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engineering and environmental consultants

Technical Memorandum

To: Valley Branch Watershed District Landlocked Basin Comprehensive Planning Study Project Stakeholders
From: Jay Hawley (Barr), Jeremiah Jazdzewski (USACE), Jennifer Koehler (Barr)
Subject: VBWD Landlocked Basin Flood Mitigation Comprehensive Planning Study—Hydrologic and Hydraulic (H&H) Modeling Results
Date: December 7, 2023
Project: 23821268.00
c: John Hanson, Nicholas Vottero

1 Project Background

The Valley Branch Watershed District (VBWD) partnered with the United States Army Corp of Engineers (USACE) through the Planning Assistance to States program (PAS) to perform a comprehensive planning study to determine how to manage high-water conditions at ten landlocked basins within VBWD listed below:

- Cloverdale Lake
- Downs Lake
- Eden Park Pond
- Friedrich's Pond
- Goetschel Pond
- Klawitter Pond
- Legion Pond
- McDonald Lake
- Reid Park Ponds
- Sunfish Lake

This comprehensive planning study included performing groundwater and hydrologic and hydraulic (H&H) modeling and flood risk and damage assessments for dwellings around each basin. We used the modeling and damage assessment to provide preliminary sizing of high-water management alternatives for each basin (either pumping or gravity outlets) and evaluate the impact of the alternatives on receiving waters from a flood risk and mitigation standpoint.

This memo summarizes the design event and continuous H&H modeling for the VBWD landlocked basins, including "without project" and "with project" conditions.

1.1 Without Project

"Without project" conditions reflect a scenario where no constructed project exists (e.g., do nothing or existing conditions). However, for this study, the VBWD managers directed us to evaluate both existing land-use and watershed conditions and future land-use conditions. We used the future conditions "without project" modeling results to estimate flood risk, identify impacted dwellings, and inform the development of concepts for the high-water-level management alternatives.

We also asked project stakeholders if any planned drainage projects outside this study's project areas would significantly impact conveyance patterns within the watersheds or along the Project 1007 system since these could impact our proposed alternatives. Based on these conversations, there were no anticipated large-scale drainage re-routing projects that we needed to incorporate into our modeling.

1.2 With Project

"With project" conditions reflect alternatives with a constructed project to manage high-water conditions and reduce flood risk. We used the future conditions modeling results to evaluate the performance of "with project" alternatives.

Further discussion of these alternatives and results are outlined in Section 3.3 and the *VBWD Landlocked Basin Comprehensive Planning Study* report.

2 Hydraulics & Hydrology Model Overview

For this study, Barr used the VBWD's existing XPSWMM models of the Downs Lake/Eden Park Pond, Friedrich's Pond, Goetschel Pond, and Sunfish Lake watersheds. USACE built new PCSWMM models of the Cloverdale Lake, McDonald Lake, Klawitter Pond, Legion Pond, and Reid Park Ponds watersheds, as detailed in **Appendix 11**.

Barr originally built the existing landlocked basin VBWD models during the period of 2014–2018. For this project, we made several updates to the VBWD's existing models, including:

- Updating the hydraulics and hydrology of the Downs Lake/Eden Park Pond and Goetschel models, including revisions to subwatersheds, storage, and conveyance based on recent development data.
- Recalculating the existing conditions impervious area estimates for all the models based on more accurate and recent data from the Metropolitan Council (Met Council, 2016 and Met Council, 2023) and the University of Minnesota (UMN, 2015), as described in **Appendix 11**.
- Incorporating the net groundwater flux time series produced by the calibrated groundwater modeling as described in **Appendix 10** rather than a single groundwater flow value for the continuous simulations.

Figure 2-1 through Figure 2-8 show the subwatersheds to each of the landlocked basins in the study area.

In addition to the landlocked basin models, Barr also used VBWD's existing models of the Project 1007 drainage system, including the Silver Lake, Long Lake, Lake DeMontreville, Olson Lake, Lake Jane, Raleigh Creek, Eagle Point Lake, Lake Elmo, Horseshoe Lake, West Lakeland Storage Sites, and Rest Area Pond watersheds to evaluate the downstream impacts of the proposed landlocked basin outlets. These models were updated with the same impervious area estimates as the landlocked basin models; otherwise, these models were not modified. Once the new models were created (USACE) or updated (Barr), we ran the suite of H&H models (XPSWMM and PCSWMM) for both continuous simulations as well as for design storm events.

We used the results of these simulations to:

- Calibrate the new models and validate the new and existing models to observed water surface elevations under existing land-use conditions, including the impact of the net groundwater flux.
- Update models to evaluate the impact of future land-use conditions, including the impact of the net groundwater flux, on water levels in the landlocked basins.
- Determine a range of possible 100-year, 24-hour peak water surface elevations in the landlocked basins to better understand flood risk at each basin.
- Estimate potential damages to primary dwellings around each basin (see **Appendix 3**).
- Establish operating levels, size potential pump stations, and gravity outlets, and evaluate their impact on the 100-year, 24-hour peak water surface elevations in the landlocked basins.
- Evaluate water quantity mitigation measures for potential pump stations and gravity outlets.
- Evaluate the multi-year impact of the proposed pumping and gravity outlets on the water surface elevations in the landlocked basins.
- Conduct a sensitivity analysis to see how multi-year water surface elevations in the landlocked basins might change over time, both with and without projects, due to higher precipitation and corresponding changes to net groundwater flux. (See further discussion in **Appendix 14** and **Appendix 10**.)
- Inform planning-level water quality evaluations to estimate downstream water quality impacts on receiving waters (see **Appendix 15**).

WATERSHED MAP
Klawitter Pond
Landlocked Basin Study
Valley Branch Watershed District

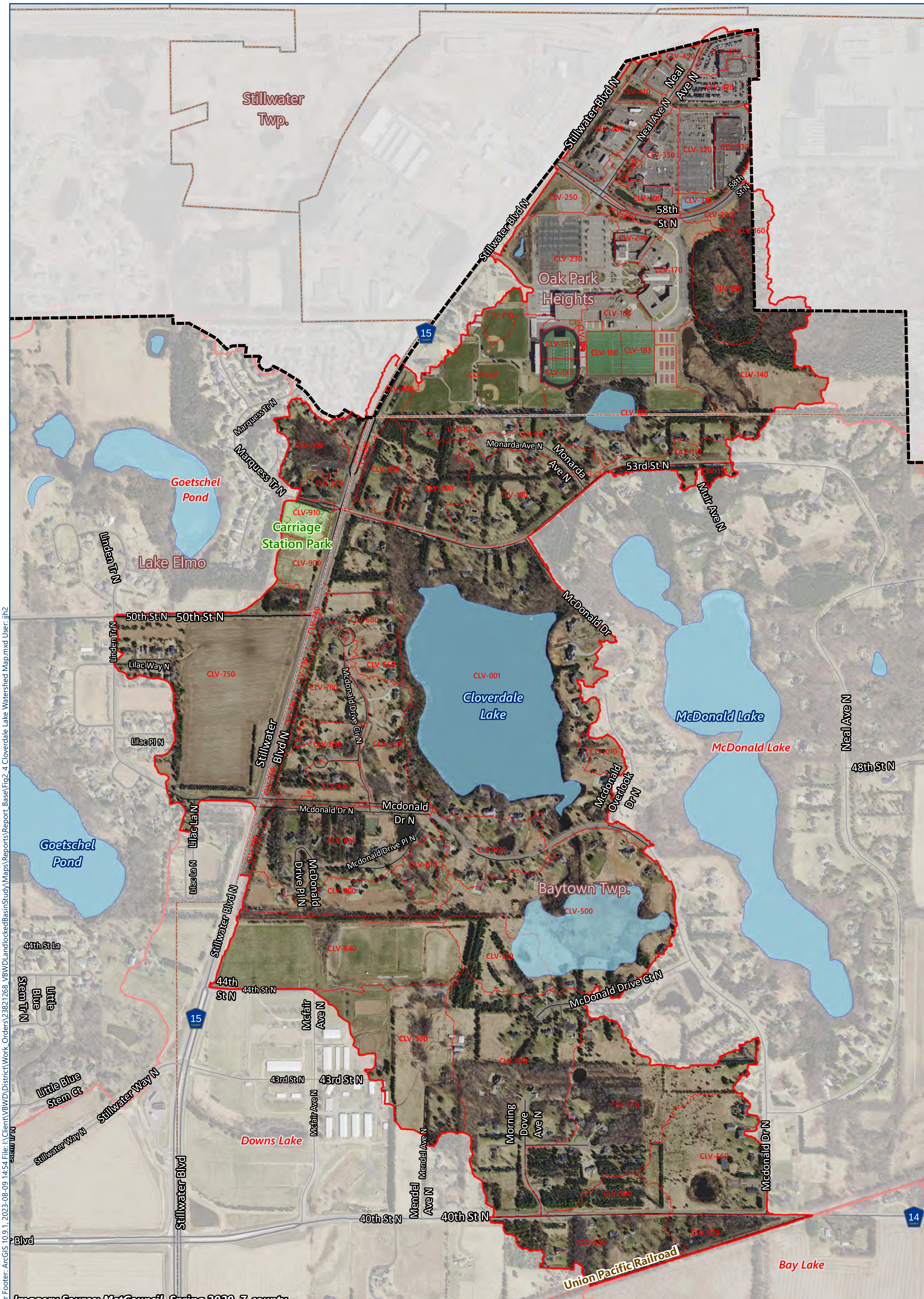
FIGURE 2-1

WATERSHED MAP
Sunfish Lake
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 2-2

WATERSHED MAP
Friedrichs Pond
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 2-3

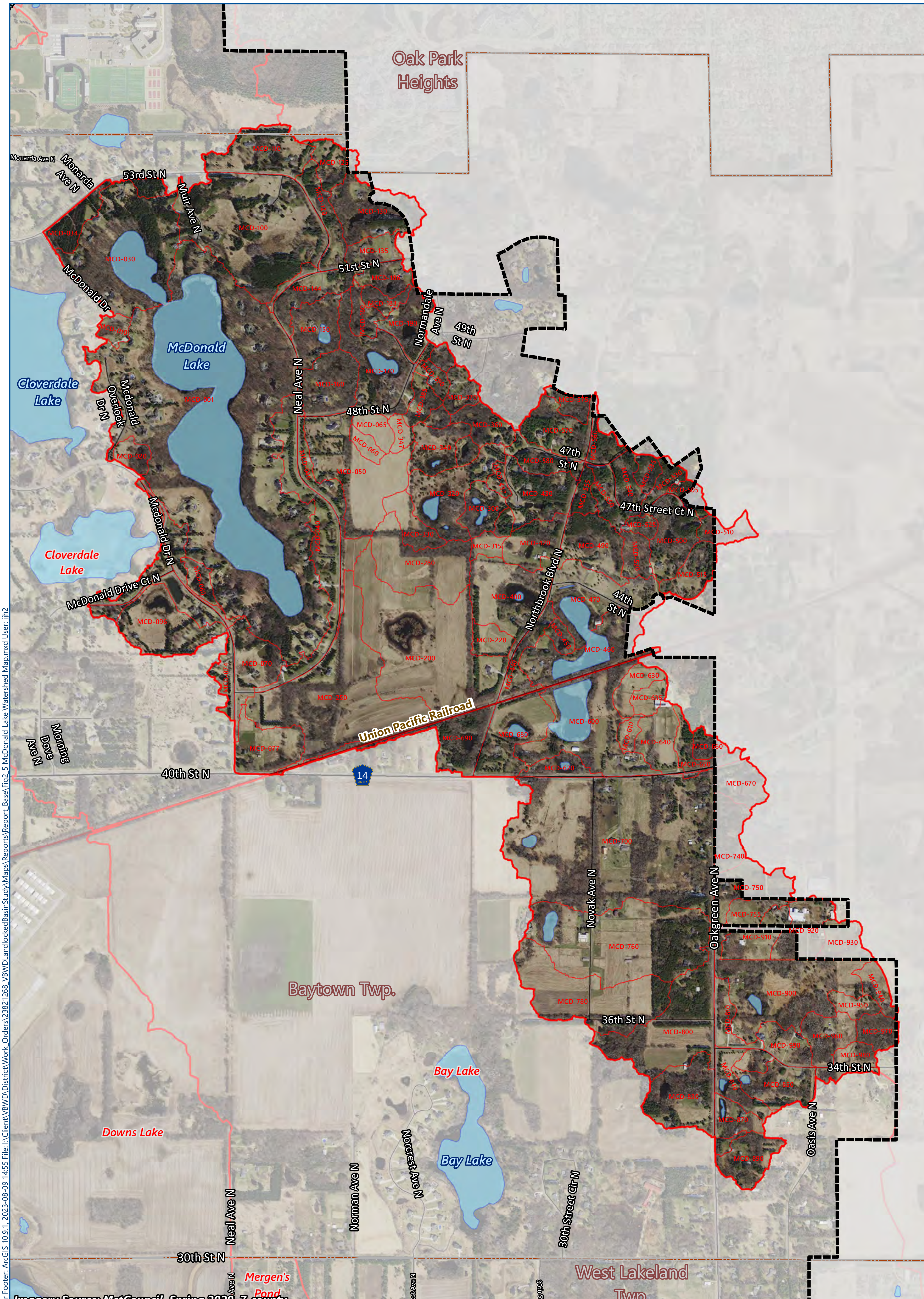


Lake/Pond/Wetland
Minor Subwatershed Boundary
Major Subwatershed Boundary
Park Boundary
VBWD Legal Boundary
Municipal Boundary

800 0 800
Feet
250 0 250
Meters

WATERSHED MAP
Cloverdale Lake
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 2-4



Lake/Pond/Wetland
Minor Subwatershed Boundary
Major Subwatershed Boundary
Park Boundary
VBWD Legal Boundary
Municipal Boundary

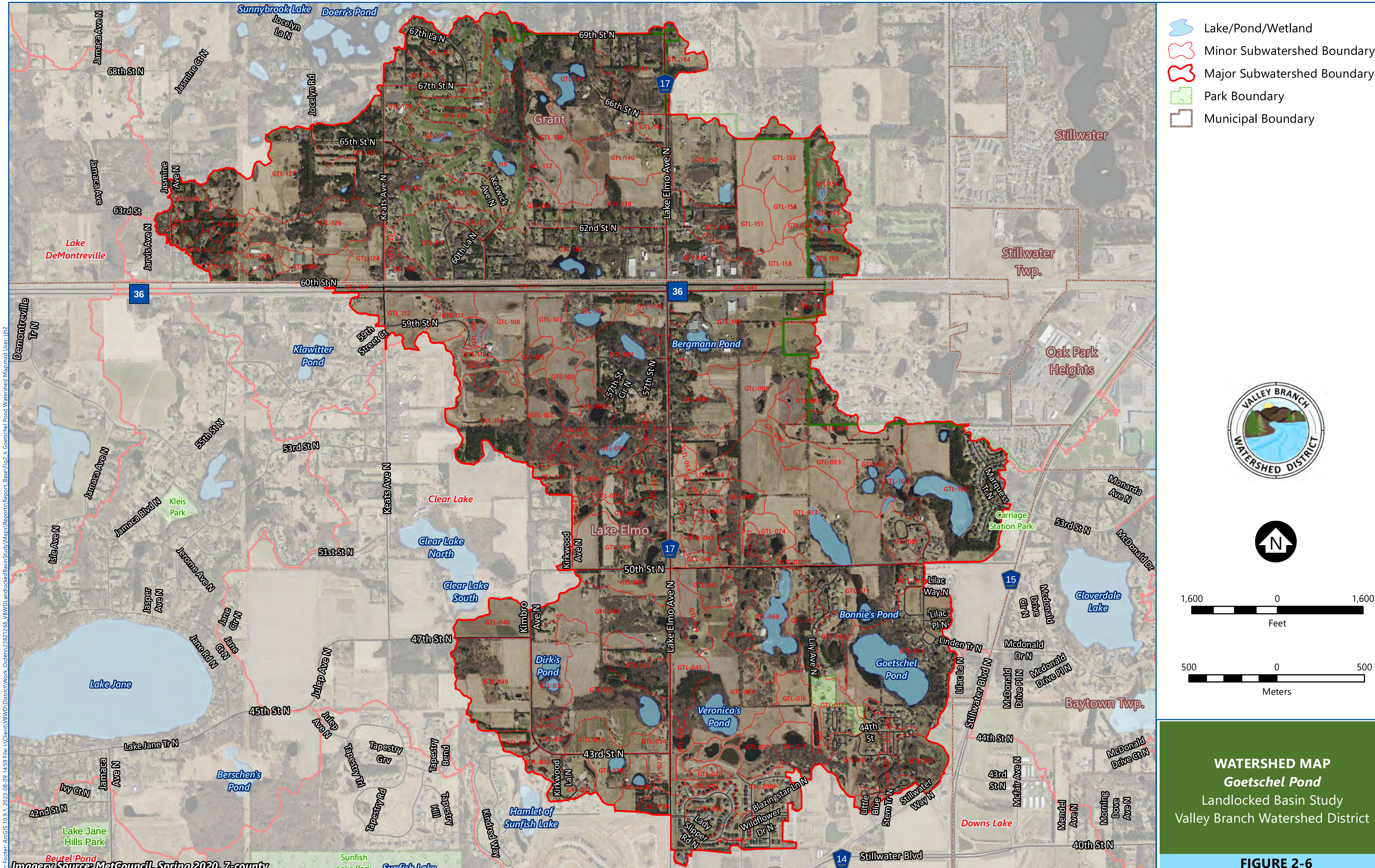
N

1,000 0 1,000
Feet

300 0 300
Meters

WATERSHED MAP
McDonald Lake
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 2-5



WATERSHED MAP
Goetschel Pond
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 2-6

VALLEY BRANCH WATERSHED DISTRICT

- Lake/Pond/Wetland
- Minor Subwatershed Boundary
- Major Subwatershed Boundary
- Park Boundary
- Municipal Boundary

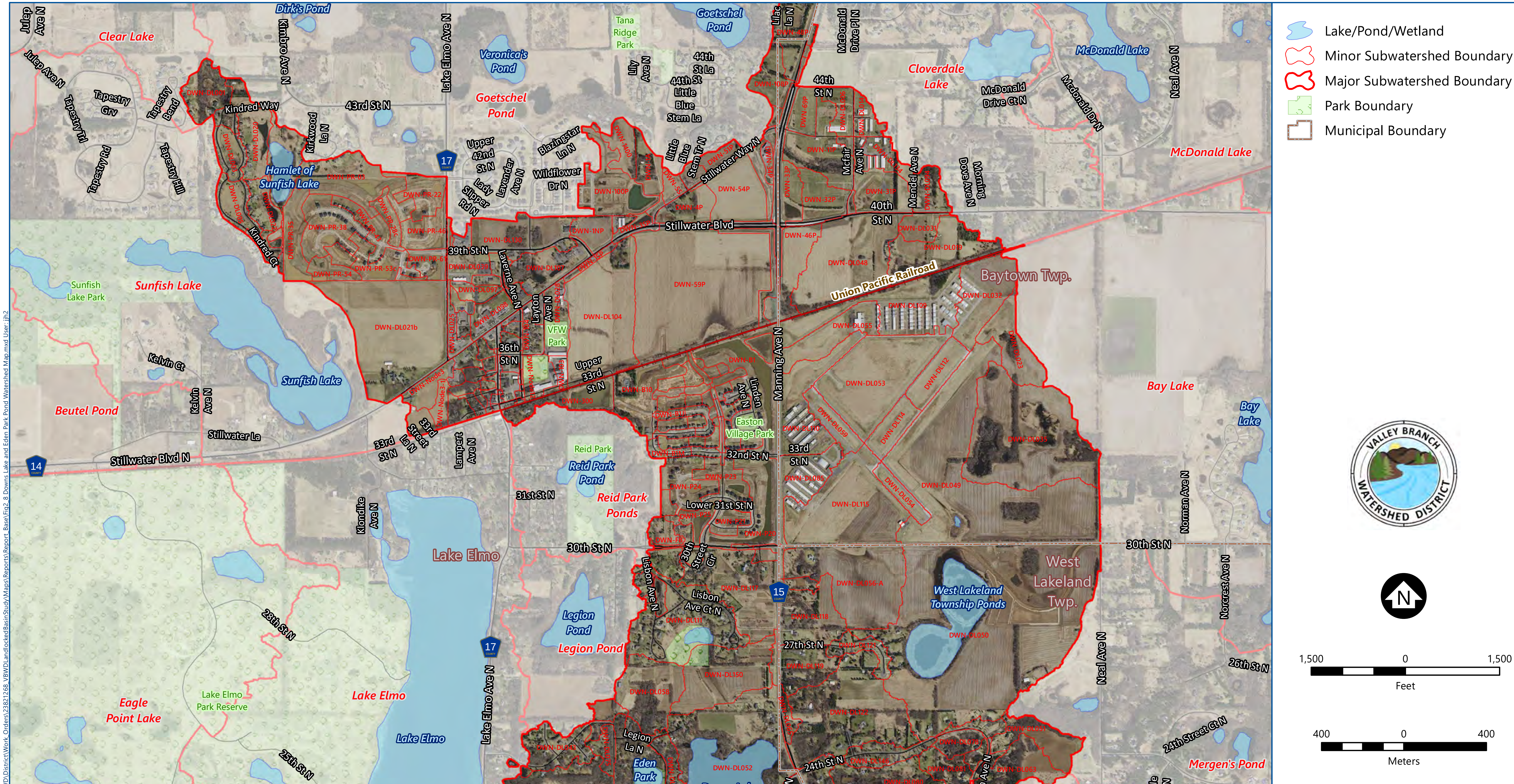
N

400 0 400
Feet

120 0 120
Meters

WATERSHED MAP
Legion Pond & Reid Park Ponds
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 2-7



WATERSHED MAP

Downs Lake & Eden Park Pond

Landlocked Basin Study

Valley Branch Watershed District

FIGURE 2-8

3 Design Event Modeling

The following sections discuss the "without" and "with project" design event modeling results for each basin and include summary tables of the peak elevations in each water body.

We developed the design storms using the National Resources Conservation Service's (NRCS) 24-hour MSE3 rainfall distribution and the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 precipitation depths for the VBWD area. We ran the models using the 2-year, 10-year, 100-year, and 500-year, 24-hour design events; the Atlas 14 depths for these events are shown in Table 3-1.

Table 3-1 Atlas 14 Design Storm Precipitation Depths

Design Storm Event	Atlas 14 Precipitation Depth (in)
2-year, 24-hour	2.8
10-year, 24-hour	4.2
100-year, 24-hour	7.3
500-year, 24-hour	10.3

We also incorporated potential groundwater impacts during the design event by adding the estimated peak net groundwater flux rate from the 1998–2021 calibrated groundwater modeling simulation period as a constant inflow to the basin during the design event. If the peak net groundwater flux rate was less than zero (indicating flow out of the basin), we conservatively assumed a constant zero groundwater flux value. The constant groundwater flux values we used are summarized in Table 3-2.

Table 3-2 Design Storm Constant Net Groundwater Flux Rates

Landlocked Basin	Net Groundwater Flux Value (cfs)
Cloverdale Lake	0.0000
Downs Lake	0.0000
Eden Park Pond	0.1972
Friedrich's Pond	0.0171
Goetschel Pond	0.0856
Klawitter Pond	0.0183
Legion Pond	0.0607
McDonald Lake	0.0898
Reid Park Ponds	0.0658
Sunfish Lake	0.2001

3.1 Future Land Use Without Project Modeling Results

We ran the design events for the future land use "without project" XPSWMM and PCSWMM models at five different starting elevations to evaluate a range of possible peak elevations. We based the five different starting elevations on regulatory requirements and observed water elevations as listed below:

- Maximum measured water level: highest observed water level in the basin.
- Average long-term water level: average observed water-level elevations for the entire record. Records varied by waterbody. Some basins have long water-level records dating back several decades, such as Klawitter Pond, Sunfish Lake, Cloverdale Lake, McDonald Lake, Goetschel Pond, and Downs Lake. Others like Friedrich's Pond, Legion Pond, Reid Park Ponds, and Eden Park Pond have limited data with only a year to a few years of data.
- Average high water (2014–2021) level: average observed water-level elevations during the historically wet period from 1/1/2014–12/31/2021.
- Ordinary high water level (OHWL): regulatory elevation determined by a Minnesota Department of Natural Resources (MnDNR) survey used for regulations and permitting of projects and outlets on MnDNR public waters.
- Ordinary high water level minus 1.5 feet: lowest potential outlet elevation allowed by the Minnesota State statute and the MnDNR for a landlocked basin without getting a variance.

We summarized the results of the future land use "without project" design event model runs in Table 3-3 through Table 3-12.

Table 3-3 Cloverdale Lake Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]
Maximum Measured Water Level	908.21	908.36	908.69	909.06	909.27
Average Long-Term Water Level	904.07	905.13	906.16	908.07	908.64
Average High Water Level (2014–2021)	906.41	907.15	907.88	908.76	909.02
OHWL	900.81	902.05	903.25	905.92	908.01
OHWL Minus 1.5 Feet	899.31	900.65	901.95	904.79	907.25

(1) Future land-use conditions "without project"

Table 3-4 Downs Lake Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)(1)	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)(1)	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)(1)	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)(1)
Maximum Measured Water Level	891.82	892.37	893.19	894.58	895.03
Average Long-Term Water Level	887.79	889.77	891.92	892.86	894.44
Average High Water Level (2014–2021)	888.47	890.36	892.05	892.89	894.51
OHWL	889.15	890.96	892.20	892.94	894.55
OHWL Minus 1.5 Feet	887.65	889.64	891.89	892.85	894.37

(1) Future land-use conditions "without project"

Table 3-5 Eden Park Pond Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)(1)	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)(1)	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)(1)	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)(1)
Maximum Measured Water Level	891.82(2)	892.37	893.19	894.58	895.03
Average Long-Term Water Level	884.80	884.76	885.82	892.68	894.44
Average High Water Level (2014–2021)	884.80	884.76	886.03	892.85	894.51
OHWL	882.05	884.16	885.92	892.94	894.55
OHWL Minus 1.5 Feet	880.55	883.62	884.88	892.52	894.37

(1) Future land-use conditions "without project"

(2) The maximum measured water level is the highest recorded water elevation in Downs Lake and is above the overflow elevation between these basins, so they were assumed to be a level pool at the start of the model run.

Table 3-6 Friedrich's Pond Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Year Peak Elevation (ft MSL, NAVD88)[1]	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]
Maximum Measured Water Level	909.54	909.92	910.34	911.28	912.15
Average Long-Term Water Level	907.43	907.84	908.15	909.60	910.68
Average High Water Level (2014–2021)	908.79	909.12	909.64	910.67	911.62
OHWL	909.40	909.78	910.22	911.16	912.05
OHWL Minus 1.5 Feet	907.90	908.27	908.63	909.98	910.99

(1) Future land-use conditions "without project"

Table 3-7 Goetschel Pond Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]
Maximum Measured Water Level	895.65	896.17	896.69	898.08	902.64
Average Long-Term Water Level	889.25	890.06	890.71	892.76	899.97
Average High Water Level (2014–2021)	894.77	895.31	895.76	897.36	901.40
OHWL	894.00	894.56	895.03	896.75	901.74
OHWL Minus 1.5 Feet	892.50	893.12	893.63	895.31	900.30

(1) Future land-use conditions "without project"

Table 3-8 Klawitter Pond Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]
Maximum Measured Water Level	955.32	956.13	957.17	959.21	960.70
Average Long-Term Water Level	949.83	950.92	952.43	955.99	958.70
Average High Water Level (2014–2021)	950.96	951.99	953.45	956.77	959.18
OHWL	954.97	955.81	956.91	959.02	960.68
OHWL Minus 1.5 Feet	953.47	954.40	955.68	958.23	960.22

(1) Future land-use conditions "without project"

Table 3-9 Legion Pond Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]
Maximum Measured Water Level	886.29	886.76	887.12	887.94	888.77
Average Long-Term Water Level	881.82	882.46	882.94	884.00	885.07
Average High Water Level (2014–2021)	885.73	886.21	886.59	887.44	888.30
OHWL	884.00	884.53	884.95	885.88	886.84
OHWL Minus 1.5 Feet	882.50	883.10	883.55	884.57	885.60

(1) Future land-use conditions "without project"

Table 3-10 McDonald Lake Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]
Maximum Measured Water Level	890.75	892.16	893.26	895.76	898.49
Average Long-Term Water Level	887.52	888.20	888.72	890.54	893.70
Average High Water Level (2014–2021)	887.95	888.61	889.54	892.43	895.40
OHWL	887.62	888.29	888.81	890.01	891.96
OHWL Minus 1.5 Feet	886.12	886.85	887.41	888.72	890.31

(1) Future land-use conditions “without project”

Table 3-11 Reid Park Ponds Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]
Maximum Measured Water Level	887.27	887.68	887.91	888.52	889.14
Average Long-Term Water Level	886.86	887.31	887.54	888.17	888.81
Average High Water Level (2014–2021)	886.86	887.31	887.54	888.17	888.81
OHWL	885.53	886.06	886.35	887.09	887.79
OHWL Minus 1.5 Feet	884.03	884.68	884.98	885.89	886.72

(1) Future land-use conditions “without project”

Table 3-12 Sunfish Lake Design Event Starting and Peak Water Surface Elevations

Starting Water Elevation Criteria	Model Starting Water Surface Elevation (ft MSL, NAVD88)	2-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]	500-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)[1]
Maximum Measured Water Level	905.73	906.01	906.29	906.98	907.70
Average Long-Term Water Level	895.21	895.62	895.99	896.89	897.80
Average High Water Level (2014–2021)	896.44	896.83	897.17	898.02	898.89
OHWL	896.33	896.72	897.06	897.92	898.80
OHWL Minus 1.5 Feet	894.83	895.25	895.62	896.54	897.46

(1) Future land-use conditions "without project"

3.2 Establishing Target Water Levels and Pumping Rates

Barr used the results of the future land use "without project" design event modeling and the estimated number of impacted dwellings from the damage/cost assessment described in **Appendix 3** to estimate a range of target water levels and potential pump rates or gravity outlet sizes for the landlocked basins that could reduce flood risk and impacts to dwellings. We used a spreadsheet to estimate preliminary pumping rates based on:

- Peak net groundwater flux into basins from a calibrated groundwater model continuous simulation period.
- Design storm event results.
- Basin storage/volume information between the 100-year, 24-hour flood elevations and the basin starting water levels.
- Assumed 100-year, 24-hour design event drawdown rates over 4-day, 7-day, and 14-day periods.

We used this preliminary assessment to quickly evaluate the effectiveness of a range of pumping rates and gravity outlet sizes in reducing the flood risk and number of potentially impacted dwellings. The detailed results of this preliminary pumping analysis for each landlocked basin are shown in Table 3-13 through Table 3-23.

Table 3-13 Cloverdale Lake Preliminary Pumping Analysis

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 10-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
Average Long-Term Water Level[5]	909.30	909.30	904.07	2,700; 6.0	5,600; 12.5	9,400; 21.0	907.6	907.16	906.85
Average High Water Level (2014–2021)[5]	909.30	909.30	906.41	2,700; 6.0	5,600; 12.5	9,400; 21.0	908.68	908.59	908.44
Prevent Basement Impacts[4]	909.30	909.30	903.20	2,700; 6.0	5,600; 12.5	9,400; 21.0	906.99	906.51	906.17

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.

(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.

(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

(4) Starting elevation set to keep 100-year, 24-hour elevation below 907.35 (overflow elevation to Lake McDonald with 2 feet of freeboard below basement elevation).

(5) The starting water elevation criteria for Cloverdale Lake used the average water levels rather than the OHWL elevations used by the other landlocked basins because the published OHWL (900.81) for Cloverdale Lake is too low to use as a realistic outlet elevation based on the typical water levels in the lake.

Table 3-14 Downs Lake Preliminary Outlet Analysis—Pump Station

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	893.15	892.20	889.15	5,400; 12.0	11,700; 26.0	20,600; 46.0	894.46	894.37	894.22
OHWL Minus 1.5 Feet	893.15	892.20	887.65	5,400; 12.0	11,700; 26.0	20,600; 46.0	894.18	894.05	893.85
Prevent Low Opening Impacts[4]	893.15	892.20	884.50	8,100; 18.0	16,200; 36.0	29,200; 65.0	893.28	892.99	892.41

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.

(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.

(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

(4) Outlet elevation set to keep 100-year, 24-hour elevation below the low opening will require an OHWL variance.

Table 3-15 Downs Lake Preliminary Outlet Analysis—Gravity Pipe

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Gravity Pipe Diameter (inches)	Mid-Range[2] Gravity Pipe Diameter (inches)	High-End[3] Gravity Pipe Diameter (inches)	Low-End[1] Pipe, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pipe, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pipe, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	893.15	892.20	889.15	21	30	42	894.47	894.37	894.11
OHWL Minus 1.5 Feet	893.15	892.20	887.65	24	30	42	894.15	894.06	893.71
Prevent Low Opening Impacts[4]	893.15	892.20	884.50	27	36	48	893.26	892.96	892.23

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.

(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.

(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

(4) Outlet elevation set to keep 100-year, 24-hour elevation below the low opening will require an OHWL variance.

Table 3-16 Eden Park Pond Preliminary Outlet Analysis

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
Downs Lake OHWL[5]	890.31	890.31	889.15	900; 1.9	1,600; 3.6	2,700; 6.0	890.91	890.88	890.84
Downs Lake OHWL Minus 1.5 Feet[5]	890.31	890.31	887.65	900; 1.9	1,600; 3.6	2,700; 6.0	889.64	889.61	889.56
Prevent Low Opening Impacts[4]	890.31	890.31	888.30	900; 1.9	1,600; 3.6	2,700; 6.0	890.19	890.15	890.12

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.

(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.

(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

(4) Outlet elevation set to keep 100-year, 24-hour elevation below the low opening will require an OHWL variance.

(5) We used the Downs Lake OHWL elevation for this preliminary analysis of the Eden Park Pond outlet, as Eden Park Pond OHWL was unknown at the time.

Table 3-17 Friedrich's Pond Preliminary Outlet Analysis

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	913.86	913.86	909.40	500; 1.2	1,100; 2.5	1,900; 4.2	911.06	911.00	910.93
OHWL Minus 1.5 Feet	913.86	913.86	907.90	500; 1.2	1,100; 2.5	1,900; 4.2	910.05	910.46	910.05

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.
(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.
(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

Table 3-18 Goetschel Pond Preliminary Outlet Analysis

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	909.05	909.05	894.00	1,800; 3.9	3,500; 7.7	5,800; 13.0	896.55	896.31	896.08
OHWL Minus 1.5 Feet	909.05	909.05	892.50	1,800; 3.9	3,500; 7.7	5,800; 13.0	895.45	895.09	894.75

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.
(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.
(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

Table 3-19 Klawitter Pond Preliminary Outlet Analysis

Starting Water Elevation Criteria	Low Opening Elevation[5] (ft MSL, NAVD88)	Low Basement Elevation[5] (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	954.72	954.72	954.97	400; 1.0	900; 2.1	1,600; 3.5	958.88	958.79	958.69
OHWL Minus 1.5 Feet	954.72	954.72	953.47	400; 1.0	900; 2.1	1,600; 3.5	958.07	957.96	957.83
Prevent Low Opening Impacts[4]	954.72	954.72	948.00	400; 1.0	900; 2.1	1,600; 3.5	954.38	954.18	953.95

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.
(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.
(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.
(4) Outlet elevation set to keep 100-year, 24-hour elevation below the low opening will require an OHWL variance.
(5) The VBWD is in the process of purchasing this lowest dwelling.

Table 3-20 Legion Pond Preliminary Outlet Analysis

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	886.40	886.40	884.00	500; 1.2	1,000; 2.3	1,700; 3.8	885.76	885.72	885.69
OHWL Minus 1.5 Feet	886.40	886.40	882.50	500; 1.2	1,000; 2.3	1,700; 3.8	884.44	884.4	884.36
Pump-On Elevation at Low Basement[4]	886.40	886.40	880.35	500; 1.2	1,000; 2.3	1,700; 3.8	882.71	882.66	882.61

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.

(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.

(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

(4) The pump-on at low basement elevation is based on the estimated low basement floor elevation at the time of the analysis; the low basement elevation has since been revised to 886.40.

Table 3-21 McDonald Lake Preliminary Outlet Analysis

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	901.41	901.41	887.62	1,800; 4.0	3,600; 8.0	5,800; 13.0	889.82	889.75	889.68
OHWL Minus 1.5 Feet	901.41	901.41	886.12	1,800; 4.0	3,600; 8.0	5,800; 13.0	889.23	888.61	888.37

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.
(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.
(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

Table 3-22 Reid Park Ponds Preliminary Outlet Analysis

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	890.19	887.10	885.53	200; 0.5	400; 1.0	600; 1.4	886.82	886.8	886.78
OHWL Minus 1.5 Feet	890.19	887.10	884.03	200; 0.5	400; 1.0	600; 1.4	885.58	885.55	885.53
Maintain NWL 2 Feet below Basement[4]	890.19	887.10	884.85	200; 0.5	400; 1.0	600; 1.4	886.25	886.22	886.21

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.

(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.

(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

(4) Pump-on elevation 2 feet below the low basement chosen to draw down pond levels below the basement floor.

Table 3-23 Sunfish Lake Preliminary Outlet Analysis

Starting Water Elevation Criteria	Low Opening Elevation (ft MSL, NAVD88)	Low Basement Elevation (ft MSL, NAVD88)	Proposed Model Starting Water Surface Elevation (ft MSL, NAVD88)	Low-End[1] Pumping Rate (gpm; cfs)	Mid-Range[2] Pumping Rate (gpm; cfs)	High-End[3] Pumping Rate (gpm; cfs)	Low-End[1] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	Mid-Range[2] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)	High-End[3] Pumping, 100-Year, 24-Hour Peak Elevation (ft MSL, NAVD88)
OHWL	912.01	904.01	896.33	1,800; 4.0	3,600; 8.0	6,100; 13.5	897.84	897.78	897.71
OHWL Minus 1.5 Feet	912.01	904.01	894.83	1,800; 4.0	3,600; 8.0	6,100; 13.5	896.45	896.39	896.32

(1) Low-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 14 days.
(2) Mid-range pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 7 days.
(3) High-end pumping rate based on rate needed to draw down 100-year, 24-hour inflow volume in approximately 4 days.

3.3 Future Land Use With Project Modeling

Based on the flood risk and damage assessments, the high-water-level management alternatives (with project) include either pumped or gravity outlets from the following landlocked basins:

- Downs Lake: gravity outlet
- Eden Park Pond: pumped outlet
- Klawitter Pond: pumped outlet
- Legion Pond: pumped outlet
- Reid Park Ponds: pumped outlet

Based on the flood risk assessment, the limited number of estimated impacted dwellings and damages, and discussion with project stakeholders, we decided that high-water-level management was not necessary and would not be further developed or evaluated for the following landlocked basins:

- Cloverdale Lake
    - The existing overflow to McDonald Lake (907.32) is approximately 2 feet below the lowest low floor (909.30).
    - The lowest low floor elevation (909.30) is above the most conservative 100-year, 24-hour storm event peak-water elevation (909.06).
    - High cost and difficulty of pumping along Manning Avenue to a point downstream of Downs Lake.
- McDonald Lake
    - The lowest low floor elevation (901.41) is approximately 3 feet above the most conservative 100-year, 24-hour storm event peak-water elevation (898.49).
    - Residents do not want to pump water out of the lake.
    - High cost and difficulty of pumping along Manning Avenue to a point downstream of Downs Lake.
- Goetschel Pond
    - The lowest low floor elevation (909.05) is approximately 11 feet above the most conservative 100-year, 24-hour storm event peak-water elevation (898.08).
    - High cost and difficulty of pumping along Manning Avenue to a point downstream of Downs Lake.
- Sunfish Lake
    - The most conservative 100-year, 24-hour storm event peak-water elevation (906.98) is approximately 5 feet below the lowest low opening (912.01).

  - High cost and difficulty of pumping across Stillwater Boulevard and the railroad tracks to the Lake Elmo Preserve.
- Friedrich's Pond:
  - The VBWD recently acquired and demolished the lowest dwelling on Friedrich's Pond that experienced flooding in recent years.
  - The lowest low floor elevation is more than 2 feet above the most conservative 100-year, 24-hour storm event peak-water elevation.

3.3.1 Alternatives Assessment

We evaluated three project alternatives as part of this planning study, discussed in the subsequent sections:

- Alternative 1: Evaluated the most complex outlet configurations. It included a pumped outlet from the Klawitter Pond and a combined system with pumped outlets from Reid Park Ponds, Legion Pond and Eden Park Pond into Downs Lake and a gravity outlet from Downs Lake. Necessary mitigation measures were also modeled.
- Alternative 2: Acquisition of at-risk (impacted) dwellings.
- Alternative 3: Evaluated simpler outlet systems. It included individual pumped outlets from Reid Park Ponds and Legion Pond as well as a Reid Park Ponds and Legion Ponds combined system. It also looked at a combined Eden Park Pond (pumped) and Downs Lake (gravity) system with no upstream inflows from Reid Park Pond or Legion Pond. Necessary mitigation measures were also modeled.

Figure 3-1 through Figure 3-12 show the proposed alternatives.

3.3.1.1 Alternative 1 Comprehensive Pumped and Gravity Outlets System

Alternative 1 included a comprehensive system of outlets (pumped or gravity) from Klawitter Pond, Reid Park Ponds, Legion Pond, Eden Park Pond, and Downs Lake. Two options were developed for this alternative, looking at different locations of mitigation volumes.

- <u>Alternative 1, Option 1</u>: Pumped or gravity outlets on select landlocked basins, including mitigation measures, as described below (listed from upstream to downstream):
  - Klawitter Pond pumped outlet to Goetschel Pond; see Figure 3-1:
    - Install a 900 gpm pump to maintain the water surface elevation at 954.97 ft MSL (OHWL) and 12-inch-diameter pipe to Goetschel Pond
    - Acquire two dwellings
  - Reid Park Pond pumped outlet to Downs Lake; see Figure 3-2:

    - Install a 600 gpm pump to maintain the water surface elevation at 884.03 ft MSL (OHWL minus 1.5 feet) to ponds upstream of Downs Lake
    - Construct a 2.4-acre mitigation basin for rate control and water quality treatment
    - Provide floodproofing for two basements
  - Legion Pond pumping to Downs Lake; see Figure 3-2:
    - Install a 1,000 gpm pump to maintain the water surface elevation at 882.5 ft MSL (OHWL minus 1.5 feet) to Downs Lake
    - Provide floodproofing for four basements
  - Eden Park Pond pumping to Downs Lake; see Figure 3-3:
    - Block overflows from Downs Lake
    - Install a 900 gpm pump to maintain the water surface elevation at 884.0 ft MSL to Downs Lake (Note: the MnDNR designated the official OHWL of Eden Park Pond at 882.05 ft MSL in late June 2023; however, our project assessment was not revised to reflect this number due to the study being nearly complete and long model run times.)
  - Downs Lake gravity outlet to the proposed Regional Mitigation Basins; see Figure 3-3:
    - Block overflows to Eden Park Pond
    - Excavate 43.0 acres of floodplain storage
    - Install weir at 887.65 ft MSL (OHWL minus 1.5 feet) and 24-inch-diameter pipe along Manning Trail
  - Regional Mitigation Basins to the Project 1007 system; see Figure 3-4:
    - Construct 9.3- and 62.1-acre mitigation basins for rate control and water quality treatment

- <u>Alternative 1, Option 2:</u> Pumped or gravity outlets on select landlocked basins, including mitigation measures, as described below:
  - Klawitter Pond pumped outlet to Goetschel Pond; see Figure 3-1 (same as Option 1 above)
  - Reid Park Pond pumped outlet to Downs Lake; see Figure 3-2 (same as Option 1 above)
  - Legion Pond pumped outlet to Downs Lake; see Figure 3-2 (same as Option 1 above)
  - Eden Park Pond pumped outlet to Downs Lake; see Figure 3-5:
    - Allow overflows from Downs Lake
    - Excavate 15.2 acres of floodplain storage on Durand's Pond

- Install a 1,800 gpm pump to maintain the water surface elevation at 884.0 ft MSL to Downs Lake
- Provide floodproofing for one basement

o Downs Lake gravity outlet to the proposed regional mitigation basins; see Figure 3-5:
- Allow overflows to Eden Park Pond
- Excavate 12.3 acres of floodplain storage
- Install weir at 887.65 ft MSL (OHWL minus 1.5 feet) and 18-inch-diameter pipe along Manning Trail

o Regional mitigation basins to the Project 1007 system, Figure 3-6:
- Construct 9.3- and 18.1-acre mitigation basins for rate control and water quality treatment

3.3.1.2 Alternative 2 Acquisition of All At-Risk Dwellings

Alternative 2 assumes the voluntary acquisition of at-risk dwellings (as discussed in more detail in **Appendix 3**). This assumes that for any dwellings where peak water elevations were estimated to be above the low floor elevation, the property would be acquired. This alternative assumes no outlets are installed on any of the landlocked basins.

Table 3-24 summarizes the estimated number of acquisitions for each landlocked basin.

Table 3-24 Estimated Number of Acquisitions

Basin	Estimated Number of Acquired At-Risk Dwellings[1]
Cloverdale Lake	1
Downs Lake	4
Eden Park Pond	3
Friedrich's Pond	0
Goetschel Pond	0
Klawitter Pond	2
Legion Pond	14
McDonald Lake	0
Reid Park Pond	2
Sunfish Lake	1
Project Total	27

(1) Estimated number of acquisitions based on the 100-year, 24-hour water elevation with the wet groundwater factor. See Appendix 3 for details on how this elevation was calculated.

3.3.1.3 Alternative 3 Individual Pumped and Gravity Outlets Systems

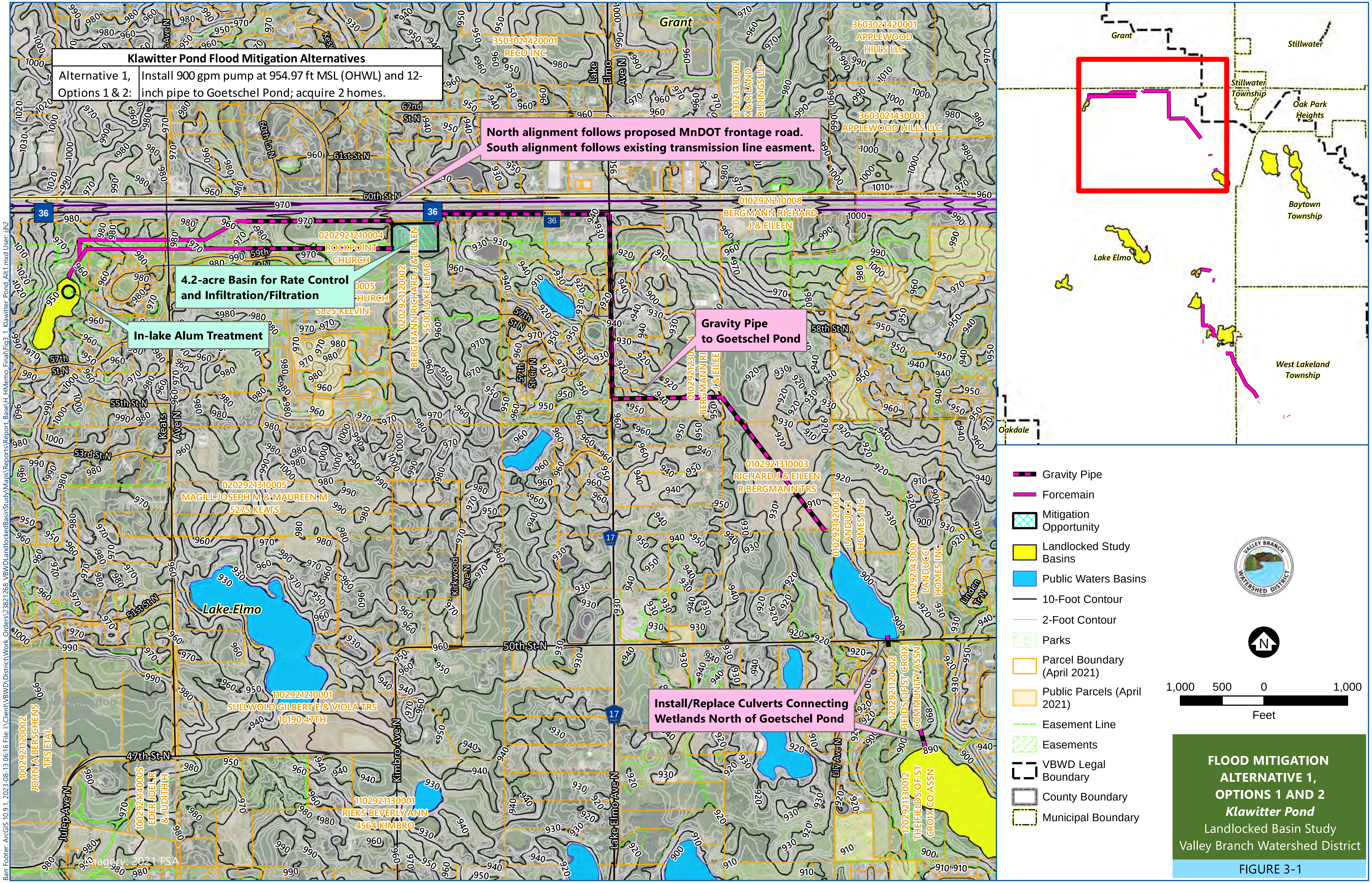
Based on discussions with stakeholders in response to Alternative 1, four options for individual outlet systems (pumped or gravity) from the various landlocked basins and the associated mitigation volumes needed to implement any of these options were evaluated for Alternative 3. Brief descriptions of the four options are provided below.

- Alternative 3, Option 1: Reid Park Ponds pumped outlet to proposed regional mitigation basins along Project 1007 system; see Figure 3-7 and Figure 3-8:
  - Install a 600 gpm pump to maintain the water surface elevation at 884.03 ft MSL (OHWL minus 1.5 feet) and 8-inch-diameter pipe to regional mitigation basins
  - Provide floodproofing for two basements
  - Construct 2.6- and 6.9-acre regional mitigation basins for rate control and water quality treatment
- Alternative 3, Option 2: Legion Pond pumped outlet to proposed regional mitigation basins along Project 1007 system; see Figure 3-9 and Figure 3-10:
  - Install a 1,000 gpm pump to maintain the water surface elevation at 882.5 ft MSL (OHWL minus 1.5 feet) and 10-inch-diameter pipe to regional mitigation basins
  - Provide floodproofing for four basements
  - Construct 4.9-and 7.8-acre regional mitigation basins for rate control and water quality treatment
- Alternative 3, Option 3: Reid Park Pond and Legion Pond combined pumping to proposed regional mitigation basins along Project 1007 system; see Figure 3-11 and Figure 3-12:
  - Install a 600 gpm pump to maintain the water surface elevation at 884.03 ft MSL (OHWL minus 1.5 ft) in Reid Park Ponds, a 1,000 gpm pump to maintain the water surface elevation at 882.5 ft MSL (OHWL minus 1.5 feet) in Legion Pond, and 18-inch-diameter pipe to regional mitigation basins
  - Provide floodproofing for six basements
  - Construct 6.7- and 10.0-acre regional mitigation basins for rate control and water quality treatment
- Alternative 3, Option 4: Downs Lake and Eden Park Pond outlet to proposed regional mitigation basins along the Project 1007 system; see Figure 3-13 and Figure 3-14. Removing the Reid Park Pond and Legion Pond inflows to Downs Lake did not significantly change the results from Alternative 1, Option 2.
  - Eden Park Pond pumped outlet to Downs Lake; see Figure 3-13:
    - Allow overflows from Downs Lake

- Excavate 15.2 acres of floodplain storage on Durand's Pond
- Install a 1,800 gpm pump to maintain the water surface elevation at 884.0 ft MSL to Downs Lake
- Provide floodproofing for one basement

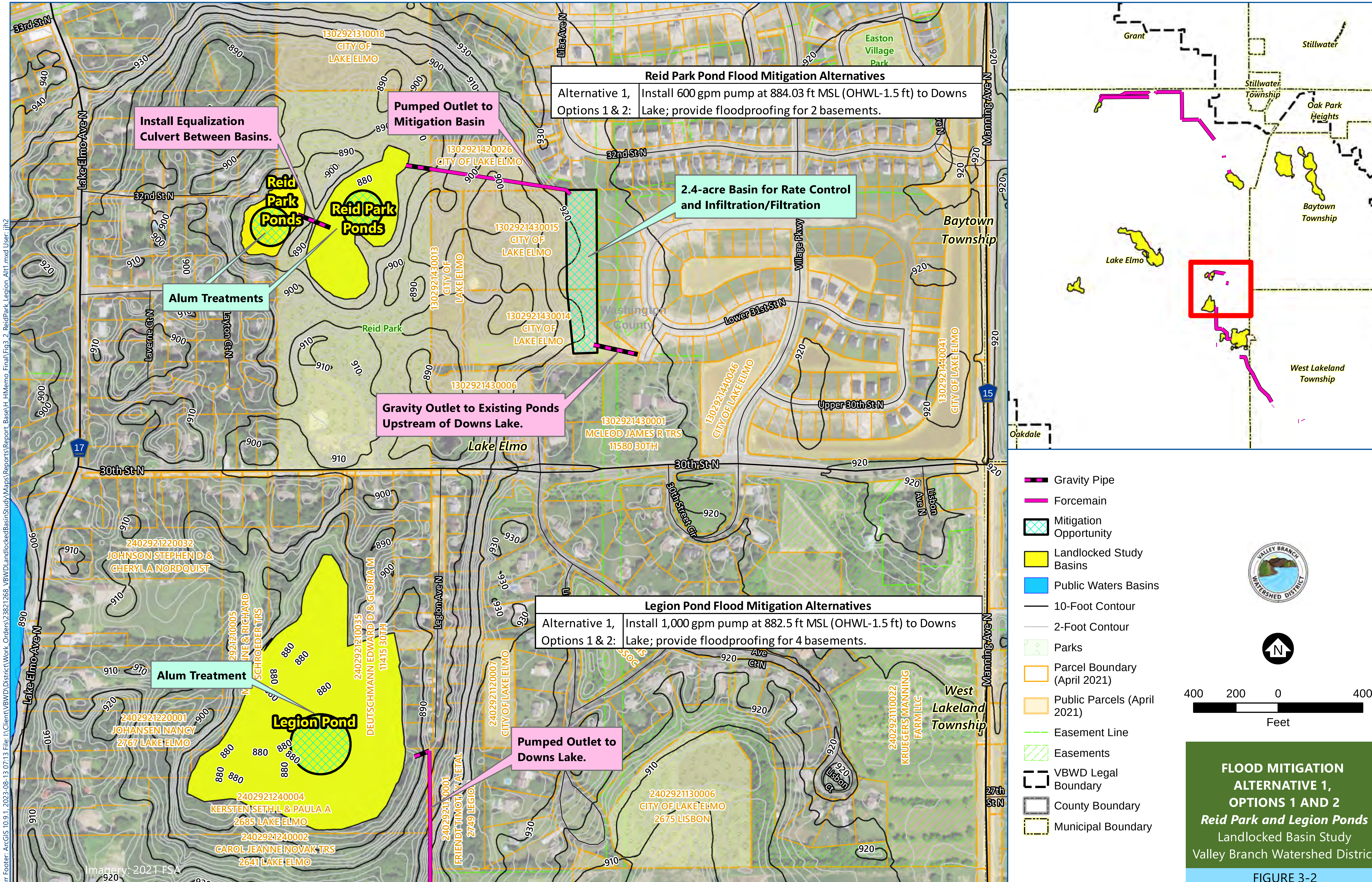
- Downs Lake gravity outlet to the proposed regional mitigation basins; see Figure 3-13:
  - Allow overflows to Eden Park Pond
  - Excavate 12.3 acres of floodplain storage
  - Install weir at 887.65 ft MSL (OHWL minus 1.5 feet) and 18-inch-diameter pipe along Manning Trail
- Regional mitigation basins to the Project 1007 system, see Figure 3-14:
  - Construct 9.3- and 18.1-acre mitigation basins for rate control and water quality treatment

For more information on these alternatives, see the figures, discussion, and costs as discussed in the *VBWD Landlocked Basin Comprehensive Planning Study* report.



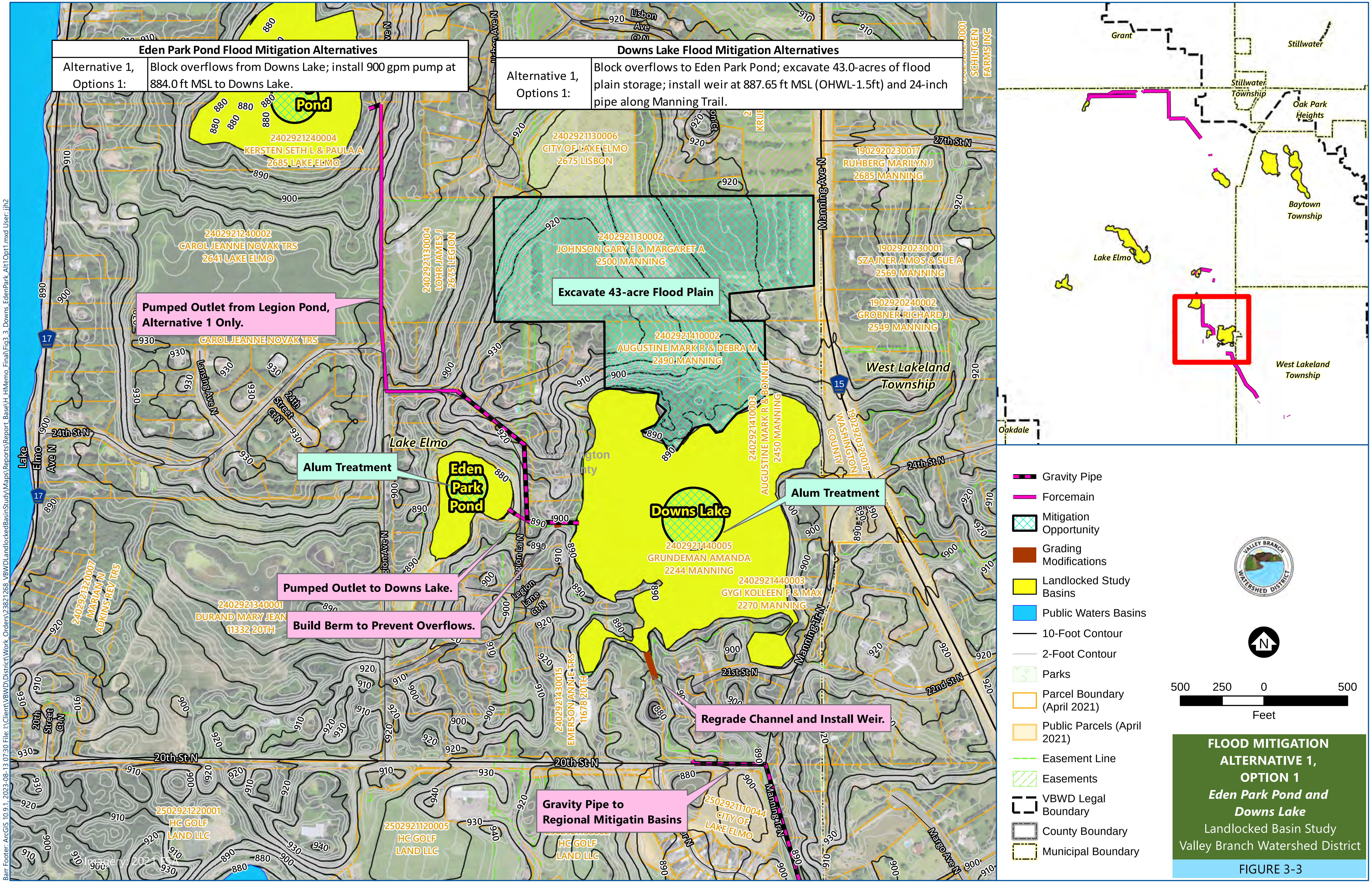
FLOOD MITIGATION ALTERNATIVE 1, OPTIONS 1 AND 2
Klawitter Pond
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 3-1

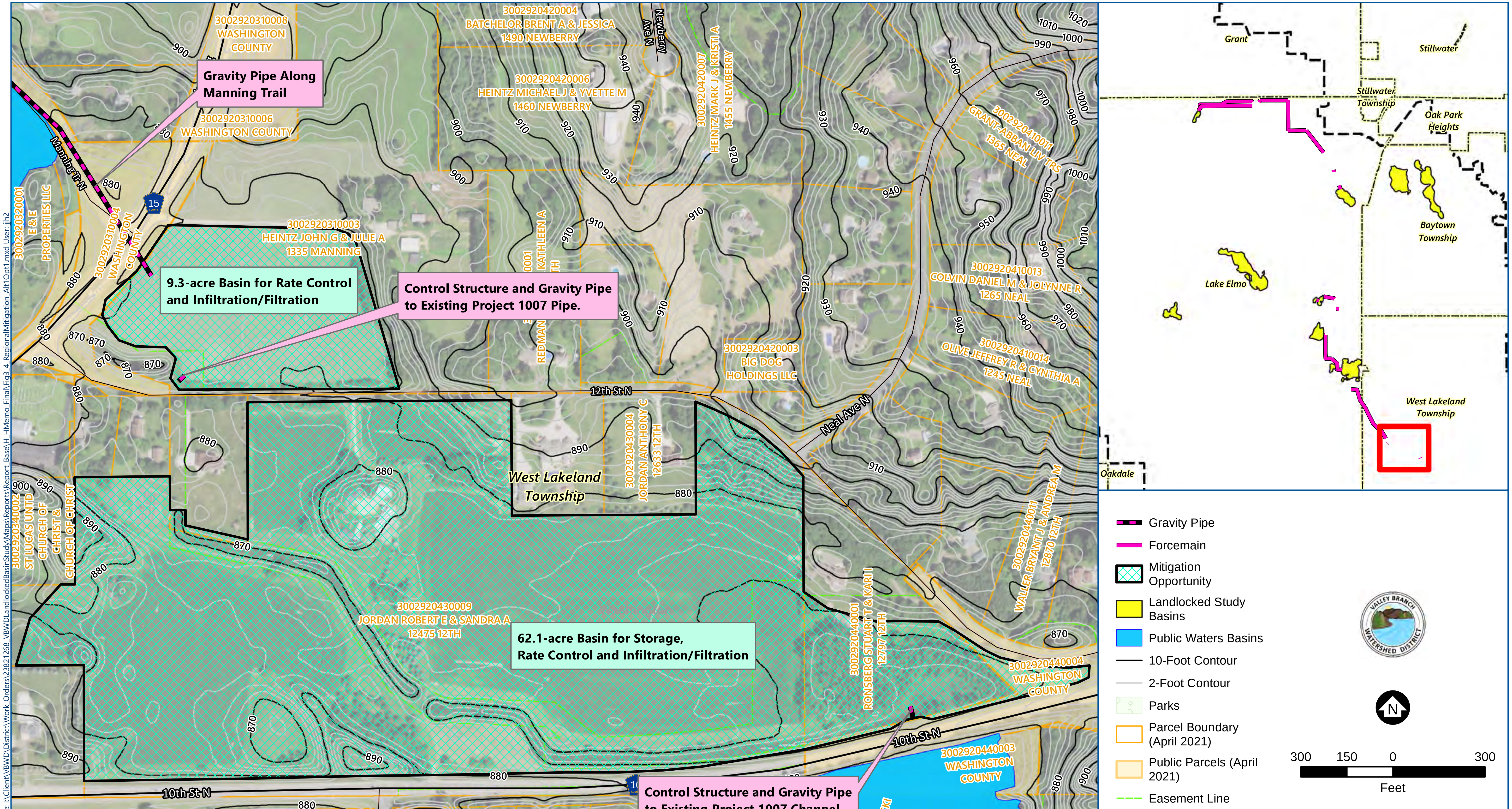


FLOOD MITIGATION ALTERNATIVE 1, OPTIONS 1 AND 2
Reid Park and Legion Ponds
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 3-2



Eden Park Pond Flood Mitigation Alternatives
Alternative 1, Options 1:
Block overflows from Downs Lake; install 900 gpm pump at 884.0 ft MSL to Downs Lake.
Downs Lake Flood Mitigation Alternatives
Alternative 1, Options 1:
Block overflows to Eden Park Pond; excavate 43.0-acres of flood plain storage; install weir at 887.65 ft MSL (OHWL-1.5ft) and 24-inch pipe along Manning Trail.
Pond
2402921240004
KERSTEN SETH L & PAULA A
2685 LAKE ELMO
2402921130006
CITY OF LAKE ELMO
2675 LISBON
1902920230017
RUHBERG MARILYN J
2685 MANNING
2402921240002
CAROL JEANNE NOVAK TRS
2641 LAKE ELMO
2402921130004
LOHR JAMES J
2675 LEGION
2402921130002
JOHNSON GARY E & MARGARET A
2500 MANNING
1902920230001
SZAJNER AMOS & SUE A
2569 MANNING
Excavate 43-acre Flood Plain
1902920240002
GROBNER RICHARD J
2549 MANNING
Pumped Outlet from Legion Pond, Alternative 1 Only.
CAROL JEANNE NOVAK TRS
2402921410002
AUGUSTINE MARK R & DEBRA M
2490 MANNING
West Lakeland Township
2402921410003
AUGUSTINE MARK R & BONNIE
2450 MANNING
Lake Elmo
Alum Treatment
Eden Park Pond
Downs Lake
Alum Treatment
2402921440005
GRUNDEMAN AMANDA
2244 MANNING
2402921440003
GYGI KOLLEEN F & MAX
2270 MANNING
Pumped Outlet to Downs Lake.
2402921340001
DURAND MARY JEAN
11332 20TH
Build Berm to Prevent Overflows.
Regrade Channel and Install Weir.
2402921430015
EMERSON ANN E TRS
11678 20TH
Gravity Pipe to Regional Mitigatin Basins
2502921220001
HC GOLF LAND LLC
2502921120005
HC GOLF LAND LLC
HC GOLF LAND LLC
2502921110044
CITY OF LAKE ELMO
Lisbon Ave
27th St N
24th St N
21st St N
22nd St N
20th St N
Manning Ave N
Manning Tr N
Lake Elmo Ave N
Legion Lane Ct N
24th Street Ct N
20th Street Ct N
Margo Ave N
Lansing Ave N
WASHINGTON COUNTY
Imagery: 2021 FSA
Grant
Stillwater
Stillwater Township
Oak Park Heights
Baytown Township
Lake Elmo
West Lakeland Township
Oakdale
Gravity Pipe
Forcemain
Mitigation Opportunity
Grading Modifications
Landlocked Study Basins
Public Waters Basins
10-Foot Contour
2-Foot Contour
Parks
Parcel Boundary (April 2021)
Public Parcels (April 2021)
Easement Line
Easements
VBWD Legal Boundary
County Boundary
Municipal Boundary
500 250 0 500
Feet
FLOOD MITIGATION ALTERNATIVE 1, OPTION 1
Eden Park Pond and Downs Lake
Landlocked Basin Study
Valley Branch Watershed District
FIGURE 3-3



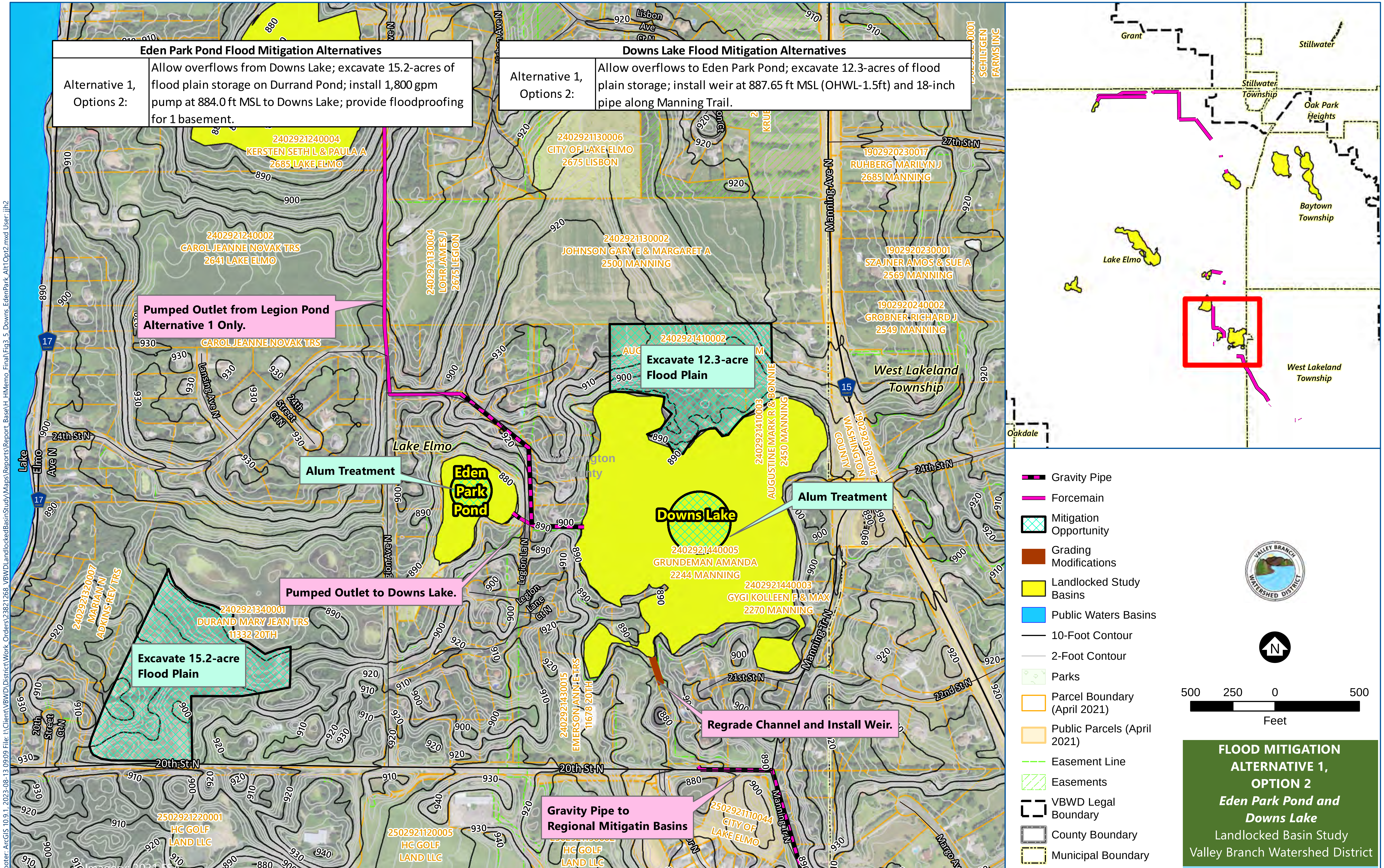
FLOOD MITIGATION ALTERNATIVE 1, OPTION 1

Regional Mitigation Basins

Landlocked Basin Study

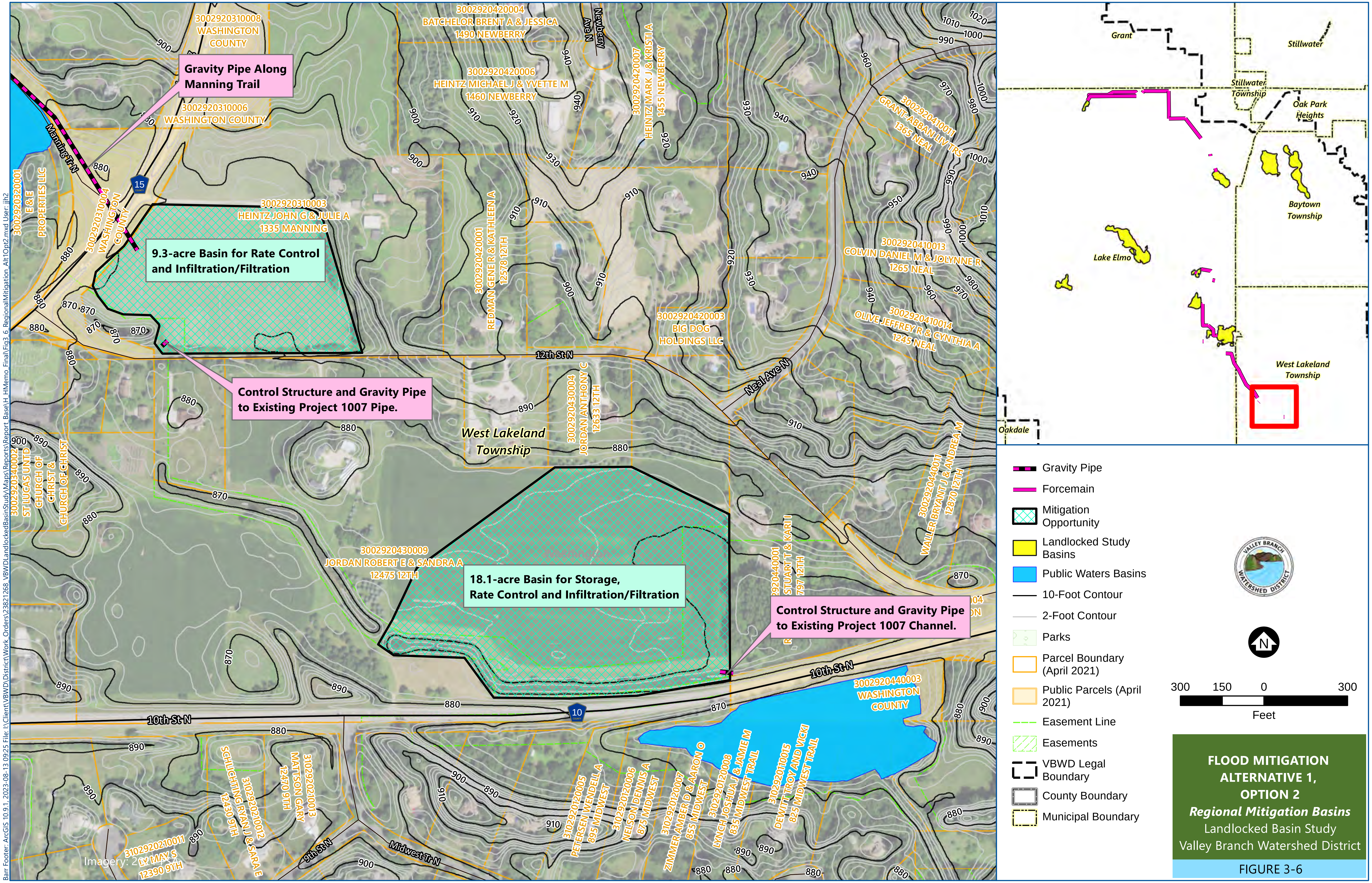
Valley Branch Watershed District

FIGURE 3-4



FLOOD MITIGATION ALTERNATIVE 1, OPTION 2
Eden Park Pond and Downs Lake
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 3-5



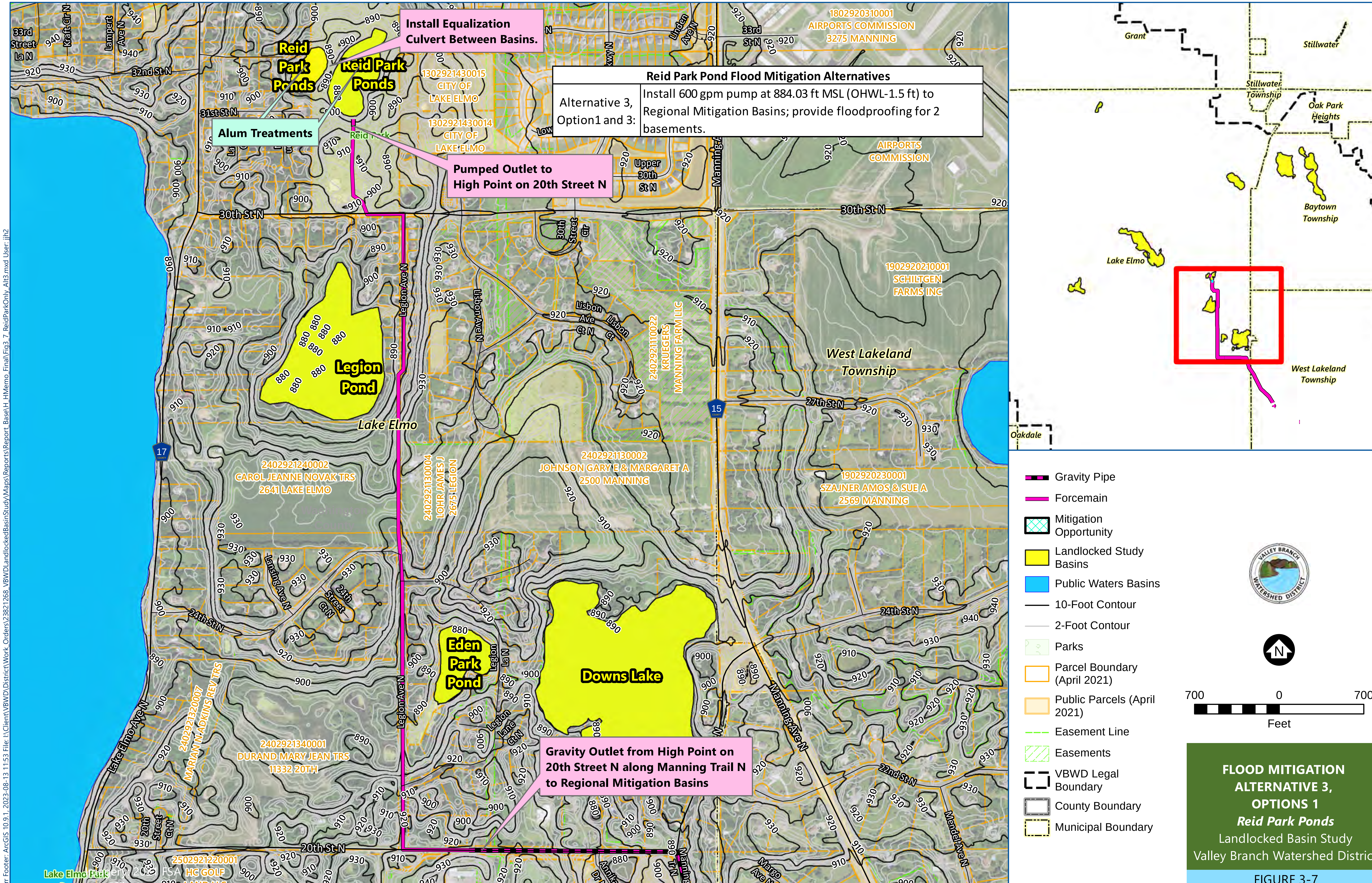
FLOOD MITIGATION ALTERNATIVE 1, OPTION 2

Regional Mitigation Basins

Landlocked Basin Study

Valley Branch Watershed District

FIGURE 3-6



Reid Park Pond Flood Mitigation Alternatives	
Alternative 3, Option1 and 3:	Install 600 gpm pump at 884.03 ft MSL (OHWL-1.5 ft) to Regional Mitigation Basins; provide floodproofing for 2 basements.

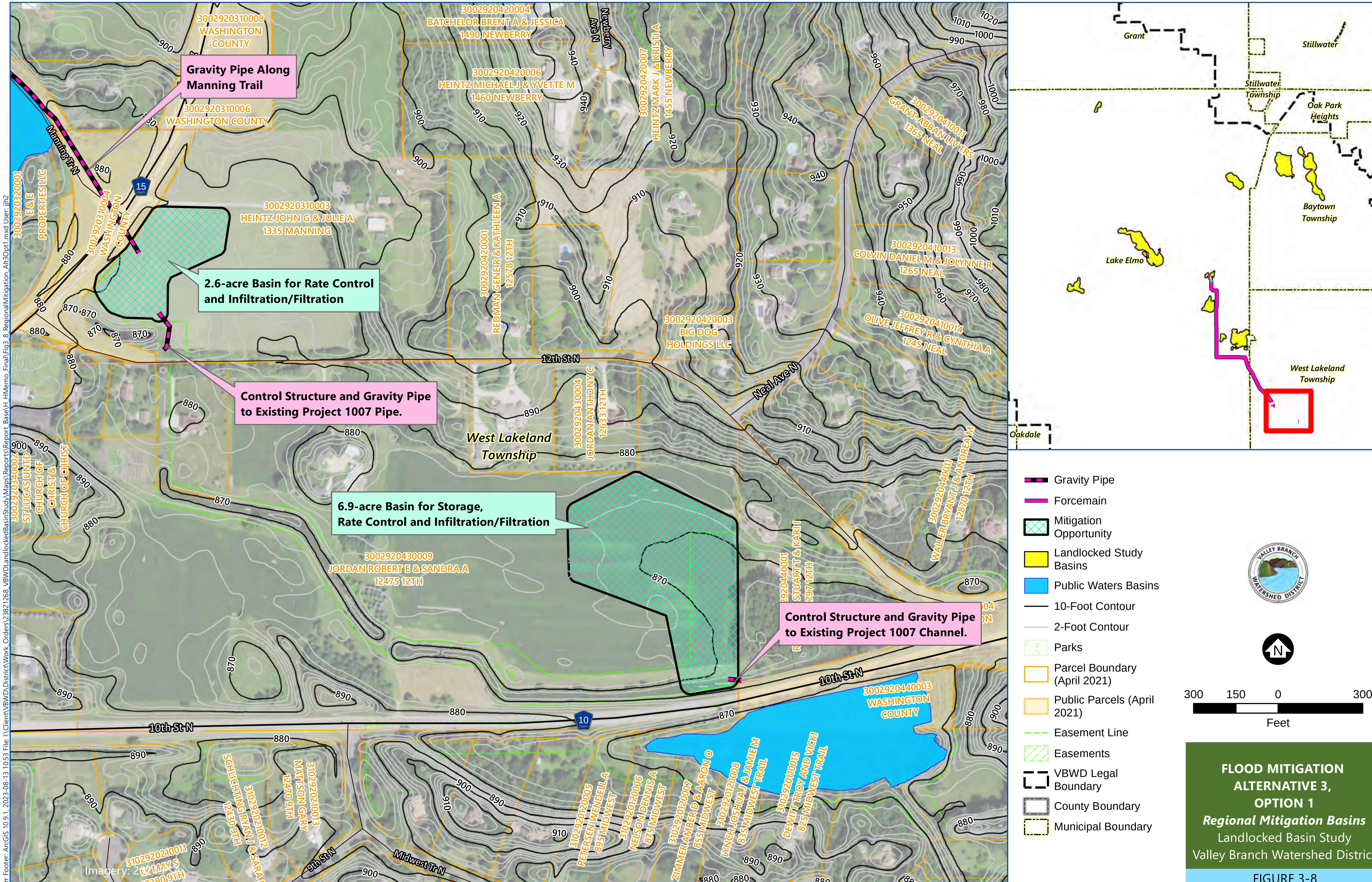
FLOOD MITIGATION ALTERNATIVE 3, OPTIONS 1

Reid Park Ponds

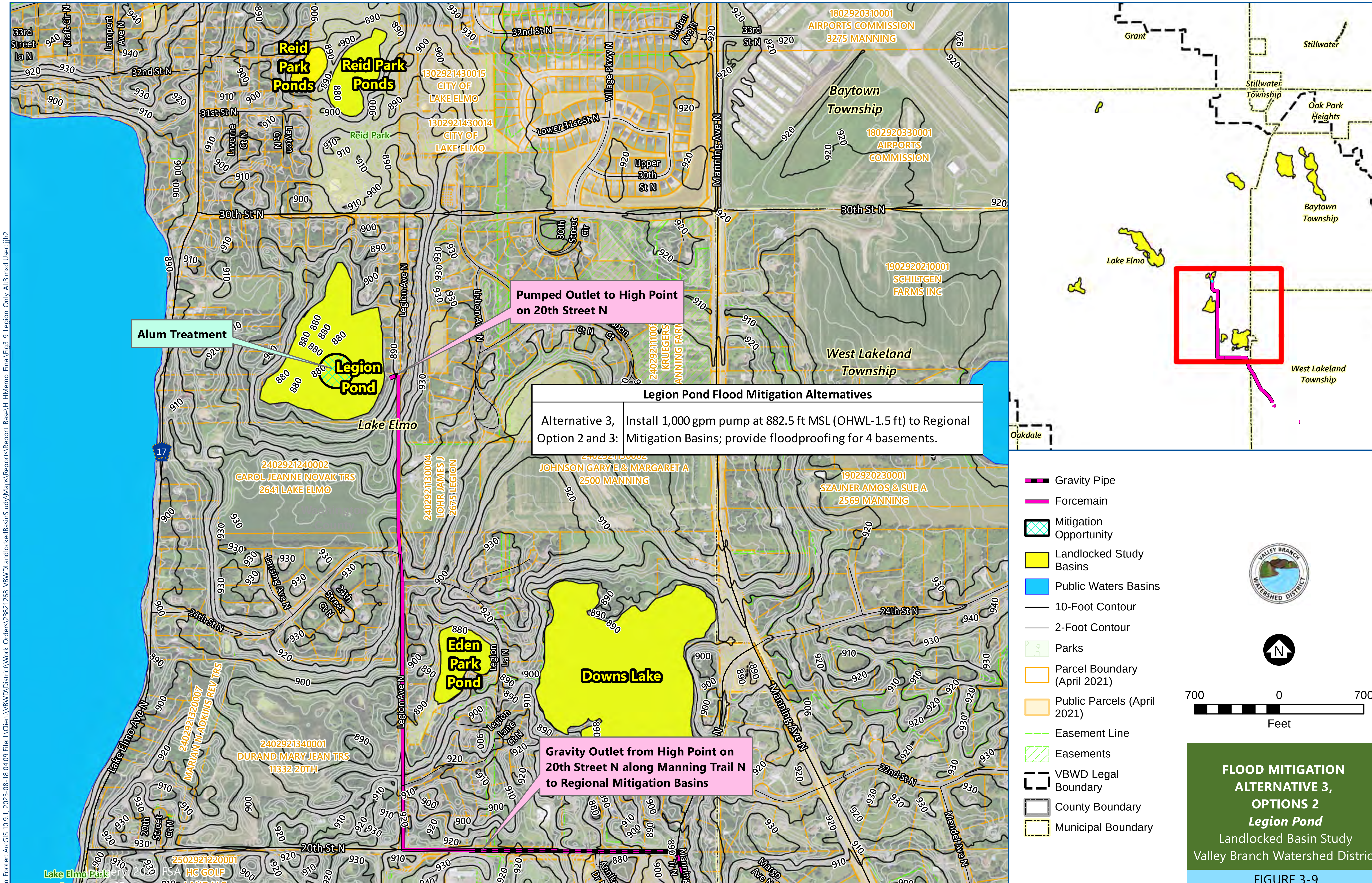
Landlocked Basin Study

Valley Branch Watershed District

FIGURE 3-7

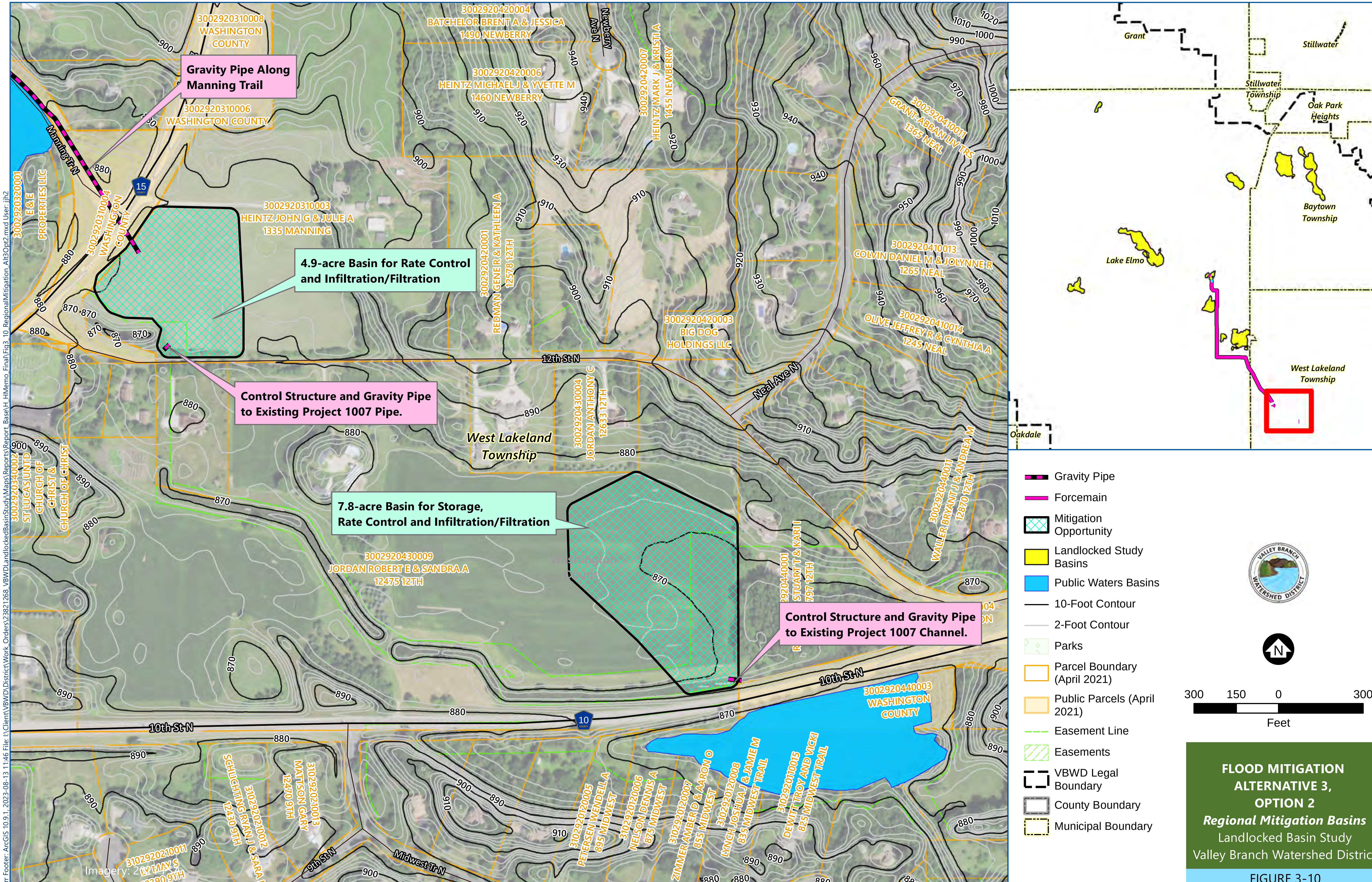


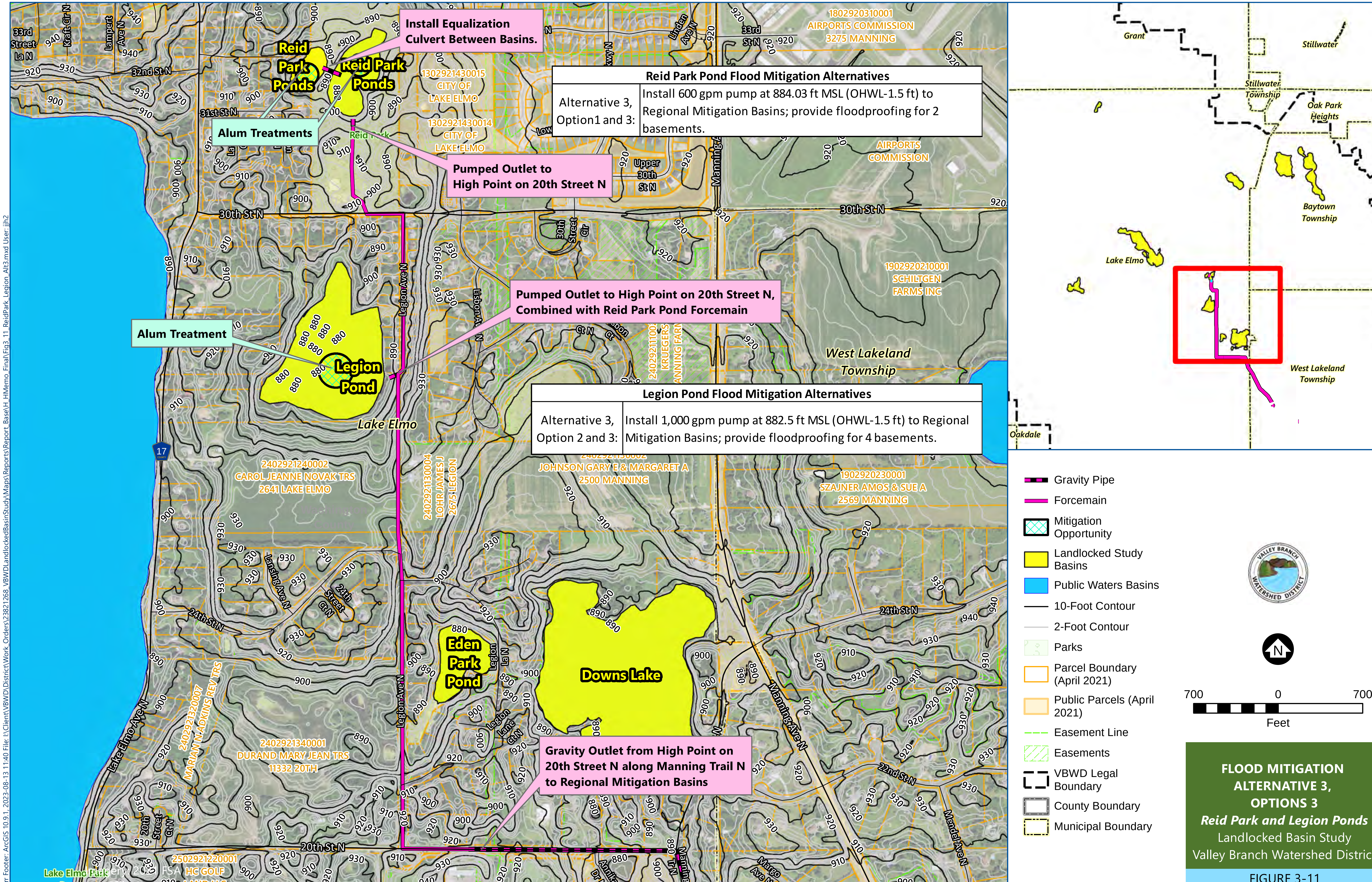
Gravity Pipe Along Manning Trail
2.6-acre Basin for Rate Control and Infiltration/Filtration
Control Structure and Gravity Pipe to Existing Project 1007 Pipe.
6.9-acre Basin for Storage, Rate Control and Infiltration/Filtration
Control Structure and Gravity Pipe to Existing Project 1007 Channel.
West Lakeland Township
12th St N
10th St N
Neal Ave N
Manning Tr N
Newberry Ave N
9th St N
Midwest Tr N
3002920310008 WASHINGTON COUNTY
3002920420004 BATCHELOR BRENT A & JESSICA 1490 NEWBERRY
3002920420006 HEINTZ MICHAEL J & YVETTE M 1460 NEWBERRY
3002920310006 WASHINGTON COUNTY
3002920420007 HEINTZ MARK J & KRISTI A 1455 NEWBERRY
3002920410011 GRANT ABBAN LIV TRS 1365 NEAL
3002920310003 HEINTZ JOHN G & JULIE A 1335 MANNING
3002920320001 E & E PROPERTIES LLC
3002920410013 COLVIN DANIEL M & JOLYNNE R 1265 NEAL
3002920420001 REDMAN GENE R & KATHLEEN A 12578 12TH
3002920420003 BIG DOG HOLDINGS LLC
3002920410014 OLIVE JEFFREY R & CYNTHIA A 1245 NEAL
3002920430004 JORDAN ANTHONY C 12633 12TH
3002920430009 JORDAN ROBERT E & SANDRA A 12475 12TH
3002920440011 WALLER BRYANT J & ANDREA M 12870 12TH
3002920440003 WASHINGTON COUNTY
Grant
Stillwater
Stillwater Township
Oak Park Heights
Baytown Township
Lake Elmo
West Lakeland Township
Oakdale
Gravity Pipe
Forcemain
Mitigation Opportunity
Landlocked Study Basins
Public Waters Basins
10-Foot Contour
2-Foot Contour
Parks
Parcel Boundary (April 2021)
Public Parcels (April 2021)
Easement Line
Easements
VBWD Legal Boundary
County Boundary
Municipal Boundary
VALLEY BRANCH WATERSHED DISTRICT
N
300 150 0 300
Feet
FLOOD MITIGATION ALTERNATIVE 3, OPTION 1
Regional Mitigation Basins
Landlocked Basin Study
Valley Branch Watershed District
FIGURE 3-8



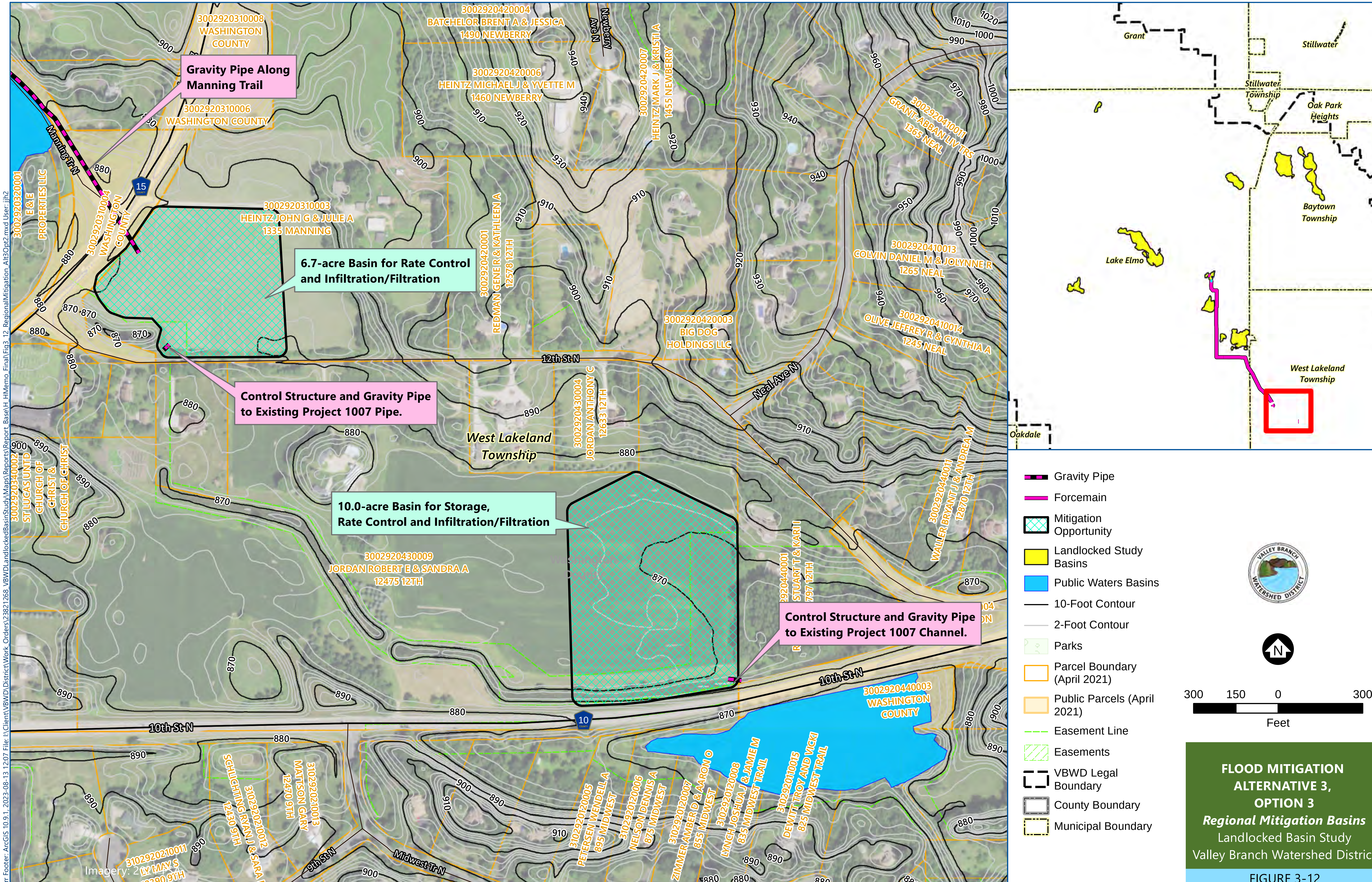
FLOOD MITIGATION ALTERNATIVE 3, OPTIONS 2
Legion Pond
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 3-9

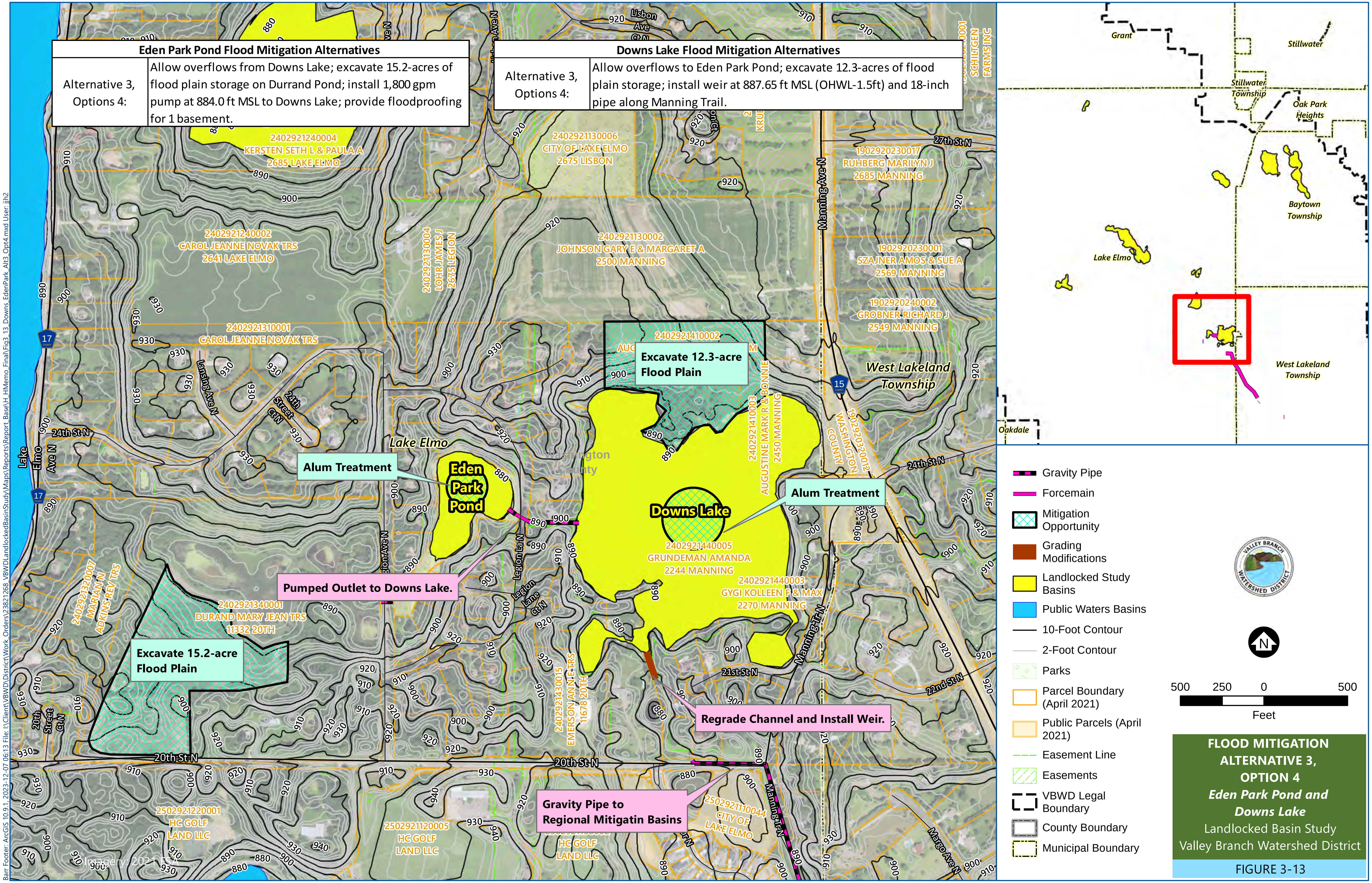

Gravity Pipe Along Manning Trail
4.9-acre Basin for Rate Control and Infiltration/Filtration
Control Structure and Gravity Pipe to Existing Project 1007 Pipe.
7.8-acre Basin for Storage, Rate Control and Infiltration/Filtration
Control Structure and Gravity Pipe to Existing Project 1007 Channel.
West Lakeland Township
12th St N
10th St N
Neal Ave N
Manning Tr N
Midwest Tr N
9th St N
Grant
Stillwater
Stillwater Township
Oak Park Heights
Baytown Township
Lake Elmo
West Lakeland Township
Oakdale
Gravity Pipe
Forcemain
Mitigation Opportunity
Landlocked Study Basins
Public Waters Basins
10-Foot Contour
2-Foot Contour
Parks
Parcel Boundary (April 2021)
Public Parcels (April 2021)
Easement Line
Easements
VBWD Legal Boundary
County Boundary
Municipal Boundary
300 150 0 300
Feet
N
Valley Branch Watershed District
FLOOD MITIGATION ALTERNATIVE 3, OPTION 2
Regional Mitigation Basins
Landlocked Basin Study
Valley Branch Watershed District
FIGURE 3-10



Barr Footer: ArcGIS 10.9.1, 2023-08-13 11:40 File: I:\Client\VBWD\District\Work_Orders\23821268_VBWDLandlockedBasinStudy\Maps\Reports\Report_Base\H_HMemo_Final\Fig3_11_ReidPark_Legion_Alt3.mxd User: jjh2

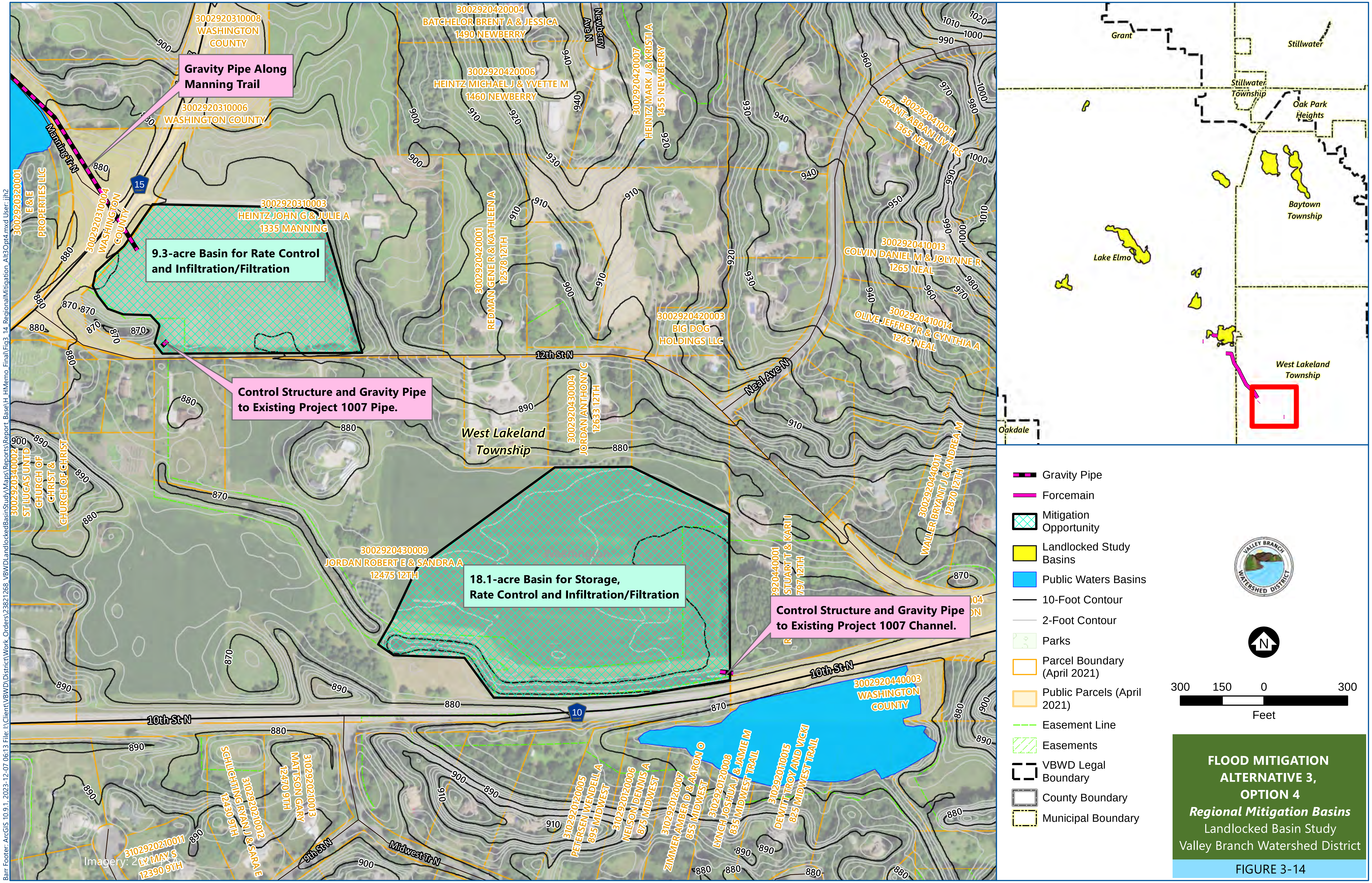


FLOOD MITIGATION ALTERNATIVE 3, OPTION 3
Regional Mitigation Basins
Landlocked Basin Study
Valley Branch Watershed District
FIGURE 3-12



FLOOD MITIGATION ALTERNATIVE 3, OPTION 4
Eden Park Pond and Downs Lake
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 3-13



FLOOD MITIGATION ALTERNATIVE 3, OPTION 4
Regional Mitigation Basins
Landlocked Basin Study
Valley Branch Watershed District

FIGURE 3-14

4 Continuous Hydraulics and Hydrology Model Results

In addition to the design event modeling, we performed continuous simulations aligning with the groundwater model simulation period. The continuous simulations used hourly precipitation data and the net groundwater flux times series from the calibrated groundwater model. These simulations were run for the period from January 1, 1998, through December 31, 2021.

The continuous simulations were completed for the following scenarios:

- Without project (existing land use)
- Without project (future land use)
- With project (future land use)
- Without project (future land use and sensitivity analysis)
- With project (future land use and sensitivity analysis)

The “without project” and “with project” conditions are described in Section 1.

As for the sensitivity analysis (see **Appendix 14**), Barr conducted a statistical analysis of historical precipitation data for the study area and concluded that VBWD could experience wet conditions similar to, or wetter than, the recent wet period from 2014–2020. The statistical analysis of the historical data indicated it may be possible to experience another wet period with as much as 9% more total annual precipitation than the VBWD received from 2014–2020. See **Appendix 14** for more information on the analysis of the historical precipitation data.

Consistent with the upper bound from the statistical analysis, the hourly precipitation data was increased by 9% between January 1, 2014, and December 31, 2020. This increased precipitation was used in the calibrated groundwater modeling to evaluate the impact of wetter conditions on the net groundwater flux at each basin (see **Appendix 10**). The basin-groundwater flow time series from the groundwater model sensitivity runs were exported for use in H&H model sensitivity scenarios along with the scaled hourly precipitation data.

We plotted these continuous model results in Figure 4-1 through Figure 4-12. The plots include the modeled water surface elevations from the model runs summarized in Table 4-1, observed water surface elevations, critical surface overflow elevations, and the groundwater flux time series used in the H&H model. We also summarized the proposed outlet’s flow frequency and flow volumes in Table 4-2 and water elevation statistics including the minimum (Table 4-3), average (Table 4-4), median (Table 4-5), and maximum (Table 4-6) water elevations from the modeled scenarios.

Some general observations from the results of the continuous modeling include the following:

- Pumping occurs during less than 2% of the continuously modeled period for the Klawitter Pond, Reid Park Ponds, Legion Pond, and Eden Park Pond “with project” alternatives.

- The Downs Lake gravity outlet has outflows during 25–30% of the continuously modeled period and has much larger outflow volumes than the other basins.
- The impact of future land-use conditions varies greatly depending on the basin, ranging from almost no change in average or maximum water elevations in Klawitter and Reid Park ponds to approximately 6 feet of increase in McDonald Lake.
- The impact of the climate sensitivity analysis (9% more precipitation over the period from 2014–2020) also varied between the watersheds but not as much as the future land use, ranging from a two-tenths of a foot increase in the average and maximum water elevations in Cloverdale Lake to approximately 2 feet of increase in Legion Pond.

We discuss the results of the continuous modeling in more detail in the *VBWD Landlocked Basin Flood Mitigation Comprehensive Planning Study* report.

Table 4-1 Continuous Model Scenarios by Waterbody

Waterbody	"Without Project" Existing Land-Use Conditions	"Without Project" Future Land-Use Conditions	"With Project" Future Land-Use Conditions	"Without Project" Future Land-Use Conditions and Sensitivity Analysis	"With Project" Future Land-Use Conditions and Sensitivity Analysis
Cloverdale Lake	X	X	(1)	X	(1)
Downs Lake	X	X	X(2)	X	X(2)
Eden Park Pond	X	X	X(2)	X	X(2)
Friedrich's Pond	X	X	(1)	X	(1)
Goetschel Pond	X	X	X(3)	X	X(3)
Klawitter Pond	X	X	X	X	X
Legion Pond	X	X	X	X	X
McDonald Lake	X	X	(1)	X	(1)
Reid Park Ponds	X	X	X	X	X
Sunfish Lake	X	X	(1)	X	(1)

(1) We did not run the continuous simulations for "with project" scenarios in the Cloverdale Lake, Friedrich's Pond, McDonald Lake, and Sunfish Lake models because we are not recommending outlets from these waterbodies.
(2) The Downs Lake and Eden Park Pond continuous modeling includes both Alternative 1 outlet options.
(3) We ran "with project" continuous simulations in the Goetschel Pond model to evaluate the impact of the Klawitter Pond inflows on Goetschel Pond's multi-year water levels if Goetschel Pond does not have an outlet.

Table 4-2 "With Project" Continuous Model Proposed Outlet Flow Frequency and Volume

Waterbody[1] (listed generally upstream to downstream)	"With Project" Future Land-Use Conditions			"With Project" Future Land-Use Conditions and Sensitivity Analysis		
	Flow Frequency[2] (%)	Total Flow Volume (ac-ft)	Annual Average Flow Volume (ac-ft/year)	Flow Frequency[2] (%)	Total Flow Volume (ac-ft)	Annual Average Flow Volume (ac-ft/year)
Klawitter Pond	0.10%	36.27	1.51	0.19%	69.42	2.89
Reid Park Ponds	0.56%	135.20	5.63	0.76%	184.02	7.67
Legion Pond	1.15%	459.52	19.15	1.38%	551.14	22.96
Downs Lake Alternative 1: Option 1	26.01%	4,285.48	178.56	25.97%	4,316.05	179.84
Downs Lake Alternative 1: Option 2	29.48%	4,265.84	177.74	29.40%	4,297.32	179.05
Eden Park Pond Alternative 1: Option 1	0.86%	300.50	12.52	0.77%	266.28	11.10
Eden Park Pond Alternative 1: Option 2	0.45%	316.36	13.18	0.39%	272.73	11.36

(1) Cloverdale Lake, Friedrichs Pond, McDonald Lake, and Sunfish Lake are not included in this table because we are not recommending outlets from these water bodies and did not run continuous simulations for "with project" scenarios.

(2) Flow frequency is calculated by summing the pumped or gravity flow periods and dividing this sum by the total modeled time (24 years).

Table 4-3 Comparison of Modeled Minimum Water Elevations in Each Landlocked Basin

<table>
<tr><th>Waterbody (listed generally upstream to downstream)</th><th>“Without Project” Existing Land-Use Conditions</th><th>“Without Project” Future Land-Use Conditions</th><th>“With Project” Future Land-Use Conditions Alternative 1: Option 1</th><th>“With Project” Future Land-Use Conditions Alternative 1: Option 2</th><th>“Without Project” Future Land-Use Conditions and Sensitivity Analysis</th><th>“With Project” Future Land-Use Conditions and Sensitivity Analysis Alternative 1: Option 1</th><th>“With Project” Future Land-Use Conditions and Sensitivity Analysis Alternative 1: Option 2</th></tr>
<tr><td>Klawitter Pond</td><td>946.24</td><td>946.19</td><td colspan="2">946.19</td><td>946.22</td><td colspan="2">946.22</td></tr>
<tr><td>Sunfish Lake</td><td>892.30</td><td>894.11</td><td>NA</td><td>NA</td><td>894.13</td><td>NA</td><td>NA</td></tr>
<tr><td>Friedrich’s Pond</td><td>905.68</td><td>906.68</td><td>NA</td><td>NA</td><td>906.69</td><td>NA</td><td>NA</td></tr>
<tr><td>Cloverdale Lake</td><td>902.36</td><td>903.53</td><td>NA</td><td>NA</td><td>903.54</td><td>NA</td><td>NA</td></tr>
<tr><td>McDonald Lake</td><td>885.51</td><td>888.97</td><td>NA</td><td>NA</td><td>888.97</td><td>NA</td><td>NA</td></tr>
<tr><td>Goetschel Pond</td><td>889.00</td><td>891.04</td><td colspan="2">891.04</td><td>891.04</td><td colspan="2">891.04</td></tr>
<tr><td>Reid Park Ponds</td><td>882.43</td><td>882.55</td><td colspan="2">881.58</td><td>882.56</td><td colspan="2">881.58</td></tr>
<tr><td>Legion Pond</td><td>880.53</td><td>883.23</td><td colspan="2">880.72</td><td>883.25</td><td colspan="2">880.72</td></tr>
<tr><td>Downs Lake</td><td>882.07</td><td>886.85</td><td>882.21</td><td>882.20</td><td>886.89</td><td>882.21</td><td>882.21</td></tr>
<tr><td>Eden Park Pond</td><td>873.26</td><td>881.57</td><td>879.37</td><td>879.45</td><td>881.57</td><td>869.82</td><td>869.82</td></tr>
</table>

Table 4-4 Comparison of Modeled Average Water Elevations in Each Landlocked Basin

Waterbody (listed generally upstream to downstream)	"Without Project" Existing Land-Use Conditions	"Without Project" Future Land-Use Conditions	"With Project" Future Land-Use Conditions Alternative 1: Option 1	"With Project" Future Land-Use Conditions Alternative 1: Option 2	"Without Project" Future Land-Use Conditions and Sensitivity Analysis	"With Project" Future Land-Use Conditions and Sensitivity Analysis Alternative 1: Option 1	"With Project" Future Land-Use Conditions and Sensitivity Analysis Alternative 1: Option 2
Klawitter Pond	951.83	951.84	951.33		952.09	951.44	
Sunfish Lake	895.50	897.10	NA	NA	897.55	NA	NA
Friedrich's Pond	907.76	908.77	NA	NA	909.07	NA	NA
Cloverdale Lake	904.66	905.15	NA	NA	905.19	NA	NA
McDonald Lake	888.65	894.24	NA	NA	894.38	NA	NA
Goetschel Pond	891.81	894.95	895.01		895.41	895.52	
Reid Park Ponds	885.21	885.25	883.44		885.43	883.46	
Legion Pond	883.60	885.97	882.23		886.46	882.24	
Downs Lake	887.97	890.10	886.15	886.16	890.14	886.14	886.16
Eden Park Pond	880.97	887.79	882.95	882.95	887.91	882.19	882.20

Table 4-5 Comparison of Modeled Median Water Elevations in Each Landlocked Basin

Waterbody (listed generally upstream to downstream)	"Without Project" Existing Land-Use Conditions	"Without Project" Future Land-Use Conditions	"With Project" Future Land-Use Conditions Alternative 1: Option 1	"With Project" Future Land-Use Conditions Alternative 1: Option 2	"Without Project" Future Land-Use Conditions and Sensitivity Analysis	"With Project" Future Land-Use Conditions and Sensitivity Analysis Alternative 1: Option 1	"With Project" Future Land-Use Conditions and Sensitivity Analysis Alternative 1: Option 2
Klawitter Pond	951.21	951.21	951.21		951.28	951.27	
Sunfish Lake	895.30	896.42	NA	NA	896.44	NA	NA
Friedrich's Pond	907.63	908.54	NA	NA	908.55	NA	NA
Cloverdale Lake	904.72	905.12	NA	NA	905.14	NA	NA
McDonald Lake	888.10	893.55	NA	NA	893.57	NA	NA
Goetschel Pond	891.20	894.41	894.41		894.45	894.45	
Reid Park Ponds	884.92	885.00	883.67		885.02	883.73	
Legion Pond	882.93	884.99	882.42		885.02	882.43	
Downs Lake	888.08	890.26	886.40	886.41	890.27	886.38	886.40
Eden Park Pond	880.98	888.25	883.35	883.35	888.29	883.06	883.07

Table 4-6 Comparison of Modeled Maximum Water Elevations in Each Landlocked Basin

Waterbody (listed generally upstream to downstream)	"Without Project" Existing Land-Use Conditions	"Without Project" Future Land-Use Conditions	"With Project" Future Land-Use Conditions Alternative 1: Option 1	"With Project" Future Land-Use Conditions Alternative 1: Option 2	"Without Project" Future Land-Use Conditions and Sensitivity Analysis	"With Project" Future Land-Use Conditions and Sensitivity Analysis Alternative 1: Option 1	"With Project" Future Land-Use Conditions and Sensitivity Analysis Alternative 1: Option 2
Klawitter Pond	958.01	958.05	955.83		958.54	955.86	
Sunfish Lake	899.61	901.85	NA	NA	903.81	NA	NA
Friedrich's Pond	910.12	911.49	NA	NA	912.60	NA	NA
Cloverdale Lake	906.67	907.37	NA	NA	907.59	NA	NA
McDonald Lake	893.34	899.16	NA	NA	899.56	NA	NA
Goetschel Pond	896.99	900.07	900.48		901.95	902.56	
Reid Park Ponds	887.98	887.97	885.59		888.32	885.59	
Legion Pond	888.36	891.27	883.51		893.35	883.62	
Downs Lake	892.38	892.61	889.84	890.89	892.88	889.84	890.89
Eden Park Pond	889.06	892.61	885.25	885.21	892.88	885.25	885.21

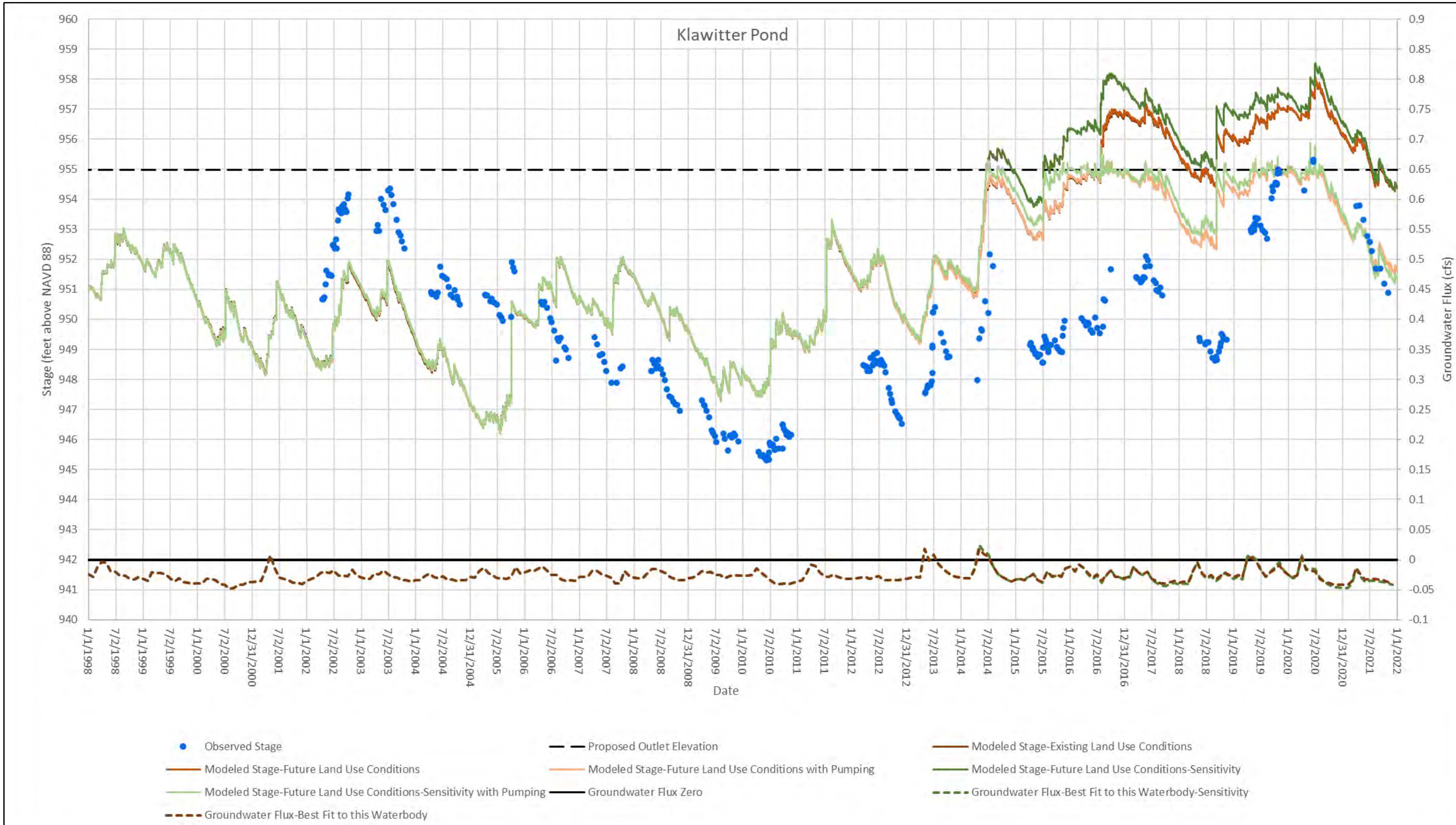


Figure 4-1 Klawitter Pond Continuous Modeling Results

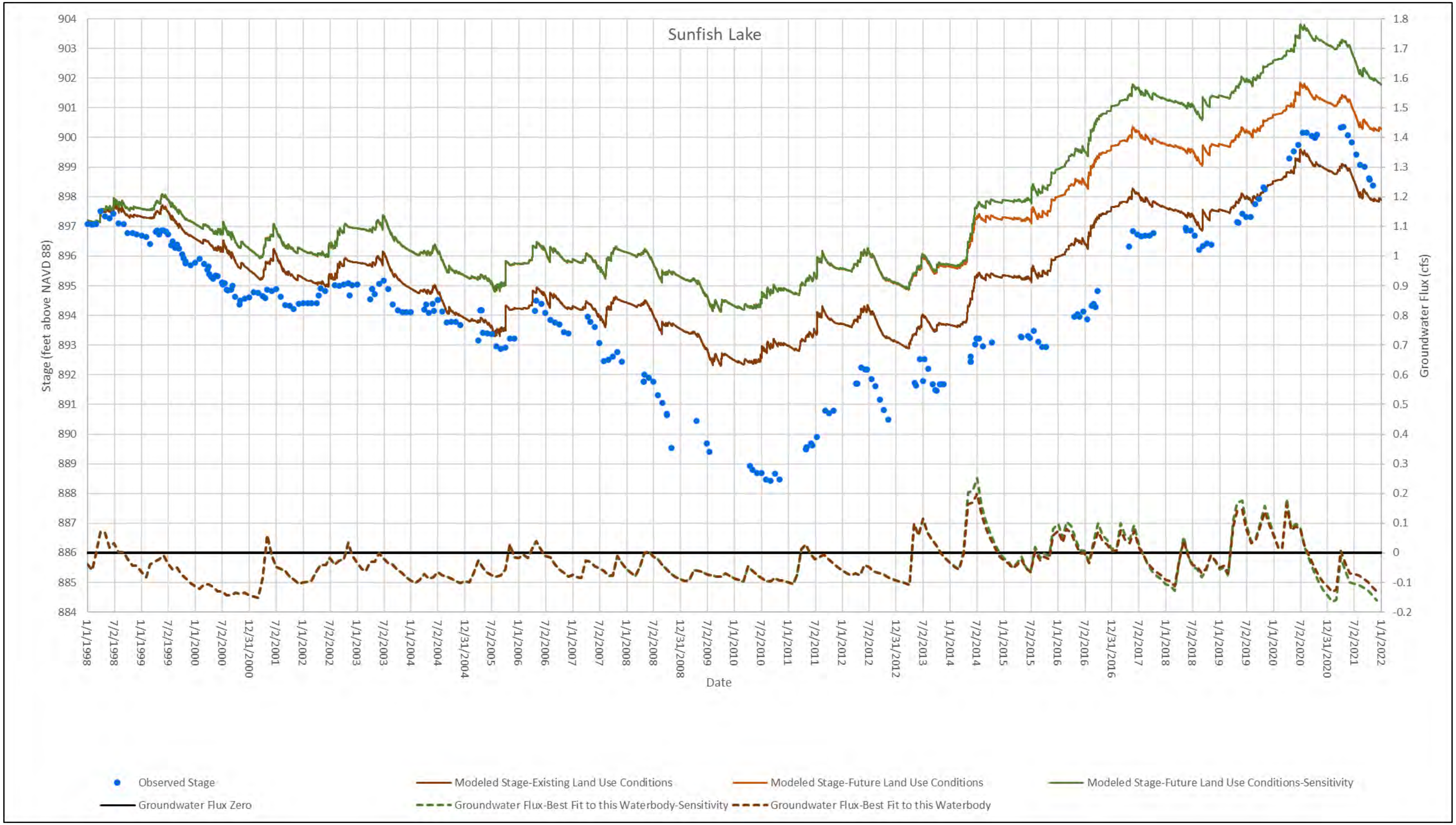


Figure 4-2 Sunfish Lake Continuous Modeling Results

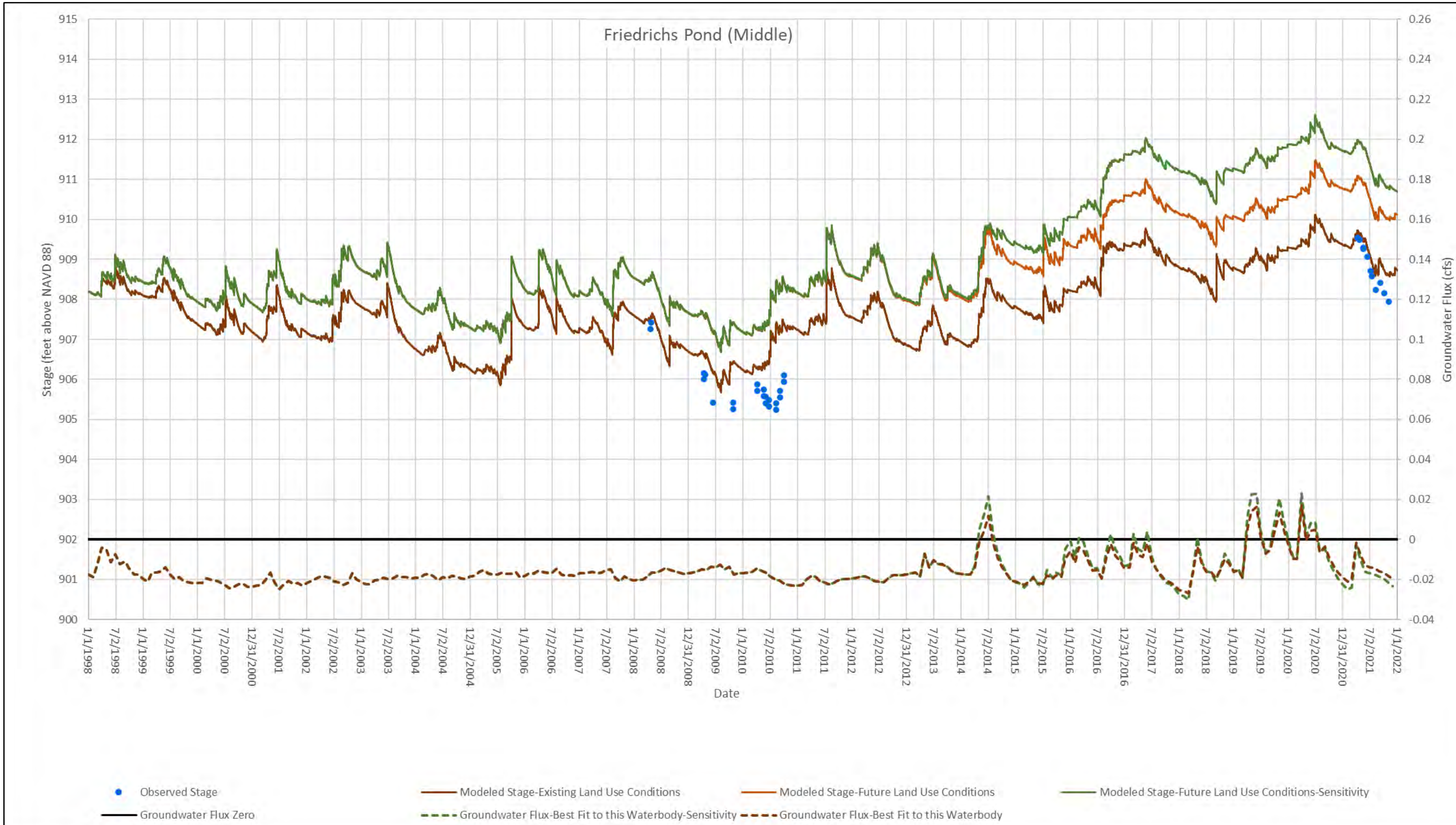


Figure 4-3 Friedrich's Pond Continuous Modeling Results

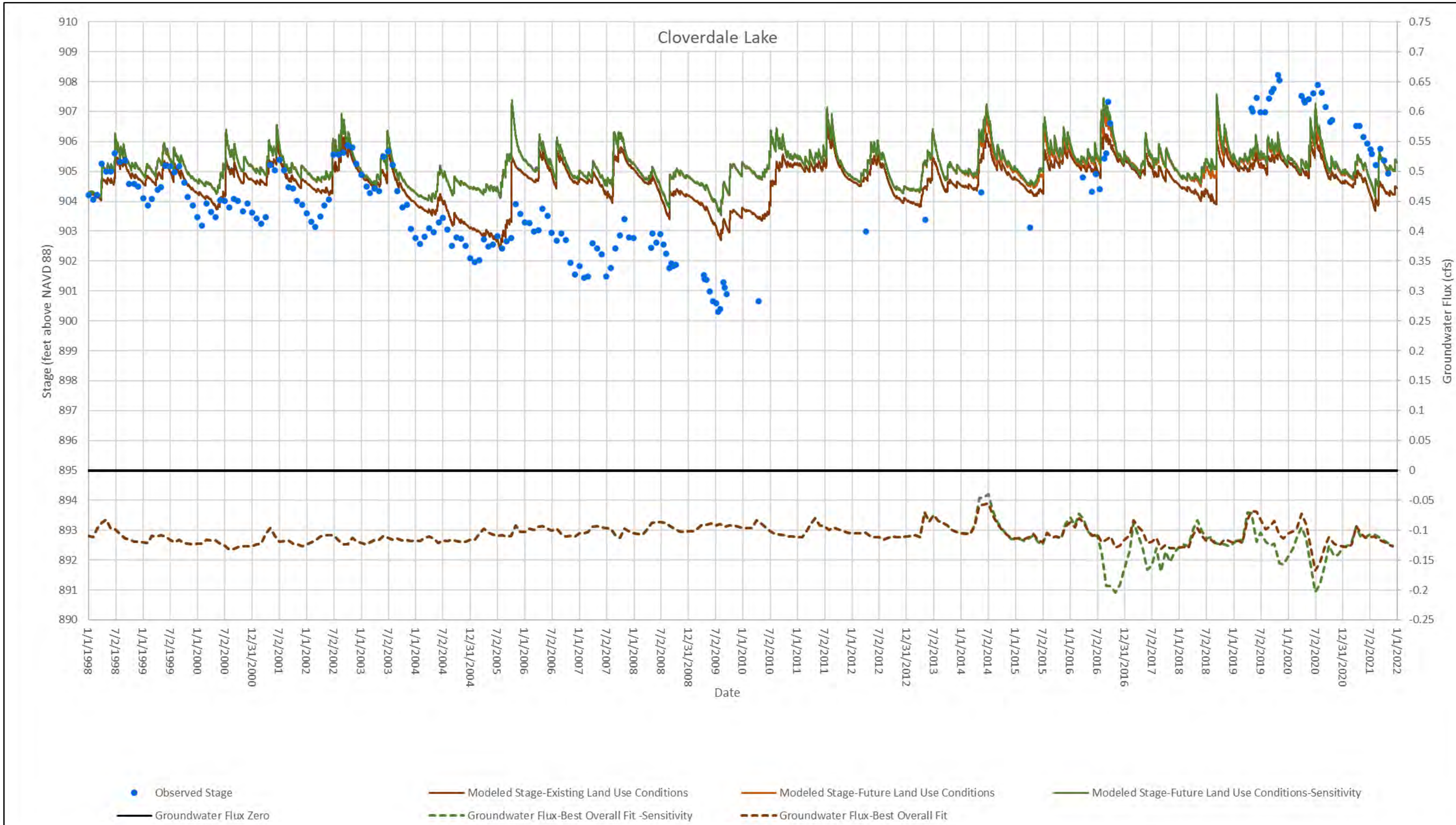


Figure 4-4 Cloverdale Lake Continuous Modeling Results

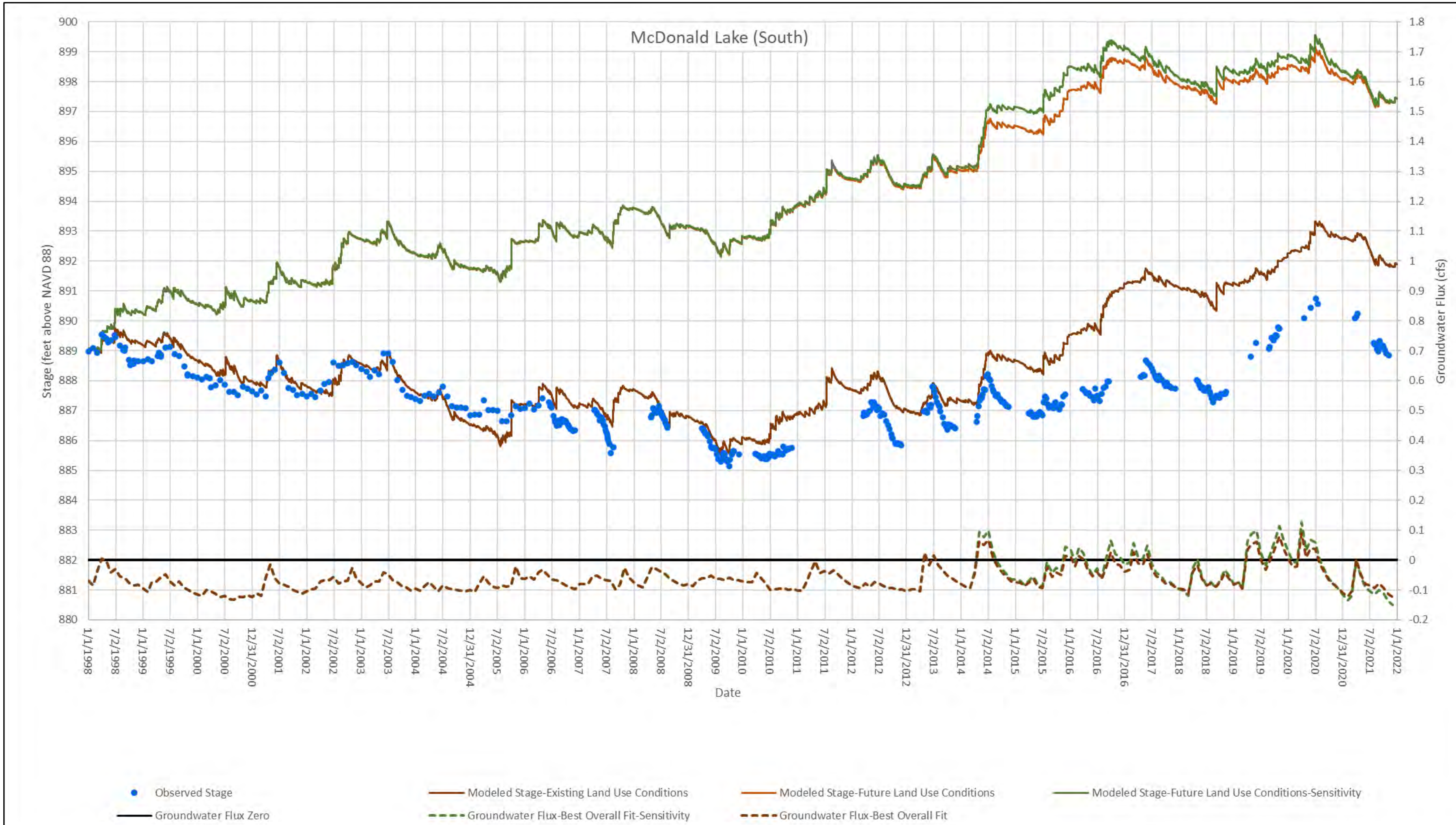


Figure 4-5 McDonald Lake (South) Continuous Modeling Results

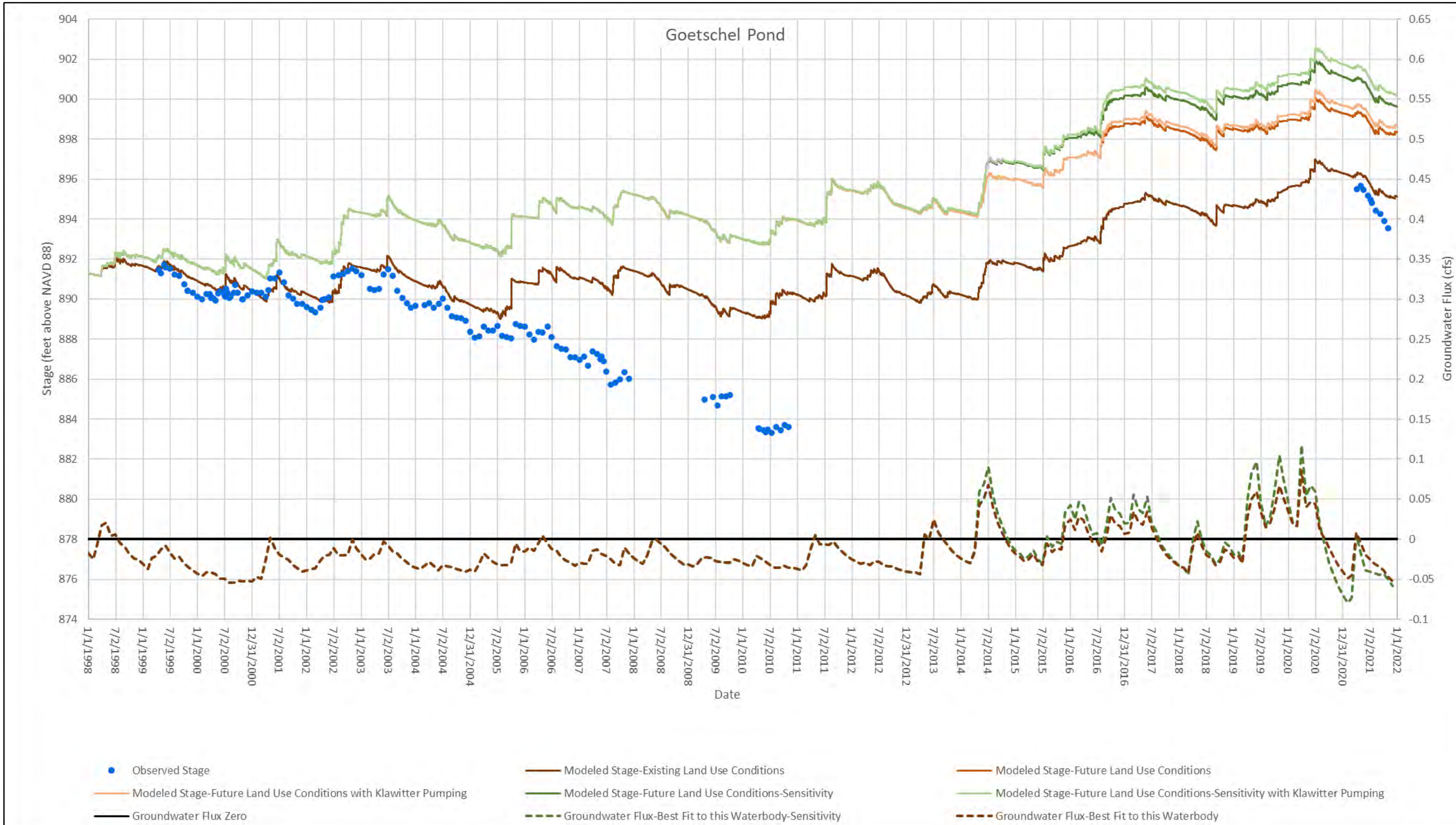


Figure 4-6 Goetschel Pond Continuous Modeling Results

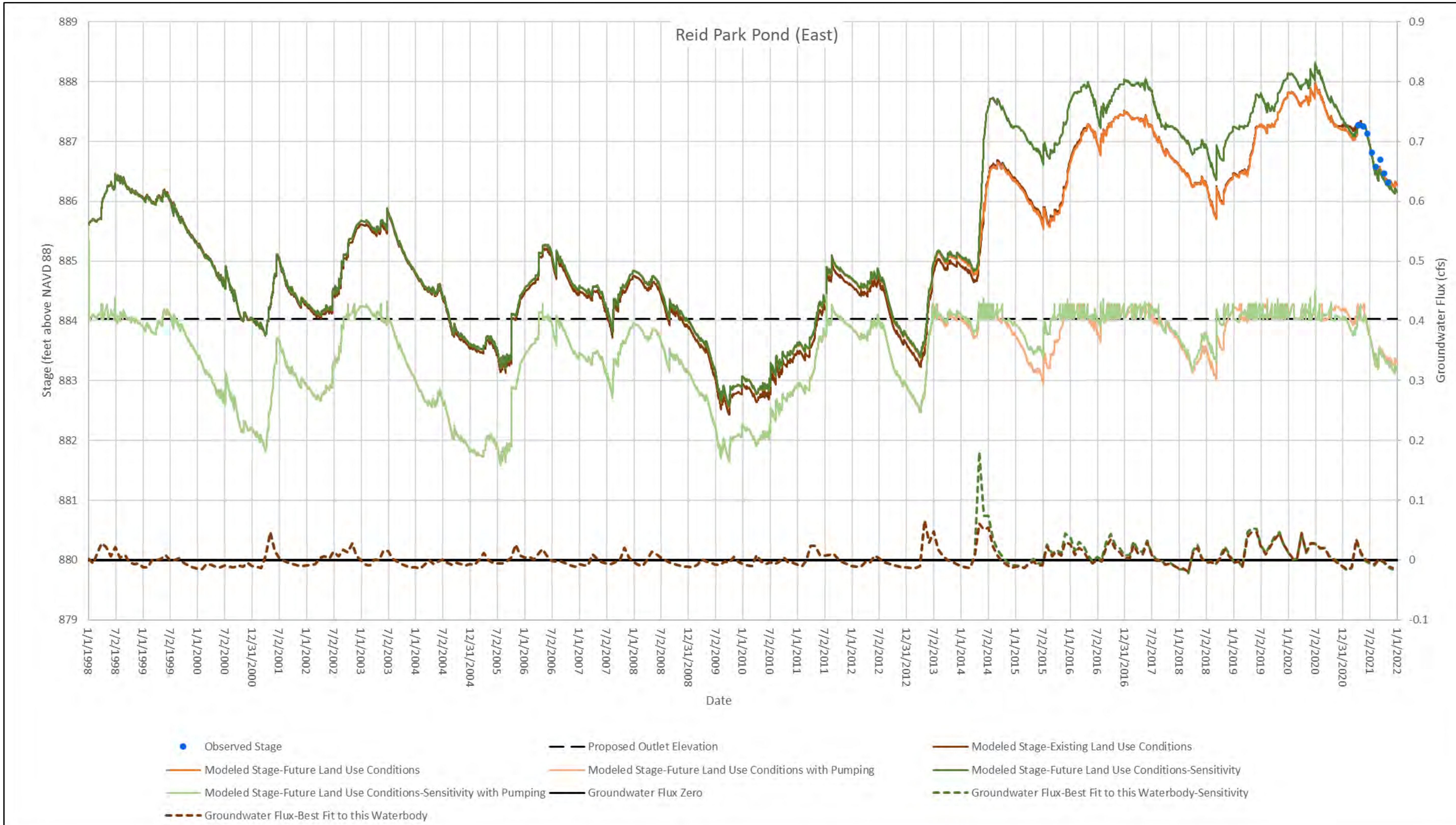


Figure 4-7 Reid Park Ponds Continuous Modeling Results

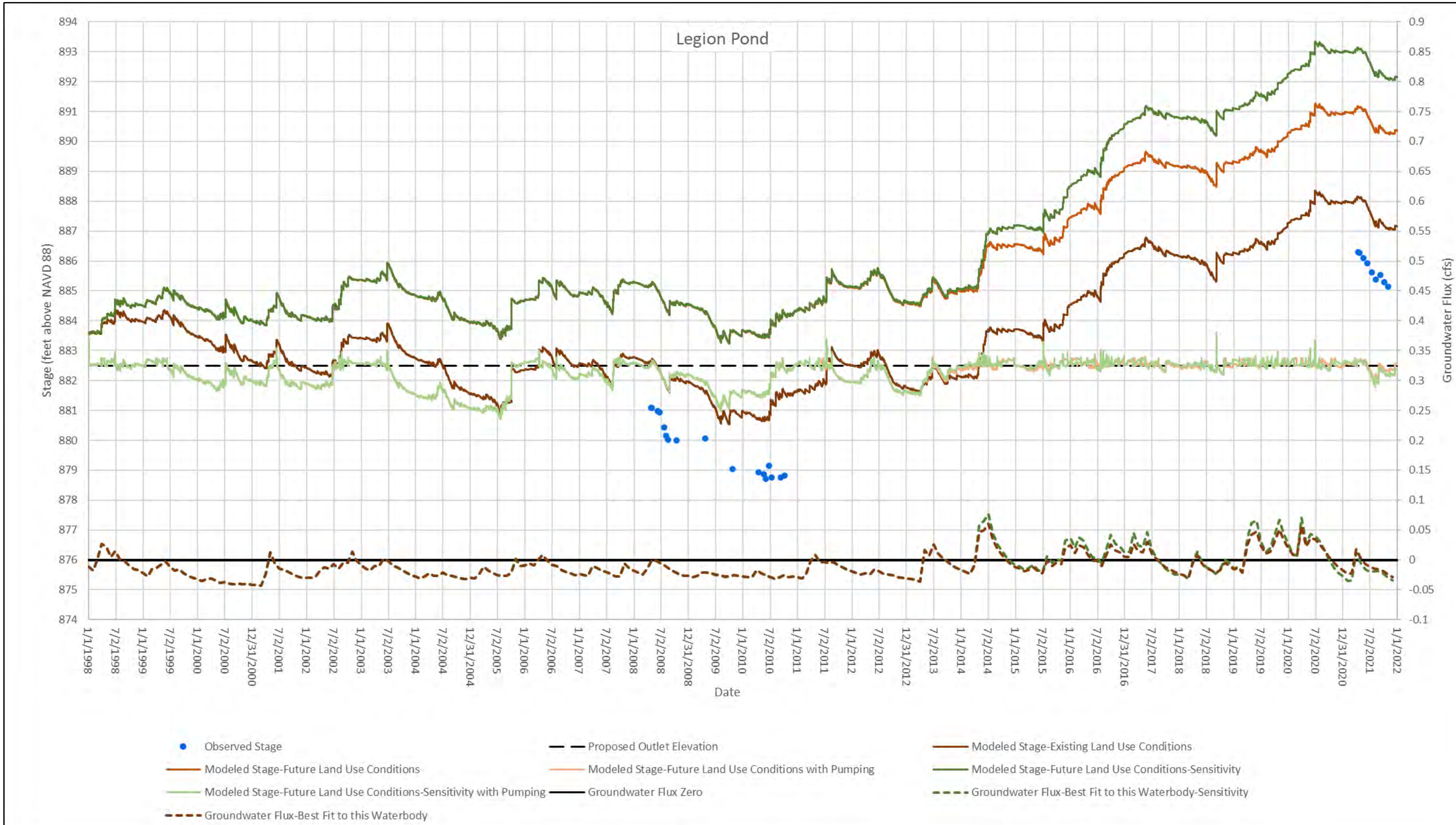


Figure 4-8 Legion Pond Continuous Modeling Results

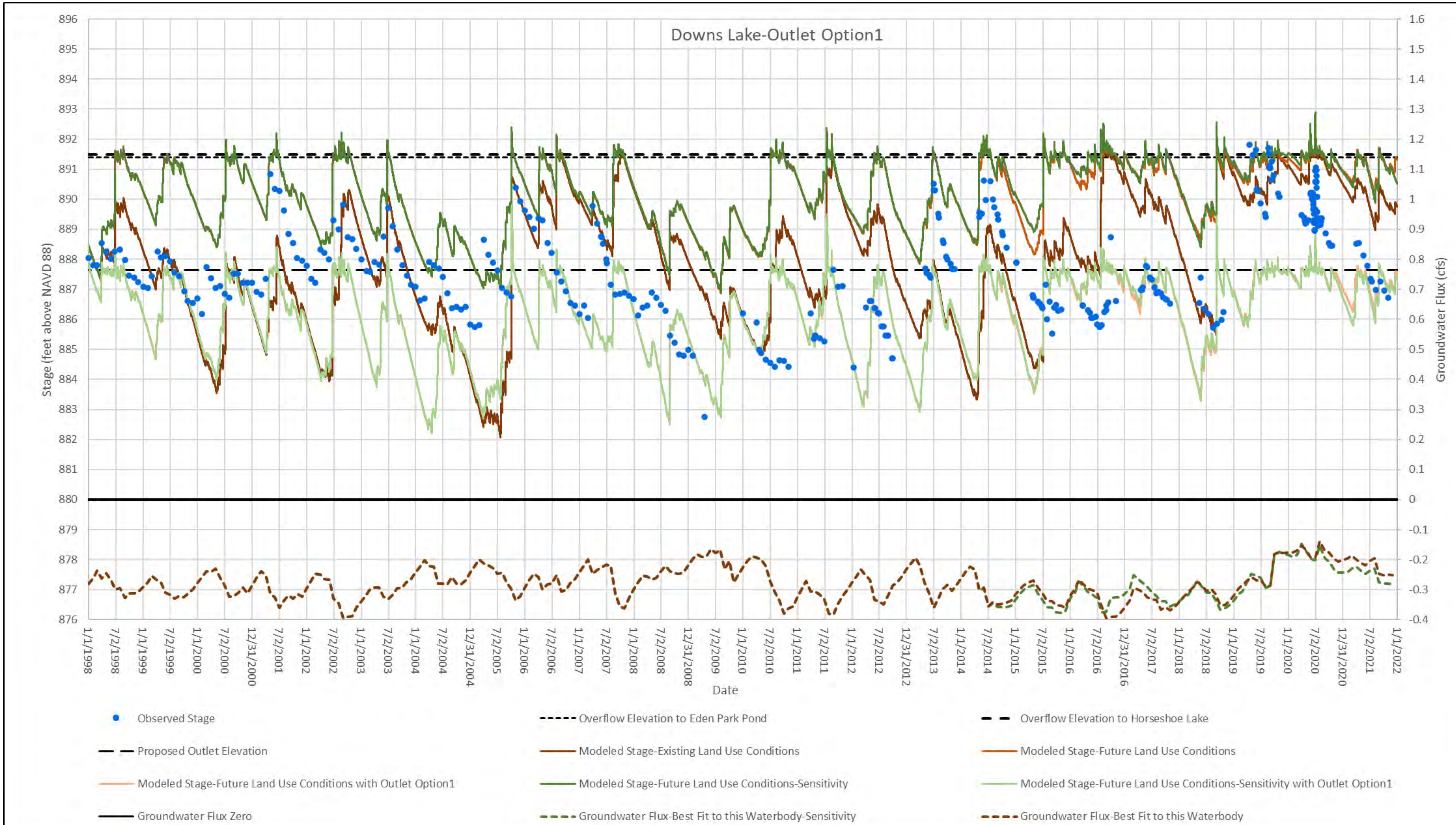


Figure 4-9 Downs Lake Continuous Modeling Results—Outlet Option 1

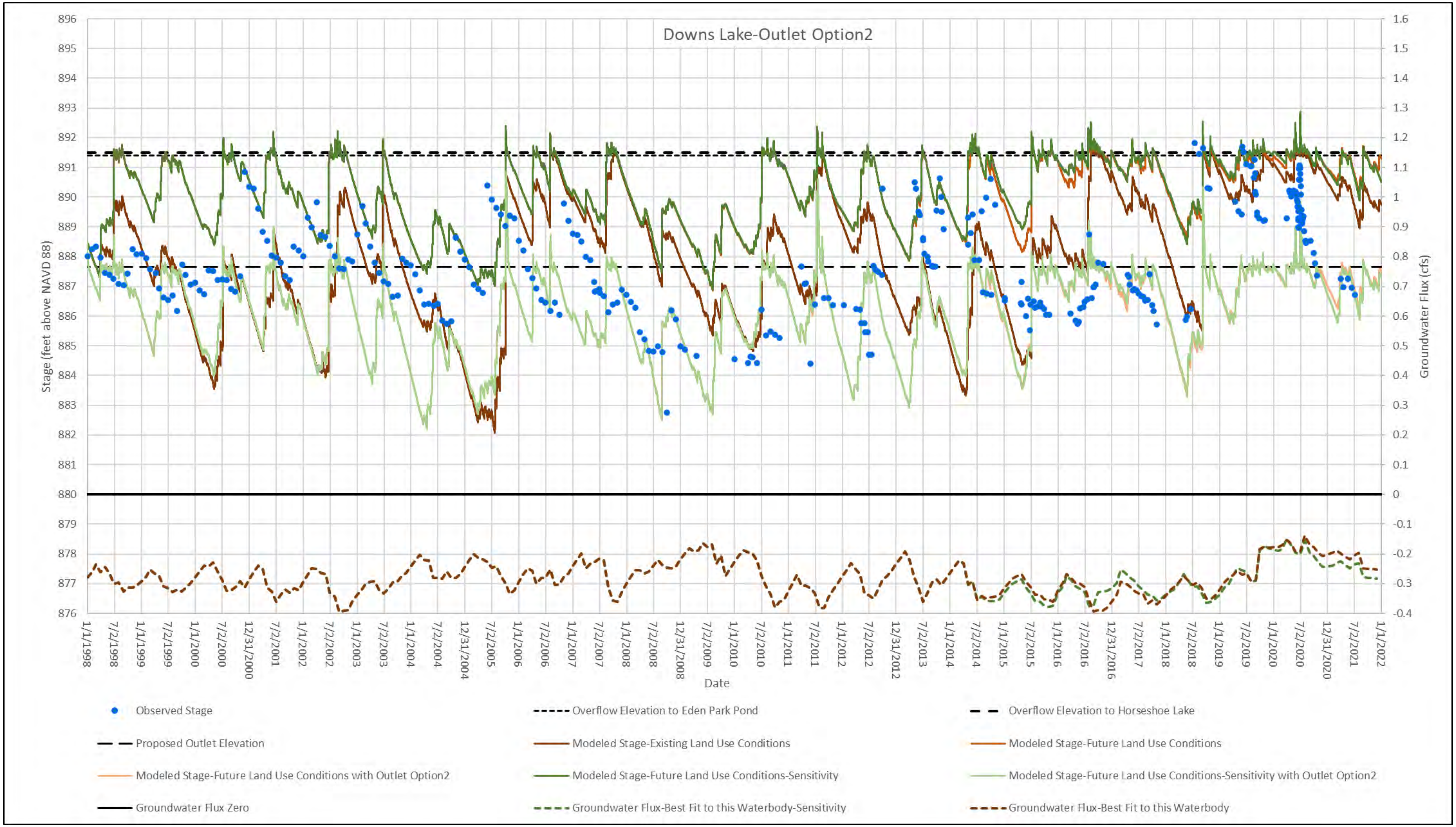


Figure 4-10 Downs Lake Continuous Modeling Results—Outlet Option 2

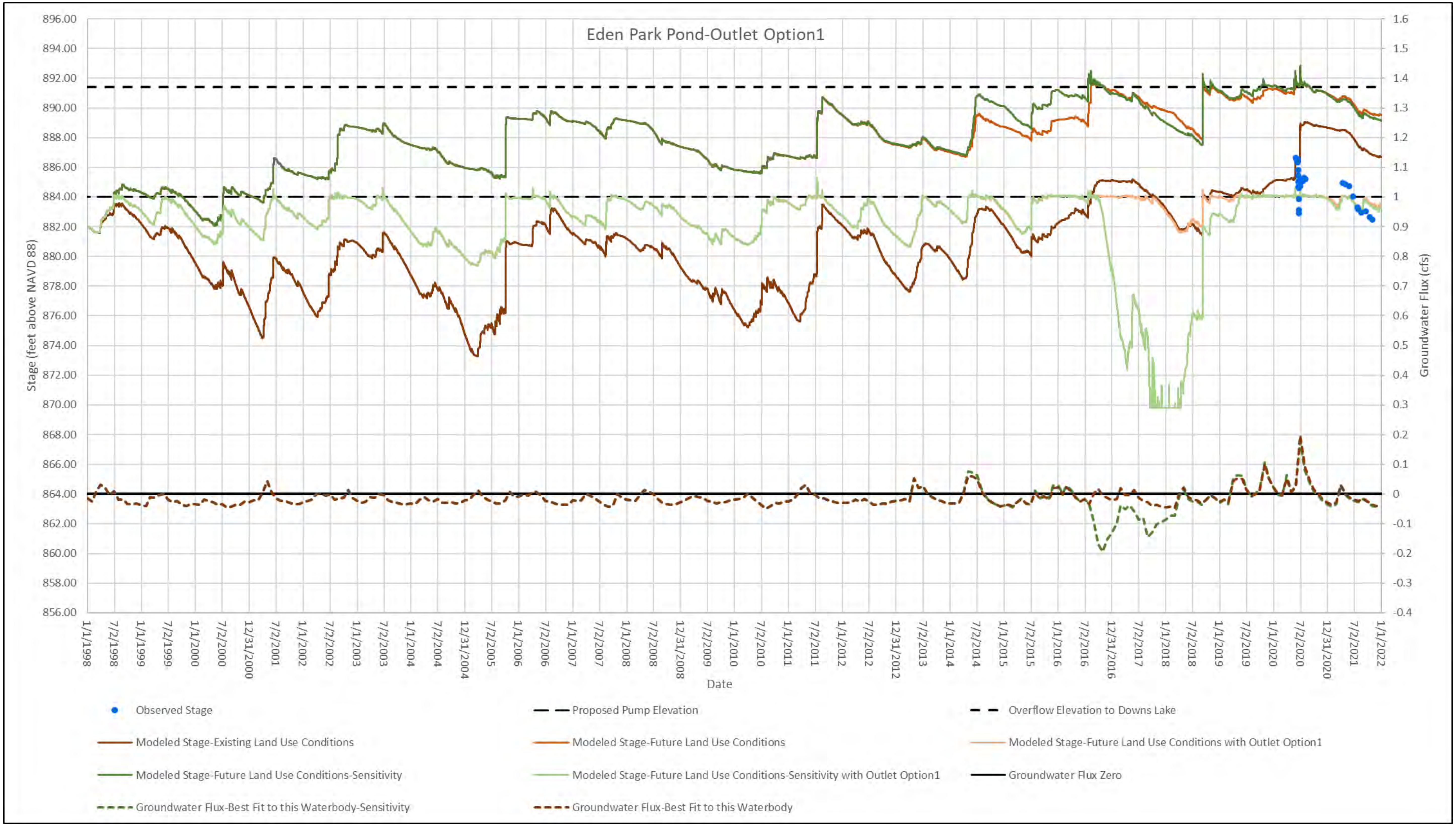


Figure 4-11 Eden Park Pond Continuous Modeling Results—Outlet Option 1

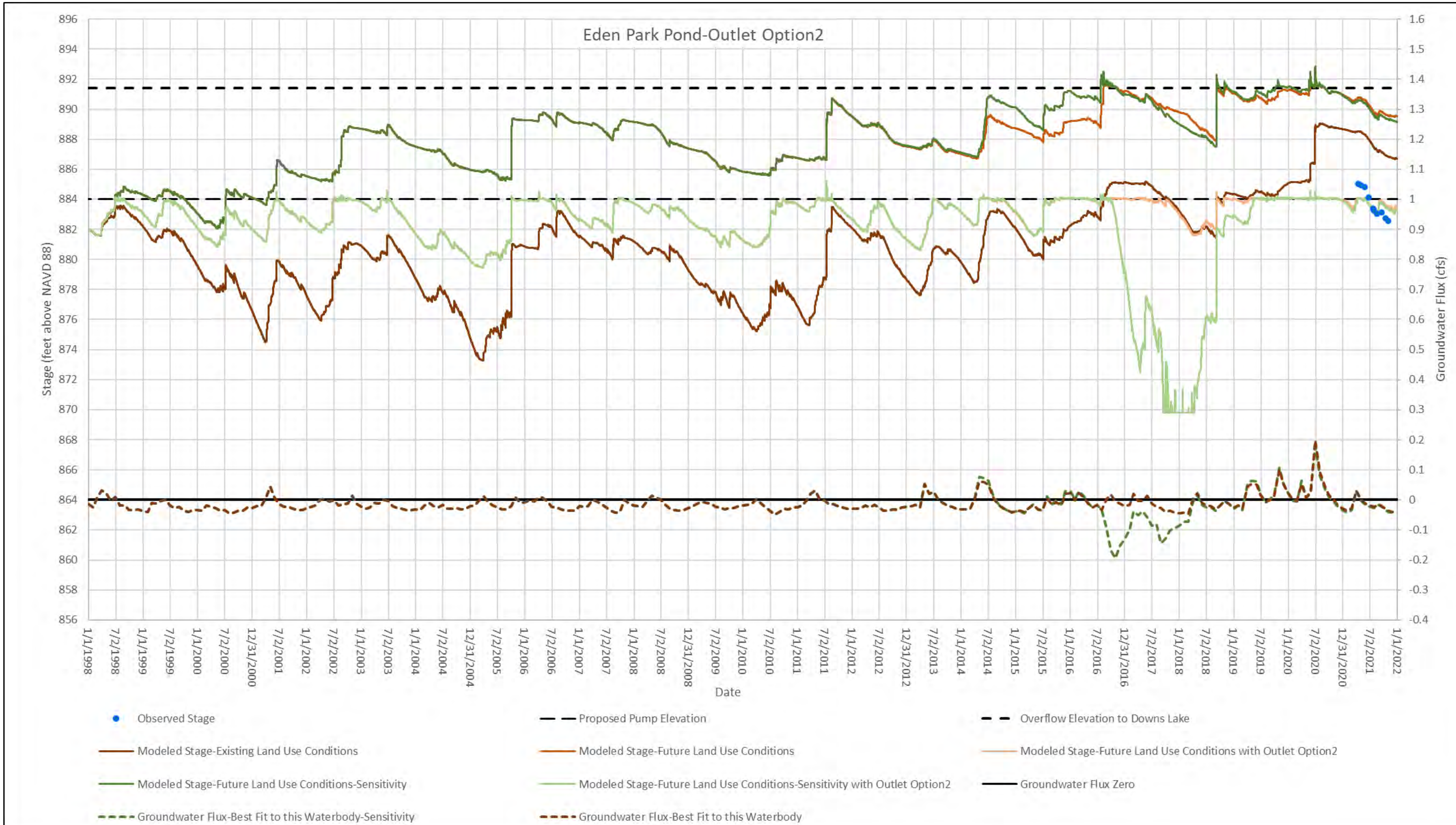


Figure 4-12 Eden Park Pond Continuous Modeling Results—Outlet Option 2

5 References

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UMN Remote Sensing and Geospatial Analysis Laboratory. (2015). Land Cover & Impervious: TCMA 1-Meter 2015. UMN Remote Sensing and Geospatial Analysis Laboratory - Data. https://rs.umn.edu/data/data-list