spot along E 44th St. between 16th Ave S and 17th Ave S	821.0	821.0	0.0	821.0	0.0	820.7	-0.3	820.7	-0.3	821.0	0.0
#2	1844B	Low spot in alley between 18th Ave S and Cedar Ave S just north of E 44th St.	820.2	820.7	0.5	820.7	0.0	817.8	-2.9	817.9	-2.7	820.7	0.0
#3	MH6	Low spot on corner of 19th Ave S and E 44th St.	815.59	814.9	-0.6	815.5	0.6	815.5	0.6	816.1	1.1	816.2	1.2
#4	MH-9	Low spot on corner of 19th Ave S and E 44th St.	815.46	816.1	0.6	816.1	0.1	816.0	0.0	816.1	0.1	816.2	0.1
#5	LO44D	Low spot in alley between Longfellow Ave S and 19th Ave S just north of E 44rd St.	816.11	816.7	0.6	816.7	0.0	816.6	-0.1	816.6	-0.1	816.7	0.0
#6	MH7	Low spot in alley between 16th Ave S and 17th Ave S just south of E 44th St.	816.0	817.9	1.9	818.0	0.1	817.1	-0.8	817.2	-0.7	818.1	0.1
#7	CB8	Low spot in alley between 18th Ave S and Cedar Ave S just south of E 44th St.	816.8	818.1	1.3	818.1	0.0	817.4	-0.7	817.4	-0.6	818.1	0.1
GOLF COURSE WATERSHED													
	Pond E	Golf Course Pond Node		814.5		813.2	-1.3	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond F	Golf Course Pond Node		814.5		813.2	-1.2	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond D	Golf Course Pond Node		814.5		813.3	-1.1	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond C	Golf Course Pond Node		814.5		814.2	-0.3	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond B	Golf Course Pond Node		814.5		814.2	-0.3	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond A	Golf Course Pond Node		814.5		814.2	-0.3	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond H	Golf Course Pond Node		814.5		814.7	0.3	814.7	0.2	816.0	1.5	816.1	1.7
	Pond M	Golf Course Pond Node		814.5		813.8	-0.7	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond I	Golf Course Pond Node		814.5		813.2	-1.2	814.4	-0.1	816.0	1.5	816.1	1.7
	Depres L	Golf Course Depression Node		814.5		813.8	-0.7	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond J	Golf Course Pond Node		814.5		813.2	-1.2	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond G	Golf Course Pond Node		814.5		813.2	-1.2	814.4	-0.1	816.0	1.5	816.1	1.7
	Pond K	Golf Course Pond Node		814.5		813.2	-1.2	814.4	-0.1	816.0	1.5	816.1	1.7



Scenario 1[1]

Golf Course Drainage Area

Stormsewer

Inundation Area

Minimum Building Ground Elevation

Feet NGVD29[2]

815.0 - 820.0

820.0 - 830.0

830.0 - 840.0

840.0 - 850.0

850.0 - 860.0

860.0 - 870.0

Surface Elevation Contours

2-Ft NGVD29 (MnDNR 2011)

10-Foot Contour

2-Foot Contour

[1]Atlas 14 100-year Flood Inundation area developed using MnDNR 2011 LiDAR, based on Existing Conditions, Hiawatha Elevation at 812.8, Golf Course ponds at 808.5 and pumping at 85% of original capacity. (approx. 900 GPM/pump).

[2]Estimated based on City of Minneapolis building data and MnDNR 2011 LiDAR

N

0 300 600

Feet

SCENARIO 1:
EXISTING CONDITIONS
100-YEAR FLOOD INUNDATION AREA
Hiawatha Golf Course
Minneapolis Park & Recreation Board

FIGURE 13

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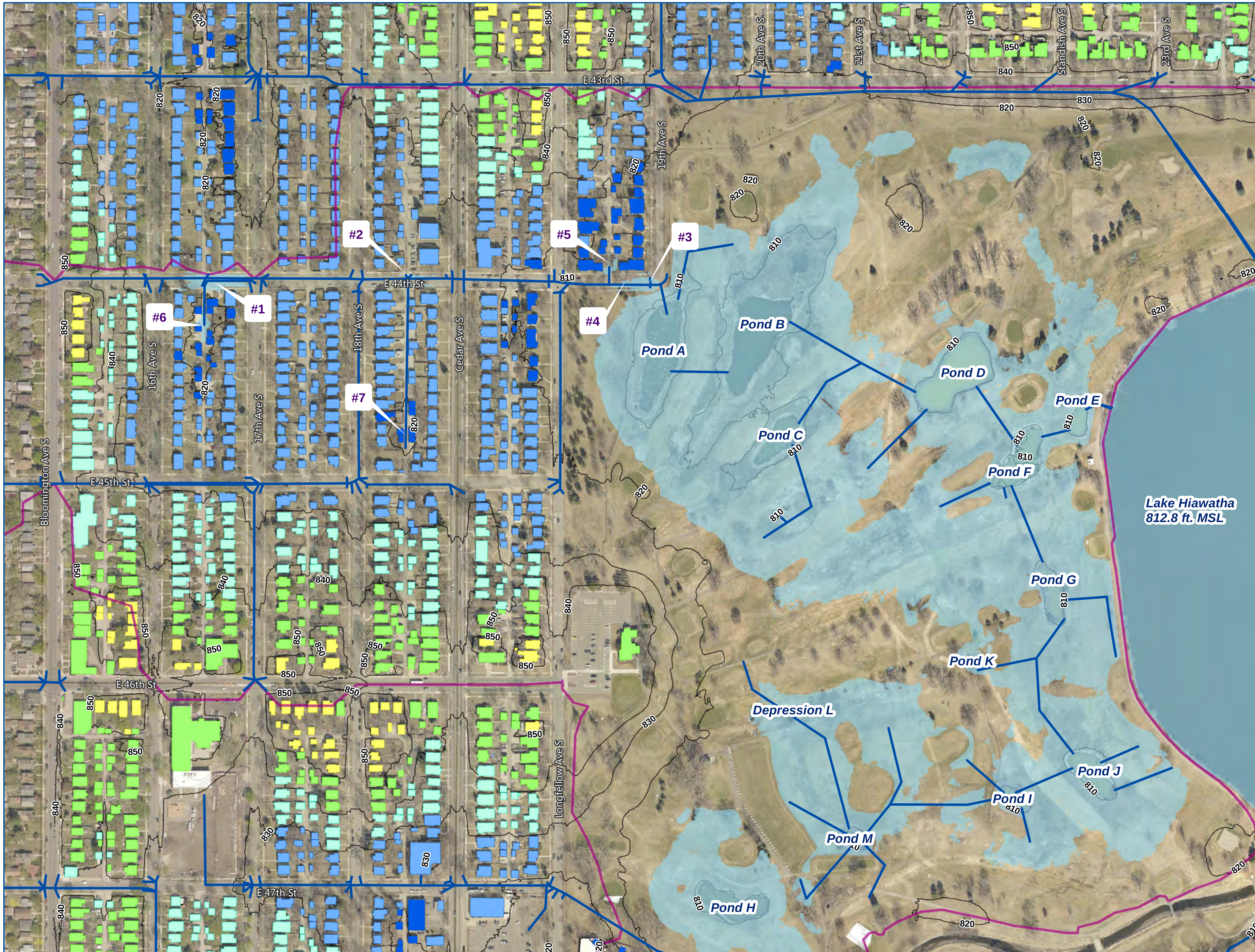

Scenario 2[1]

Golf Course Drainage Area

Stormsewer

Inundation Area

Minimum Building Ground Elevation

Feet NGVD29[2]

815.0 - 820.0

820.0 - 830.0

830.0 - 840.0

840.0 - 850.0

850.0 - 860.0

860.0 - 870.0

Surface Elevation Contours

2-Ft NGVD29 (MnDNR 2011)

10-Foot Contour

2-Foot Contour

[1]Atlas 14 100-year Flood Inundation area developed using MnDNR 2011 LiDAR, based on Future Conditions, Hiawatha Elevation at 812.8, Golf Course ponds at 812.8 with gravity connection to lake.
[2]Estimated based on City of Minneapolis building data and MnDNR 2011 LiDAR

0 300 600

Feet

SCENARIO 2:
FUTURE CONDITIONS
100-YEAR FLOOD INUNDATION AREA
Hiawatha Golf Course
Minneapolis Park & Recreation Board

FIGURE 14

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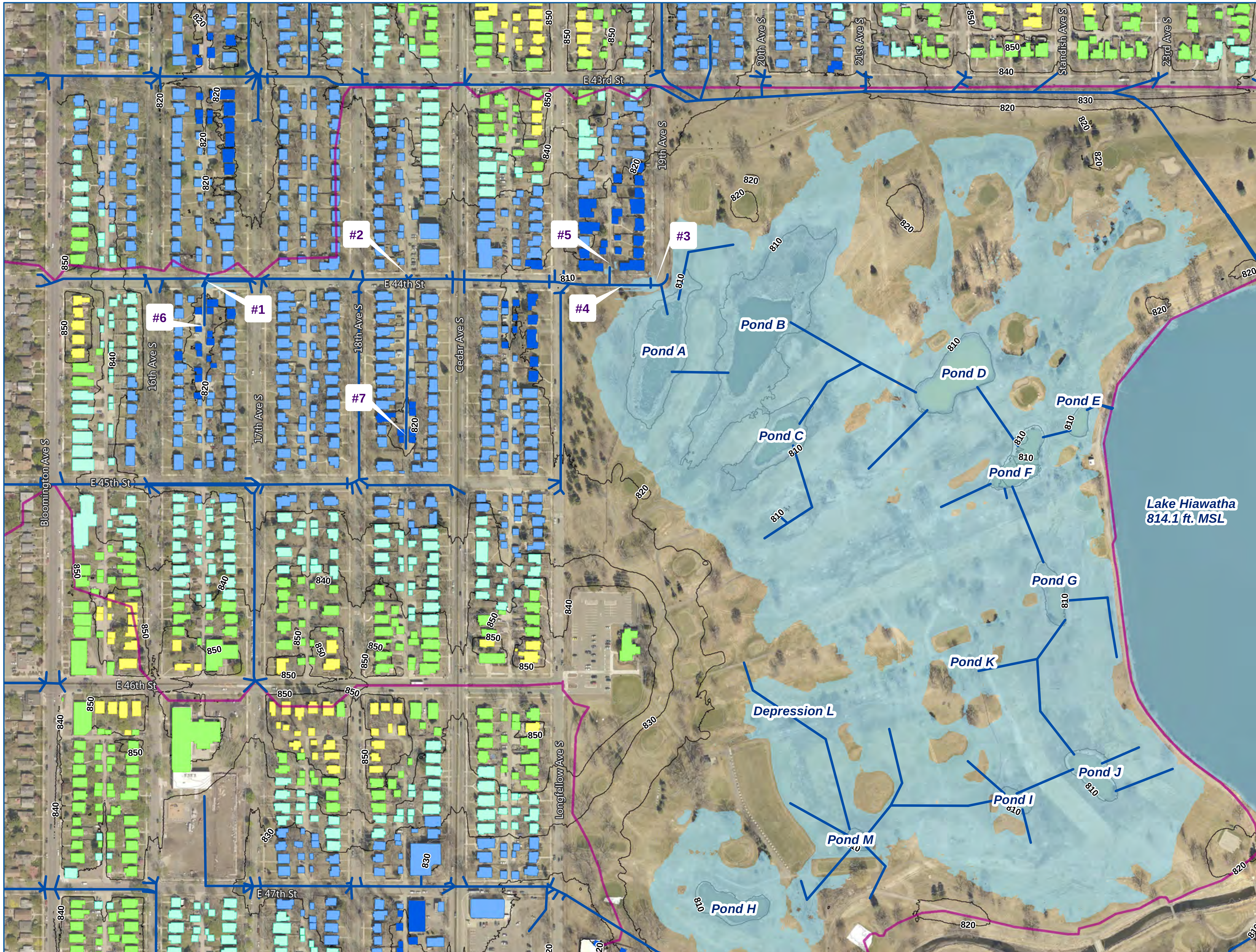

Scenario 3[1]

- Golf Course Drainage Area
- Stormsewer
- Inundation Area

Minimum Building Ground Elevation
Feet NGVD29[2]

- 815.0 - 820.0
- 820.0 - 830.0
- 830.0 - 840.0
- 840.0 - 850.0
- 850.0 - 860.0
- 860.0 - 870.0

Surface Elevation Contours
2-Fet NGVD29 (MnDNR 2011)

- 10-Foot Contour
- 2-Foot Contour

[1]Atlas 14 10-year Flood Inundation area developed using MnDNR 2011 LiDAR, based on Future Conditions, Hiawatha Elevation at 814.1, Golf Course ponds at 814.1 with gravity connection to lake.
[2]Estimated based on City of Minneapolis building data and MnDNR 2011 LiDAR

0 300 600
Feet

SCENARIO 3:
FUTURE CONDITIONS
10-YEAR FLOOD INUNDATION AREA
Hiawatha Golf Course
Minneapolis Park & Recreation Board

FIGURE 15

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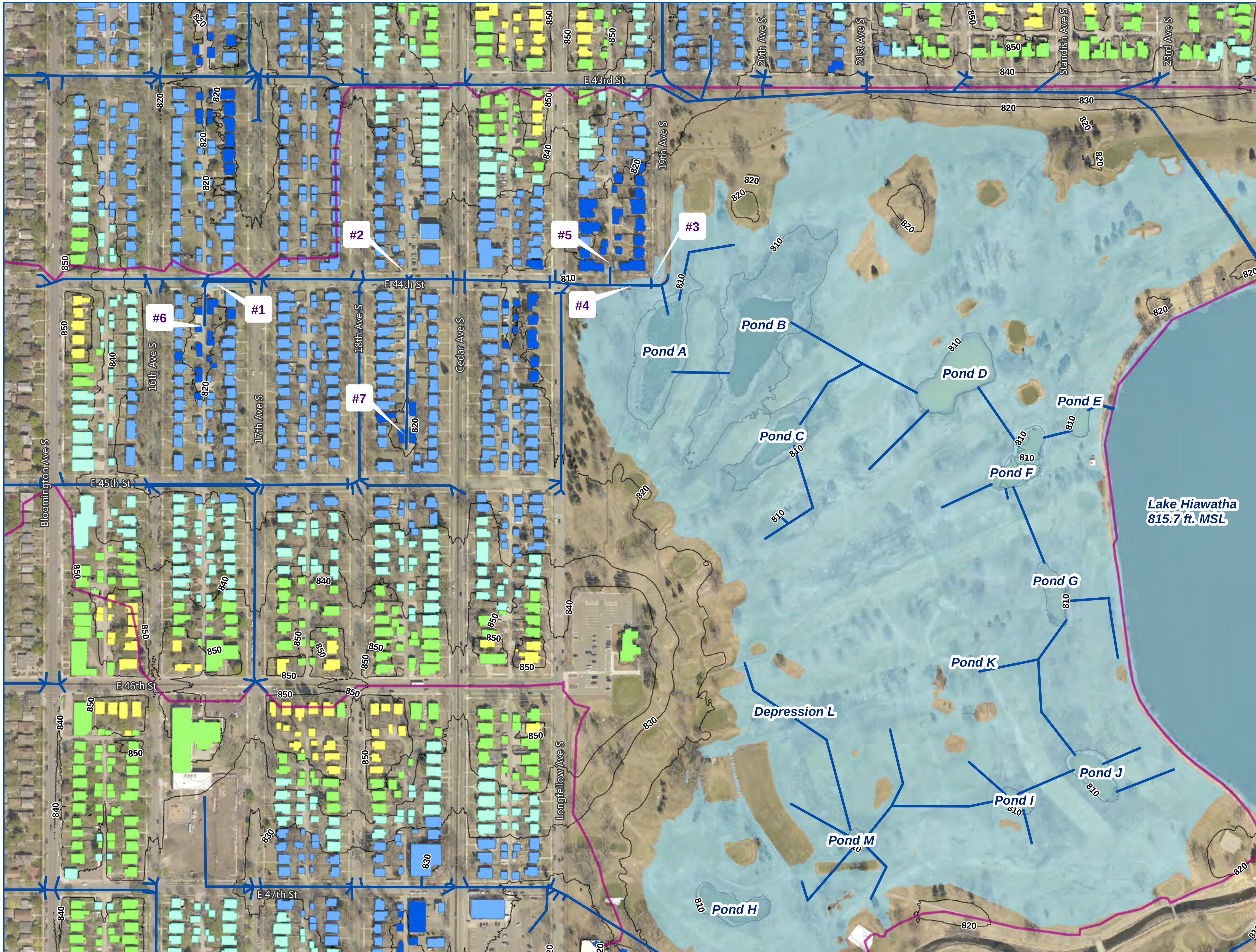

Scenario 4[1]

Golf Course Drainage Area

Stormsewer

Inundation Area

Minimum Building Ground Elevation

Feet NGVD29[2]

- 815.0 - 820.0
- 820.0 - 830.0
- 830.0 - 840.0
- 840.0 - 850.0
- 850.0 - 860.0
- 860.0 - 870.0

Surface Elevation Contours

2-Ft NGVD29 (MnDNR 2011)

- 10-Foot Contour
- 2-Foot Contour

[1]Atlas 14 10-year Flood Inundation area developed using MnDNR 2011 LiDAR, based on Future Conditions, Hiawatha Elevation at berm elevation 815.7, Golf Course ponds at 815.7 with gravity connection to lake.
[2]Estimated based on City of Minneapolis building data and MnDNR 2011 LiDAR

0 300 600

Feet

SCENARIO 4:
FUTURE CONDITIONS
10-YEAR FLOOD INUNDATION AREA
Hiawatha Golf Course
Minneapolis Park & Recreation Board

FIGURE 16

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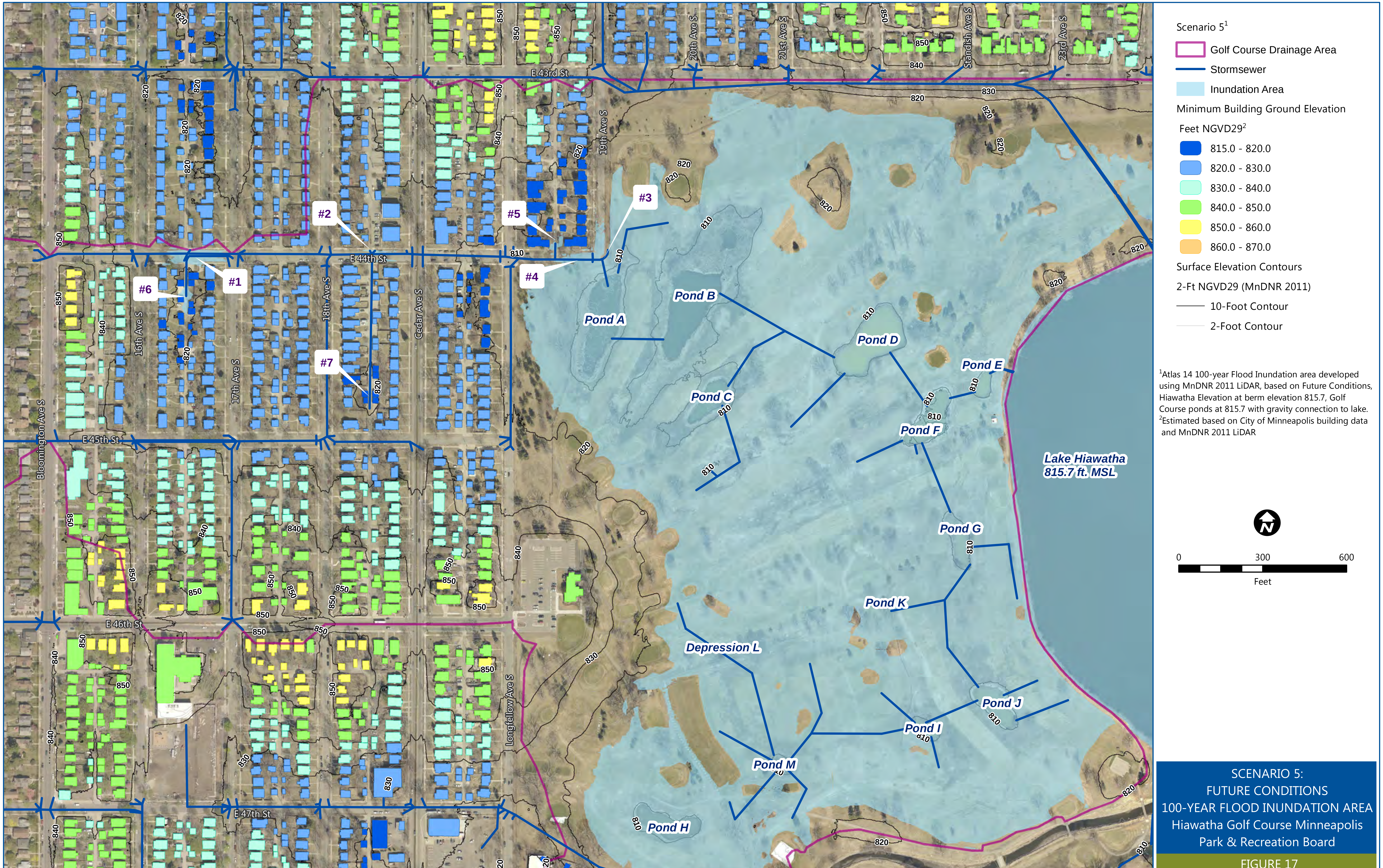

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9.2 Annual Stormwater Runoff Estimates

The average annual runoff to the Hiawatha Golf Course from the contributing watershed to the west and the direct watershed within the park will vary from year to year. However, to understand the average annual volume of stormwater runoff to the golf course, Barr utilized the watershed area and estimated runoff coefficients based on the land use type, imperviousness, and other characteristics to estimate an annual stormwater runoff volume. For average precipitation conditions in the Twin Cities area (30.0 inches per year), Barr estimated an average annual runoff volume to the golf course of 49 million gallons.

The average runoff for the period between January 9, 2016 and January 13, 2017 (the pumping period used for the groundwater model steady state calibration) was required for the 2017 expansion and recalibration of the groundwater model (see Section 10). Using the watershed area and estimated runoff coefficients based on the land use type and imperviousness, a stormwater runoff volume of 66 million gallons was estimated based on the total precipitation of 40.59 inches that fell at the MSP airport during the calibration period.

10.0 Groundwater Modeling

10.1 Hiawatha Golf Course Groundwater Modeling History

The original groundwater flow model of the Hiawatha Golf Course area was developed in the winter of 2014-2015. This model was calibrated to pond water level data collected during the 2014 pumping and recovery test (see Section 3.3.1 above) and was used to derive a relationship between Lake Hiawatha stage and groundwater inflow to the course ponds for XPSWMM surface water modeling of the golf course. This modeling is described in Barr (2015). Updates were made to this groundwater model in the fall of 2015 to better simulate no-pumping scenarios that would cause inundation of the golf course.

The 2014-2015 groundwater flow model was revised and recalibrated in early 2016 to incorporate the groundwater, surface water, and pumping data collected in the two 2015-2016 recovery tests (see Sections 3.3.2 and 3.3.3 above). This model was used to derive an updated relationship between Lake Hiawatha stage, golf course pond stage, and groundwater inflow rate to the golf course ponds for additional XPSWMM surface water modeling of the golf course. This stage-pumping relationship is shown below on Table 7.

Table 7 Lake Hiawatha Stage/Pond Groundwater Inflow Relationship

Lake Hiawatha Stage (ft NAVD88)	Ponds A-F Stage (ft NAVD88)	Ponds A-F Groundwater Inflow Rate (gpm)
812.8	808.0	679
	808.5	618
	809.0	556
	810.0	422
	811.0	287
	812.0	147
	812.8	31
810.3	809.0	324
811.0		387
811.8		462
812.8		556
813.5		620
814.1		682
815.0		771
816.4		914

In early 2017, the 2016 version of the groundwater model was expanded and recalibrated so that the model could be used to predict potential impacts to Lake Nokomis, Powderhorn Lake, Diamond Lake, Taft Lake, and Mother Lake related to altered pumping at the golf course. The following sections will describe the construction, calibration, and application of the most current (2017) version of the groundwater flow model.

10.2 Groundwater Model Description

The three-dimensional numerical groundwater modeling code MODFLOW-NWT (Niswonger et al., 2011), developed by the U.S. Geological Survey, was used for this study. Groundwater Vistas (ESI, 2011), a graphical user interface and preprocessor for MODFLOW, was used to construct and visualize the model.

The current model domain extent and boundary conditions are shown on Figure 18, along with the 2014-2015 and 2016 versions of the groundwater models for reference. The golf course is approximately centered within the domain. The model domain extent was delineated using water table contours generated by Metro Model 3, a regional groundwater model of the Twin Cities metropolitan area recently developed by Barr Engineering for the Metropolitan Council (Metropolitan Council, 2014). The regional groundwater flow direction in the vicinity of the golf course is easterly towards the Mississippi River. The northern and southern model boundaries are no-flow boundaries that correspond to assumed flow paths traced perpendicular to the water table contours produced by Metro Model 3. The western and eastern model boundaries are constant head boundaries that correspond to the 830 ft NAVD88 and 780 ft NAVD88 water table contours, respectively, from Metro Model 3. A better fit to the groundwater level data was obtained by increasing the eastern constant head boundary elevation to 800 ft NAVD88, which is consistent with the Quaternary aquifer contour map in the Hennepin County Geologic Atlas (Kanivetsky, 1989).

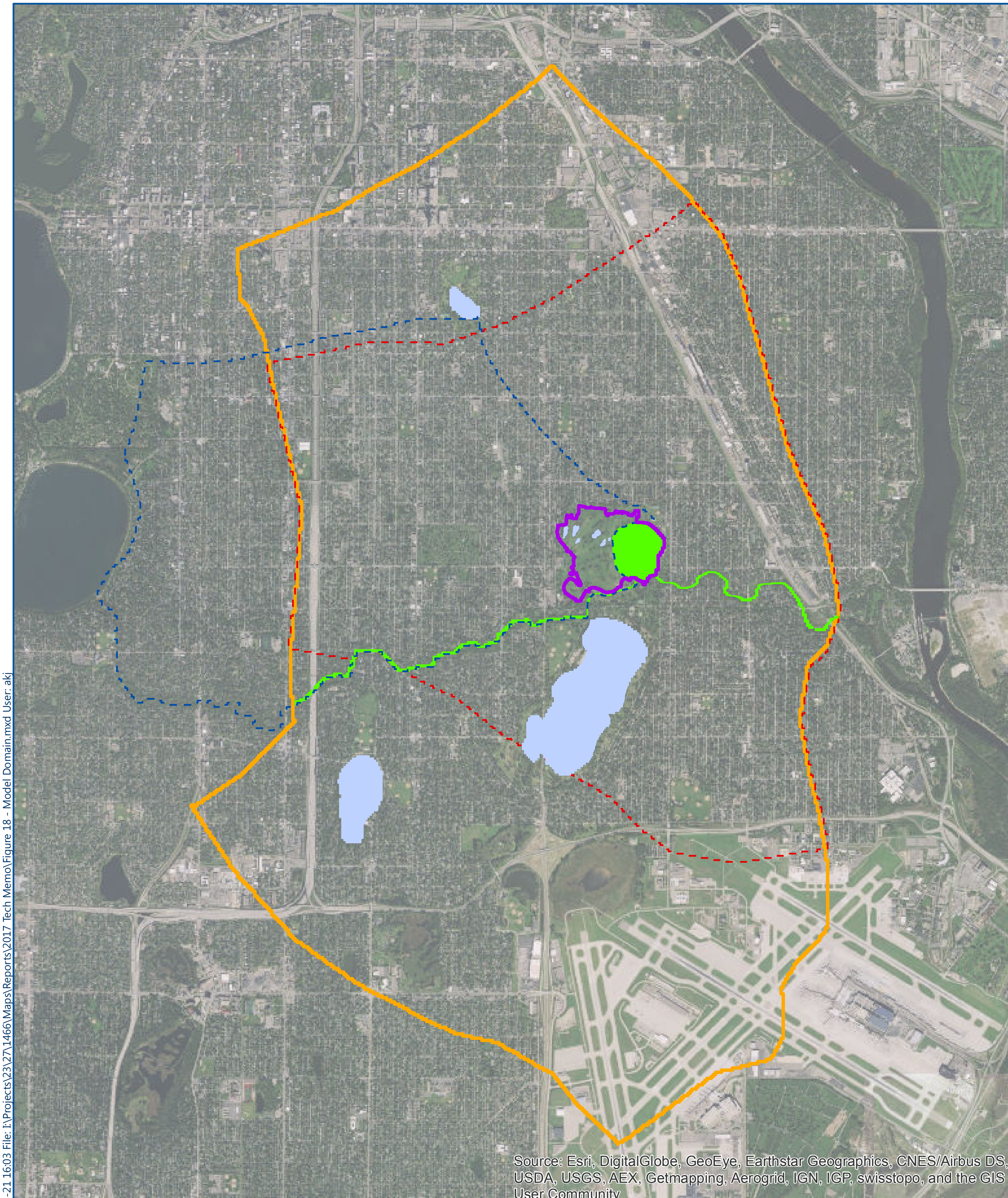
The model domain was discretized on a rectilinear grid with 20 meter by 20 meter grid cell spacing in the far-field refined to 5 meter by 5 meter grid cells on the golf course property. The grid has two layers. Layer 2, the lower layer, represents the unconsolidated (i.e., not bedrock) water table aquifer. Ground surface elevations from the Hennepin County LiDAR data (MnDNR, 2011) were used to define the top of Layer 2. The base of layer 2 is a top of bedrock surface based on Minnesota Geological Survey mapping for the Twin Cities area (Mossler, 2013).

Layer 1 of the model is mostly inactive cells except for the region within the purple outline on Figure 18. The portion of this area located west of Lake Hiawatha, which was delineated using the 816-foot ground surface elevation contour generated from the LiDAR data, is intended to facilitate simulation of golf course inundation using the MODFLOW Lake package (Merritt and Konikow, 2000). The Lake package was also used to represent the golf course ponds. The Lake package performs a water balance for each simulated lake and computes the stage from a user-specified stage-volume relationship. Lake cells were added to Layer 2 of the model in six separate groups within the Pond A-F footprints. For modeling purposes, the golf course pond system is considered a single lake that separates into six separate footprints at lower stages. A composite stage-volume relationship was developed using bathymetric contours for the golf course ponds digitized from dredging plans provided by the City of Minneapolis for stages below 810 feet and the LiDAR data for stages above 810 feet. While the Lake package only performs a single water balance for the entire group and returns a single lake stage, the individual pond footprints were assigned separate lakebed leakance terms in order to account for varying degrees of hydraulic connection between each pond and the water table aquifer.

The pipes connecting the ponds are not explicitly represented in the model. Because these pipes remained fully submerged during both 2015-2016 recovery tests, there is no change in their storage that must be accounted for in the model. Therefore, the assumption of a single lake is valid.

Lake Nokomis, Powderhorn Lake, and Diamond Lake were also represented in the model using the Lake package. Insufficient information was available to simulate Taft and Mother Lakes using the Lake package

Lake Hiawatha and Minnehaha Creek are represented using the MODFLOW River package. Each River cell is assigned a stage and a conductance; the latter controls how much water can pass between the River cell and the adjacent aquifer and can simulate the effects of low-permeability lakebed sediments. Lake Hiawatha stages measured by the transducer installed near the lift station were used in the model. River cells representing Minnehaha Creek were assigned elevations from the Hennepin County LiDAR data. Lake Hiawatha is represented by River cells in both Layers 1 and 2 of the model; the berm along the western shore of Lake Hiawatha is represented in the model by a thin strip of active cells in Layer 1 between the River cells representing Lake Hiawatha and the Lake cells representing the golf course. Minnehaha Creek is represented in Layer 2 of the model only.



GROUNDWATER MODEL DOMAIN
Hiawatha Golf Course
Minneapolis Park
& Recreation Board

FIGURE 18

Barr Footer: ArcGIS 10.4.1, 2017-02-21 16:03 File: I:\Projects\23\27\1466\Maps\Reports\2017 Tech Memo\Figure 18 - Model Domain.mxd User: akj

10.3 Groundwater Model Calibration

Groundwater model calibration involves changing model parameters until the model acceptably matches observed conditions. In this case, the model calibration consisted of two parts:

1. Steady-state calibration to match average observed 2016 water levels in the course ponds, monitoring wells, and nearby lakes.
2. Transient calibration to match the observed water levels in the ponds, monitoring wells, and piezometers during the two 2015-2016 recovery tests.

10.3.1 Steady-State Calibration

The steady-state calibration simulated average conditions from January 9, 2016 through January 13, 2017. The starting date is when the lift station resumed regular operation following the second 2015 recovery test. The end date corresponds to the most recent flow meter totalizer readings. A total of 308,668,436 gallons of water were pumped by the lift station from 9:00 am on January 9, 2016 to 1:27 pm on January 13, 2017. This total includes both groundwater and stormwater pumped by the lift station. The groundwater model only simulates the groundwater component of this total, so the stormwater component must be removed from the total volume before calculating the golf course groundwater pumping rate for use in the model. The estimated stormwater runoff volume for the calibration period was 66 million gallons from January 9, 2016 to January 13, 2017 (Section 9.2). This estimated stormwater volume was then subtracted from the metered pumped volume and divided by the time interval to obtain a groundwater pumping rate of 455 gpm for use in the steady-state model.

Average water levels in MW-1, MW-2, MW-3, and MW-4 were calculated from the transducer data collected over the same time interval as the pumping rate averaging. Water level data was not available for this entire time interval for the course ponds, so a correlation between water levels in MW-2 and Pond D was developed from simultaneous measurements from the fall 2015 – winter 2016 monitoring. This correlation was then used to estimate an average water level for the course ponds from the complete MW-2 data record. The average Lake Hiawatha stage of 812.9 ft NAVD88, calculated from the transducer data, was assigned to the Lake Hiawatha River cells in the steady-state model.

MPRB supplied 2016 lake level data in NGVD29 for Lake Nokomis, Powderhorn Lake, and Diamond Lake. Averages of the 2016 data were calculated for each lake and then converted to NAVD88 for use as calibration targets. Water levels for Taft Lake and Mother Lake were obtained from the Hennepin County LiDAR.

10.3.2 Transient Calibration

The first 2015 recovery test was simulated using three “stress periods” in MODFLOW. The first stress period consisted of a steady-state model run to establish the observed initial conditions. The lift station pumping rate in this first stress period was treated as an unknown to be adjusted in the calibration in order to arrive at the correct water level starting point for the test. The recovery test itself was represented with two transient stress periods: the second stress period represented the period from December 9-12, 2015 when both pumps were off and the third stress period represented the period from December 12-14, 2015 when both pumps were operational at an average combined rate of 1,460 gpm. The end time of the second stress period was chosen just before a rainfall event on December 14, 2015 that noticeably impacted measured water levels in the wells and ponds. The Lake Hiawatha stage used in the modeled first recovery test was 813.9 feet NAVD88.

The second recovery test was simulated using five stress periods. The first stress period consisted of a steady-state model run to establish the observed initial conditions. As with the simulated first recovery test, the lift station pumping rate in this first stress period was treated as an unknown to be adjusted in the calibration. The recovery test was simulated with four transient stress periods: the second stress period represented the period from December 31, 2015 - January 4, 2016 when both pumps were off, the third stress period represented the period from January 4-6, 2016 when both pumps were operational at an average combined rate of 1,450 gpm, the fourth stress period represented the period from January 6-7, 2016 with no pumping after both pumps had automatically shut off, and the fifth stress period represented the period from January 7-9, 2016 with one pump operational at an average rate of 530 gpm. The Lake Hiawatha stage used in the modeled second recovery test was 811.9 feet NAVD88.

10.3.3 Calibration Procedure

Parameters adjusted in the calibration included the hydraulic conductivity of the aquifer (uniform over the model domain), the aquifer storage parameters (specific storage and specific yield), recharge to the aquifer (uniform over the model domain), River cell conductances, lakebed leakances for each pond, the pre-test steady-state pumping rates in advance of the recovery tests, and net runoff to Lake Nokomis, Powderhorn Lake, and Diamond Lake.

Parameters were adjusted using manual methods and the automated inverse optimization software PEST (Watermark Numerical Computing, 2005; 2009) until a good fit to the observed data was achieved. Figure 19, 20, and Figure 21 show the best matches achieved during the calibration between observed and simulated water levels for the steady-state calibration, the first 2015 recovery test, and the second 2015 recovery test, respectively. Table 8 below shows the corresponding model parameters.

Table 8 Calibrated Model Parameters

Parameter	Value	Units
Hydraulic Conductivity	33	Feet/day
Vertical Anisotropy	62	dimensionless
Specific Storage	4e-3	1/feet
Specific Yield	0.07	Dimensionless
Steady-state 2016 Recharge	0.0	Inches/year
Recharge during recovery tests	0.0	Inches/year
Ponds A, E, F Lakebed Leakance	0.05	1/day
Ponds B, C, D Lakebed Leakance	790	1/day
Lake Hiawatha River Cell Conductance	0.27	$Feet^2/day$
Minnehaha Creek River Cell Conductance	10,800	$Feet^2/day$
Pre-first recovery test pumping rate	440	Gallons/minute
Pre-second recovery test pumping rate	350	Gallons/minute
Net Runoff to Lake Nokomis[1]	4.6	Inches/year
Net Runoff to Powderhorn Lake[2]	8.1	Inches/year
Net Runoff to Diamond Lake[2]	2.6	Inches/year

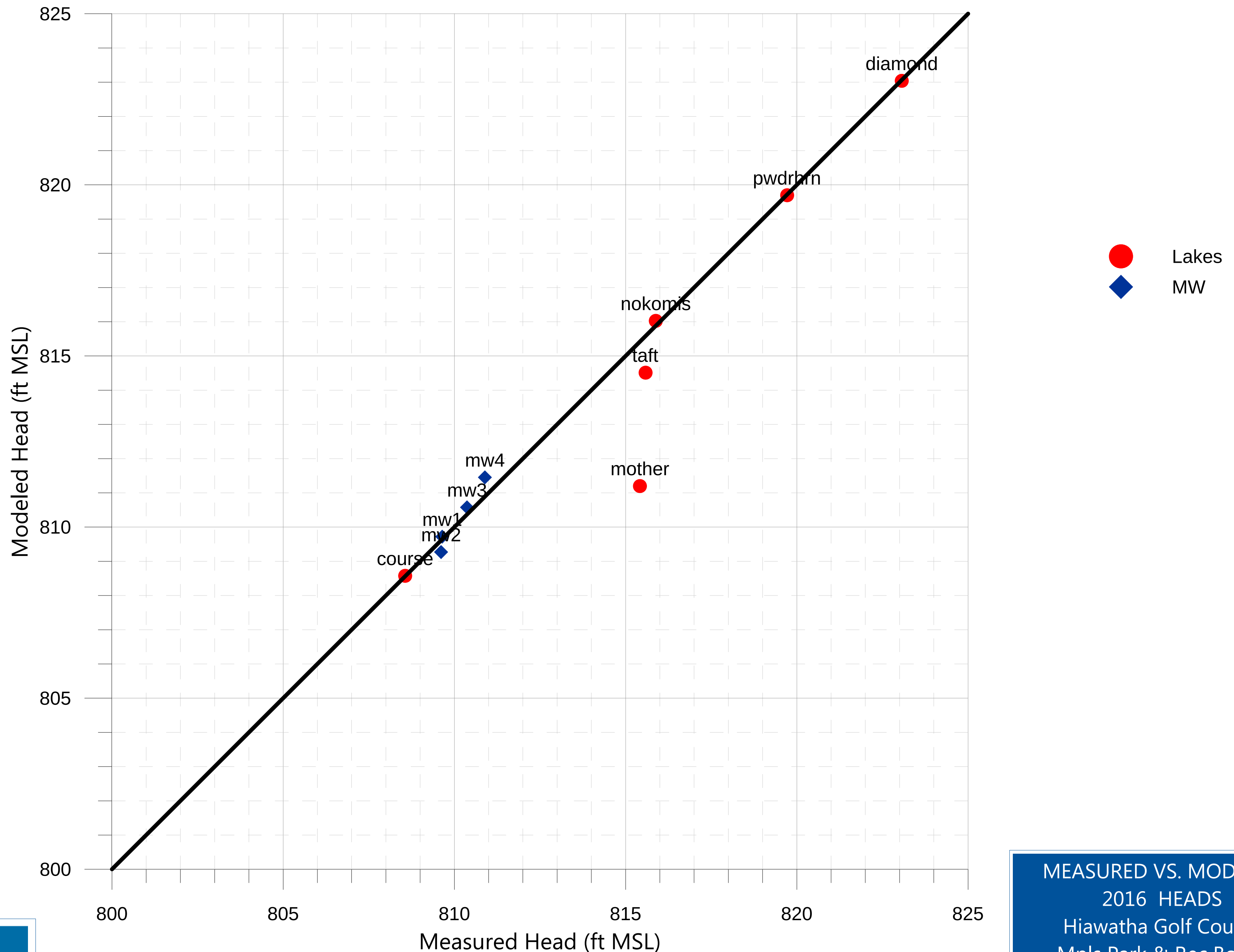
[1] Assuming 2,634-acre watershed (Emmons & Olivier, 2011)

[2] Assuming 286-acre watershed (City of Minneapolis Public Works, 2006)

[3] Assuming 685-acre watershed (City of Minneapolis Public Works, 2006)

The four monitoring wells were screened in fine- to medium-grained sand beneath variable thicknesses of peat – no peat at MW-2 up to approximately 20 feet of peat at MW-4. The calibrated hydraulic conductivity of 33 feet per day is reasonable for the sand.

Ponds A, E, and F have recently been dredged while Ponds B, C, and D have not. The calibrated model lakebed leakances are consistent with the dredging; the dredged ponds A, E, and F have excellent hydraulic connection with the unconsolidated aquifer while the undredged ponds B, C, and D are much less connected.

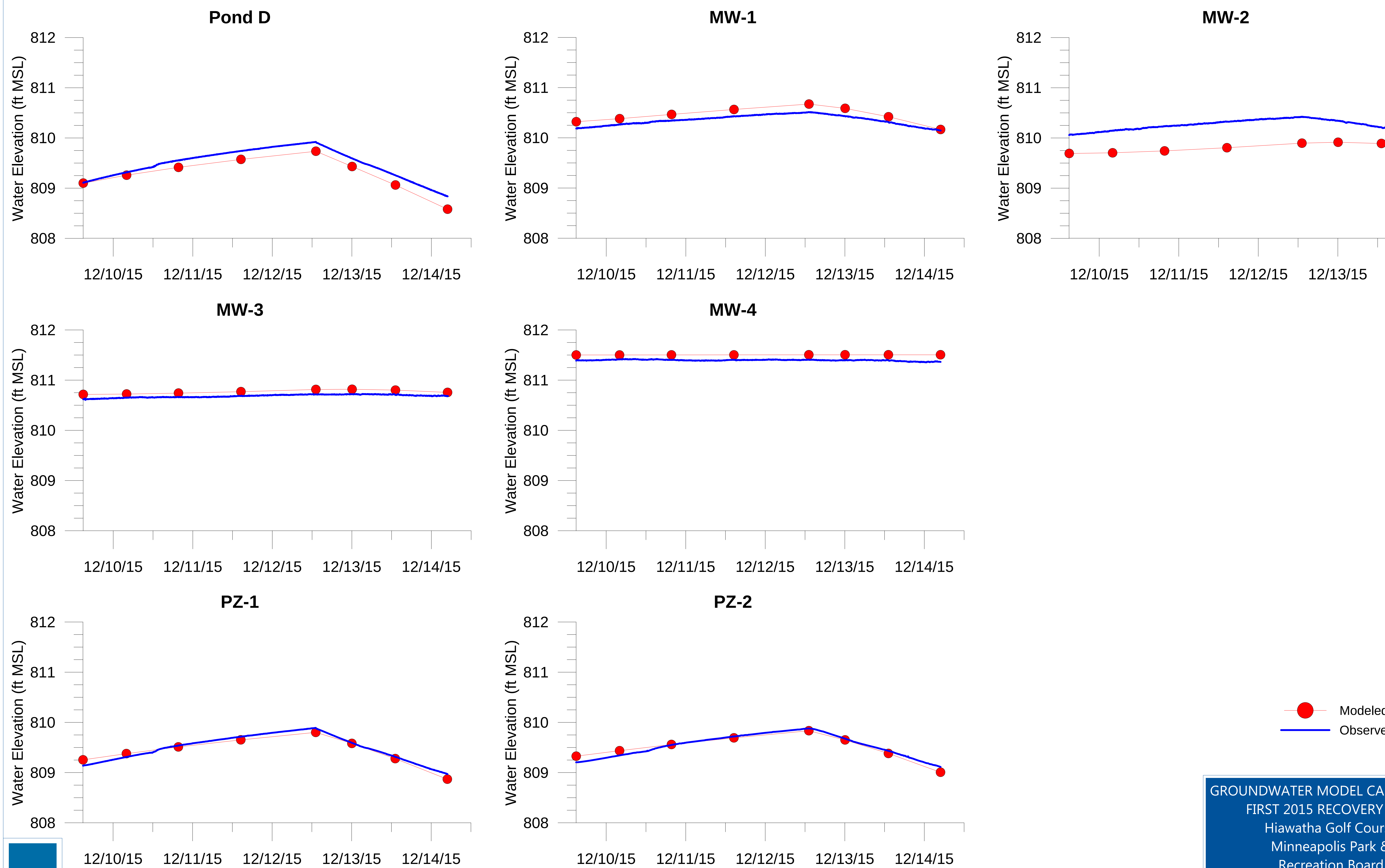


MEASURED VS. MODELED
2016 HEADS
Hiawatha Golf Course
Mpls Park & Rec Board

FIGURE 19

BARR

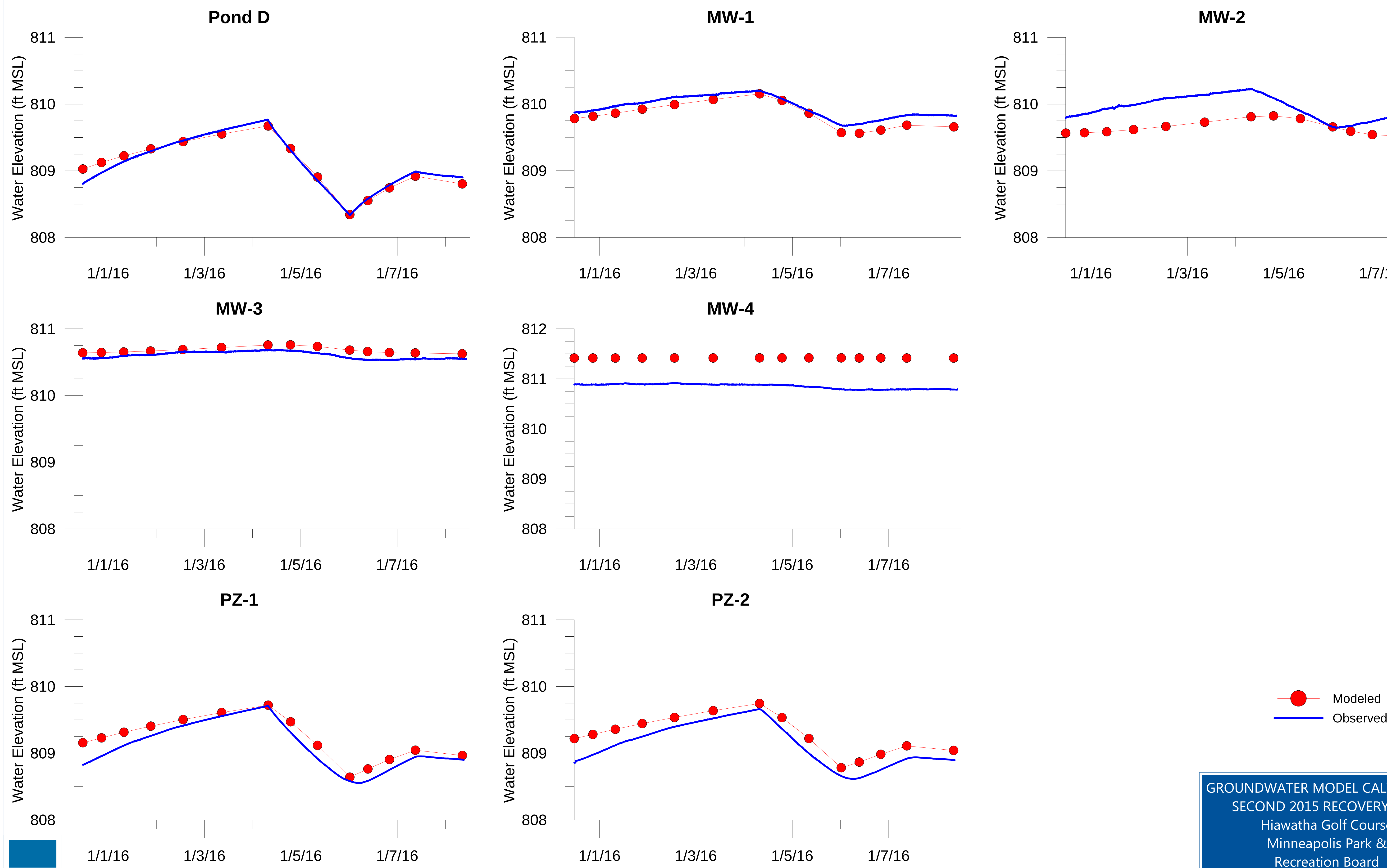
P:\Mpls\23 MN\27\23271466 Hiawatha Golf Course Analyses\WorkFiles\2017Scope\TechnicalMemo\Figures\Draft\grapher\Figure 19 - Hiawatha Steady State Calibration.grf



GROUNDWATER MODEL CALIBRATION
FIRST 2015 RECOVERY TEST
Hiawatha Golf Course
Minneapolis Park &
Recreation Board

FIGURE 20

P:\Mpls\23 MN\27\23271466 Hiawatha Golf Course Analyses\WorkFiles\2017Scope\TechnicalMemo\Figures\Draft\grapher\Figure 20 - Hiawatha First Test Calibration.grf



GROUNDWATER MODEL CALIBRATION
SECOND 2015 RECOVERY TEST
Hiawatha Golf Course
Minneapolis Park &
Recreation Board

FIGURE 21

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P:\Mpls\23 MN\27\23271466 Hiawatha Golf Course Analyses\WorkFiles\2017Scope\TechnicalMemo\Figures\Draft\grapher\Figure 21 - Hiawatha Second Test Calibration.grf

The calibrated River cell conductance values suggest that Lake Hiawatha has a weaker hydraulic connection to the unconsolidated aquifer than does Minnehaha Creek. It is physically plausible that fine-grained, low-conductivity sediments from Minnehaha Creek and storm sewers have accumulated on the bed of Lake Hiawatha over the years. Such sediments would add resistance to flow between the lake and the aquifer.

Natural lakes in Minnesota are often surface expressions of the water table. Assuming that direct precipitation over the lake is balanced by evaporation from the lake (a reasonable assumption for this part of the country), a groundwater flow model that accurately represents the regional groundwater flow field should also be able to match observed lake levels. The urban lakes of South Minneapolis, however, are not natural lakes because their levels are managed by outlet structures and because they receive significant stormwater from storm sewers and/or direct runoff from urbanized, highly impervious watersheds. This human interaction justifies the addition of nonzero net runoff to Lake Nokomis, Powderhorn Lake, and Diamond Lake in the calibration in order to raise the modeled lake levels to match the observed lake levels. While the data necessary to accurately quantify surface water inflows and outflows to Lake Nokomis, Powderhorn Lake, and Diamond Lake are not available, the runoff numbers shown above in Table 8 seem reasonable primarily because they are much less than annual precipitation.

10.4 Existing Pumping Summary

Through the course of the initial investigations of the groundwater conditions at the Hiawatha Golf Course, we helped quantify the existing pumping rates and inflows to the golf course to understand the magnitude of the pumping. We also determined that the pumping of surface groundwater from the golf course to Lake Hiawatha was not impacting the deep groundwater aquifers in the region, but rather, just recirculating the surface groundwater inflows from the golf course ponds to Lake Hiawatha and back. Although energy intensive, the existing pumping is likely having minimal ecological impact.

On an annual basis, this excessive pumping is due to regional groundwater inflows (~50%), inflow from Lake Hiawatha where lake levels are above the existing golf course pond elevations (~30%), and a stormwater diversion project to the golf course from the neighborhood to the west (~20%).

As discussed above in Section 10.3.1, total pumping from the Hiawatha Golf Course from January 9, 2016 to January 13, 2017 was approximately 309 million gallons, of which 66 million gallons was estimated to be stormwater and 243 million gallons was estimated to be groundwater.

10.5 Future Pumping Analysis

The calibrated 2017 groundwater model was used to run a series of twelve steady-state future pumping scenarios. Four general conditions were each simulated for three different Lake Hiawatha levels derived from the analysis of lake water level data described above in Section 4: a high-water elevation of 814.1 ft NGVD29, a typical water elevation of 812.8 ft NGVD29, and a low-water elevation of 811.8 ft NGVD29.

Channel improvements in Minnehaha Creek downstream of Lake Hiawatha would be required to maintain the OHWL of Lake Hiawatha at the 811.8 ft NGVD29 elevation. Table 9 below summarizes the forward scenario definitions.

Table 9 Future Pumping Scenario Definitions

Scenario	Lake Hiawatha Elevation (ft NGVD29)	Conditions
1	814.1	Existing conditions, golf course ponds maintained at approximately 808.5 – 809 ft NGVD29
2	812.8	
3	811.8	
4	814.1	No groundwater pumping, berm between golf course and Lake Hiawatha remains in place, stormwater pumping required
5	812.8	
6	811.8	
7	814.1	Berm remains in place, pumping near Longfellow Ave to protect basements, stormwater pumping required
8	812.8	
9	811.8	
10	814.1	Gravity connection between course and Lake Hiawatha (i.e., berm removed – no stormwater pumping required), pumping near Longfellow Ave to protect basements
11	812.8	
12	811.8	

For the scenarios with pumping near Longfellow Avenue to protect nearby basements (scenarios 7-12), the second-lowest basement, 4354 19th Avenue, was used as the limiting case for determining necessary pumping rates in this area. The basement containing the sport court, 4432 Longfellow Avenue, was not used as the limiting case due to its greater depth than typical basements in the area. The limiting basement elevation used in the modeling (812.4 ft NGVD29) was determined from the surveyed basement floor elevation at 4354 19th Avenue (812.9 ft NGVD29) minus freeboard of 0.5 feet (6.0 inches). This freeboard number is based on the average capillary fringe thicknesses for sand and sandy clay soils of 12.1 cm (4.7 inches) and 15.3 cm (6.0 inches), respectively (Dingman, 2008). According to field observations during the monitoring well installation and review of the City of Minneapolis sewer plats, the soils around the low area to the west of the golf course are typically sands overlying peat.

The pumping near Longfellow Avenue in scenarios 7-12 was assumed to use an L-shaped tile drain extending parallel to Longfellow Avenue from approximately 4450 Longfellow Avenue north to the intersection with 44th Street and thence parallel to 44th Street east to the intersection with 19th Avenue.

Preliminary evaluation of alternative pumping methods, including vertical wells and longer tile drains, indicated that the chosen configuration would be most efficient for protecting multiple basements in this area. The necessary drain tile elevation was determined for each scenario as part of the analysis and these values are included in Table 10 with the scenario results.

For the purposes of estimating total pumping rates (i.e., groundwater and surface water together), stormwater pumping of 66 million gallons per year, an estimate based on 2016 conditions, was assumed for scenarios 1-9. It is assumed that no pumping of stormwater would be required for scenarios 10-12 because without the berm in place the stormwater would drain by gravity to the lake.

Table 10 summarizes the results of the future pumping scenarios. Modeled groundwater levels presented with red text and shading are above the surveyed basement elevations minus six inches of freeboard (see Section 7.0) and therefore indicate homes where basement flooding is a concern. The results of scenarios 4-6 illustrate that multiple basements may experience flooding if there is no groundwater pumping in the area. All other scenarios are protective of all of the surveyed basements except the one containing the sport court (4432 Longfellow Avenue).

The scenarios with the gravity connection between the course and Lake Hiawatha (scenarios 10-12) tend to result in the lowest total pumping rates of the reduced pumping scenarios since the stormwater component of the total no longer needs to be pumped up into the lake. However, the groundwater pumping rates for scenarios 10 and 11 are higher than those for scenarios 7 and 8 since water levels on the former golf course are higher in scenarios 10 and 11.

Table 10 Future Pumping Scenario Results

Description			Existing Conditions			No Pumping			Golf Course at 812.8 NGVD29, Longfellow Drain Active			Berm Removed, Longfellow Drain Active		
Scenario			1	2	3	4	5	6	7	8	9	10	11	12
			Groundwater Pumping Rates (gpm)											
Golf Course Groundwater Pumping Rate			521	460	419	0	0	0	0	0	0	0	0	0
Longfellow Drain Groundwater Pumping Rate			0	0	0	0	0	0	107	77	50	264	124	23
Total Groundwater Pumping Rate			521	460	419	0	0	0	107	77	50	264	124	23
			Drain Elevation (ft NGVD29)											
Drain Elevation			--	--	--	--	--	--	812.3	812.3	812.4	812.0	812.2	812.4
			Annual Pumping Volumes (MG)											
Golf Course Groundwater Pumping			274	242	220	0	0	0	0	0	0	0	0	0
Longfellow Drain Groundwater Outflow			0	0	0	0	0	0	56	40	26	139	65	12
Stormwater Pumping			66	66	66	66	66	66	66	66	66	0	0	0
Total Pumping			340	308	286	66	66	66	122	106	92	139	65	12
			Lake Water Levels (ft NGVD29)											
Lake Hiawatha			814.1	812.8	811.8	814.1	812.8	811.8	814.1	812.8	811.8	814.1	812.8	811.8
Course Ponds			808.4	808.4	808.4	813.1	812.7	812.4	812.7	812.4	812.1	814.1	812.8	811.8
Lake Nokomis			815.7	815.8	815.8	815.6	815.8	815.8	815.7	815.8	815.8	815.6	815.8	815.8
Powderhorn Lake			819.5	819.5	819.5	820.3	820.2	820.1	820.0	820.0	820.0	820.2	820.1	820.0
Diamond Lake			822.8	822.8	822.8	822.8	822.8	822.8	822.8	822.8	822.8	822.8	822.8	822.8
Taft Lake			814.2	814.3	814.3	814.2	814.3	814.3	814.2	814.3	814.3	814.2	814.3	814.3
Mother Lake			810.9	811.0	811.0	810.9	811.0	811.0	810.9	811.0	811.0	810.9	811.0	811.0
Address	**Basement Elevation (ft NGVD29)**	**Basement Elev. Minus Freeboard**	**Groundwater Elevations Below Surveyed Basements (ft NGVD29)**											
4354 Longfellow Ave	814.6	814.1	810.9	810.9	810.8	814.0	813.7	813.4	812.7	812.7	812.7	812.7	812.7	812.7
4400 Longfellow Ave	813.7	813.2	810.8	810.8	810.8	814.0	813.7	813.4	812.6	812.6	812.6	812.5	812.6	812.7
4406 Longfellow Ave	814.0	813.5	810.8	810.8	810.8	813.9	813.6	813.3	812.5	812.6	812.6	812.4	812.5	812.6
4432 Longfellow Ave	810.8	810.3	810.7	810.7	810.7	813.8	813.5	813.2	812.5	812.5	812.5	812.3	812.4	812.6
4434 Longfellow Ave	816.1	815.6	810.7	810.7	810.7	813.8	813.5	813.2	812.5	812.5	812.5	812.3	812.5	812.6
4446 Longfellow Ave	817.9	817.4	810.7	810.8	810.7	813.7	813.5	813.2	812.5	812.5	812.6	812.4	812.5	812.6
4454 Longfellow Ave	819.0	818.5	810.8	810.8	810.8	813.7	813.4	813.2	812.6	812.6	812.6	812.6	812.6	812.6
4250 21st Avenue	820.6	820.1	810.6	810.5	810.4	813.6	813.3	812.9	813.1	812.8	812.6	813.9	813.1	812.5
4254 21st Avenue	819.4	818.9	810.6	810.4	810.3	813.6	813.2	812.9	813.0	812.8	812.6	813.9	813.0	812.4
4255 19th Avenue	823.1	822.6	811.0	811.0	810.9	814.0	813.7	813.4	813.3	813.1	813.0	813.8	813.3	812.9
4255 20th Avenue	818.3	817.8	810.7	810.6	810.5	813.8	813.4	813.1	813.1	812.9	812.8	813.9	813.1	812.6
4300 19th Avenue	832.7	832.2	811.0	811.0	810.9	814.0	813.7	813.4	813.2	813.1	813.0	813.7	813.2	812.9
4310 19th Avenue	820.3	819.8	810.8	810.8	810.7	813.9	813.6	813.3	813.1	813.0	812.9	813.6	813.1	812.8
4316 19th Avenue	819.7	819.2	810.7	810.7	810.7	813.9	813.6	813.3	813.1	813.0	812.9	813.5	813.1	812.8
4340 19th Avenue	814.2	813.7	810.2	810.2	810.1	813.7	813.4	813.1	812.7	812.6	812.6	813.1	812.7	812.5
4354 19th Avenue	812.9	812.4	810.0	810.0	810.0	813.6	813.3	813.0	812.4	812.4	812.4	812.4	812.4	812.3

11.0 Regulatory Implications

11.1 Wetland Delineation

On November 7, 2014, Kjolhaug Environmental Services completed a wetland delineation on the Hiawatha Golf Course site for the MPRB. This wetland delineation was reviewed by the Technical Evaluation Panel (TEP) on September 9, 2015 and follow-up on several wetlands was completed. The final wetland delineation report was submitted on November 25, 2015 along with a December 9, 2015 addendum showing the revised wetland boundaries. A Notice of Decision as issued on December 18, 2015.

Through this process, 16 wetlands were delineated within the Hiawatha Golf Course area and along the Lake Hiawatha shoreline. However, several of the wetlands (Wetlands 1-4 and 6-12) were determined to be created from nonwetland for nonwetland purposes and are considered incidental (nonregulated) under the Wetland Conservation Act (WCA).

Figure 22 shows the final wetland delineation, wetland type, and if the wetland is nonregulated based on the wetland delineation process outlined above for the Hiawatha Golf Course area.

11.2 Federal Emergency Management Agency (FEMA) Floodplain

The Hiawatha Golf Course is located in the one percent (1%, 100-yr) chance flood FEMA-mapped floodplain for Minnehaha Creek. The FEMA maps effective as of November 4, 2016 show the flood elevation as 817.0 ft NGVD29. At this elevation, the berm separating the golf course from Lake Hiawatha would overtop and the entire golf course would be inundated.

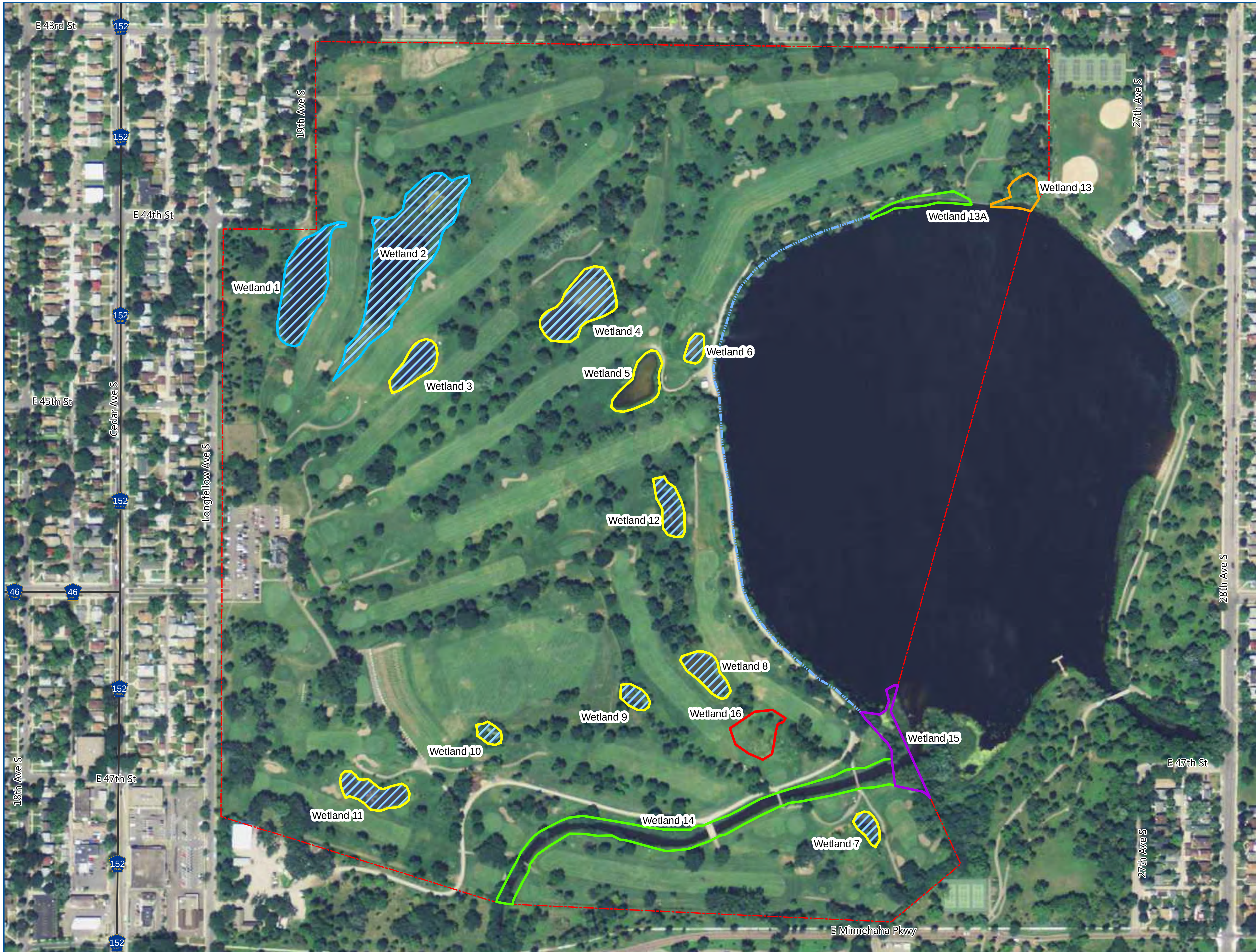
Figure 23 shows the effective FEMA-mapped floodplain for Minnehaha Creek, Lake Hiawatha, and the Hiawatha Golf Course.

11.3 Minnesota Department of Natural Resources (MnDNR) Water Appropriations

The MPRB currently has an existing Minnesota Department of Natural Resources (MnDNR) appropriations permit that only allows for the pumping of 36.5 million gallons per year from the surface ponds for irrigation.

The MPRB also has a 2.0 million gallons per year appropriations permit to pull from the deep irrigation well in the Prairie du Chien aquifer; however, the golf course has historically not pumped from this well.

The MPRB has had conversations with MnDNR staff regarding the magnitude of pumping at the Hiawatha Golf Course and the exceedance of permitted volumes. The MnDNR recognized that the MPRB is working to find a solution to the groundwater and surface water management issues and recommended the MPRB to continue pumping at existing rates until a long-term solution has been identified.



Wetland Type

- Type 1
- Type 2
- Type 3
- Type 3/5
- Type 3/6
- Type 5
- Incidental (Not Regulated by WCA)
- Lake Edge
- Wetland Delineation Boundary[1]

[1] Wetland delineation by Kjolhaug Environmental Service Company approved in 2015.

0 150 300 450 600

Feet

WETLAND DELINEATION SUMMARY
Hiawatha Golf Course
Minneapolis Park & Recreation Board

FIGURE 22

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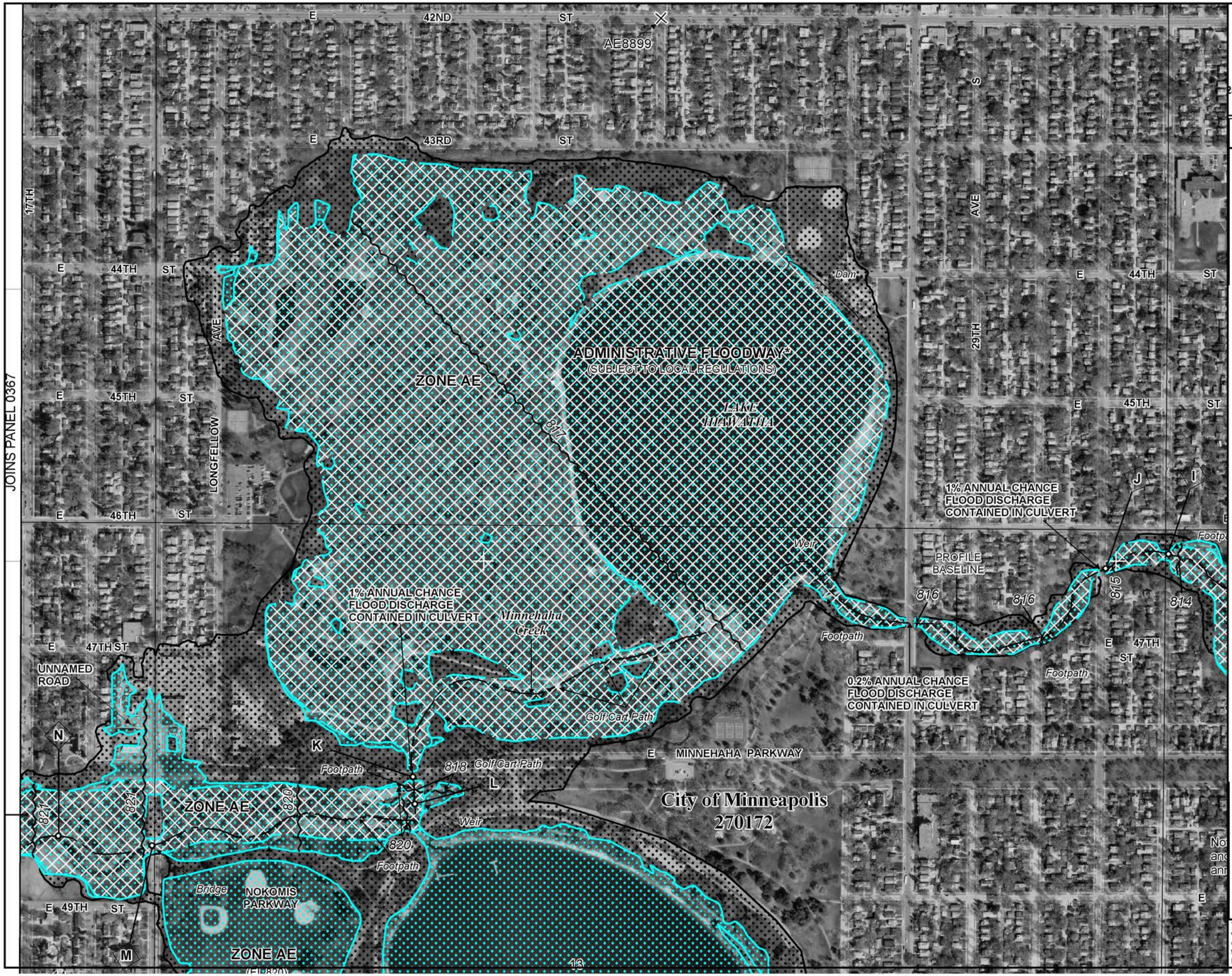

MAP SCALE 1" = 500'

250 0 500 1000 FEET

METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0386F

FIRM

FLOOD INSURANCE RATE MAP

HENNEPIN COUNTY, MINNESOTA

(ALL JURISDICTIONS)

PANEL 386 OF 500

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
MINNEAPOLIS, CITY OF	270172	0386	F

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER 27053C0386F

MAP REVISED NOVEMBER 4, 2016

Federal Emergency Management Agency

FIGURE 23

FEMA-MAPPED FLOODPLAIN
Hiawatha Golf Course
Minneapolis Park & Recreation Board

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

12.0 Future Projects

Additionally, there are existing flooding issues in the larger watershed adjacent to the golf course. The City is looking at flood mitigation opportunities including creation of an open channel though the golf course area as a means to alleviate some of the localized surface flooding in the nearby watershed. Depending on the future of this area, the Minnehaha Creek Watershed District has expressed interest in the opportunity to realign Minnehaha Creek to its historic location (within the existing golf course).

13.0 References

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Attachment A – Well Construction Records

Barr

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes, Chapter 103I

MINNESOTA UNIQUE WELL AND BORING NO. **804420**

WELL OR BORING LOCATION

County Name: Hennepin

Township Name	Township No.	Range No.	Section No.	Fraction
Minneapolis	28N	24W	12	NE ¼ SE ¼ SW ¼

GPS LOCATION: Latitude ___ degrees ___ minutes ___ seconds ___
Longitude ___ degrees ___ minutes ___ seconds ___

House Number, Street Name, City, and ZIP Code of Well Location: 4553 Longfellow Ave S, Minneapolis 55407

Show exact location of well/boring in section grid with "X." (N, S, E, W; ½ Mile; 1 Mile) X

Sketch map of well/boring location. Showing property lines, roads, buildings, and direction.

MW-1

see attached map

PROPERTY OWNER'S NAME/COMPANY NAME: Minneapolis Park & Recreation Board

Property owner's mailing address if different than well location address indicated above.
Attn: Michael Schroeder
2117 W River Rd N
Minneapolis, MN 55411

WELL OWNER'S NAME/COMPANY NAME: Minneapolis Park & Recreation Board

Well/boring owner's mailing address if different than property owner's address indicated above.

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
top soil	black		0	2
peet & clay	black		2	10
sand	gray		10	30

Use a second sheet, if needed.

REMARKS, ELEVATION, SOURCE OF DATA, etc.

WELL/BORING DEPTH (completed): 30 ft.

DATE WORK COMPLETED: Oct. 29, 2015

DRILLING METHOD: ☐ Cable Tool ☐ Driven ☒ Auger ☐ Rotary ☐ Other

DRILLING FLUID: —

WELL HYDROFRACTURED? ☐ Yes ☒ No From ___ ft. To ___ ft.

USE: ☐ Domestic ☒ Monitoring ☐ Heating/Cooling ☐ Noncommunity PWS ☐ Environ. Bore Hole ☐ Industry/Commercial ☐ Community PWS ☐ Irrigation ☐ Remedial ☐ Elevator ☐ Dewatering ☐ ___

CASING MATERIAL: ☐ Steel ☒ Plastic — Drive Shoe? ☐ Yes ☒ No — ☐ Threaded ☐ Welded ☐ ___

HOLE DIAM.

CASING Diameter		Weight	Specifications	HOLE DIAM.
2 in.	To 20 ft.	lbs./ft.		8½ in. To 30 ft.
in.	To ft.	lbs./ft.		in. To ft.
in.	To ft.	lbs./ft.		in. To ft.

SCREEN: Make Johnson; Type PVC; Slot/Gauze 10; Diam. 2"; Length 10'; Set between 20 ft. and 30 ft.; FITTINGS thread

OPEN HOLE: From ___ ft. To ___ ft.

STATIC WATER LEVEL: 9 ft. ☒ Below ☐ Above land surface. Measured from grade. Date measured 10/29/15

PUMPING LEVEL (below land surface): ___ ft. after ___ hrs. pumping 10 g.p.m.

WELLHEAD COMPLETION: ☐ Pitless/adapter manufacturer ___ Model ___ ☒ Casing protection pyramid ☒ ~~12 in.~~ 24" above grade ☐ At-grade ☐ Well House ☐ Hand Pump

GROUTING INFORMATION (specify bentonite, cement-sand, neat-cement, concrete, cuttings, or other)

Material	From	To			
neat cement	0 ft.	15 ft.		2	☐ Yds. ☒ Bags
			ft.		☐ Yds. ☐ Bags
			ft.		☐ Yds. ☐ Bags
Driven casing seal					Bags

NEAREST KNOWN SOURCE OF CONTAMINATION: ___ feet ___ direction ___ type

Well disinfected upon completion? ☐ Yes ☒ No

PUMP: ☒ Not installed Date installed ___
Manufacturer's name ___
Model Number ___ HP ___ Volts ___
Length of drop pipe ___ ft. Capacity ___ g.p.m.
Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐ ___

ABANDONED WELLS: Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

VARIANCE: Was a variance granted from the MDH for this well? ☐ Yes ☒ No TN# ___

WELL CONTRACTOR CERTIFICATION
This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Stevens Drilling & Env. Svc. Inc. — Licensee Business Name — 2255 Lic. or Reg. No.

[signature] ~~Certified~~ Representative Signature — 556 Certified Rep. No. — 11/5/15 Date

Randy Johnson — Name of Driller

IMPORTANT - FILE WITH PROPERTY PAPERS
WELL OWNER COPY

804420

IC 140-0020 HE-01205-14 (Rev. 5/12)

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes, Chapter 103I

MINNESOTA UNIQUE WELL AND BORING NO. 804421

WELL OR BORING LOCATION

County Name: Hennepin

Township Name	Township No.	Range No.	Section No.	Fraction	WELL/BORING DEPTH (completed)	DATE WORK COMPLETED
Minneapolis	28N	24W	12	NW SE ¼ SW ¼	20 ft	Oct 27, 2015

GPS LOCATION: Latitude ____ degrees ____ minutes ____ seconds ____ Longitude ____ degrees ____ minutes ____ seconds ____

House Number, Street Name, City, and ZIP Code of Well Location: 4553 Longfellow Ave S, Minneapolis 55407

Show exact location of well/boring in section grid with "X." Sketch map of well/boring location. Showing property lines, roads, buildings, and direction.

MW-2

N / W / E / S — X — ½ Mile — 1 Mile

see attached map

DRILLING METHOD: ☐ Cable Tool ☒ Auger ☐ Other ☐ Driven ☐ Rotary

DRILLING FLUID: ---

WELL HYDROFRACTURED? ☐ Yes ☒ No From ____ ft. To ____ ft.

USE: ☐ Domestic ☐ Noncommunity PWS ☐ Community PWS ☐ Elevator ☒ Monitoring ☐ Environ. Bore Hole ☐ Irrigation ☐ Dewatering ☐ Heating/Cooling ☐ Industry/Commercial ☐ Remedial ☐ ____

CASING MATERIAL: ☐ Steel ☒ Plastic ☐ — Drive Shoe? ☐ Yes ☒ No ☒ Threaded ☐ Welded

CASING Diameter	Weight	Specifications	HOLE DIAM.
2 in. To 10 ft.	lbs./ft		8¼ in. To 20 ft.
in. To ft.	lbs./ft.		in. To ft.
in. To ft.	lbs./ft.		in. To ft.

PROPERTY OWNER'S NAME/COMPANY NAME

Minneapolis Park & Recreation Board

Property owner's mailing address if different than well location address indicated above.

Attn: Michael Schroeder
2117 W River Rd N
Minneapolis, MN 55411

SCREEN — Make: Johnson; Type: PVC; Diam.: 2"; Slot/Gauze: 10; Length: 10'; Set between 10 ft. and 20 ft.; FITTINGS: thread

OPEN HOLE: From ____ ft. To ____ ft.

STATIC WATER LEVEL: 6 ft. ☒ Below ☐ Above land surface. Measured from: grade. Date measured: 10/27/15

PUMPING LEVEL (below land surface): ____ ft. after ____ hrs. pumping 10 g.p.m.

WELL OWNER'S NAME/COMPANY NAME

Minneapōlis Park & Recreation Board

Well/boring owner's mailing address if different than property owner's address indicated above.

WELLHEAD COMPLETION: ☐ Pitless/adapter manufacturer ____ Model ____ ☒ Casing protection: pyramid — ~~12~~ 24" in. above grade ☐ At-grade ☐ Well House ☐ Hand Pump

GROUTING INFORMATION (specify bentonite, cement-sand, neat-cement, concrete, cuttings, or other)

Material	From	To		Yds./Bags
neat cement	0	6 ft.	1	☐ Yds. ☒ Bags
		ft.		☐ Yds. ☐ Bags
		ft.		☐ Yds. ☐ Bags

Driven casing seal From ____ To ____ Bags

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
top soil	black		0	1
sand	gray		1	20

Use a second sheet, if needed.

NEAREST KNOWN SOURCE OF CONTAMINATION: ____ feet ____ direction ____ type

Well disinfected upon completion? ☐ Yes ☒ No

PUMP: ☒ Not installed Date installed ____
Manufacturer's name ____
Model Number ____ HP ____ Volts ____
Length of drop pipe ____ ft. Capacity ____ g.p.m.
Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐ ____

ABANDONED WELLS: Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

VARIANCE: Was a variance granted from the MDH for this well? ☐ Yes ☒ No TN# ____

REMARKS, ELEVATION, SOURCE OF DATA, etc.

WELL CONTRACTOR CERTIFICATION

This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Stevens Drilling & Env. Svc. Inc. — Licensee Business Name; 2255 — Lic. or Reg. No.

[signature] — Certified Representative Signature; 556 — Certified Rep. No.; 11/6/15 — Date

Randy Johnson — Name of Driller

IMPORTANT - FILE WITH PROPERTY PAPERS
WELL OWNER COPY

804421

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
Minnesota Statutes, Chapter 103I

MINNESOTA UNIQUE WELL AND BORING NO. 804422

WELL OR BORING LOCATION

County Name: Hennepin

Township Name	Township No.	Range No.	Section No.	Fraction
Minneapolis	28N	24W	12	NW ¼ SW ¼ SW ¼

GPS LOCATION: Latitude ____ degrees ____ minutes ____ seconds ____
Longitude ____ degrees ____ minutes ____ seconds ____

House Number, Street Name, City, and ZIP Code of Well Location: 4553 Longfellow Ave S, Minneapolis 55407

Show exact location of well/boring in section grid with "X." Sketch map of well/boring location. Showing property lines, roads, buildings, and direction.

MW-3

N, W, E, S, X, ½ Mile, 1 Mile

see attached map

WELL/BORING DEPTH (completed): 25 ft

DATE WORK COMPLETED: Oct 29, 2015

DRILLING METHOD: ☐ Cable Tool ☒ Auger ☐ Other ☐ Driven ☐ Rotary

DRILLING FLUID: ——

WELL HYDROFRACTURED? ☐ Yes ☒ No From ____ ft. To ____ ft.

USE: ☐ Domestic ☐ Noncommunity PWS ☐ Community PWS ☐ Elevator ☒ Monitoring ☐ Environ. Bore Hole ☐ Irrigation ☐ Dewatering ☐ Heating/Cooling ☐ Industry/Commercial ☐ Remedial ☐ ____

CASING MATERIAL: ☐ Steel ☒ Plastic ☐ ____ Drive Shoe? ☐ Yes ☒ No ☒ Threaded ☐ Welded

HOLE DIAM.

CASING Diameter	Weight	Specifications	HOLE DIAM.
2 in. To 15 ft.	____ lbs./ft.		8¼ in. To 25 ft.
____ in. To ____ ft.	____ lbs./ft.		____ in. To ____ ft.
____ in. To ____ ft.	____ lbs./ft.		____ in. To ____ ft.

SCREEN
Make: Johnson
Type: PVC Diam.: 2"
Slot/Gauze: 10 Length: 10'
Set between 15 ft. and 25 ft. FITTINGS: thread

OPEN HOLE: From ____ ft. To ____ ft.

STATIC WATER LEVEL: 5 ft. ☒ Below ☐ Above land surface Measured from: grade Date measured: 10/29/15

PUMPING LEVEL (below land surface): ____ ft. after ____ hrs. pumping 15 g.p.m.

PROPERTY OWNER'S NAME/COMPANY NAME
Minneapolis Park & Recreation Board

Property owner's mailing address if different than well location address indicated above.
Attn: Michael Schroeder
2117 W River Rd N
Minneapolis, MN 55411

WELL OWNER'S NAME/COMPANY NAME
Minneapolis Park & Recreation Board

Well/boring owner's mailing address if different than property owner's address indicated above.

WELLHEAD COMPLETION
☐ Pitless/adapter manufacturer ____ Model ____
☒ Casing protection: pyramid ☒ ~~12~~ 24" in. above grade
☐ At-grade ☐ Well House ☐ Hand Pump

GROUTING INFORMATION (specify bentonite, cement-sand, neat-cement, concrete, cuttings, or other)
Material: neat cement From 0 To 11 ft. 2 ☐ Yds. ☒ Bags
Material ____ From ____ To ____ ft. ____ ☐ Yds. ☐ Bags
Material ____ From ____ To ____ ft. ____ ☐ Yds. ☐ Bags
Driven casing seal From ____ To ____ ____ Bags

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
peat	black		0	13
sand	gray		13	25

Use a second sheet, if needed

REMARKS, ELEVATION, SOURCE OF DATA, etc.

NEAREST KNOWN SOURCE OF CONTAMINATION: ____ feet ____ direction ____ type

Well disinfected upon completion? ☐ Yes ☒ No

PUMP
☒ Not installed Date installed ____
Manufacturer's name ____
Model Number ____ HP ____ Volts ____
Length of drop pipe ____ ft. Capacity ____ g.p.m.
Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐ ____

ABANDONED WELLS
Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

VARIANCE
Was a variance granted from the MDH for this well? ☐ Yes ☒ No TN# ____

WELL CONTRACTOR CERTIFICATION
This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Stevens Drilling & Env. Svc. Inc. — Licensee Business Name
2255 — Lic. or Reg. No.

Certified Representative Signature
556 — Certified Rep. No.
11/6/15 — Date

Randy Johnson — Name of Driller

IMPORTANT - FILE WITH PROPERTY PAPERS
WELL OWNER COPY
804422

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes, Chapter 103I

MINNESOTA UNIQUE WELL AND BORING NO. 804423

WELL OR BORING LOCATION

County Name: Hennepin

Township Name	Township No.	Range No.	Section No.	Fraction
Minneapolis	28N	24W	13	NE NE ¼ NW ¼

GPS LOCATION: Latitude ____ degrees ____ minutes ____ seconds ____ Longitude ____ degrees ____ minutes ____ seconds ____

House Number, Street Name, City, and ZIP Code of Well Location: 4553 Longfellow Ave S, Minneapolis 55407

Show exact location of well/boring in section grid with "X." Sketch map of well/boring location. Showing property lines, roads, buildings, and direction.

N W E S X ½ Mile 1 Mile

MW-4

see attached map

PROPERTY OWNER'S NAME/COMPANY NAME: Minneapolis Park & Recreation Board

Property owner's mailing address if different than well location address indicated above.

Attn: Michael Schroeder
2117 W River Rd N
Minneapolis, MN 55411

WELL OWNER'S NAME/COMPANY NAME: Minneapolis Park & Recreation Board

Well/boring owner's mailing address if different than property owner's address indicated above.

GEOLOGICAL MATERIALS	COLOR	HARDNESS OF MATERIAL	FROM	TO
top soil	black		0	2
peat	black		2	22
sand	gray		22	35

Use a second sheet, if needed.

REMARKS, ELEVATION, SOURCE OF DATA, etc.

WELL/BORING DEPTH (completed): 35 ft

DATE WORK COMPLETED: Oct 26, 2015

DRILLING METHOD: ☐ Cable Tool ☐ Driven ☒ Auger ☐ Rotary ☐ Other

DRILLING FLUID: ---

WELL HYDROFRACTURED? ☐ Yes ☒ No From ____ ft. To ____ ft.

USE: ☐ Domestic ☒ Monitoring ☐ Heating/Cooling ☐ Noncommunity PWS ☐ Environ. Bore Hole ☐ Industry/Commercial ☐ Community PWS ☐ Irrigation ☐ Remedial ☐ Elevator ☐ Dewatering ☐ ____

CASING MATERIAL: ☐ Steel ☒ Plastic ☐ ____ Drive Shoe? ☐ Yes ☒ No ☒ Threaded ☐ Welded

CASING Diameter: 2 in. To 25 ft. ____ lbs./ft. Weight ____ Specifications ____
in. To ____ ft. ____ lbs./ft.
in. To ____ ft. ____ lbs./ft.

HOLE DIAM.: 8¼ in. To 35 ft. ____ in. To ____ ft. ____ in. To ____ ft.

SCREEN Make: Johnson Type: PVC Diam.: 2" Slot/Gauze: 10 Length: 10' Set between 25 ft. and 35 ft. FITTINGS: thread

OPEN HOLE From ____ ft. To ____ ft.

STATIC WATER LEVEL: 11 ft ☒ Below ☐ Above land surface Measured from: grade Date measured: 10/26/15

PUMPING LEVEL (below land surface): ____ ft. after ____ hrs. pumping 10 g.p.m.

WELLHEAD COMPLETION
☐ Pitless/adapter manufacturer ____ Model ____
☒ Casing protection: pyramid ☒ in. above grade
☐ At-grade ☐ Well House ☐ Hand Pump 24"

GROUTING INFORMATION (specify bentonite, cement-sand, neat-cement, concrete, cuttings, or other)
Material: neat cement From 0 To 21 ft. 3 ☐ Yds. ☒ Bags
Material ____ From ____ To ____ ft. ____ ☐ Yds. ☐ Bags
Material ____ From ____ To ____ ft. ____ ☐ Yds. ☐ Bags
Driven casing seal From ____ To ____ ____ Bags

NEAREST KNOWN SOURCE OF CONTAMINATION: ____ feet ____ direction ____ type

Well disinfected upon completion? ☐ Yes ☒ No

PUMP: ☒ Not installed Date installed ____
Manufacturer's name ____
Model Number ____ HP ____ Volts ____
Length of drop pipe ____ ft. Capacity ____ g.p.m.
Type: ☐ Submersible ☐ L.S. Turbine ☐ Reciprocating ☐ Jet ☐ ____

ABANDONED WELLS: Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

VARIANCE: Was a variance granted from the MDH for this well? ☐ Yes ☒ No TN# ____

WELL CONTRACTOR CERTIFICATION
This well was drilled under my supervision and in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

Stevens Drilling & Env. Svc. Inc. — Licensee Business Name
2255 — Lic. or Reg. No.

Certified Representative Signature
556 — Certified Rep. No.
11/6/15 — Date

Randy Johnson — Name of Driller

IMPORTANT - FILE WITH PROPERTY PAPERS
WELL OWNER COPY 804423

IC 140-0020 HE-01205-14 (Rev. 5/12)

Attachment B – Settlement Monitoring

resourceful. naturally.
engineering and environmental consultants

Memorandum

To: Minneapolis Park and Recreation Board
From: Barr Engineering Company
Subject: Geotechnical Engineering Analysis and Settlement Monitoring Plan Alternatives for the Hiawatha Golf Course
Date: February 20, 2017
Project: 23/27-1466.01

1.0 Introduction

The Hiawatha Golf Course area was historically a wetland. The existing 18-hole golf course was created by the Minneapolis Park and Recreation Board (MPRB) in the late 1920's with dredged spoils from the bottom of Lake Hiawatha. Anecdotal evidence indicates that settlement has been an issue for the golf course and for adjacent homes to the west of the golf course.

The following presents our understanding of the geotechnical existing conditions based on the information available to date, a proposed geotechnical analysis plan, proposed monitoring solutions, and a planning level cost estimate for each.

2.0 Existing Conditions

The Hiawatha Golf Course lays over organic deposits. In the late 1920s, area lakes were dredged to deepen them for recreational use (Albrecht, 2008). For Lake Hiawatha, the dredged organic material was placed on the western side, likely on more organic material. It appears the fill soils have had approximately 90 years to consolidate. Figure 1 shows the historic wetland overlaid with the current Hiawatha Golf Course layout.

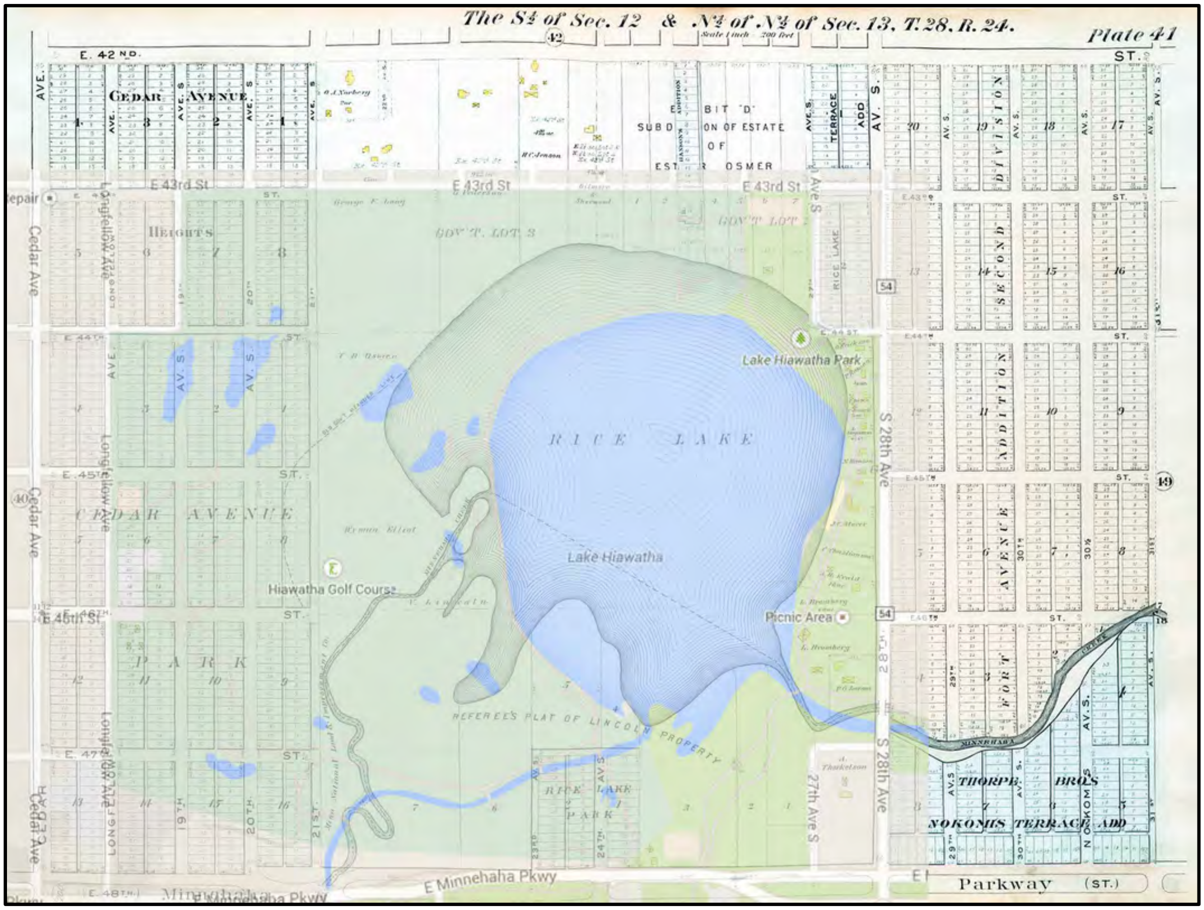
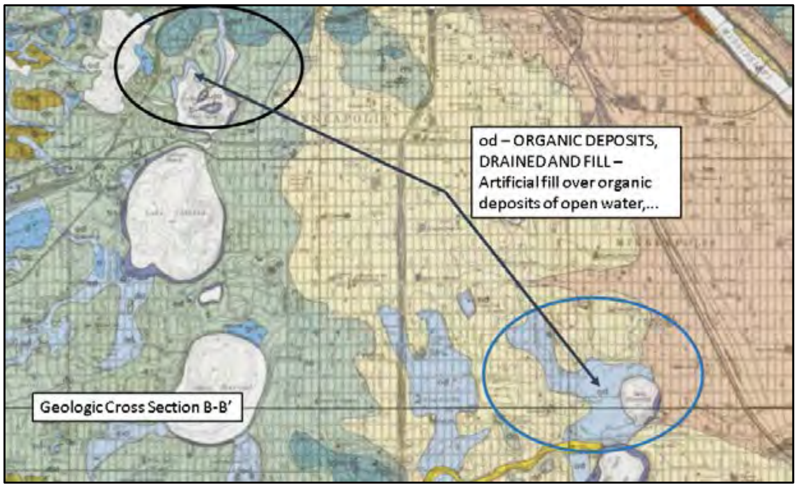


Figure 1 Historic location of Lake Hiawatha (Rice Lake) compared to existing Lake Hiawatha and the Hiawatha Golf Course

Figure 2 is a portion of the quaternary geology for the site (Quaternary Geologic Map of the Minneapolis-St. Paul Urban Area, Gary N. Meyer, 1985). Figure 2 (A) shows organic deposits on the western side of Lake Hiawatha. Figure 2 (B) shows a conceptual cross section from the quaternary map. The conceptual cross section show the thickness of the organic deposit to be less than approximately 25 feet.

The soil observations for three of the four monitoring wells installed in the golf course in 2015 also encountered peat. The well logs show approximately 8 feet of peat below the topsoil in the well location nearest to the berm and Lake Hiawatha (MW-1), approximately 13 feet of peat above sand at the monitoring well closest to Longfellow Avenue and 44th Street (MW-3), and approximately 22 feet of peat at the monitoring well nearest to where Minnehaha Creek currently flows into Lake Hiawatha. However, according to the Minnesota Well Index (MDI), well 482891 (the irrigation well in the Hiawatha Golf Course installed in 1992) shows approximately 70 feet of peat before encountering clay and gravel (https://apps.health.state.mn.us/cwiinfo/index.xhtml?wellId=0000482891).



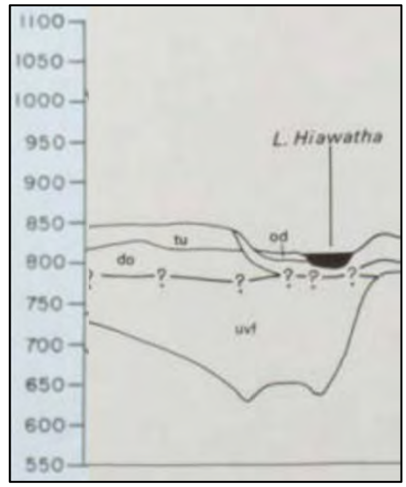


Figure 2 (A) Geologic Map (Left) and (B) Conceptual Cross Section (Right)

No geotechnical testing has been performed on the soils in the Hiawatha Golf Course, including the peat. Although the rate of settlement in peat can vary based on the type of peat and loading changes, settlement in peat over time typically follows the pattern shown in Figure 3 with the primary consolidation happening over a relatively short period of time and continual creep occurring over the long term.

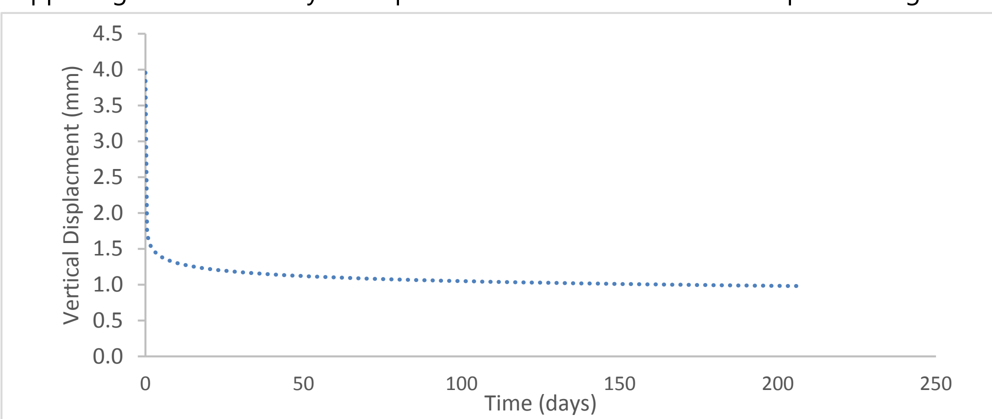


Figure 3 Example Peat Settlement over Time (Ajlouni, 2000)

Given that the golf course was constructed approximately 90 years ago, the rate of settlement happening today in the golf course is likely very slow. If the settlement rate is on the order of ¼ to ½ inch per year, it may be difficult to measure this amount of settlement during a short monitoring period with any monitoring approach.

In the absence of geotechnical information and settlement rates, Figure 2 (A) also shows a similar deposit on the northern shoreline of Lake of the Isles. Lake of the Isles underwent a similar transformation in the early 1900s as well. Similar fill deposits are noted in Figure 2. A geotechnical research paper was written and presented on the geotechnical and instrumentation program completed to remediate ground settlement for the park at Lake of the Isles (Albrecht, 2008). For the Lake of the Isles restoration project, several geotechnical investigations resulted in a total of 87 geotechnical borings ranging in depths of 6 to 61 feet. Hemic peat soil samples collected from the field investigation were tested. Laboratory testing included testing for organic content, consolidation testing, moisture content, and Atterbergs limits (for plasticity). A field testing and monitoring program consisted of in-situ strength testing, electronic (in ground) piezometers, and survey shots on settlement plates. Based on the geotechnical investigation and analyses, a surcharge program was implemented to compact the soils around the edge of the lake. The conclusions of the work were that:

- the time rate of consolidation was actually 2 to 4 times faster in the field than was observed in the laboratory (very fast settlement),
- the secondary compression rates were greater (faster settlement than anticipated), and
- secondary consolidation magnitudes were 4 times greater than expected (up to 10 inches of settlement in some locations).

If the peat in the Hiawatha area is similar to the peat around Lake of the Isles, we would suspect that the primarily consolidation in the Hiawatha golf course also happened rapidly after material was placed and after the golf course was constructed. Primary consolidation is complete and the current rate of settlement (secondary consolidation or creep) is very slow.

3.0 Potential Geotechnical Analysis Plan

To better understand and evaluate the geotechnical reasons for the potential settlement in the Hiawatha Golf Course, the MPRB could consider conducting a much more detailed geotechnical analysis drawing on the work completed around Lake of the Isles.

The geotechnical approach could consisting of:

- Analyzing the available data (well logs, pumping rates) for consolidation estimates and estimate future consolidation potential
- Depending on results of review, potentially investigate and collect more data (in-line with Lake of the Isles goals).
- Review and revise consolidation estimates.

It is likely that settlement in the golf course is decreasing with time; however, settlement may have lowered the general ground elevations to a point that rainfalls and groundwater fluctuations have an impact on flooding and play. Constant groundwater pumping may also be inducing more settlement as it draws water from the soils during drier periods. These issues and impacts would be analyzed to understand the reasons for ground settlement.

If more geotechnical information would be needed to fully understand the factors impacting settlement, the cost of a geotechnical investigation plan consisting of 4 to 8 soil borings to a depth of 75 feet, has also been included. Soil samples from the investigation would be sent to a local soil testing laboratory to determine compressibility and consolidation characteristics. Following testing, analyses and geotechnical computations would be completed to estimate future settlement. Should a remediation technique be employed similar to Lake of the Isles (i.e. surcharging or overbuild), then this information would be helpful in determining the effectiveness of a geotechnical solution.

4.0 Proposed Settlement Monitoring Alternatives

It is not necessary for the MPRB to conduct the full geotechnical analysis to quantify the historic or current rate of settlement. The following sections present various settlement monitoring alternatives that could be utilized to help quantify the historic or current rates of settlement in the Hiawatha Golf Course. For each solution, the advantages and disadvantages are listed.

As previously mentioned, there is a strong likelihood that monitoring for a short monitoring period (e.g. 3 or 6 months) will not lead to conclusive estimates of settling rate, especially if the peat soils in the Hiawatha Golf Course are only settling at a rate of ¼ to ½ inch per year. This rate begins reaching the accuracy limits of all the monitoring methods outlined below. A longer monitoring plan, on the order of a few years may provide a better estimate of the average settlement rate.

4.1 Historical Data Review

This alternative would include a desktop review of historic information to try and quantify the magnitude of the settlement that has historically occurred in the Hiawatha Golf Course. This effort would require coordination with MPRB, golf course, and City of Minneapolis staff to help compile historic and anecdotal information related to design, construction, and other recent projects in the golf course, such as historic plans, as-builts, and other drawings. Historic drawings may consist of historic golf course information with elevation or survey information and study sheets from the City of Minneapolis that include random point elevations at locations in or around the golf course. This approach would also utilize available electronic data that is available for the area including any historic contour information for the City of Minneapolis (e.g. 2 ft contours), the 2008 elevation data collected by National Geospatial-Intelligence Agency (NGIA) for the Twin Cities metropolitan area, and the 2011 Minnesota Department of Natural Resources (MnDNR) LiDAR elevation data for Hennepin County, and surveys (historic or recent) completed within the golf course.

One disadvantage of this method is related to the potential resolution of the elevation data (resolution might only be on the order of 0.5 ft to a foot or more. So unless significant settlement has occurred between the data sources, it might not result in a conclusive estimate or rate of settlement.

4.2 InSAR Historic Review

Using publically available historical radar imagery and radar data, the MPRB could contract with a specialized contractor (e.g. NHAZCA or TRE) to estimate historical ground subsidence. The contractor will apply a series of algorithms (mathematical functions) to satellite imagery and radar data and potentially estimate subsidence to the quarter inch accuracy, typically based on satellite imagery collected from 1992 – 2000. A phased approach is recommended consisting of a feasibility study to determine if other satellite data exists, a preliminary study to survey the available data for quality, and lastly, a final study to estimate settlement rates with time. Without canvasing available satellite databases, there is no understanding if the data exists for the Minneapolis area as our experience has been based on using this approach for projects not located in the Twin Cities

4.3 Manual Measurements (PLS Approach)

This method includes collecting manual survey measurements at key points located throughout the golf course. Using generally accepted, traditional manual surveying techniques, seven reference points would be set in areas that are thought to have not settled, 20 monitoring points would be set in flood prone areas or areas thought to be settling in the golf course, and 7 PK nails (short survey markers nailed into the side of the bituminous trail) would be set along the berm. The monitoring points could either be set on 6 inch diameter concrete columns or bolted directly to buildings (i.e. pump house). The monitoring points would be at ground (flush with the ground) and measured for vertical movements every two months for a period of 6 months. These monitoring points could be Borros type settlement gages and PK nails (as described above along the berm). Figure 4 shows an example of a Borros-type settlement point for manual monitoring. This method would estimate the current settlement rate with measurements collected on a quarterly or semiannually routine.

This is typically the first method used for settlement monitoring as it is relatively low cost to start and the data is easily interpreted. Drawbacks to this approach are:

- low measurement frequency (3 shots over 6 months of time per point)
  - difficult to determine cause and timing of settlement, should it occur during that timeframe.
- potential low accuracy
  - dependent on the experience and quality of survey company
  - ¼ inch to ½ inch of vertical measurement variation has been observed which can mask the potential subsidence events.
  - Using reference points spread across the site aids in troubleshooting erroneous measurements.
- Cost per measurement over an extended time
  - The startup cost to this approach is typically low. However, with time, this approach can exceed the cost of a more rigorous automated instrumentation techniques.

Figure 5 shows potential location of Borros type settlement gages. The exact location of the proposed monitoring locations should be confirmed with golf course staff to make sure they correspond with areas where settling was observed.

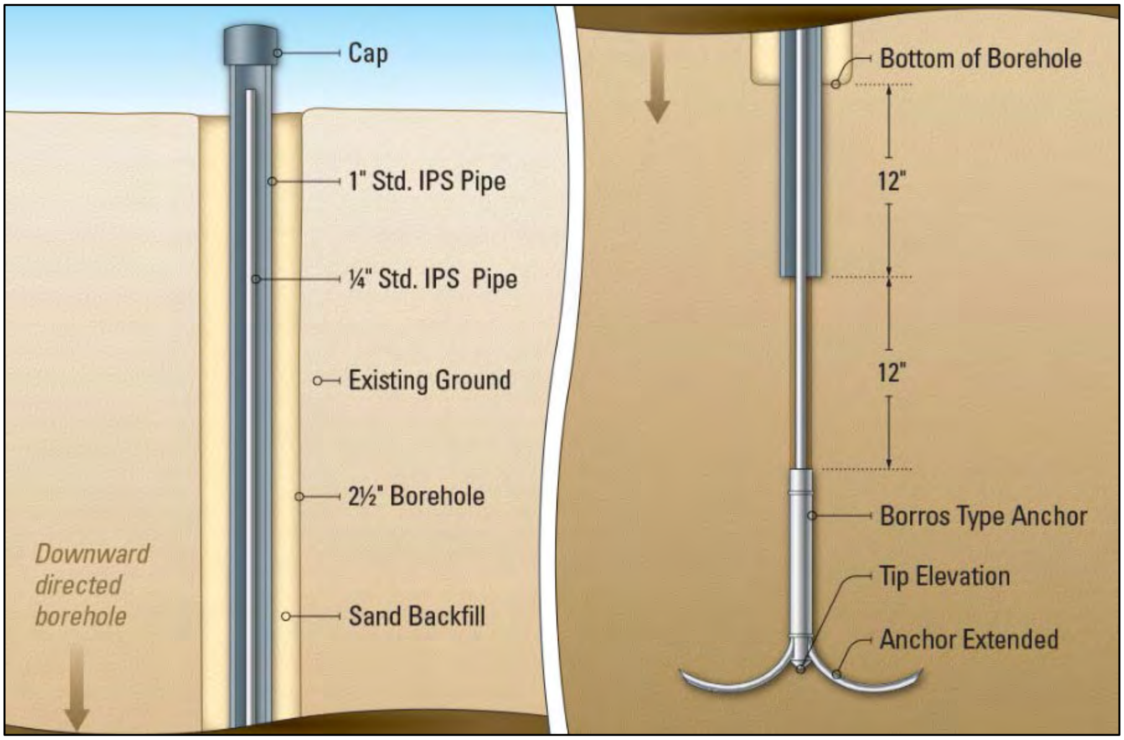
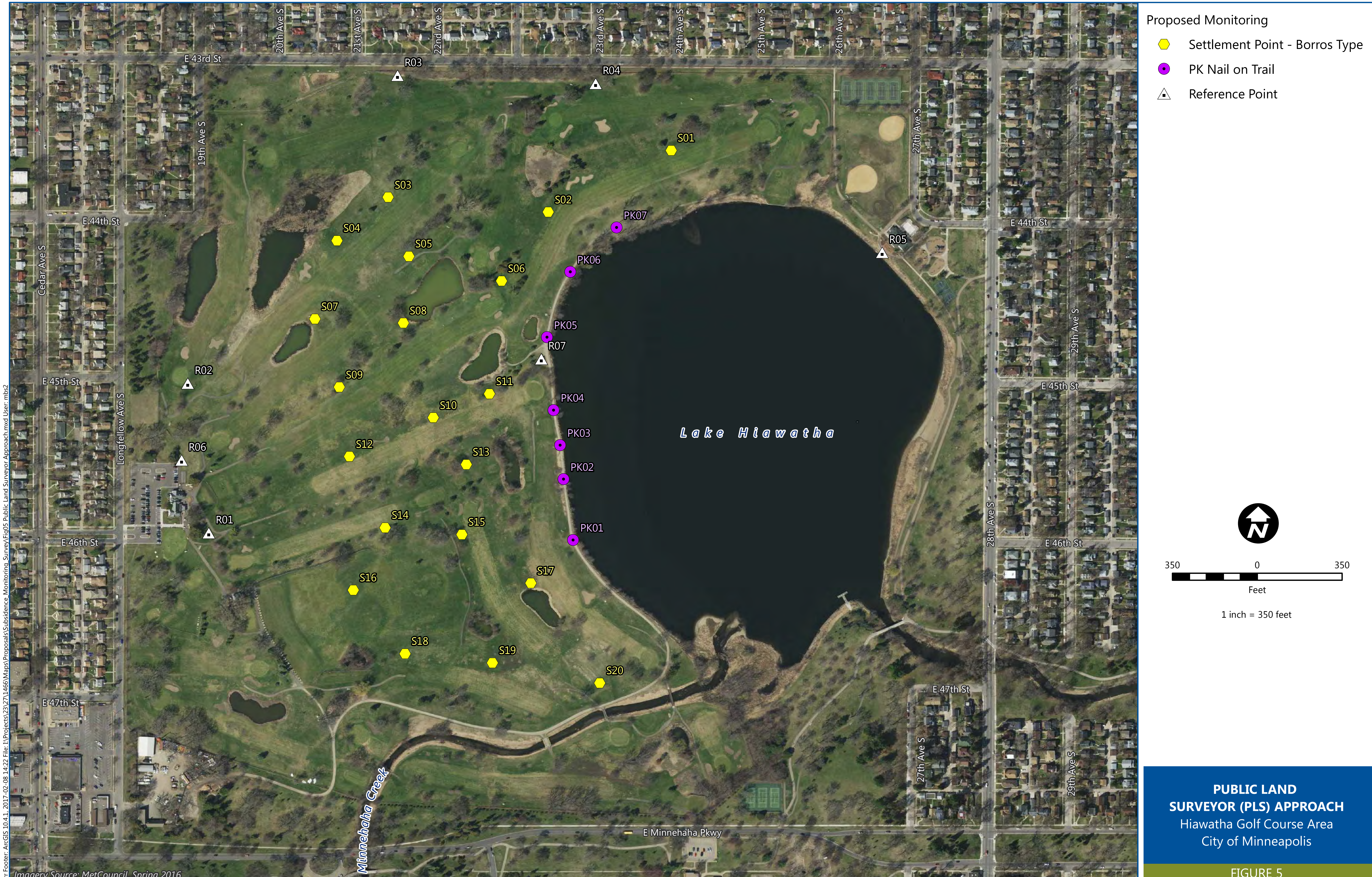


Figure 4 Borros-Type Settlement Point for Manual Monitoring (Geokon-1950)



PUBLIC LAND SURVEYOR (PLS) APPROACH

Hiawatha Golf Course Area

City of Minneapolis

FIGURE 5

4.4 Automated Monitoring Total Station (AMTS)

This approach includes the installation of an AMTS system. The system, as shown in Figure 6, could be installed on the northeast corner of the Hiawatha Golf Course parking lot, in the vicinity of the parking lot, or on top of the pump house with optimal view of the areas prone to settlement (locations A01 or A02). The AMTS system utilizes a network of reference prisms (backsights) to check for station movement and monitoring prisms to measure displacements. The AMTS runs automatically with measurement cycles typically between every 4 to 24 hours. Before each measurement cycle, the AMTS would measure each reference prism and compute an updated station coordinate. If the station hasn't moved beyond preset tolerances or is tilting, then it will measure each monitoring prism automatically. Monitoring prism measurements are compared to baseline measurements to estimate displacements. For some projects, this system was capable of measuring displacements to 1/32 inch. However, for this application, the length of shot reduces accuracy. Accuracy of this system could range between 1/10 to 1/4 inch.

Reference prisms would ideally be located in areas of no settlement (i.e. higher ground for this case) on the golf course property. Reference prisms are typically mounted to small diameter concrete columns (approximately 6 inches in diameter). Monitoring prisms would be mounted to posts driven into the ground for automatic measurement by the AMTS. Monitoring prisms would be placed in locations of previous settlement to understand current rates of movement. Data would be automatically sent to offsite computers for analysis and email alerts. This method would estimate the current settlement rate.

Figure 6 AMTS System with Monitoring Prism on Post

Benefits to this solution are that is very accurate (1/4 inch or less depending on atmospheric conditions), automated (daily measurements to understand potential causes as they occur), provides coverage of much of the golf course, and the price per measurement is an order of magnitude less than manual survey monitoring. However, a drawback to this method is that it requires line of sight to each prism which can limit its effect (tree trimming has been completed in previous projects to offset this impact), and the above ground prisms are subject to disturbance and vandalism which can impact the accuracy of the survey.

Figure 7 shows the potential locations of the ATMS (1 location) and the reference (4 locations) and monitoring prisms (in 20 locations) and assumes this system would be installed and monitor settlement for up to 6 months. These locations were selected based on the expected line of site from the ATMS while trying to be out of the way of golf play. The exact location of the proposed monitoring locations should be confirmed with golf course staff to make sure they correspond with areas where settling has been observed, verify line of site, and do not interfere with golf.

Proposed Monitoring

- Automated Total Station
- Monitoring Point
- Reference Point

350 0 350

Feet

1 inch = 350 feet

AUTOMATED TOTAL STATION (AMTS) APPROACH

Hiawatha Golf Course Area

City of Minneapolis

FIGURE 7

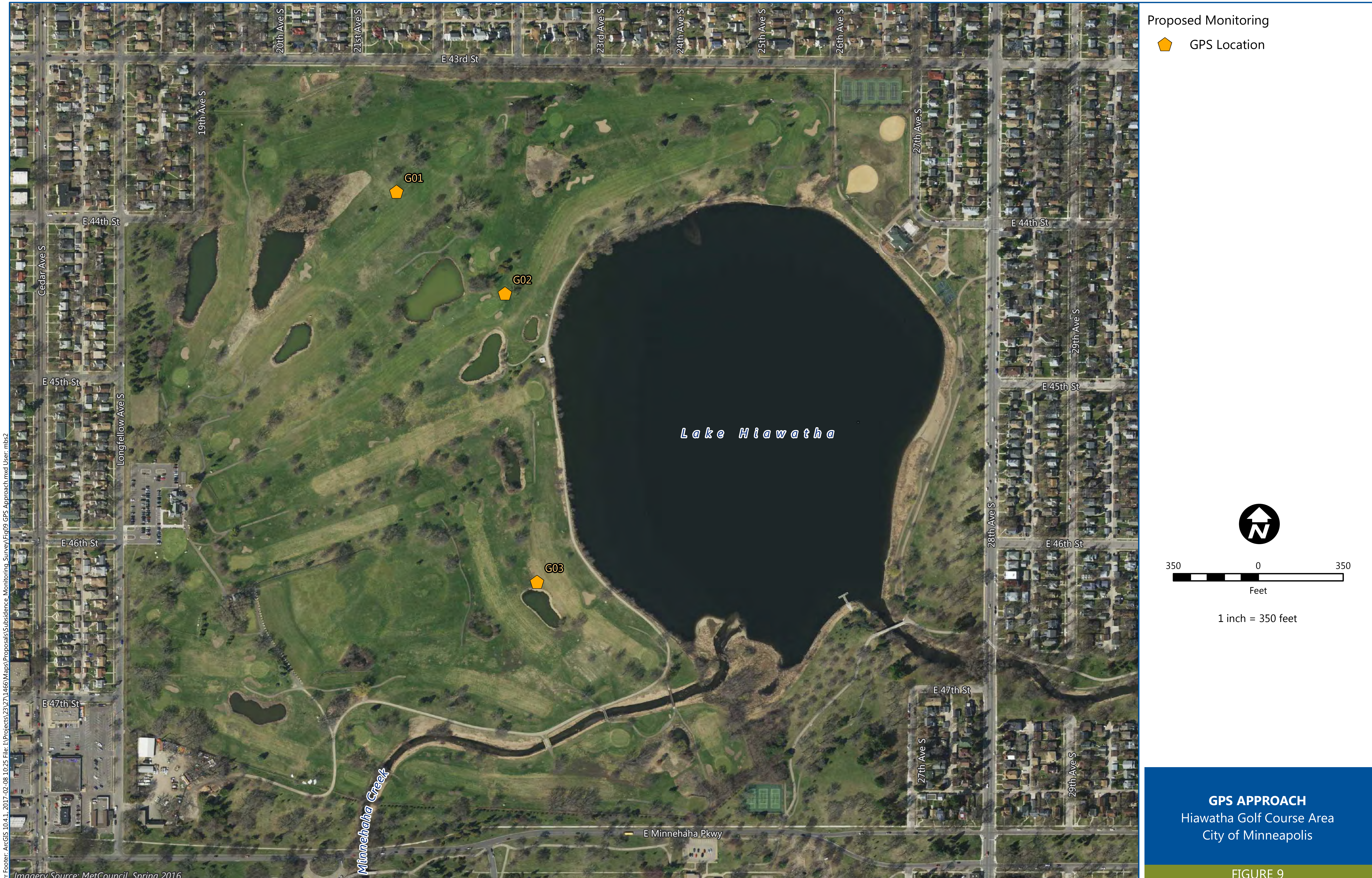
4.5 GPS Settlement Monitoring

GPS sensors are capable of measuring horizontal and vertical movements (Figure 8). Using a satellite network, three sensors are proposed to be set in areas of the golf course that have exhibited settlement to monitor rates moving forward. This method would estimate the current settlement rate.

Figure 8 GPS Sensors

Accuracy of the measurement depends on several variables, but under fairly good conditions (i.e. good visibility of the sky with no tree cover), these are capable of measuring vertical displacements to ¼ inch. Just as with AMTS measurements, a daily data log would be created to analyze displacements and investigate the time at which most vertical movement occurs.

Figure 9 shows the potential locations of the three proposed GPS units and assumes this system would be installed and monitor settlement for up to 6 months. These locations were selected based on good visibility to the sky while trying to be out of the way of golf play. The exact location of the proposed monitoring locations should be confirmed with golf course staff to make sure they correspond with areas where settling was observed and do not interfere with golf.



GPS APPROACH
Hiawatha Golf Course Area
City of Minneapolis

FIGURE 9

Barr Footer: ArcGIS 10.4.1, 2017-02-08 10:25 File: I:\Projects\23\27\1466\Maps\Proposals\Subsidence Monitoring_Survey\Fig09 GPS Approach.mxd User: mbs2

5.0 Cost Estimate

The following table lists planning level cost ranges for each proposed settlement monitoring alternatives (Historic data review, InSAR, manual survey and observation (PLS), AMTS monitoring, and GPS monitoring). We have also included an estimated cost of the additional geotechnical analysis and investigation costs assuming the MPRB would like a better understanding of the reasons for settlement.

With each instrumentation alternative proposed, the costs of acquisition, installation and operation have been included. For the automated monitoring techniques (ATMS and GPS sensors), the cost of providing data on a publically-accessible and secure website is included. Excluded costs consist of damage due to equipment by vandalism, and costs of tree trimming (for manual survey or AMTS monitoring).

The automated monitoring techniques will require some concrete columns to be constructed. The concrete columns are typically 6 inch to 10 inch diameter columns installed with 5 feet below ground and 5 feet above ground. The purpose of the concrete columns are to support the ATMS, reference prisms, or the GPS sensors. The final placement of these columns along with all proposed work onsite, would be discussed with golf course and MPRB staff prior to installation.

	Planning Level Cost Range	
Task	**Low**	**High**
3.0 Geotechnical Analysis	**$34,500**	**$82,200**
Analyze Available Data and Report	$4,000	$6,000
Develop and Execute Geotechnical Investigation and Analysis (if needed) - 4-8 soil borings and testing	$30,500	$76,200
4.1 Historical Data Review	**$4,000**	**$8,000**
Analyze Available Data and Report		
4.2 InSAR (Historical Satellite Data Review)	**$46,000**	**$60,500**
Phase 1: Feasibility Study	$1,000	$3,000
Phase 2: Preliminary Study	$5,000	$7,500
Phase 3: Final Study	$40,000	$50,000
4.3 General Surveying and Observation (PLS Method)	$16,500	$23,000
Setup 7 Ref. Points, 20 Mon. Points and 7 PK Nails, Survey Per Visit (assumed 3 Surveys over 6 months), Manual Reporting (each survey)		
4.4 AMTS Monitoring	**$35,000**	**$45,000**
Setup of 1 AMTS with 5 Reference and 20 Monitoring Points, Monthly Monitoring (assumed for 6 months), Final Reporting		
4.5 GPS Monitoring	**$30,000**	**$45,000**
Setup 3 GPS points, Monthly Monitoring (assumed for 6 Months), Final Reporting		