Task 8.1: Alewife Brook Pump Station Optimization Evaluation

CSO Post Construction Monitoring and Performance Assessment
MWRA Contract No. 7572

April 27, 2021

Project number: 60559027

Table of Contents

1. BACKGROUND 4

1.1 Alewife Brook System Overview 4
1.2 History of Activities to Reduce CSO to Alewife Brook/Upper Mystic River 5
1.3 Context and Objectives for the Alewife Brook Pump Station Optimization Evaluation 8
1.4 Overview of Technical Approach for ABPS Optimization Evaluation 9

2. DATA REVIEW 10

2.1 Data Sources 10
2.2 ABPS Operating Strategy 10
2.3 Hand Calculations 12

3. SITE INVESTIGATION AND FIELD WORK 15

3.1 Dry Weather Pump Test 15
3.2 Wet Weather Pump Test 15

4. HYDRAULIC AND HYDROLOGIC MODELING EVALUATIONS 16

4.1 Description of Baseline Model 16
4.2 Initial Evaluation of Alternative ABPS Operating Strategies 21
4.3 MWRA Field Testing of the Alternative Operating Strategy (12/5/2020) 25

5. CONCLUSIONS AND NEXT STEPS 28

5.1 Summary and Recommendations 28
5.2 Implementation and Next Steps 28

6. REFERENCES 29

APPENDIX A: DRY WEATHER PUMP TEST REPORT 30

APPENDIX B: WET WEATHER PUMP TEST REPORT 31

APPENDIX C: BASELINE MODEL REGULATOR AND INTERCEPTOR HGL PROFILES FOR THE OCTOBER 23RD AND AUGUST 18TH TYPICAL YEAR STORM EVENTS 32

Figures

Figure 1-1: Alewife Brook System Schematic 5
Figure 1-2: Alewife Brook Pump Station Schematic 5
Figure 1-3. Location of Completed CSO Control Projects for Alewife Brook/Upper Mystic River 7
Figure 2-1. Existing ABPS Operating Strategy Displayed on the Manager Setpoint Screen 12
Figure 2-2. ANSI/HI 9.8 Calculated Minimum Submergence for the Wet Weather Pumps 13
Figure 2-3. ANSI/HI 9.8 Calculated Minimum Submergence for the Dry Weather Pump 14
Figure 4-1. MWRA Full System Model with Alewife Region of Interest Highlighted in Red 16
Figure 4-2. Regulator Profile at SOM001A for the 10/23/92 Storm 18
Figure 4-3. Regulator Profile at SOM001A for the 8/18/92 Storm 19
Figure 4-4. ABC Interceptor Profile for the 10/23/92 Storm 20
Figure 4-5. ABC Profile for the 8/18/1992 Storm 20
Figure 4-6. Proposed Alternative ABPS Operating Strategy Displayed on the Manager Setpoint Screen 22
Figure 4-7. Comparison Plots of ABPS Wet Well Level for the Four Model Runs 24
Figure 4-8. Comparison Plots of ABC HGL at the Dry Weather Flow Connection at SOM001A 24
Figure 4-9. Comparison Plots of ABPS Total Station Discharge Flow for the Baseline and Scenario 1, and ABPS Influent Flow from the ABC for Scenarios 2 and 3 25
Figure 4-10. Final Wet Weather ABPS Operating Strategy Displayed on the Manager Setpoint Screen 26

Tables

TABLE 1-1. SUMMARY OF CSO CONTROL PROJECTS IMPLEMENTED FOR THE ALEWIFE BROOK/UPPER MYSTIC RIVER....6
TABLE 1-2. SUMMARY OF PROGRESS ON REDUCING CSO DISCHARGES TO ALEWIFE BROOK/UPPER MYSTIC RIVER 8
TABLE 4-1. COMPARISON OF TYPICAL YEAR SIMULATION RESULTS FOR THE MID-2020 SYSTEM CONDITIONS MODEL, UPDATED BASELINE MODEL, AND LONG TERM CONTROL PLAN 17
TABLE 4-2. COMPARISON OF ALTERNATIVE ABPS MODEL RUNS TO BASELINE AND LTCP GOALS 23
TABLE 4-3. COMPARISON OF MWRA AND ALTERNATIVE ABPS OPERATING STRATEGIES MODEL RUNS TO BASELINE AND LTCP GOALS 27

1. Background

This section provides the following background information for the Alewife Brook Pump Station (ABPS) Assessment:

- An overview of the combined sewer system along Alewife Brook,
- A review of projects that have been completed as part of the MWRA's CSO Program to reduce CSOs to the Alewife Brook/Upper Mystic River,
- The context and objectives of the ABPS Assessment, and
- A summary of the procedure used to complete the ABPS assessment.

1.1 Alewife Brook System Overview

The ABPS receives flow from four upstream MWRA sewers: Alewife Brook Conduit (ABC), Alewife Brook Branch Sewer (ABBS), Belmont Branch Sewer, and Lexington Branch Sewer. Flow is lifted and discharged downstream to the North Metropolitan Trunk Sewer and North Metropolitan Relief Sewer, continuing by gravity to the Chelsea Creek Headworks. The tributary area includes portions of Arlington, Belmont, Cambridge, Somerville and Medford. A schematic of the Alewife Brook system is presented in Figure 1-1. The light and dark blue lines in Figure 1-1 depict the ABC and ABBS, and the three locations between the ABPS and SOM001A where the two lines intersect represent physical inter-connections, but the location where the interceptors cross upstream of SOM001A is not an interconnection. The six red arrows represent the six CSO outfalls that discharge to Alewife Brook. The blue-bounded boxes upstream of the red arrows represent the regulators associated with each outfall.

The ABPS consists of two influent/screening channels, a wet well, one dry weather pump, and three wet weather pumps. A schematic of the ABPS is shown in Figure 1-2. In 2019, as part of the ABPS Rehabilitation project, three new wet weather pumps were installed with individual capacities greater than the previously installed pumps. These increased capacities allow for the use of two wet weather pumps in parallel while a third wet weather pump serves as a stand-by. Additionally, the facility has a dry weather pump to control the wet well level during normal, non-storm operating conditions. This pump is also operated during wet weather to provide additional wet weather pumping capacity. The dry weather pump was not replaced as part of the 2019 upgrade due to its recent installation in 2008 and continued operation as intended.

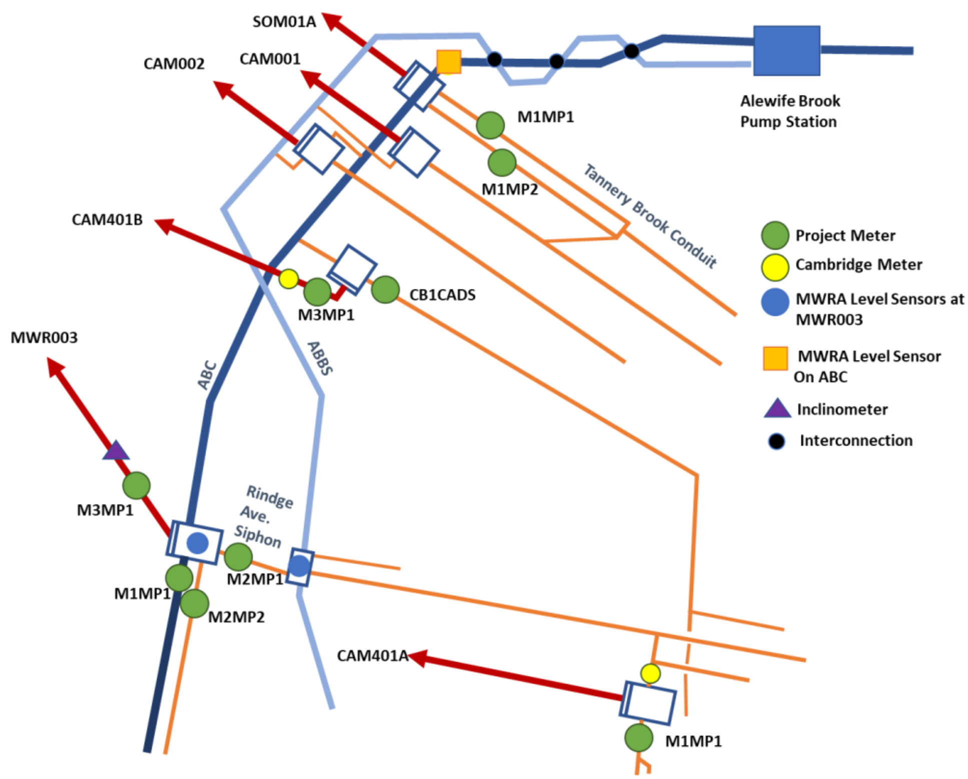

Figure 1-1: Alewife Brook System Schematic

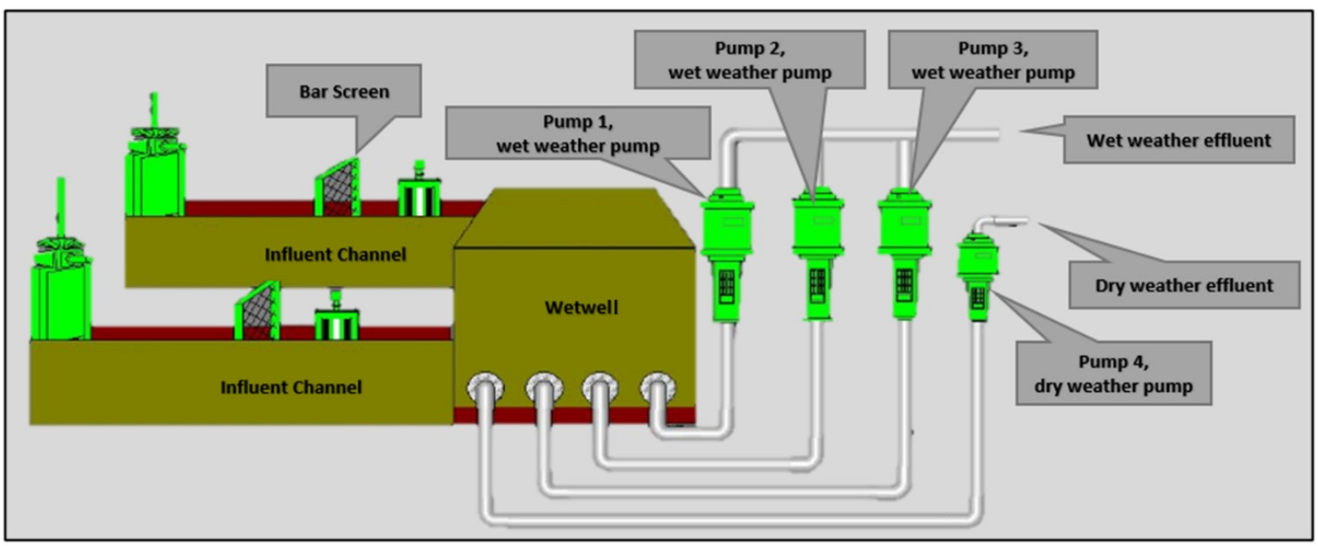

Figure 1-2: Alewife Brook Pump Station Schematic

1.2 History of Activities to Reduce CSO to Alewife Brook/Upper Mystic River

The ABPS Assessment and subsequent evaluations to be conducted as required under the Alewife Brook/Upper Mystic River Variance follow many years of progress towards reducing CSOs to the Alewife Brook/Upper Mystic River. The original recommended CSO control plan for the Alewife Brook/Upper Mystic River was presented in the 1997 Combined Sewer Overflow Facilities Plan and Environmental Impact Report (Metcalf & Eddy, 1997). The plan was subsequently revised during implementation, as described in the 2003 Final Variance Report for Alewife Brook/Upper Mystic River (Metcalf & Eddy, 2003). The final plan has been fully implemented, and Table 1-1 summarizes the projects that benefitted the Alewife Brook/Upper Mystic River along with their completion dates. The general locations of the projects are shown in Figure 1-3.

Table 1-1. Summary of CSO Control Projects Implemented for the Alewife Brook/Upper Mystic River

Project	Description	Completion Date
Somerville Baffle Manhole Separation	Separation of baffle manholes allowed for closure of SOM001, SOM002A/003, and SOM004 as CSO outfalls to Alewife Brook, and SOM006 and SOM007 as CSO outfalls to the Upper Mystic River.	1996
Somerville Marginal CSO Facility Upgrade	The chlorine disinfection system was upgraded, and dechlorination was added along with process control and safety improvements. These improvements benefited the quality of treated discharge at outfall SOM007A/MWR205A into the Upper Mystic River.	2001
Interceptor Connection Relief/Floatables Control for CAM002, CAM401B and CAM001	Relief of the connection between the regulator for CAM002 and the interceptor system reduced CSO activations and volume; floatables control was provided for the remaining discharges from CAM002, CAM401B and CAM001. See text below for subsequent modifications to the CAM002 interceptor connection.	2010
CAM400 Manhole Separation	Separation of combined manholes allowed for closure of CAM400 as a CSO outfall to Alewife Brook	2011
CAM004 Stormwater Outfall and Detention Basin	As part of implementation of sewer separation and upgrading of the drainage level of service in the CAM004 tributary area, a new stormwater outfall conduit was constructed along with a stormwater wetlands detention basin to mitigate peak flows and pollutant loads to Alewife Brook	2013
Interceptor Connection Relief and Floatables Control for SOM001A	The drop connection between the SOM001A regulator and the ABC was enlarged, to reduce CSO activation frequency and volume. An underflow baffle for floatables control was also installed. See text below for subsequent modifications to this interceptor connection.	2013
MWR003 Gate and Rindge Avenue Siphon Relief	A downward-opening sluice gate was provided at the regulator associated with MWR003, to allow the overflow weir to be set at a relatively high elevation to reduce overflows during most storms, but to be lowered to mitigate potential flooding in larger storms. The siphon between the ABC and ABBS was relieved to improve the balance of flows between those interceptors and reduce overflows.	2015
CAM004 Sewer Separation	The approximately 211-acre area tributary to outfall CAM004 was separated, with stormwater routed to the new CAM004 Stormwater Outfall and Stormwater Detention Basin that had been completed in 2013. As a result of this work CAM004 was eliminated as a CSO outfall.	2015

The total capital cost of the projects listed in Table 1-1 was $110 million, not including the Somerville Marginal CSO Facility Upgrade, which was part of a $22.4 million program to upgrade five of the MWRA's CSO Treatment Facilities that were in operation at that time. These projects resulted in closure of a total of eight CSO outfalls that previously discharged to Alewife Brook or the Upper Mystic River.

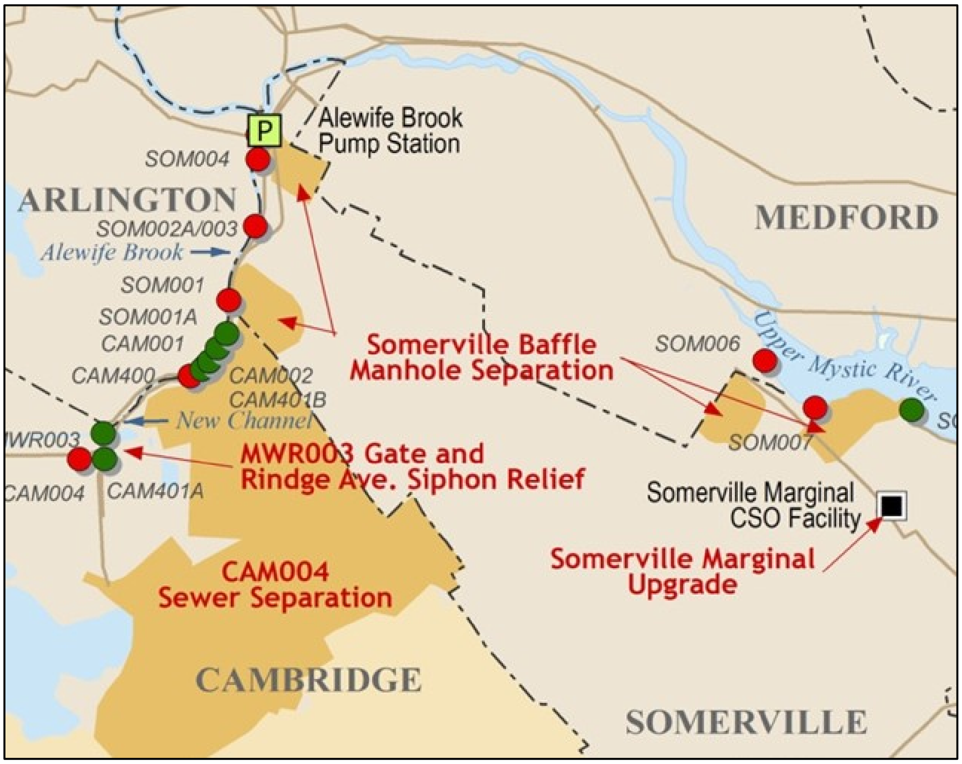

Figure 1-3. Location of Completed CSO Control Projects for Alewife Brook/Upper Mystic River

More recently, additional improvements have been implemented to further reduce CSOs to Alewife Brook. These activities have included the following:

- SOM001A: A restricting orifice plate was removed from the dry weather flow connection between the City of Somerville's Tannery Brook Conduit and the ABC, changing the connection from a 24-inch diameter opening to the equivalent of a 36-inch diameter opening, thereby increasing the hydraulic capacity of the connection.

- CAM002: A plate was removed from the weir, changing the overflow elevation from 112.08 feet-MDC to 111.08 feet-MDC. An additional plate was removed which opened a connection between the influent line to the CAM002 regulator and the ABC.

- CAM401A: The City of Cambridge undertook a project to remove sediment in the community's sewers between the regulator associated with outfall CAM401A and the ABBS.

Table 1-2 below summarizes the improvements in annual CSO activations and volumes that have been achieved for the Alewife Brook/Upper Mystic River between 1992 and 2020, along with the overall targets per the LTCP.

Table 1-2. Summary of Progress on Reducing CSO Discharges to Alewife Brook/Upper Mystic River

			Typical Year Performance		
		Number of CSO Outfalls	Frequency of Most Active Outfall	Total Untreated Discharge Volume (MG)	Total Treated Discharge Volume (MG)[(1)]
Alewife Brook/Upper Mystic River	1992	15	63	50.0	7.6
	2020	7	8	6.26	5.01
	LTCP Goal	7	7	7.29	3.5

Notes:

(1) Treated discharge from Somerville Marginal CSO Facility to outfall SOM007A/MWR205A in Upper Mystic River.

1.3 Context and Objectives for the Alewife Brook Pump Station Optimization Evaluation

The 2019 Alewife Brook/Upper Mystic River Variance specified a range of activities to be undertaken by MWRA during the Variance period to further evaluate opportunities to reduce CSO discharges to Alewife Brook. In particular, Exhibit A of the Variance identifies a series of

> specific additional system optimization measures that MWRA will undertake during a 5-year variance period…intended to further MWRA's goals of improving water quality in … the Upper Mystic River, and Alewife Brook. These measures are consistent with the requirements of 40CFR 131.14, and allow for progress to be made towards attaining the designated use(s) and water quality criteria. Collectively with the other elements of the CSO Variance requirements, these efforts comprise the pollutant Minimization Program to be implemented during the coures of the CSO Variance (DEP, 2019).

Specifically for the ABPS, Exhibit A states that

> MWRA will assess alternative pumping strategies and expected upstream benefits using the MWRA's calibrated hydraulic model. Alternatives determined to provide potential benefits will be tested for a range of storm events. MWRA will develop an Alewife Brook Pump Station Optimization Report with findings and recommendations, including modeled control alternatives and testing, and an implementation plan to establish a schedule for any required programming of automated facility control changes and operator training, which shall become the standard operating procedure to minimize CSO discharges. Implementation will proceed unless the feasibility evaluation clearly demonstrates that construction is technically infeasible, that the project will not provide water quality benefits through the reduction of CSO volume or frequency, or that the costs, alone or in conjunction with other activities specified in Exhibit A, would cause widespread social and economic impact (DEP, 2019).

In accordance with the Variance requirements, the ABPS pump operational control strategy was investigated to assess if adjusting pump operation could reduce or eliminate upstream CSOs without adversely affecting downstream conditions. The investigation of alternative pump operation strategies focused on pump sequencing, on-off level setpoints, and pump speed versus the pump suction-side wet well elevation settings.

The work for this evaluation included:

- Field testing of the single dry weather pump to assess its field performance and ability to safely operate at low wet well levels.
- Evaluating new operating level and pumping strategies to potentially reduce or eliminate upstream CSOs without adversely affecting the downstream system using the MWRA's collection system model.

- Field testing of the wet weather pumps to assess the feasibility of operational changes if the model indicated such changes could result in CSO reduction benefits.
- Documenting the modeling and field testing performed and the predicted and observed results.

1.4 Overview of Technical Approach for ABPS Optimization Evaluation

The following steps were used to complete the evaluation of the current ABPS operating strategy, and to develop and evaluate alternative operating strategies. The text sections providing additional details are indicated in parentheses:

1. Reviewed available data sources and current ABPS operating strategy (Sections 2.1 and 2.2)
2. Conducted hand calculations for pump properties such as submergence requirements and potential impeller upgrades (Section 2.3)
3. Updated the existing model to reflect mid-2020 system conditions (Section 4.1)
4. Conducted initial evaluations of alternative operating strategies using the updated model (Section 4.2)
5. Conducted a dry weather pump test to test performance and operational limits (Section 3.1)
6. Conducted a wet weather pump test to assess operational limits (Section 3.1)
7. Updated the existing model to reflect pump field performance identified during the field tests (Section 4.1)
8. Updated and revised an alternative operation strategy and assessed impact on upstream regulators (Section 4.2)
9. Tested and revised the recommended alternative operating strategy, implemented during a wet weather storm event (Section 4.2)
10. Developed conclusions and recommendations based on the preceding steps (Section 4.2 and 5)

2. Data Review

This section presents the data sources that were reviewed and used as part of this investigation to refine and update the existing model as needed. The current ABPS operating strategy is then presented, followed by a description of hand calculations that were performed based on the available data at the onset of this investigation as a first step in assessing the feasibility and limitations of alternative operating strategies.

2.1 Data Sources

The various data sources reviewed and analyzed included the following:

- **Record Drawings and Pump Curves:** The ABPS was rehabilitated in 2019. Record drawings and pump curves were reviewed to update the model as needed.
- **Existing ABPS Meter Data:** MWRA has flow meters on the discharge piping for all station pumps as well as the combined wet weather discharge flow channel exiting the station. Two level sensors monitor the fluid level in the wet well. The meter data were evaluated for various storm events to further understand the system response to the existing operating strategy.
- **SCADA Data:** SCADA data were provided for various locations including the wet well elevation, discharge meter flow, pump speed and level at MWR003 (regulator RE032 and RE031 in the ABBS and ABC, respectively) as well as the level in the ABC downstream of the dry weather flow connection to SOM001A.
- **Additional Metering Data:** CSO communities have permanent meters installed at regulators tributary to the ABPS. Community meters are installed at the regulators associated with outfalls SOM001A, CAM001, CAM002, CAM401A, and CAM401B. MWRA has permanent meters installed at MWR003. During 2019 and the first half of 2020, temporary project meters were installed at all regulators tributary to ABPS. In addition to the remaining temporary meters and permanent meters, data from a meter located in the ABC downstream of outfall SOM001A became available in 2019. The meter locations are shown in Figure 1-1.
- **ABPS Pump Vibration Monitoring Report:** This report provided recommendations for wet weather pump operational constraints. Included in this report was a set of field performance test reports for the three new wet weather pumps following their installation in 2019.

2.2 ABPS Operating Strategy

The ABPS has three wet weather pumps (pump numbers 1 through 3) and one dry weather pump (pump no. 4). Each wet weather pump has a rated pumping capacity of 37.5 million gallons per day (mgd) and the dry weather pump has a rated pumping capacity of 15 mgd. All four pumps share a common suction side wet well. Each pump's motor is equipped with a variable frequency drive (VFD) that controls the pump speed and therefore the pumping capacity. For example, a VFD pump speed setting of 100% means that the motor and pump are operating at their maximum design capacity, likewise a 60% setting roughly translates to the pumps operating at 60% of their design capacity.

During periods of dry weather, pump no. 4 is mainly used. During storm events two wet weather pumps are operated in a lead-lag configuration as needed, with the third wet weather pump acting as a stand-by backup. When the ABPS is operating in AUTO mode, the wet weather pumps are controlled solely based on wet well level. Dry weather pump operation is controlled based on wet well level and the operational states of the wet weather pumps.

The operating strategy is input to the ABPS's Manager Setpoint Screen, shown in Figure 2-1. There are three main control settings for each pump:

- the wet well levels that trigger each pump ON or OFF,
- the wet well levels that determine the upper and lower operating pump speeds, and
- the maximum and minimum pump speeds.

In Figure 2-1, the control parameters associated with dry weather pump no. 4 are indicated in blue, while the control parameters for the lead wet weather pump are indicated in yellow, with the lag pump indicated in green. Figure 2-1 also notes the additional operating rules specific to pump no. 4.

The maximum and minimum pump speeds are 99% and 60%, respectively, and apply to all four station pumps. In Figure 2-1, the column of values to the left of the wet well indicates the ON and OFF level setpoints. The column on the right indicates the upper and lower wet well levels that correspond to the maximum and minimum pump speeds. Focusing on the lead wet weather pump settings, all shown in bounded yellow boxes, the pump will turn ON when the wet well level reaches 98.40 feet and turn OFF once the wet well level falls to 97.50 feet. Per the right column, the lead wet weather pump will reach a maximum speed of 99% at a wet well level of 99.00 feet and a minimum speed of 60% at a wet well level of 98.00 feet. Between these two setpoints, the pump speed will vary proportionally from 60% to 99%. For example, at the ON setpoint the pump should initially turn on with a set speed of approximately 76%.

Assessing the optimum value for the pump control setpoints requires the balancing of a range of factors. Theoretically, keeping the wet well elevation lower during a wet weather event would keep the upstream interceptor hydraulic grade line lower for at least some distance upstream. That in turn could allow more flow into the interceptor from upstream regulators and reduce CSO discharges. However, once the incoming flow from the interceptor exceeds the full pumping capacity of the ABPS, the wet well level will rise regardless of the control strategy. Thus, striving for a lower wet well elevation during wet weather would theoretically provide most benefit during periods when the flow rate into the pump station does not exceed the pump station capacity, and could provide a buffer to attenuate flows when the peak flows first start to exceed the station capacity.

On the other hand, lowering the wet weather pump activation setpoints too much could cause the pumps to rapidly cycle on and off. Pump cycling should be minimized to reduce fatigue wear of the pump components and to extend pump life. The lowest theoretical operating level would also be limited by the net positive suction head required on the pump to avoid cavitation. Thus, pump operations and maintenance considerations provide practical limits to lowering of pump control set points.

If the goal of the ABPS is to operate in an AUTO state then the operating strategy should be defined to optimize lowering the wet well during storm events and safe mechanical operation of the critical station equipment. The alternative operating strategies investigated and discussed in this report focused on redefining these setpoints to achieve this goal.

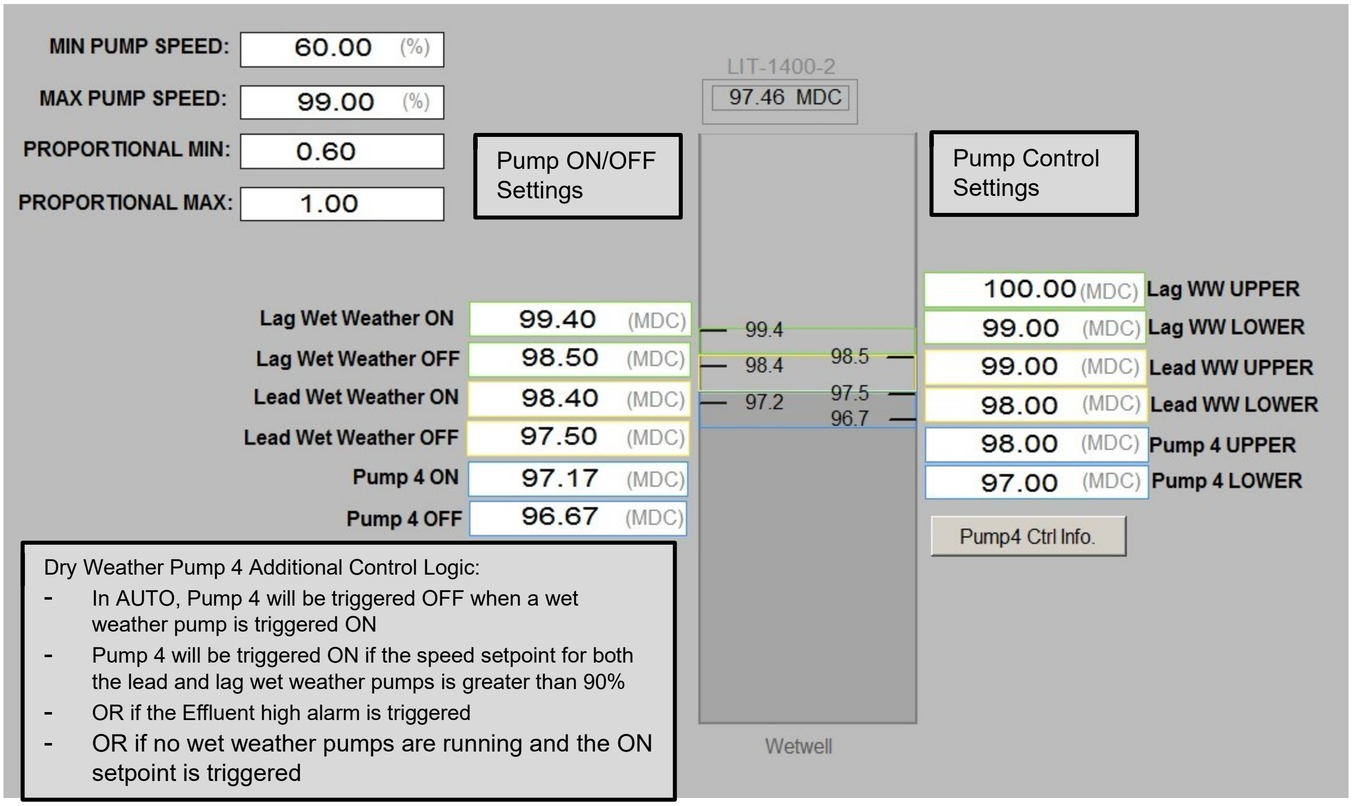

Figure 2-1. Existing ABPS Operating Strategy Displayed on the Manager Setpoint Screen

2.3 Hand Calculations

Two sets of hand calculations were performed. The first calculation assessed if the dry weather pump impeller could be replaced with a larger diameter impeller. Typically, with all other variables held constant, an increased pump impeller diameter results in an increased pump flow. According to record pump data, the existing dry weather pump impeller diameter is 22.50 inches. A review of manufacturer data yielded a maximum allowable pump impeller diameter of approximately 23.80 inches. Based on the pump affinity law (flow is proportional to impeller diameter), increasing the impeller diameter to 23.8 inches would result in a relatively small flow multiplier of 1.06 (23.80 divided by 22.50). The maximum dry weather pump flow ranges from 14.4 to 16.4 mgd. This value is relatively small compared to the maximum wet weather pump flow of 37.5 mgd. It was thus recommended that no modification be made to the dry weather pump impeller due to the minimal improvement in maximum flow demonstrated by the calculation.

The second set of calculations used the method outlined in the American National Standards Institute and Hydraulics Institute standard for Rotodynamic Pumps for Pump Intake Design (ANSI/HI 9.8) to calculate the minimum pump submergence requirements for the dry weather and wet weather pumps. These requirements suggest the theoretical lowest pump suction-side wet well level that would allow for continuous safe and efficient pump operation (i.e., to avoid severe cavitation or air entrainment). The resulting submergence values are the fluid depth above the centerline of the pump's suction bell within the wet well, not with respect to the pump's centerline. The calculation results were used to set the lower operational bands for the alternative operating strategy. Figures 2-2 and 2-3 provide the submergence curves for the wet weather and dry weather pumps, respectively. The left y-axis presents the submergence converted to an equivalent wet well level in the project datum. The right y-axis presents the submergence values as calculated. At the maximum wet weather pump flow of 37.5 mgd, the minimum calculated submergence is approximately 9.08 feet or an equivalent wet well level of 95.68 feet. Thus, the recommendation for minimum wet well level would be that the wet weather pumps should not operate at maximum speed once the wet well level drops to 95.68 feet. Likewise, for the dry weather pump with a maximum pump flow of approximately 15 mgd, the minimum wet well level is approximately 93.25 feet. As shown in the figures, as pump flow decreases, the calculated minimum submergence decreases. The results of these calculations were tested during the dry weather and wet weather pump tests, discussed in Section 3.

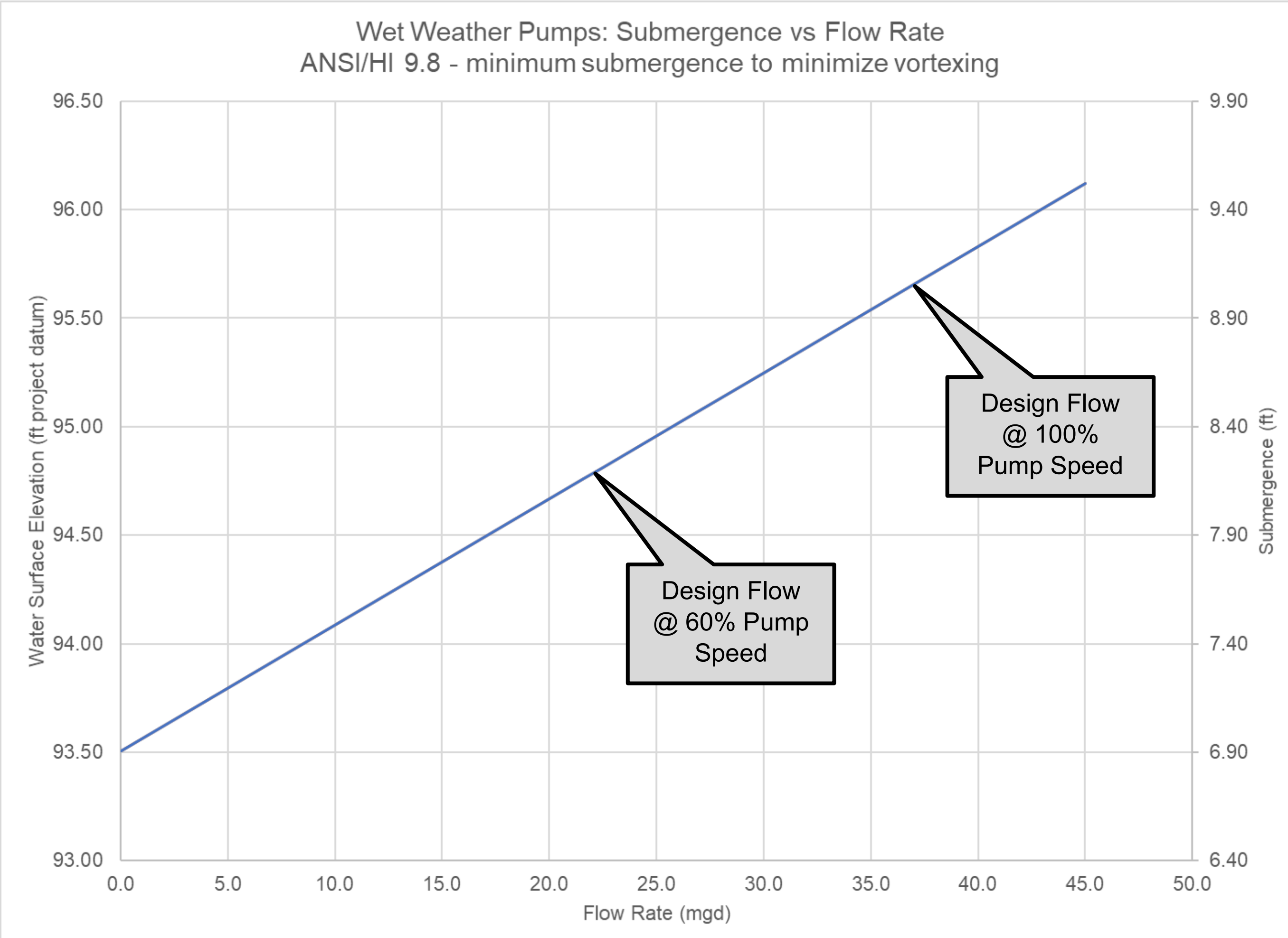

Figure 2-2. ANSI/HI 9.8 Calculated Minimum Submergence for the Wet Weather Pumps

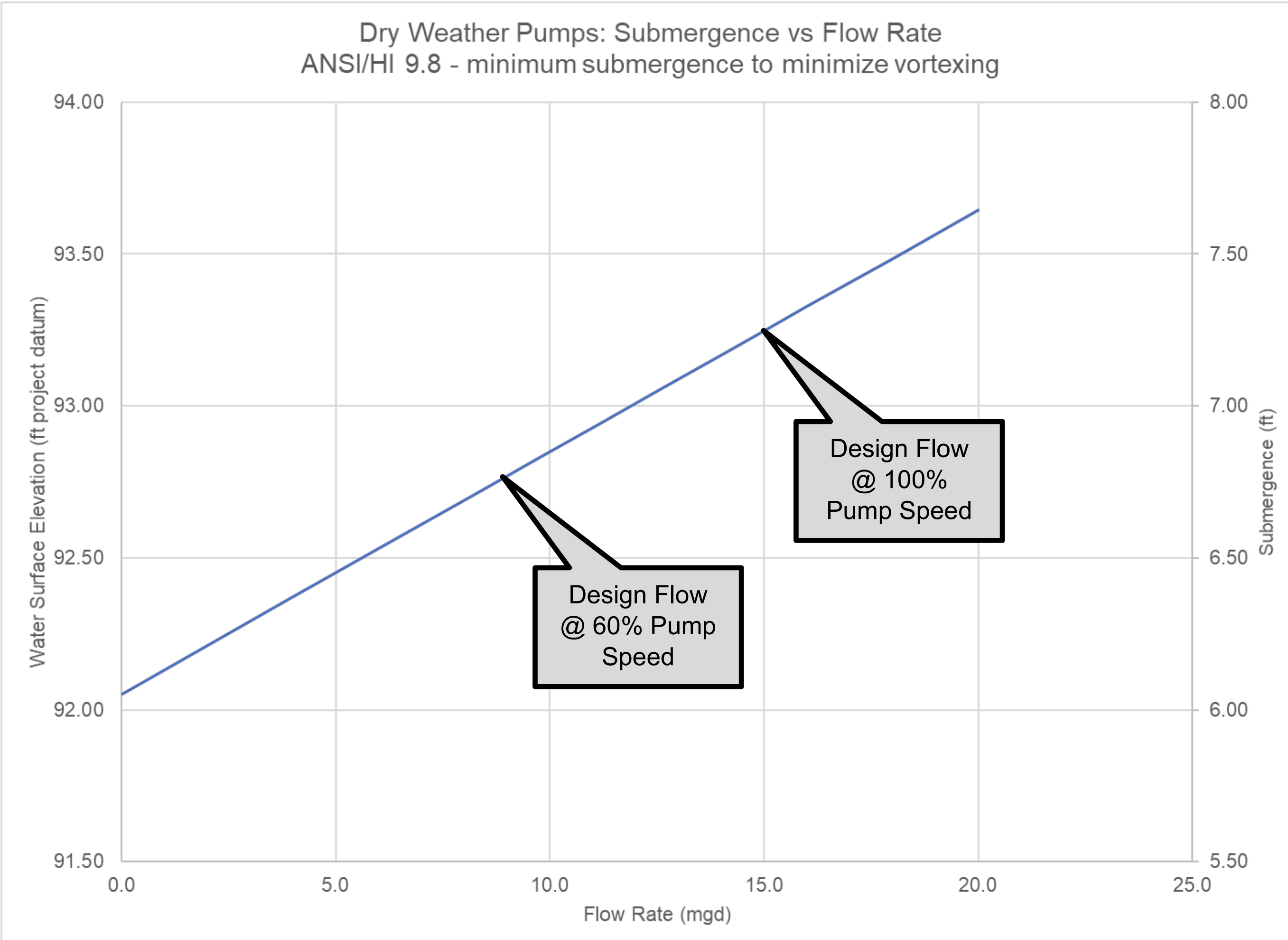

Figure 2-3. ANSI/HI 9.8 Calculated Minimum Submergence for the Dry Weather Pump

3. Site Investigation and Field Work

Two sets of field tests were conducted at the ABPS: a dry weather pump test on pump no. 4 and a wet weather pump test on pump no. 3. A goal for both tests was to validate the results of the submergence hand calculations previously discussed. The findings from each test were used to further refine the model and development of the alternative operating strategy.

3.1 Dry Weather Pump Test

Two pump tests for the dry weather pump were performed and completed on Monday, July 13th, 2020, with two goals:

1. Develop pump curves based on the field performance of the pump and compare its field performance to its factory performance.
2. Assess the minimum wet well operating level below which the pump may experience physical phenomenon that could reduce its performance and/or cause damage to the pump.

The two tests used to achieve these goals:

- A pump performance test was conducted where the dry weather pump was ramped up to 100% speed with various discharge valve positions, noting pressure and flow instrumentation data,
- A wet well level test was conducted, where the dry weather pump was run at 100% speed down to a wet well level of 92 feet.

Results of the first test indicated that the pump's field performance closely matched, yet slightly underperformed, the factory performance. The field performance data showed a slightly reduced pumped flow capacity compared to the factory performance data for a given pump head data point. However, given the variability of field conditions compared to factory test conditions, it was concluded that the field test generally confirmed the current understanding of the pump capacity. Results of the second test suggest that the dry weather pump can operate at 100% speed down to a wet well level of at least 92 feet, a level much lower than the current operational controls OFF level of 96.67 feet. The Dry Weather Pump Test report is provided as Appendix A.

3.2 Wet Weather Pump Test

A pump test for the wet weather pumps was performed and completed on Tuesday, October 13th, 2020. The goal of the test was to assess the minimum wet well operating level below which the pump may experience physical phenomenon that could reduce its performance and/or cause damage to the pump. The Wet Weather Pump Test Report is provided as Appendix B.

The wet weather pump test indicated that the subject pumps can safely operate at 100% speed down to a wet well level of 96 feet and at 80% speed down to a wet well level of 95.7 feet. Additionally, at a pump speed of 60% the wet weather pump was unable to maintain or reduce the wet well level below 98 feet. This suggests that the wet weather pumps' OFF setpoints could be set much lower than the current operating setpoint to minimize pump cycling during brief pauses in wet weather events.

4. Hydraulic and Hydrologic Modeling Evaluations

The MWRA's hydraulic model is the primary tool used to evaluate the performance of the MWRA system against the Long Term Control Plan (LTCP) goals for Typical Year levels of control. The hydraulic model was also used to model and evaluate alternative operating strategies for the ABPS. Figure 4-1 identifies in red the region of interest within the total model, used as the basis of these analyses. Environmental variables such as rainfall, tide, and evaporation serve as inputs to the model. These inputs are used by the model to estimate the flow entering the sewer system, as well as the hydraulic routing of the flow through the collection and transport system. Hydraulic modeling has historically served as the basis for evaluating performance of the CSO system.

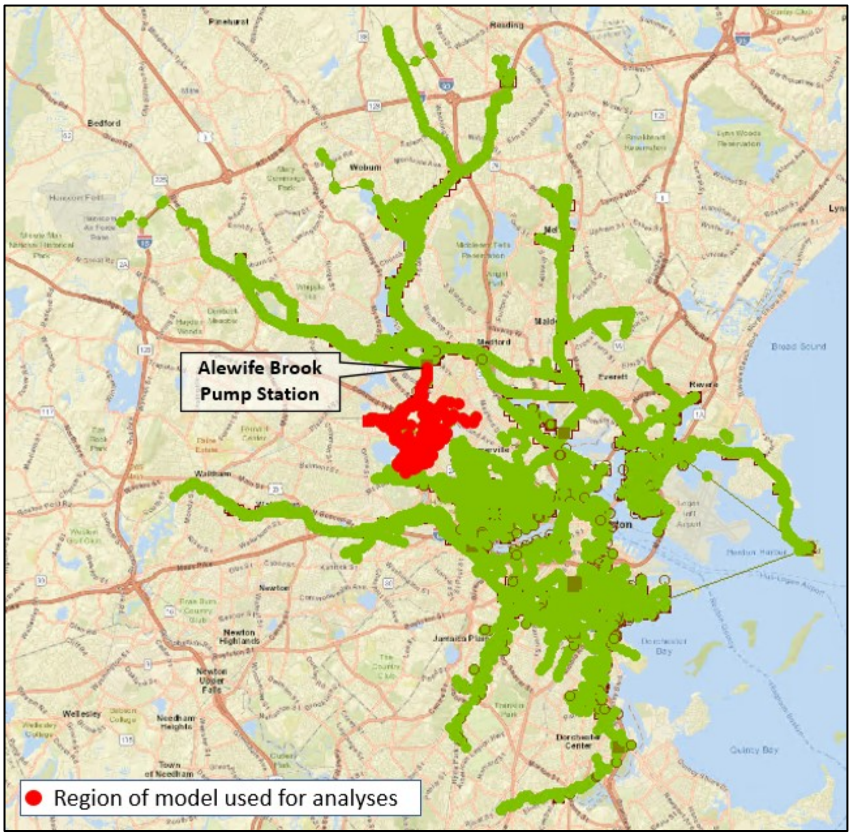

Figure 4-1. MWRA Full System Model with Alewife Region of Interest Highlighted in Red

4.1 Description of Baseline Model

The MWRA's hydraulic system is a dynamic, constantly changing system. The model is continually updated and refined to reflect the latest, known system conditions.

2019 System Conditions Model: During 2019, system modifications were made to the regulators associated with outfalls SOM001A and CAM002, and those changes and are reflected in the 2019 system conditions model. At SOM001A, the modifications included the removal of a structure that had been built over the dry weather flow connection, and the removal of the orifice plate that was used to restrict the dry weather flow connection. At outfall CAM002, the weir elevation was modified in 2019 and a plate was removed which opened a connection between the influent line to CAM002 and the MWRA downstream interceptor (ABC).

Mid-2020 System Conditions Model: During the first half of 2020, the model was revised to better represent the ABPS. The wet weather pumps, formerly modeled as a single lumped pumping element, were split into lead and lag pump elements. The modeled representation of the ABPS pump control strategy was refined to better reflect the existing operating strategy discussed in Section 2.2. The pump curves were updated to reflect the field data collected from the dry and wet weather pump tests. In addition to modifications at the pump station, metering data from 2019 and 2020 were used to adjust the model at SOM001A to account for the removal of the structure in the manhole and the orifice plate. Adjustments to the model's hydrology tributary to Tannery Brook were made to improve the model's ability to predict influent flows to SOM001A, and the orifice coefficient at SOM001A was adjusted based on comparison of the metered and modeled system responses. At CAM002, the model was revised to reflect the new weir elevation, and the model output was compared to 2019 and 2020 meter data. In conjunction with the changes at SOM001A and CAM002, further adjustments were made to improve the model's ability to predict the hydraulic grade line in the interceptor using the newly available metering data as well as data from existing temporary and permanent meters for 2019 and 2020.

Updated Baseline Conditions Model: In the fall of 2020, the City of Cambridge completed a project to remove sediment in the community's sewers between the regulator associated with outfall CAM401A and the ABBS. The mid-2020 conditions model was then updated to reflect the updated system conditions with the sediment removed. This version of the model is referred to as the "updated baseline conditions" model.

A comparison of the Mid-2020 system conditions model, updated baseline conditions model, and the LTCP goals is provided in Table 4-1. The cells highlighted in gray indicate values greater than the LTCP goals. Model results indicate that sediment removal downstream of CAM401A results in a significant reduction in CSO activation frequency and volume at CAM401A, bringing the regulator into compliance with the LTCP activation frequency and volume goal. The updated baseline model predicts a slight increase in CSO volume at outfalls MWR003, CAM401B and SOM001A. This increase is due to the additional flow from CAM401A that now reaches the MWR003 regulator on the ABC via the Rindge Avenue siphon instead of overflowing to the Alewife Brook. The updated baseline model indicates that outfall SOM001A still exceeds the LTCP goals for both volume and activation frequency.

For the updated baseline model, the total CSO volume to Alewife Brook dropped from 7.71 to 6.51 million gallons and is therefore below the LTCP target of 7.29 million gallons.

Table 4-1. Comparison of Typical Year Simulation Results for the Mid-2020 System Conditions Model, Updated Baseline Model, and Long Term Control Plan

Outfall	Regulator	Mid-2020 System Conditions Model		Updated Baseline Model		Long Term Control Plan(1)	
		Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
CAM001	RE-011	1	0.02	1	0.02	5	0.19
CAM002	RE-021	0	0.00	0	0.00	4	0.69
MWR003	RE-031	3	0.49	3	0.69	5	0.98
CAM401A	RE-401	16	2.17	5	0.69	5	1.61
CAM401B	RE-401B	4	0.53	4	0.56	7	2.15
SOM001A	RE-01A	8	4.51	8	4.55	3	1.67
Total		**16 (max.)**	**7.71**	**8 (Max)**	**6.51**	**7 (max.)**	**7.29**

1. Grey shading indicates model prediction is greater than LTCP value.

Profiles were created with the updated baseline model through the regulators to the interceptor as well as from the interceptor to the ABPS wet well. Figure 4-2 and Figure 4-3 present the peak hydraulic grade line (HGL) through the regulator at SOM001A for the 10/23 and 8/18 storm events, which are the largest and third largest storms in the Typical Year based on CSO volume discharged to Alewife Brook. As indicated, the weir crest elevation in the SOM001A regulator is 110.12 feet. When the HGL in the regulator rises above the weir crest elevation, then a CSO activation occurs.

Figures 4-4 and 4-5 present the peak HGL in the ABC for the 10/23 and 8/18 storm events, respectively. For these two figures, the ABC profile runs from the dry weather flow connection at SOM001A to the ABPS wet well. The SOM001A regulator is the final regulator tributary to the ABC until the interceptor reaches the ABPS.

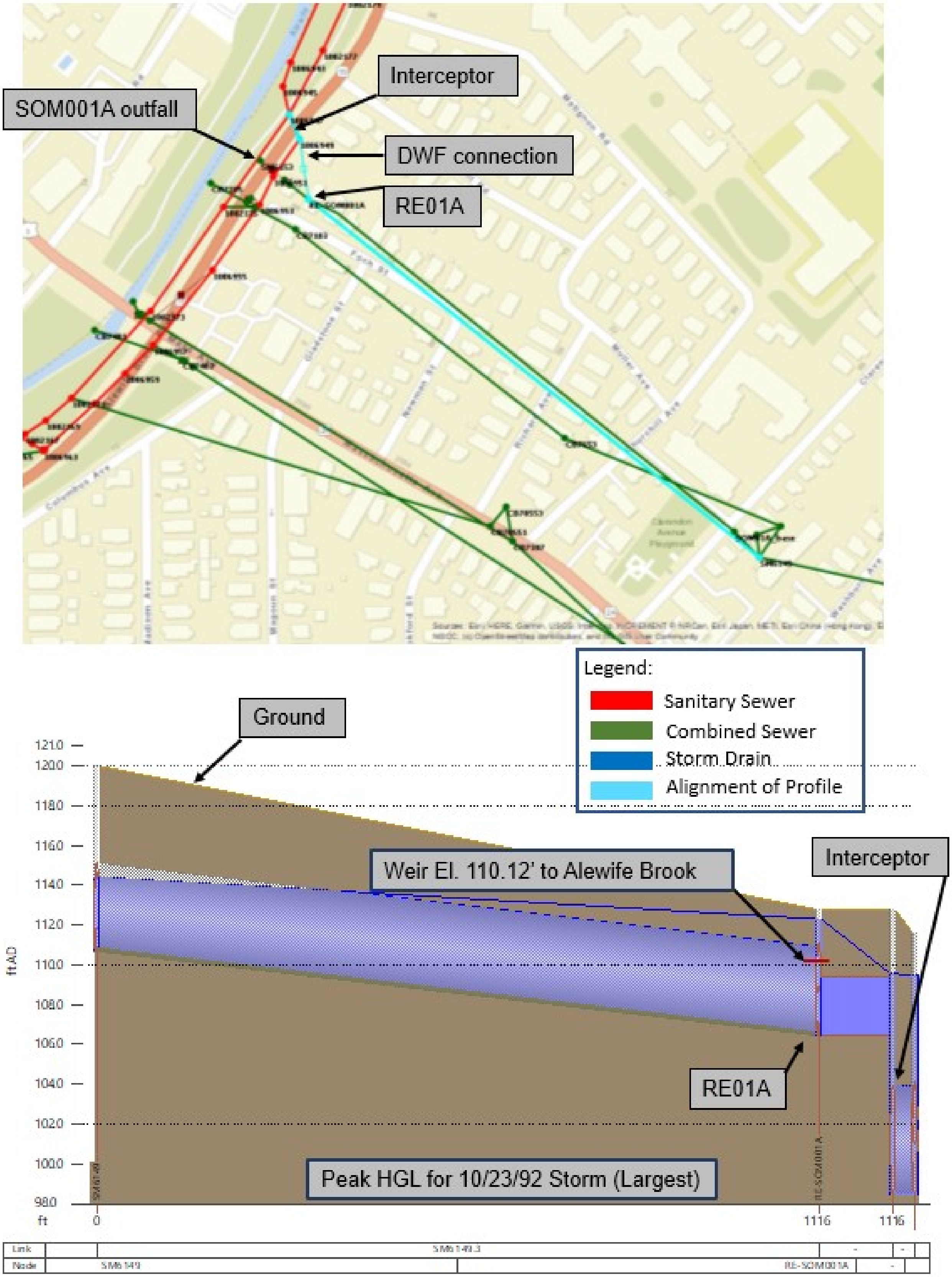

Figure 4-2. Regulator Profile at SOM001A for the 10/23/92 Storm

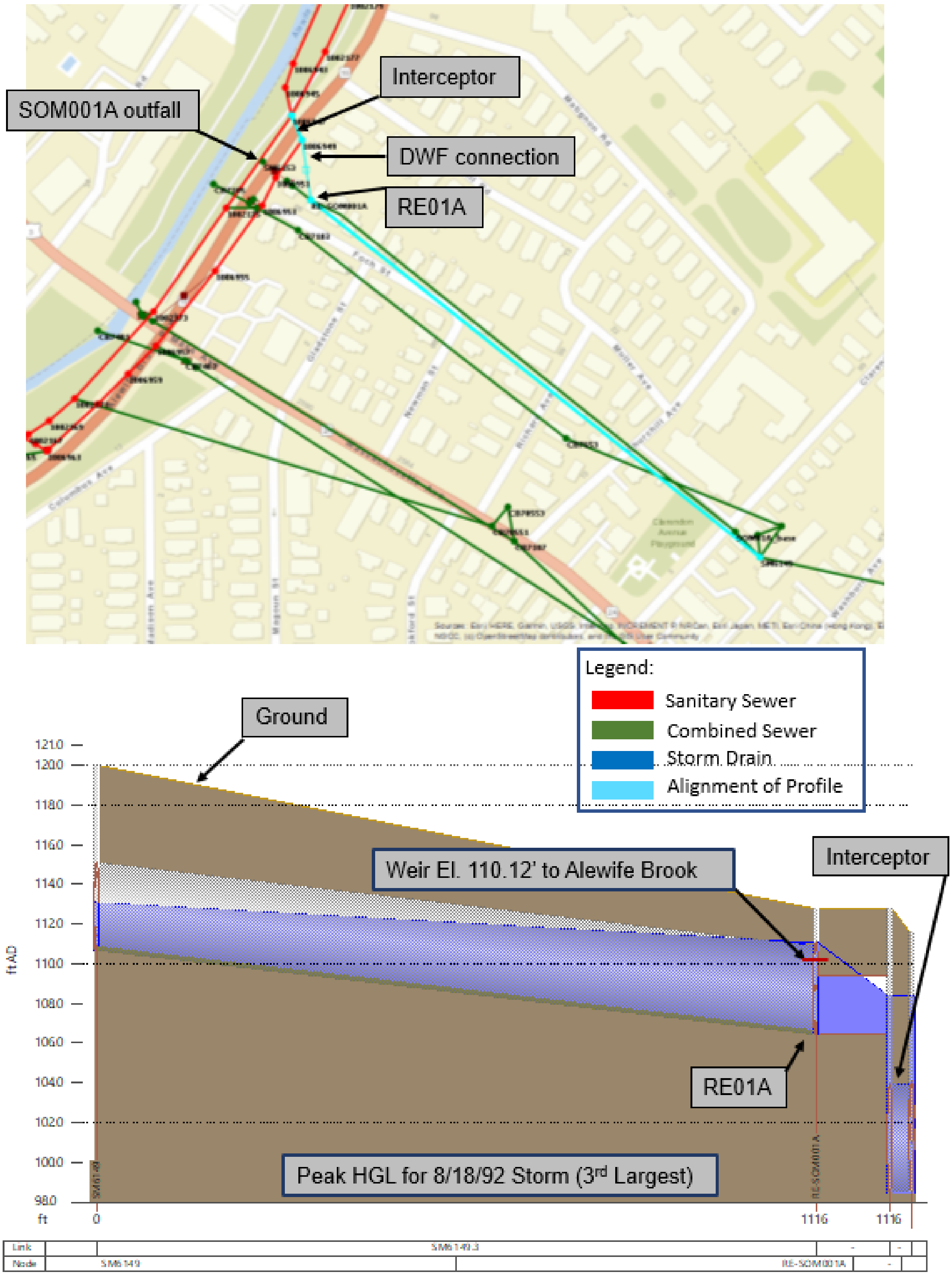

Figure 4-3. Regulator Profile at SOM001A for the 8/18/92 Storm

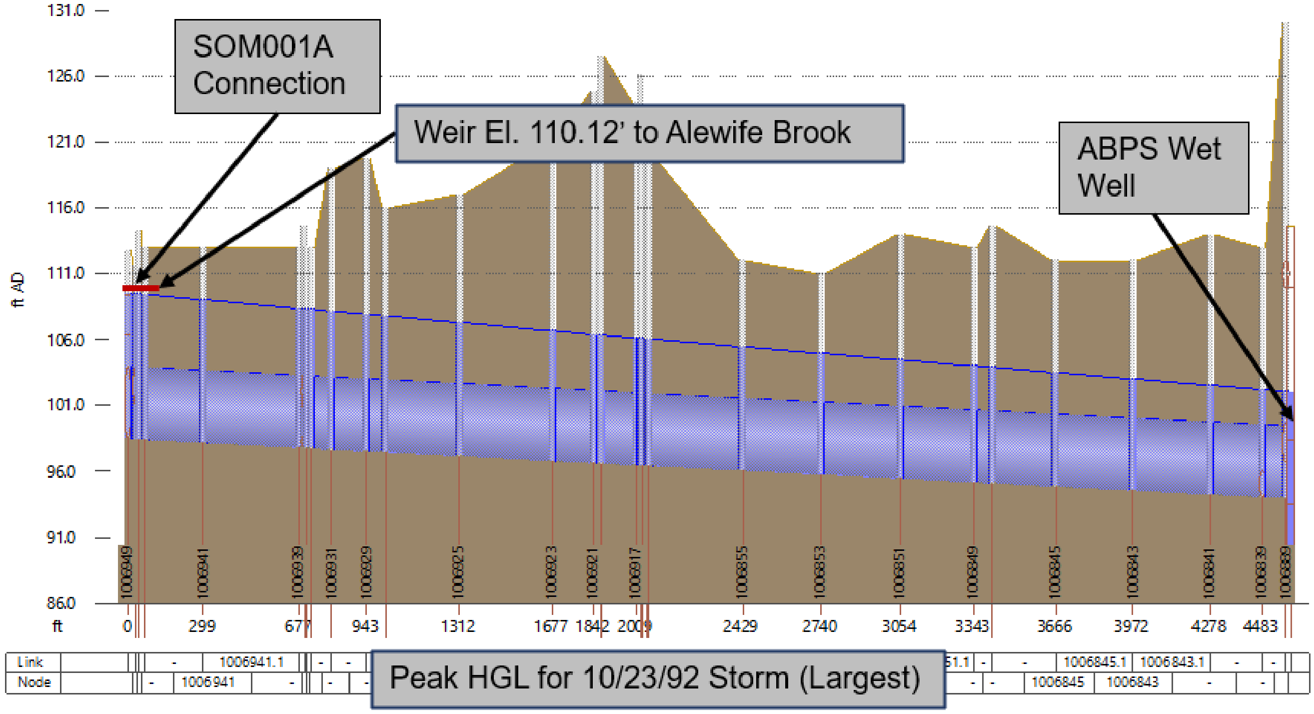

Figure 4-4. ABC Interceptor Profile for the 10/23/92 Storm

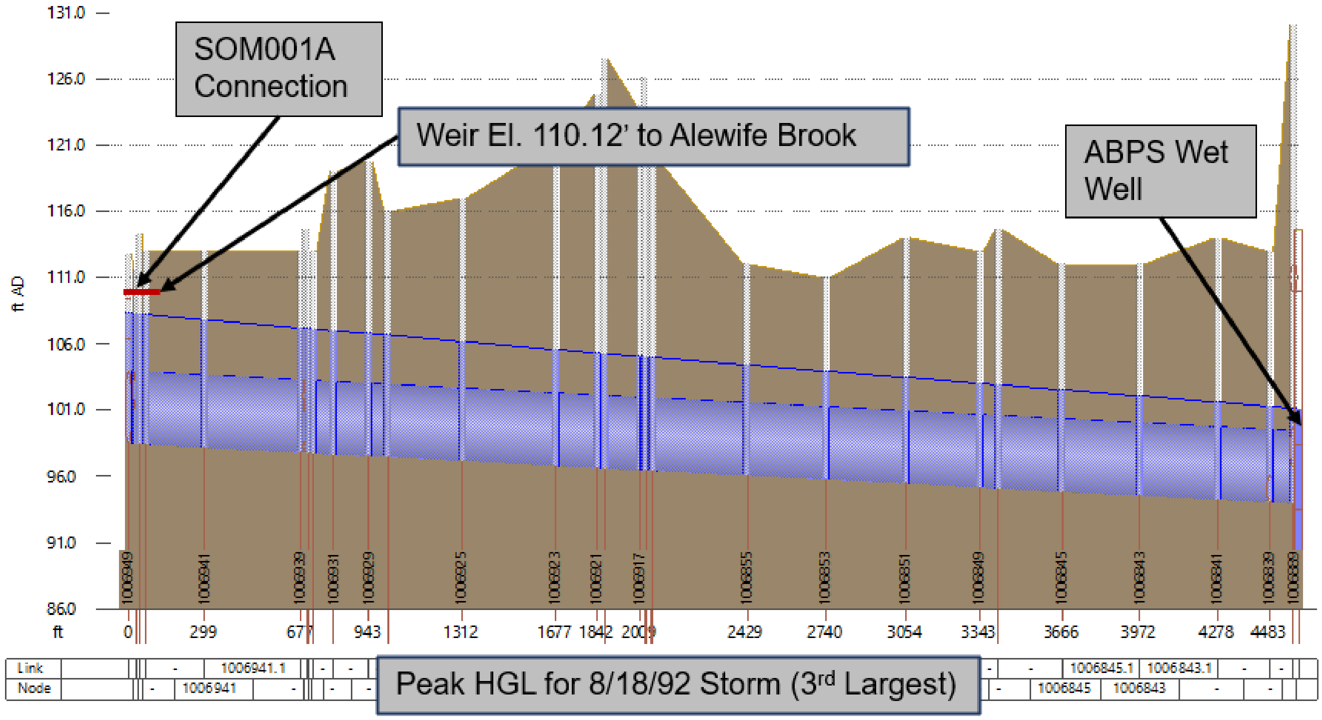

Figure 4-5. ABC Profile for the 8/18/1992 Storm

The regulator profiles at SOM001A indicate that flow from the regulator to the ABC via the dry weather flow connection conduit is outlet controlled (i.e., the flowrate is a function of the HGL in the ABC). However, the head loss across the dry weather flow connection's inlet is significant. For both storm events, the HGL in the ABC is lower than the regulator weir crest elevation yet the water cannot be diverted in the ABC quickly enough to prevent CSO activations. As shown for both storm events, the HGL rise from the ABC to the SOM001A regulating structure is approximately three to four feet. Thus, without further modification to the SOM001A regulator, the peak HGL in the ABC would need to be reduced to between approximately elevations 107 and 108 feet in order to control the activations at SOM001A for those two storms.

The ABC interceptor profiles indicate that at the peak of larger typical year storms there is no spare capacity within the interceptor conduit. The slope of the HGL for both storms exceeds the slope of the ABC, indicating that the capacity of the ABC has been exceeded. Profiles of the other five regulators in the Alewife Brook system and interceptor profiles for the Typical Year 10/23/1992 and 8/18/1992 storms can be found in Appendix C.

4.2 Initial Evaluation of Alternative ABPS Operating Strategies

The primary control parameter for operation of the ABPS pumps is the ABPS wet well level, located upstream on the suction side of the pumps. The operational strategy for the pumps uses this wet well level to set the pump speeds and to control the pump on-off set points and sequencing. The updated baseline condition model was used to evaluate several potential alternative pump operating strategies for the Typical Year conditions. Each potential alternative was evaluated in terms of CSO activation frequency/volume for the six outfalls tributary to the Alewife Brook compared to the LTCP goals. The alternatives were also evaluated in terms of feasibility and pump station longevity.

The following model run scenarios were evaluated:

- **Baseline**. This run represents the updated baseline model conditions as described above, which included the pump operating strategy that had been in place at the start of this study. This strategy is shown graphically above in Figure 2-1. This version of the baseline also included removal of the sediment downstream of the CAM401A regulator.
- **Scenario 1: Alternative Operating Strategy.** The alternative operating strategy is provided in Figure 4-6. Compared to the existing ABPS operating strategy, all pumps have ON setpoints at relatively lower wet well levels allowing for the pumps to ramp up to full speed sooner. The speed bands of each pump were also updated from a one-foot band to a two-foot band. A larger speed band dampens the transient response of the VFDs, reduces pump and pump-motor shaft fatigue, and would allow for the wet weather pumps to operate at higher speeds for wet well levels above 98 feet.
- **Scenario 2: Wet well maintained at 98 ft. MDC.** This simulation had the ABPS pumps removed from the model with the wet well assigned as an outlet boundary condition with a constant water level of 98 ft. The invert of the ABC conduit at the ABPS inlet is approximately 93.9 ft. The goal of this scenario was to assess the benefit of a constant wet well level
- **Scenario 3: Wet well maintained at 96 ft. MDC.** This simulation had the ABPS pumps removed from the model with the wet well assigned as an outlet boundary condition with a constant water level of 96 ft.
- **Free discharge at the wet well.** This simulation replaced the outlet from the ABPS wet well with a free discharge. The free discharge results are not presented because they were no different than the results for the 96-ft. constant wet well simulation. The reason the results did not change was that at higher wet weather flowrates into the ABPS the critical depth in the ABC conduit at the ABPS would be greater than or equal to approximately 96 feet. Therefore, flow would be supercritical and any further reduction in wet well level would have no impact on upstream hydraulic conditions.

The goal of Scenarios 2 and 3 was to assess the upstream benefit of a constant wet well level should an alternative operating strategy be developed to achieve this constant level goal. Model results, however, indicated that maintaining these constant wet well levels would not be feasible without increasing the capacity of the ABPS beyond its current 90 mgd capacity. As will be discussed with reference to the pertinent figures below, the peak flowrates into the ABPS wet well for Scenarios 2 and 3 exceeded the pump station capacity of 90 mgd. In reality, once the influent flowrate exceeds the current 90 mgd capacity, the wet well level would rise, and would no longer be held constant. Results for these two scenarios are nonetheless included to demonstrate the relative insensitivity in typical year response at the SOM001A regulator.

Table 4-2 presents the results of the simulations described above. As shown in Table 4-2, alternative ABPS operating strategy (Scenario 1) produced a marginal reduction in CSO volume of 0.1 million gallons. The reductions in total CSO volume for the constant wet well level model run scenarios were slightly greater, but the reduction at outfall SOM001A remained insufficient to achieve compliance with the LTCP goals. Thus, even for

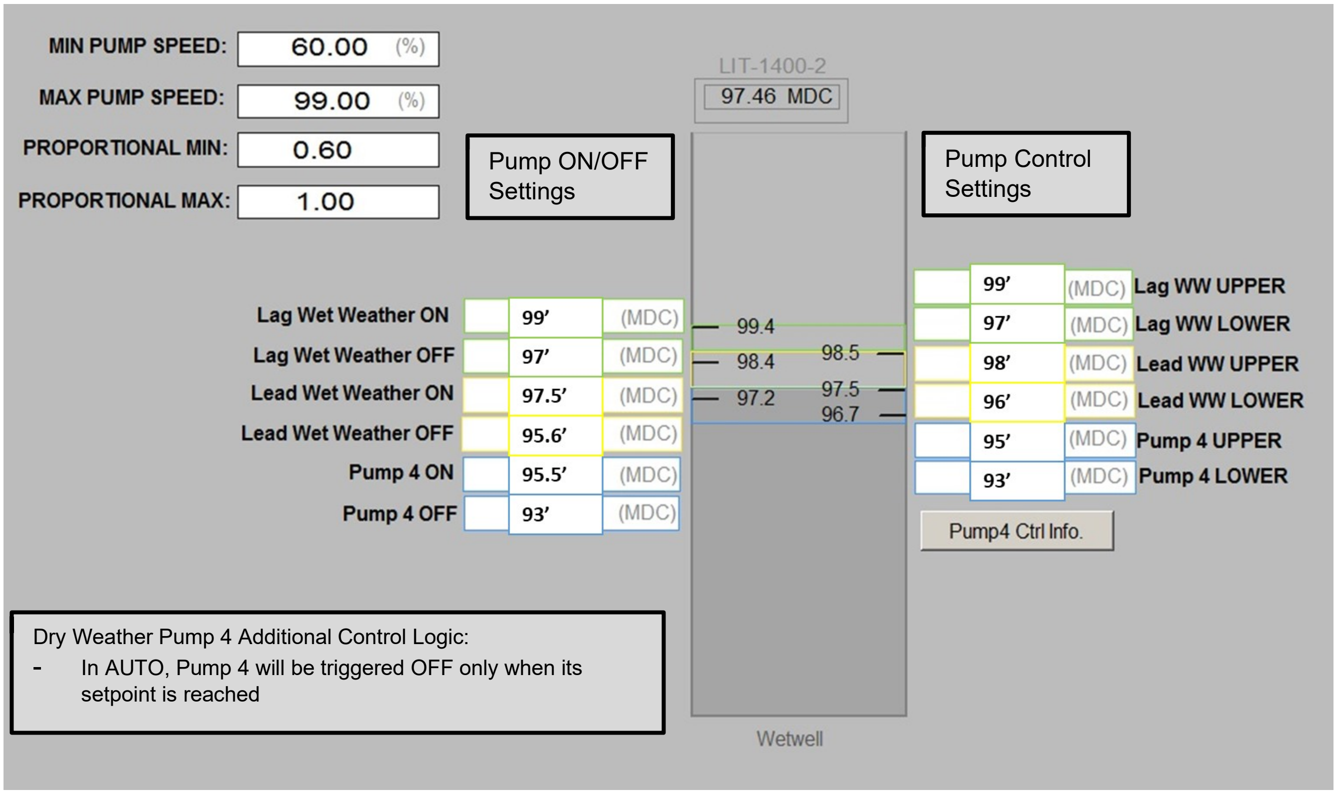

Figure 4-6. Proposed Alternative ABPS Operating Strategy Displayed on the Manager Setpoint Screen

the theoretical case of no hydraulic restriction at ABPS, outfall SOM001A would not attain compliance with the LTCP goals.

Figures 4-7 through 4-9 provide comparison plots of model run results for the baseline model and three scenarios for the largest typical year storm, October 23rd. Figure 4-7 shows the ABPS wet well level. Figure 4-8 shows the HGL in the ABC at the dry weather flow connection to SOM001A. Figure 4-9 shows the total pumped flow for the baseline model run and scenario 1, and the total influent flow for scenarios 2 and 3. The total influent flow is presented for the last two scenarios since the ABPS pumps were removed from the model for those simulations.

In Figure 4-7, the lower initial low wet well level preceding the storm event is evident for scenario 1 (Alternative Operating Strategy) compared to the baseline. At the peak of the storm the baseline and scenario 1 wet well levels nearly overlap suggesting that having a lower wet well level at the start of a storm event has minimal impact on the system response during the storm event. This finding also corresponds to the brief discussion regarding the limitations of a low wet well during high influent flow rates since the critical water level in the ABC is greater than approximately 96 feet for these larger inflows. Figure 4-7 also shows the constant wet well level settings for scenarios 2 and 3.

Figure 4-8 shows that the alternative operating strategy represented by scenario 1 had little impact on the HGL in the ABC at the connection from SOM001A. Scenarios 2 (Wet well maintained at 98 ft MDC) and 3 (Wet well maintained at 96 ft MDC) both resulted in an approximately 0.75-foot drop in the peak HGL at that location. When comparing the general trend of the HGL plots between Figures 4-7 and 4-8, it is apparent that the difference in HGL in the ABPS between the first two and last two model runs does not equivalently translate upstream in the ABC at the SOM001A dry weather flow connection. For example, the difference in HGL at the ABPS wet well between scenarios 1 and 2 is approximately four feet whereas in the ABC at SOM001A the HGL difference between the same model runs is approximately 0.75 feet. One reason for this loss of HGL benefit is the increased flow into the ABPS resulting from the lower wet well levels of scenarios 2 and 3. The increased

Table 4-2. Comparison of Alternative ABPS Model Runs to Baseline and LTCP Goals

Outfall	Regulator	Typical Year Rainfall								Long Term Control Plan[1]	
		Baseline:		Scenario 1:		Scenario 2:		Scenario 3:			
		Baseline ABPS Operating Strategy		Alternative ABPS Operating Strategy		98 ft Constant Wet Well Level[2]		96 ft Constant Wet Well Level[2]			
		Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
CAM001	**RE-011**	1	0.02	1	0.02	0	0.00	0	0.00	5	0.19
CAM002	**RE-021**	0	0.00	0	0.00	0	0.00	0	0.00	4	0.69
MWR003	**RE-031**	3	0.69	3	0.66	3	0.28	3	0.26	5	0.98
CAM401A	**RE-401**	5	0.69	5	0.67	5	0.63	5	0.62	5	1.61
CAM401B	**RE-401B**	4	0.56	4	0.54	3	0.36	3	0.34	7	2.15
SOM001A	**RE-01A**	8	4.55	8	4.53	8	4.26	8	4.25	3	1.67
Total		**8 (Max)**	**6.51**	**8 (Max)**	**6.41**	**8 (Max)**	**5.53**	**8 (Max)**	**5.47**	**7 (max.)**	**7.29**

Notes:

(1) Grey shading indicates model prediction is greater than LTCP value.

(2) Results produced under these scenarios would only be achievable with an increase in the capacity of the ABPS, which would increase the risk of adverse HGL impacts in the interceptor system downstream of ABPS (see text).

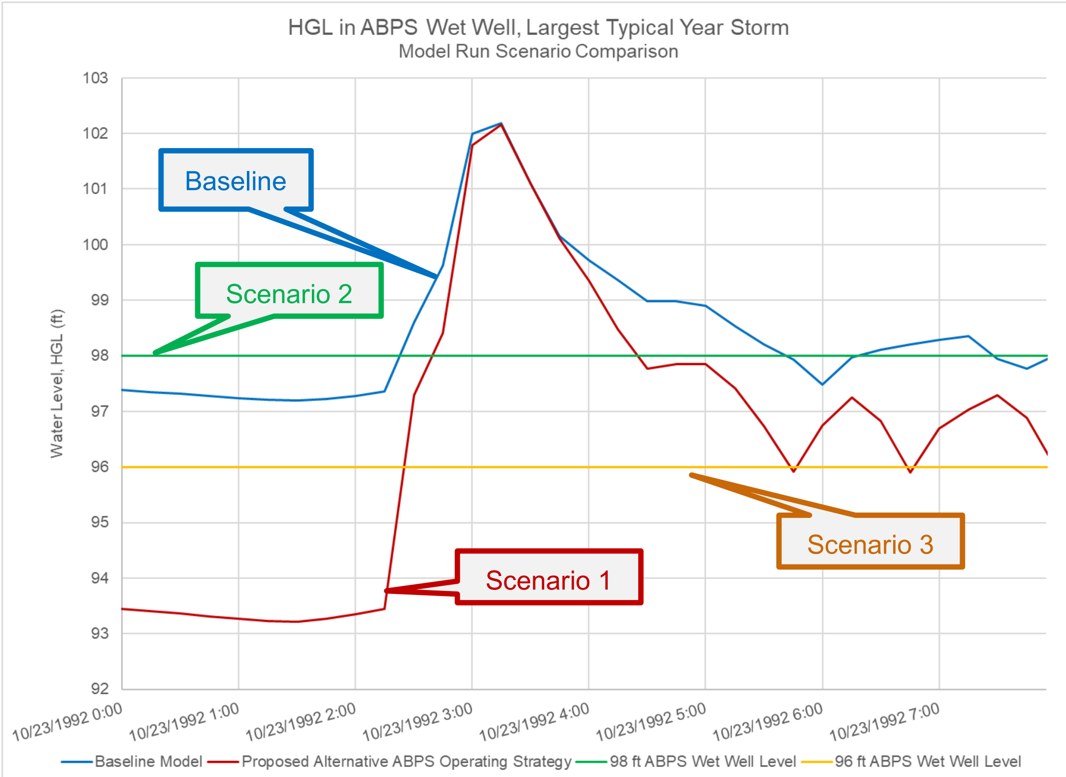

Figure 4-7. Comparison Plots of ABPS Wet Well Level for the Four Model Runs

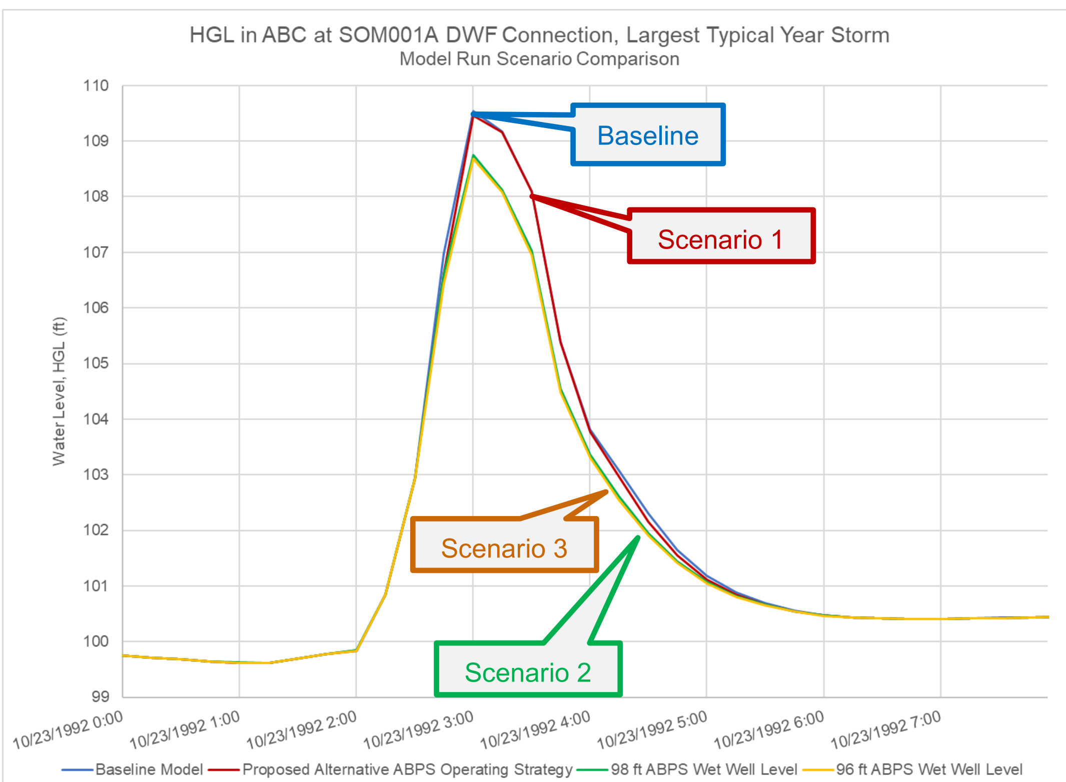

Figure 4-8. Comparison Plots of ABC HGL at the Dry Weather Flow Connection at SOM001A

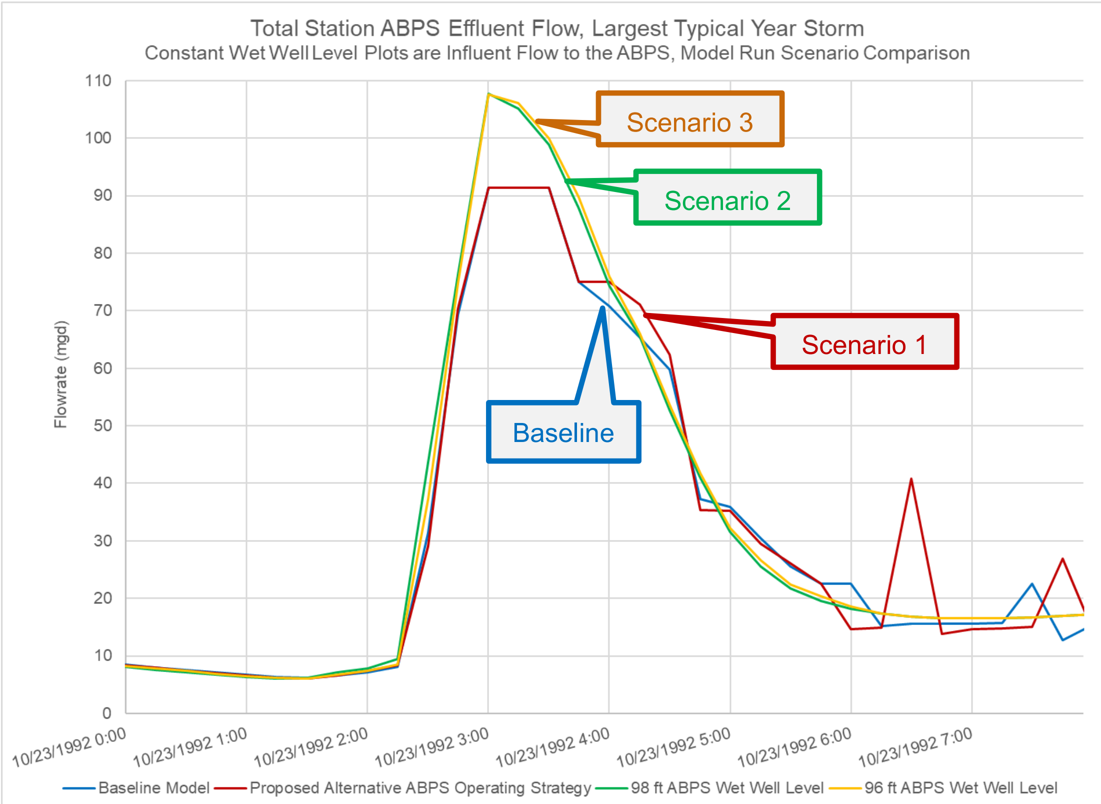

Figure 4-9. Comparison Plots of ABPS Total Station Discharge Flow for the Baseline and Scenario 1, and ABPS Influent Flow from the ABC for Scenarios 2 and 3

flow results in an increased friction loss within the ABC and ABBS. Therefore, the slope of the hydraulic grade is relatively steeper and the peak HGL nearly approaches the HGL value for the baseline near SOM001A.

The flowrate plots in Figure 4-9 depict the relative similarity in flow response between the first two model run scenarios and the constant wet well level model run scenarios. The maximum influent flow for the constant wet well model runs is approximately 107 mgd, approximately 15 mgd greater than the total ABPS pumping capacity. Thus, it would not be possible to implement an operating strategy that could successfully maintain an ABPS wet well level of 98 feet or lower with the existing pumps. Previous optimization evaluations have shown that increasing the capacity of the ABPS beyond its current 90 mgd capacity would increase the risk of adverse HGL impacts in the interceptor system downstream of ABPS.

Despite the marginal improvement in reduction of CSO volume, the alternative ABPS operating strategy was proposed for implementation due to the potential for reduced cycling of the wet weather pumps. Although model results indicated that running the dry weather pump more aggressively would not result in any discernable CSO reduction benefit, pump no. 4 was initially recommended to operate at lower wet well levels and independent of wet weather pump operation. The OFF setpoints and lower pump speed band wet well level setpoints were based on the dry and wet weather pump testing.

4.3 MWRA Field Testing of the Alternative Operating Strategy (12/5/2020)

The alternative ABPS operating strategy was provided to MWRA for field testing by MWRA operators during the December 5th, 2020 storm. Prior to its implementation, MWRA reverted the dry weather pump operation to its existing control strategy. The lag wet weather ON and OFF setpoints were also updated to lower values resulting in a slightly more aggressive operating strategy. This change was also aligned with MWRA's general pump operating principles of not starting a VFD pump at its high speed band set point. Results from the December 5th storm were positive, as all pumps operated as defined with no observed wet weather pump cycling. This reduction of cycling was a goal when developing the alternative operating strategy.

Considering the December 5th, 2020 field adjustments and model results, it was decided that the alternative ABPS operating strategy should only be implemented during wet weather events. Using two operating strategies makes sense as there would be no CSO reduction or operational benefit to maintaining a lower wet well elevation during dry weather, and the operating costs of pump no. 4 would be higher. The final strategy, now noted as the final wet weather ABPS operating strategy, is provided in Figure 4-10.

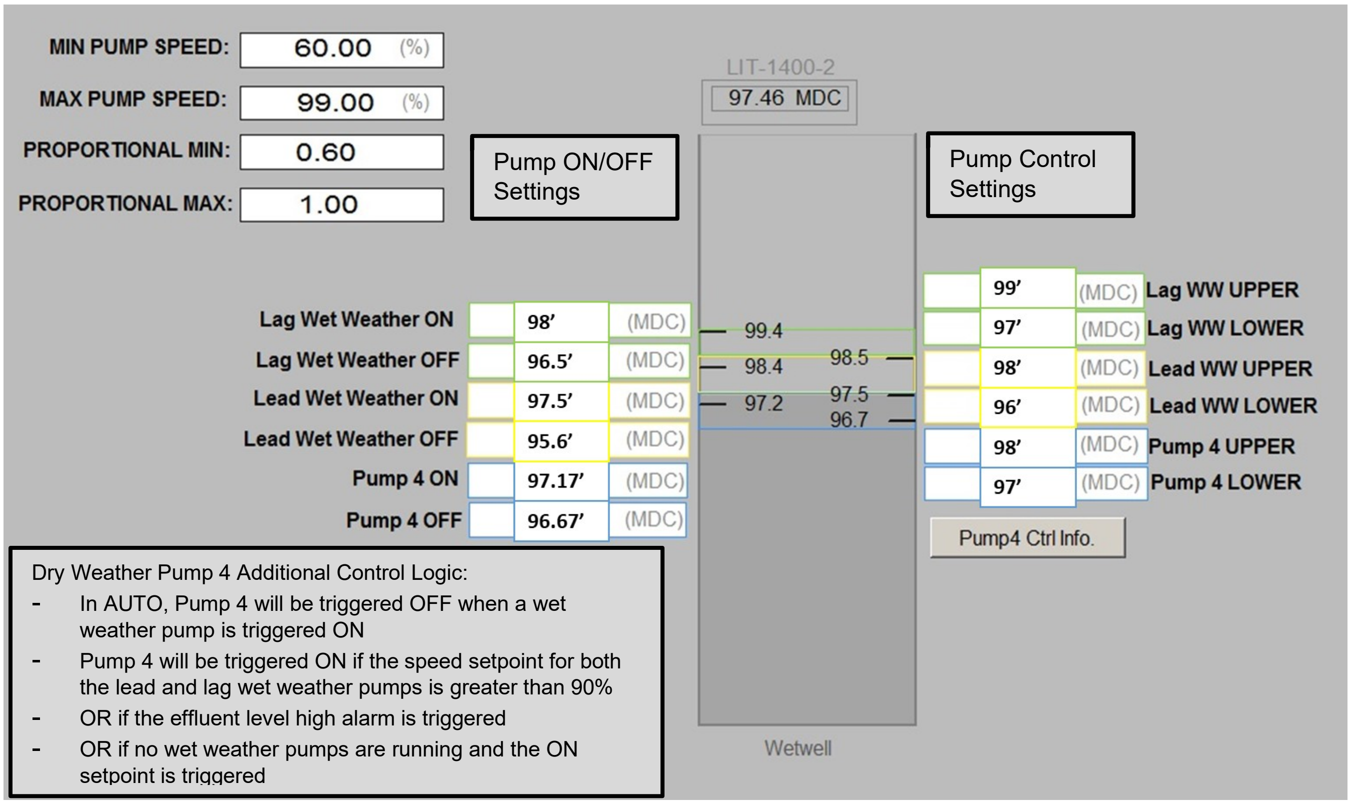

Figure 4-10. Final Wet Weather ABPS Operating Strategy Displayed on the Manager Setpoint Screen

The baseline model was updated to reflect the final wet weather ABPS operating strategy. Results for this model run (scenario 4) are provided in Table 4-3 along with the baseline model results, the scenario 1 results, and the LTCP goals. The scenario 4 model results indicate a slight reduction in CSO volume compared to baseline for each outfall with a cumulative volume reduction 0.25 million gallons, attributable to the relatively lower ON setpoint for the lag wet weather pump. Overall, there was generally little difference between the baseline, scenario 1 and scenario 4 model results in terms of reduction of upstream CSO activation frequency or volume. However, field testing of scenario 4 demonstrated an operational benefit due to reduced pump cycling.

Based on these model results and the field tests, MWRA will now implement their updated strategy during wet weather events. There would be no CSO reduction or operational benefit to maintaining a lower wet well elevation during dry weather, and the operating costs of pump no. 4 would be higher. For these reasons, the strategy for maintaining a lower wet well elevation will be limited to wet weather conditions. Moving forward, the final wet weather ABPS operating strategy will be the baseline operating condition for any further optimization evaluations for the Alewife Brook system.

Table 4-3. Comparison of MWRA and Alternative ABPS Operating Strategies Model Runs to Baseline and LTCP Goals

Outfall	Regulator	Typical Year Rainfall						Long Term Control Plan	
		Baseline: Baseline ABPS Operating Strategy		Scenario 1: Alternative ABPS Operating Strategy		Scenario 4: Implemented MWRA Operating Strategy			
		Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
CAM001	**RE-011**	1	0.02	1	0.02	1	0.02	5	0.19
CAM002	**RE-021**	0	0.00	0	0.00	0	0.00	4	0.69
MWR003	**RE-031**	3	0.69	3	0.66	3	0.61	5	0.98
CAM401A	**RE-401**	5	0.69	5	0.67	5	0.66	5	1.61
CAM401B	**RE-401B**	4	0.56	4	0.54	4	0.50	7	2.15
SOM001A	**RE-01A**	8	4.55	8	4.53	8	4.47	3	1.67
Total		**8 (Max)**	**6.51**	**8 (Max)**	6.41	**8 (Max)**	**6.26**	**7 (max.)**	**7.29**
Volume Reduction from Baseline			**n/a**		**0.10**		**0.25**		**n/a**

1. Grey shading indicates model prediction is greater than LTCP value.

5. Conclusions and Next Steps

This section provides an overall summary of the findings from the Task 8.1 efforts, recommendations, and next steps that are being taken to achieve LTCP levels of control.

5.1 Summary and Recommendations

An alternative ABPS operating strategy has been developed based on the collection, analyses, and synthesis of ABPS record drawings, operational history and SCADA station data, field-collected data from pump performance tests, hydraulic model runs, and refinements from field implementation of initially proposed alternative operating strategies.

Results suggest that an alternative operating strategy would only result in marginal improvements to the reduction of CSO activation frequency and discharge volume for the six outfalls tributary to Alewife Brook. A comparison of the typical year model results between the baseline model using the existing ABPS operating strategy and the model using the final wet weather ABPS operating strategy indicate a total reduction in CSO volume of 0.25 million gallons.

Comparative plots of HGL in the ABPS wetwell versus the HGL in the ABC at the connection from the SOM001A regulator indicated that lowering the wetwell prior to the start of a storm had very little impact on the HGL upstream at the SOM001A connection. As a result, little change was seen in the upstream CSO volumes. Keeping the wetwell at a constant lower elevation during wet weather would only be feasible if the capacity of the ABPS was increased. Under these scenarios, capacity limitations in the ABC resulted in only a 0.75-foot reduction in peak HGL at the SOM001A connection associated with reductions in ABPS wetwell depth of four feet. Of the six outfalls discharging to Alewife Brook, outfall SOM001A is the only outfall currently predicted to be out of compliance with the LTCP performance goals. The constant wetwell scenarios did not change the activation frequency at outfall SOM001A, and only marginally reduced the volume. Since increasing the capacity of ABPS would not meaningfully improve the performance of outfall SOM001A relative to the LTCP goals and would also have adverse impacts on downstream HGLs during large storms, the constant wetwell scenarios were not pursued further.

It is recommended that the final wet weather ABPS operating strategy be implemented into the station controls. As indicated during the December 5th 2020 field trial, the wet weather pump operation was greatly improved with no observed pump cycling as the wet well level fluctuated. A reduction in cycling provides a more stable operation and should result in reduced fatigue wear of the pumps which can extend their service life, reducing station maintenance costs. An additional benefit is a reduction in the risk of the wet weather pumps being simultaneously triggered OFF, followed by a quick rise in the wet well prior to the pumps cycling ON that could potentially impact upstream CSOs.

5.2 Implementation and Next Steps

This new operating strategy will be incorporated in the station controls via the MWRA SCADA system. The station will now have two operating strategies: the existing operating strategy for dry weather flow conditions and the final wet weather ABPS operating strategy for storm events.

MWRA is in process of making updates to the human-machine interface Manager Setpoint Screen and the PLC programming to simplify the process when switching from the dry weather ABPS operating strategy to the final alternative ABPS operating strategy. In-house SCADA Engineers are working to create a single button allowing for station operators to quickly select the appropriate operating strategy. This single button control reduces the potential for error when switching from the dry weather to wet weather operating mode and vice versa.

Moving forward, the final wet weather ABPS operating strategy will be incorporated into the baseline configuration for the model. This updated baseline model will be used for the subsequent evaluations of system optimization measures to further reduce CSO frequency and activation volumes for outfalls tributary to Alewife Brook as required by the Variance.

6. References

DEP. 2019. *Final Determination to Adopt a Variance for Combined Sewer Overflow Discharges to Alewife Brook/Upper Mystic River*. Massachusetts Department of Environmental Protection.

Metcalf & Eddy. 1997. *Final CSO Facilities Plan and Environmental Impact Report*. Prepared for the Massachusetts Water Resources Authority.

Metcalf & Eddy. 2003. *Final Variance Report for Alewife Brook/Upper Mystic River*. Prepared for the Massachusetts Water Resources Authority.

Appendix A: Dry Weather Pump Test Report

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Project name:
Massachusetts Water Resource Authority – Alewife Brook Pump Station Evaluation and Optimization

Project ref:
60559027

From:
Daniel Braz
Paul Moulton

Date:
July 23, 2020

Pump Test Report

Subject: MWRA – Task 8.1 ABPS Dry Weather Pump Test Report

The pump test for the dry weather pump, pump 4, at the Alewife Brook Pump Station (ABPS) was performed and completed on Monday, July 13th 2020. Two tests were performed as stated in the AECOM-developed pump test plan. The goals of the two tests were to develop pump curves based on the field performance of the pump and compare its field performance to its factory performance, and to assess the minimum wet well operating level below which the pump may experience physical phenomenon that could reduce its performance and/or cause damage to the pump.

Results of the first test indicate that the pump's field performance closely matches, yet slightly underpredicts the factory performance. The field performance data shows a slightly reduced pumped flow capacity compared to the factory performance data for a given pump head data point. Results of the second test suggest that the dry weather pump can operate at 100% speed down to a wet well level of at least 92 feet, a level much lower than the current operational controls OFF level of 96.67 feet.

SCADA data for the ABPS was provided by MWRA in order to correlate data taken in the field with the recorded station data.

In addition to having the dry weather pump's performance better characterized, the InfoworksICM model of the ABPS can now be updated to reflect the field performance.

Attachment A provides the recorded data and information from the pump tests. Attachment B provides photographs of the test site. Attachment C provides the AECOM-developed pump test plan.

1. Personnel and Procedure Summary

In addition to the MWRA staff onsite to support the various tasks required for the pump test, the lead personnel for MWRA and AECOM were as follows:

MWRA:
- Mike Barter, Pump Station Operations Lead
- Lisa Bina, Pump Station Operations and Engineering
- Kristen Hall, Pump Station Operations and Engineering

AECOM:
- Daniel Braz, Engineering
- Evelyn Grainger, Engineering
- Don Walker, Engineering

A summary of the day is provided for information:
- AECOM personnel arrived onsite at 8:00 am
- Following a tailgate and safety meeting, MWRA staff guided AECOM on a walk-through of the pump station
- As MWRA staff assembled, AECOM took the required physical measurements of the dry weather pump's suction and discharge pressure gauges
- At approximately 9:15 am, AECOM briefed MWRA personnel on the pump test plan and its general procedure
- Before beginning the first pump test, all pumps were shutoff to allow the wet well level to rise to approximately 99.75 feet
- The first pump test began at approximately 10:18 am and concluded at approximately 11:03 am
    - Due to the time it took (approximately one hour) for the wet well level to rise from 97 feet to 99.75 feet, the test procedure was altered to reduce time and energy for the MWRA discharge valve operating crew.
    - The discharge valve was initially set fully open, the pump was run at 100% speed and the pressure gauges were vented. After data was recorded at 100% speed, the pump speed was dropped to 82%, and then again to 62%, with data recorded at each speed. The pump was then shut off, and the MWRA operating crew closed the discharge valve approximately 120 rotations to a 50% closed setting. The pump was turned back on to 100% speed and the pressure gauges were vented. Data was recorded for the 50% closed valve setting for the three pump speeds. The pump was kept on for the remainder of this test with the MWRA operating crew throttling the discharge valve to 70% closed, 80% closed, 90% closed, and fully closed with data readings taken for the three pump speeds at each discharge valve setting.
    - Following completion of the test, the MWRA operating crew throttled the discharge valve to a fully open position.
- The procedure for the second pump test was reviewed and the dry weather pump speed was set fixed to 100%
- A relatively large influx of water into the ABPS required one of the wet weather pumps to be turned on in order to draw the wet well level down to a sufficiently low starting point for the second test
- Once the wet well reached and maintained a level of approximately 95.5 feet, the wet weather pump was turned off
- At approximately 12:10 pm the wet well level dropped to 94.5 feet and all personnel went to their dedicated locations within the ABPS to record data both quantitative and observational
- At 12:26 pm the wet well level dropped to 89 feet and the test was concluded

2. Test Results

The results of the two pump tests are summarized below. The filled worksheets are provided as Attachment A.

2.1 Pump Performance Testing Results

The results of the pump performance test are plotted in Figure 1 along with the 100% speed pump curve from the factory acceptance test. For the duration of this test, the wet well level fluctuated between 99.5 feet and 100 feet. For this band of wet well level, the maximum pumped flowrate was measured to be 11,520 gpm (16.60 mgd). A plot of wet well level versus pumped flowrate is provided in the results section for test 2.

In Figure 1, the red plot represents the data taken from the first pump test where the pump speed was held at 100% and the discharge valve, installed in the station yard, was sequentially throttled from fully open to fully closed. The red “x’s” on the plot indicate recorded data points. Moving from right to left along the red plot, each point corresponds to a discharge valve setting of: fully open, 50% closed, 70% closed, 80% closed, and 90% closed. Comparing the field test plot to the factory test pump curve (royal blue plot), the field data matches very well within the pump’s preferred operating range. The data shows that, for equivalent heads, in the field the pump appears to be pumping at a slightly lower flow rate than recorded during the factory test. For example, at a head of 22 feet the factory data states a pump flow of ~ 11,250 gpm whereas the field data states a flow of ~10,500 gpm, a difference of 750 gpm or 1.1 mgd. Some of this difference between the field measurement and the factory test may be attributed to the inherent greater variability of field conditions for instrument installation and recorded pressure gauge and flowmeter data, as compared to a factory test setting in accordance with ANSI/HI 14.6 testing requirements.

This test was performed for two other pump speeds of 82% and 62%, and plots of the measurements at those pump speeds are also included in Figure 1.

The field measured shutoff head readings are also provided for all three tested pump speeds in Figure 1 (the points corresponding to zero flow). For the 100% pump speed data point the field measured shutoff head is much greater than that recorded during the pump’s factory test. Typically, it is expected that field readings indicate a shutoff head equal to or lower than that reported in the factory test. Testing at shutoff resulted in poor readings due to large oscillations in pressure gauge readings, and as a result this value is only shown as a discrete point, and it is not considered to be representative of the pump performance.

As shown in all three test plots, the data points for the 50% closed and fully open discharge valve are nearly identical. This is reasonable due to the relatively low difference in head loss through the fully open and 50% open gate valve. For the lower speed curves it should be noted that these two data points are either right on top of each other as shown in the 82% speed plot or are backwards as shown in the 62% speed plot where the 50% closed discharge valve setting is indicating a larger flow rate than the fully open discharge valve setting. Overall the difference in head loss and flowrate are relatively small and the readings are close. One possible explanation for this discrepancy is that the accuracy bounds of the flow meter data for both points are overlapping. For example, for a flowmeter accuracy of plus or minus 2.5%, if the flow data point for a fully open discharge valve is truly 3,200 gpm the flowmeter may produce a reading of 3,120 gpm (0.975 * 3,200). If the flow data point for a 50% closed discharge valve is truly 3,100 gpm the flowmeter may produce a reading of 3,177 gpm (1.025 * 3,000). In this case it would appear that the 50% closed discharge valve would allow for more pump flow, a trend shown in the teal 62% speed plot in the Figure.

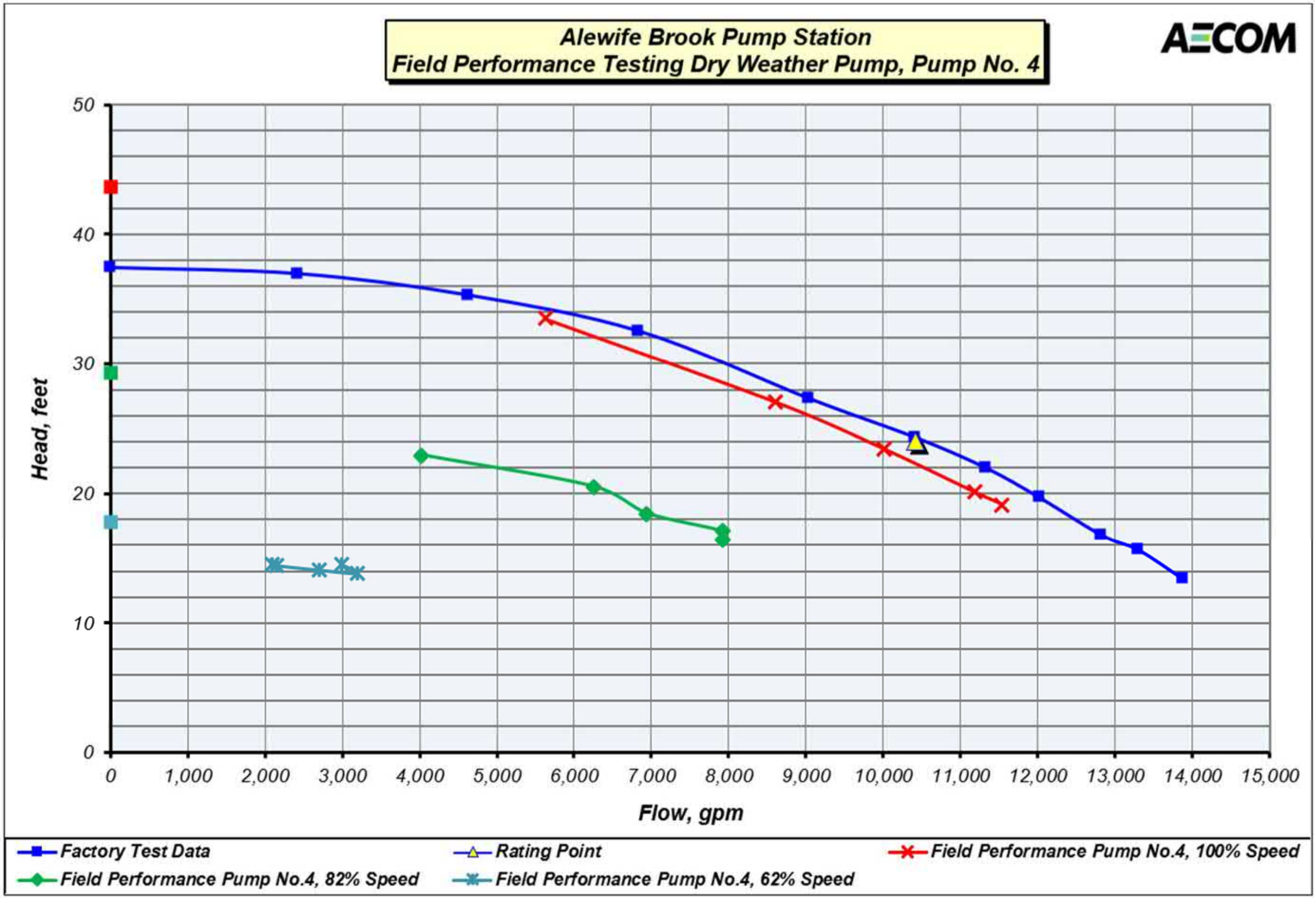


Figure 1: Field performance data from pump test 1 for three pump speeds, 100%, 82%, and 62% overlaid on the dry weather pump's factory test data.

2.2 Wet Well Level Testing Results

The wet well level test was carried out with the pump speed set to 100% for the test's duration.

The following qualitative observations were noted during the test:

- No crackling, popping or other noises typically associated with cavitation or other similar phenomena were heard emanating from pump 4.
- Once the wet well elevation fell below ~92 feet, the flowmeter read a constant value of 12.4 mgd. See below for discussion of the flow meter readout at this level.
- The wet well showed no obvious signs of surface vortex formation (e.g., an obvious depression in the water surface). Once the wet well level dropped to approximately 92 feet, and for the remainder of the test, a general swirl pattern could be seen over the entirety of the visible wet well water surface.
- Upon concluding the test, with the pump shutting down, a large ~whoosh~ sound was heard in the pump discharge piping. The sound was akin to a combination of a flushing noise and heavy rainfall. Personnel observing the wet well saw no instance of wet well level rise during this occurrence, nor was the sound audible to these personnel. Prior to the conclusion of this test, the pump was never shut down starting from 100% speed so the noted sound may simply be backflow associated with this shut down event.

Figure 2 provides a plot of wet well level verse the dry weather pumped flowrate. These data are from MWRA-provided SCADA data spanning the duration of this pump test. The plot shows the transition at the wet well level of 92 feet where the flowmeter jumps in readout value, producing a steady value of 12.4 mgd as the wet well level continues to drop. One potential explanation for the flowmeter's behavior is that a multiphase flow pattern was developed in the pump discharge piping. The presence of air in the fluid column will reduce the accuracy the flowmeter.

Based on these results, operation of the dry weather pump at 100% speed down to a wet well level of 92 feet can be considered feasible. This level is much lower than the current operational controls OFF level of 96.67 feet. A net positive suction head (NPSH) calculation was performed for the wet well level of 92 feet with a pump flow of 12 mgd. The NPSH available was calculated to be 30.77 feet and the NPSH required for this flow was found to be 9.65 feet based on available data. The resulting NPSH ratio of 3.2 (30.77 / 9.65 = 3.2) suggests good pump operating conditions.

Figure 2: Field performance data taken from MWRA-provided SCADA data from the pump test date, July 13 2020. The data shows the transition around wet well elevation 92 feet when the flowmeter readouts became a constant value of 12.4 mgd.

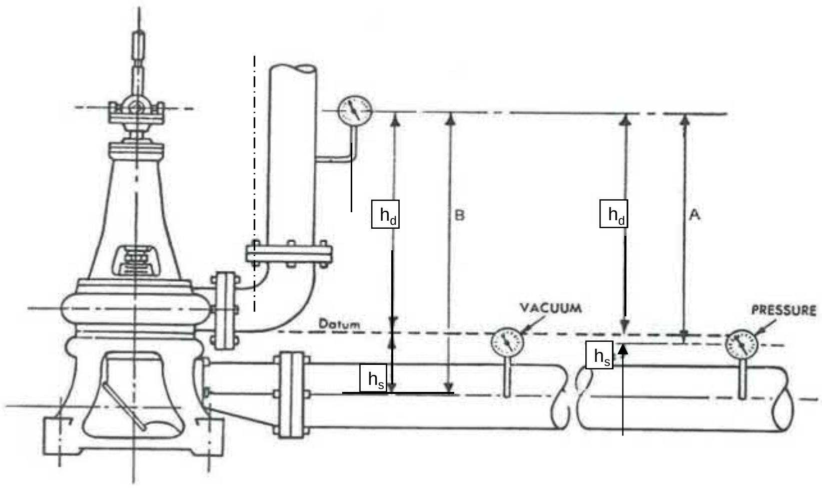
3. Conclusion

The two planned pump tests were successfully carried out. The performance of the dry weather pump is now better characterized with field performance data recorded to provide pump field performance and a newly established minimum operating wet well level that could potentially provide more operational flexibility. Additionally, the InfoworksICM model of the ABPS can now be updated to reflect this field performance.

Attachment A. Completed Test Forms

Project: MWRA Alewife Brook Pump Station
Subject: Dry Weather Pump Test
Test Date: 13-Jul-20

Pump Manufacturer:	Flowserve
Pump Tag Number:	Pump-4
Model Number:	20MNF24 FR-71
Serial Number:	0705MS004248-1
Impeller Diameter:	22.5
Rating Point:	10415 gpm at 24 feet
Motor hp:	100 hp
Motor Speed, rpm:	510 rpm



Datum	**Vacuum Readings**			**Suction Pipe, in**
	hs	**hd**	**B**	
Pump Centerline			5.05	20
	Pressure Readings			**Discharge Pipe, in**
	hs	**hd**	**A**	
			3.68	20

Speed (RPM/%): 100	Setting No.1	Setting No.2	Setting No.3	Setting No.4	Setting No.5	Setting No.6
Operating Condition/RPM:	Shutoff Head	10% Open	20% Open	30% Open	50% Open	Full Open
Suction Condition:	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure
Discharge Gauge (Pd), psi:	19.80	14.90	11.60	9.80	8.00	7.20
Suction Gauge (Ps), psi:	2.50	2.00	1.50	1.25	0.90	0.50
Flow, mgd:	0.00	8.10	12.40	14.40	16.10	16.60
Flow, gpm:	0	5,625	8,611	10,000	11,180	11,528
Static Correction:	3.68	3.68	3.68	3.68	3.68	3.68
Suction Velocity Head:	0.00	0.51	1.20	1.62	2.02	2.15
Discharge Velocity Head:	0.00	0.51	1.20	1.62	2.02	2.15
Velocity Correction:	0.00	0.00	0.00	0.00	0.00	0.00
Total Head, feet:	43.65	33.48	27.01	23.43	20.08	19.16

Project: MWRA Alewife Brook Pump Station
Subject: Dry Weather Pump Test
Test Date: 13-Jul-20

Speed (RPM/%): 82	Setting No.1	Setting No.2	Setting No.3	Setting No.4	Setting No.5	Setting No.6
Operating Condition/RPM:	Shutoff Head	10% Open	20% Open	30% Open	50% Open	Full Open
Suction Condition:	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure
Discharge Gauge (Pd), psi:	13.60	10.60	9.30	8.20	7.30	7.00
Suction Gauge (Ps), psi:	2.50	2.25	2.00	1.80	1.50	1.50
Flow, mgd:	0.00	5.80	9.00	10.00	11.40	11.40
Flow, gpm:	0	4,028	6,250	6,944	7,917	7,917
Static Correction:	3.68	3.68	3.68	3.68	3.68	3.68
Suction Velocity Head:	0.00	0.26	0.63	0.78	1.02	1.02
Discharge Velocity Head:	0.00	0.26	0.63	0.78	1.02	1.02
Velocity Correction:	0.00	0.00	0.00	0.00	0.00	0.00
Total Head, feet:	29.32	22.97	20.55	18.47	17.08	16.39

Speed (RPM/%): 62	Setting No.1	Setting No.2	Setting No.3	Setting No.4	Setting No.5	Setting No.6
Operating Condition/RPM:	Shutoff Head	10% Open	20% Open	30% Open	50% Open	Full Open
Suction Condition:	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure
Discharge Gauge (Pd), psi:	8.50	7.20	7.05	6.90	6.80	6.80
Suction Gauge (Ps), psi:	2.40	2.50	2.40	2.40	2.40	2.10
Flow, mgd:	0.00	3.00	3.10	3.90	4.60	4.30
Flow, gpm:	0	2,083	2,153	2,708	3,194	2,986
Static Correction:	3.68	3.68	3.68	3.68	3.68	3.68
Suction Velocity Head:	0.00	0.07	0.08	0.12	0.17	0.14
Discharge Velocity Head:	0.00	0.07	0.08	0.12	0.17	0.14
Velocity Correction:	0.00	0.00	0.00	0.00	0.00	0.00
Total Head, feet:	17.77	14.54	14.42	14.08	13.85	14.54

Testing Performed By: AECOM Date: 13-Jul-20

Testing Witnessed By: MWRA Date: 13-Jul-20

Project: MWRA Alewife Brook Pump Station
Subject: Dry Weather Pump Test
Test Date: 13-Jul-20

WET WELL LEVEL TEST FORM						
Description:	Dry Weather Pump Drawdown Test					
Speed/RPM:	100 % Speed					
Start Time:	11:30					
End Time:	12:27					
Data Reading Time:	12:17	12:19	12:20	12:21	12:22	12:24
Wet Well Level:	92.25	91.1	90.5	90.1	90	89.4
Discharge Gauge (Pd), psi:	7.50	7.20	7.20	7.00	7.00	7.00
Suction Gauge (Ps), in Hg:	-2.00	-3.00	-3.40	-4.00	-4.50	-5.00
Flow, gpm:	11.5	12.4	12.4	12.4	12.4	12.4
Notes: (Notes: discuss sounds/sites as wet well level is drawn down)	- No crackling, popping or other noises typically associated with cavitation or other similar phenomena were heard. - Once the wet well elevation fell below ~92 feet, the flowmeter read a constant value of 12.4 mgd. - The wet well showed no obvious signs of vortex formation (e.g., an obvious depression in the water surface). Once the wet well level dropped to approximately 92 feet, and for the remainder of the test, a general swirl pattern could be seen over the entirety of the visible wet well water surface. - Upon concluding the test, with the pump shutting down, a large ~whoosh~ sound was heard in the pump discharge piping. The sound was akin to a flushing noise. Personnel observing the wet well saw no instance of wet well level rise during this occurrence, nor was the sound audible to these personnel.					

Attachment B. Site Photos

Figure B.1: Dry weather pump, pump 4, suction and discharge pressure gauges shown

Figure B.2: Dry weather pump motor and discharge piping with flowmeter

Figure B.3: Dry weather pump discharge piping

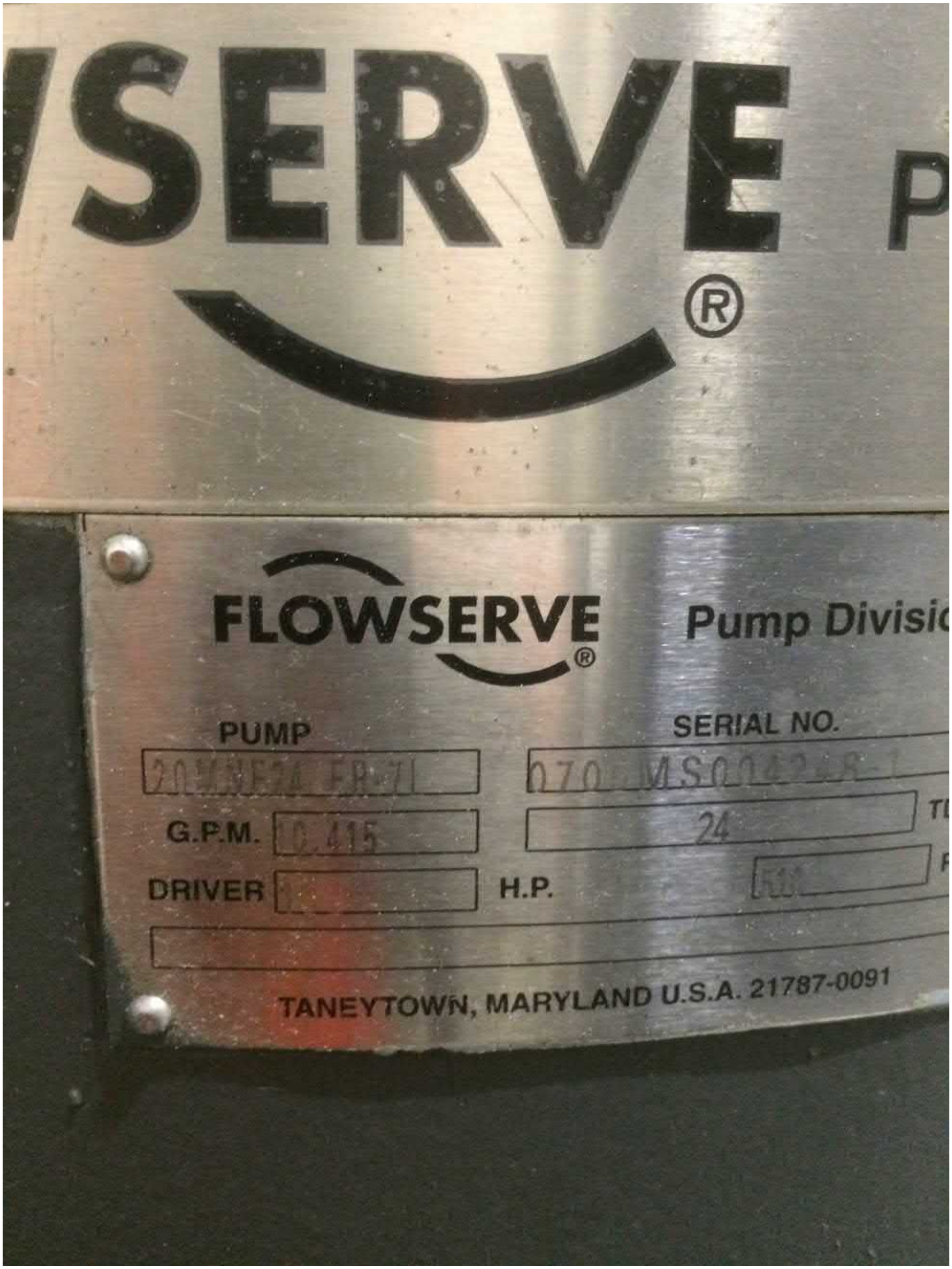


Figure B.4: Dry weather pump, pump 4 nameplate

Figure B.5: Dry weather pump, pump 4 suction pressure gauge

Figure B.6: Dry weather pump, pump 4 discharge pressure gauge

Figure B.7: Wet well drawdown test, access port used for observation

Attachment C. ABPS Dry Weather Pump Test Plan

AECOM Imagine it. Delivered.

To:
Kristen Hall, MWRA
Lisa Bina, MWRA

CC:
Brian Kubaska, MWRA
Jeremy Hall, MWRA
Erika Casarano
Evelyn Grainger
Larry Soucie
Don Walker

AECOM
250 Apollo Drive
Chelmsford, MA 01824
aecom.com

Project name:
Massachusetts Water Resource Authority – Alewife Brook Pump Station Evaluation and Optimization

Project ref:
60559027

From:
Daniel Braz
Paul Moulton

Date:
June 24, 2020

Pump Test Plan

Subject: **MWRA – ABPS Dry Weather Pump Test Plan**

The test procedure for the dry weather pump, pump 4, at the Alewife Brook Pump Station (ABPS) is provided. Two tests will be performed. The first test seeks to characterize and confirm the installed performance of the pump, measuring the flow and pressures for a variety of pump speeds and discharge valve settings. The second test is an observational drawdown test to assess the minimum acceptable wet well level for pump operation for a variety of pump speeds.

Attachment A provides the field testing forms and worksheets that will be used and filled out during the pump test. Attachment B provides the pump 4 Flowserve factory pump test for information.

1. General

The following is the recommended procedure for field performance testing of dry pit pumps.

1. Review the job specifications, drawings and shop drawings prior to any field trip to the job site.

2. Check with the Project Manager and/or Resident Engineer to confirm that the pumps, motors and controls are installed, functioning, and ready for testing. Confirm that the gauges, level instrumentation and flowmeters are installed, functioning and calibrated.

3. Once at the jobsite:
   - safety plans should be reviewed with personnel assigned to specific safety tasks
   - walk down the facility to familiarize all parties with access and building exit locations
   - review test procedure and work plan
   - test communication methods

4. The following data must be recorded for the pump of interest:
   - Pump nameplate data
   - Motor nameplate data

- Flowmeter data
- Distance between centerline of suction and discharge gauges for static correction
- Size of piping at suction and discharge gauge locations for velocity corrections

Input the above data into the testing worksheet, provided in Attachment A.

2. Testing Procedure

The dry weather pump will be subject to two sets of tests. The first test seeks to characterize and verify the installed performance of the pump, measuring the flow and pressures for a variety of pump speeds and discharge valve settings. The second test is a drawdown test to identify the minimum acceptable wet well level for pump operation for a variety of pump speeds. These tests will not include amp draw and will therefore not require an electrician for test support.

Address the following items prior to testing:

- All items in the General section of this plan have been completed
- Check datum for wet well level readings
- Assess if and how the wet well level can be visually monitored
- Inspect discharge valve, if a linear travel valve, identify number of turns from open to close, if a quarter turn valve these typically have an indicator of valve position
- Wet weather and dry weather pump operation set to manual
- Wet weather pumps to remain off unless maximum wet well level of 101 feet is reached
- Override local low wet well level controls that could initiate dry weather pump shutdown
- Allow wet well level to rise to at least 98 feet
- Record initial wet well levels
- Run dry weather pump at minimum speed (60%) to provide a warmup period and establish steady state flow conditions
- Vent pump casing and pressure gauge lines of all air
- Ensure flowmeter, pump speed, and wet well level readouts are readily available for recording from the control room

2.1 Pump Performance Testing

Prior to the testing, confirm responsibilities and procedure with personnel.

All data should be recorded in the worksheet provided in Attachment A.

Ramp dry weather pump to 100% speed. This procedure should be repeated for at least two more pump speeds, one of which should be the current minimum operating pump speed of 60% and one approximately mid speed.

The pump output and head will be recorded at as many points as necessary to properly confirm the pump performance curve, 3 to 4 points will be sufficient. For each discharge valve position, monitor pressure gauge and flowmeter readings until a steady state condition is interpreted. The speed of the pump should be checked at each setting.

The pump should be tested at the following points in the following order:

- Throttle discharge valve closed to measure shutoff head. Run the pump for at least 60 seconds and record the gauge readings, the flow meter should read zero. If the flowmeter reads a flow greater than zero than it should be assess if the discharge valve is not fully sealed or if the flowmeter is not properly calibrated.

- Adjust valve % open, typically 25%, 50% and 75% but each setting must be a reasonable flow rate for spreading the data points. Record data for each discharge valve setting

2.2 Wet Well Level Testing

Prior to the testing, confirm responsibilities and procedure with personnel.

All data should be recorded in the worksheet provided in Attachment A.

Confirm test speeds and target wet well levels based on ANSI HI 9.8 submergence to minimize surface vortices calculations.

Set discharge valve to 100% open.

Testing procedure:

- Set the pump speed to 60%
- Draw down the wet well level. Take pressure gauge and flowmeter readings throughout the testing period. At a minimum the readings should be captured at the start and finish for a given pump speed.
- As wet well level drops record descriptions of any pump/system noise, vibration and visual condition of wet well water surface. Any vortices that form on the wet well surface indicate possibility of air entrainment in the pump.
- Repeat this test for the mid speed and maximum pump speed

Following conclusion of the wet well level testing, reset all controls for wet weather and dry weather pumps to resume normal operating procedures.

2.3 SCADA Data

The following time stamped SCADA data should be requested from MWRA, covering the time span in which the above testing occurred:

- Wet well level: LIT1400-1, LIT1400-2
- Pump 4 flowmeter: FIT 1467-4
- Pump 4 speed

3. Test Results and Formalization

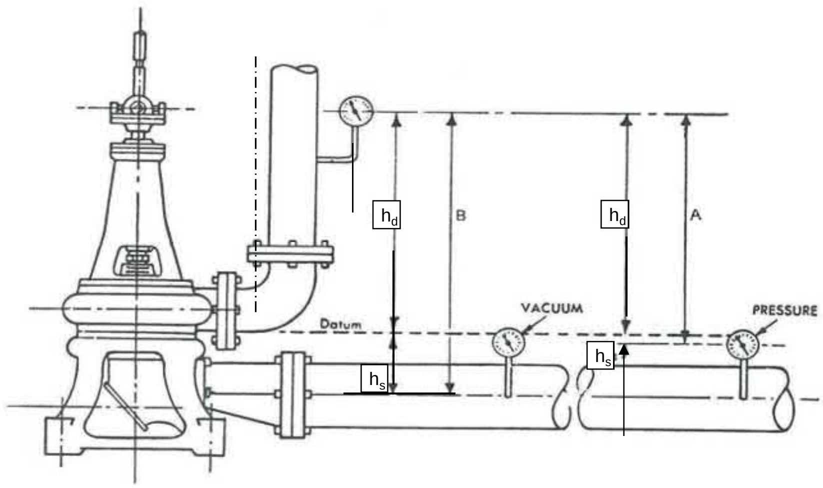
A memorandum will be written containing the following:

- Date of testing
- All people present for the test.
- Data recorded during the testing, test results and observations.
- A plot of the test results against the certified performance curve provided by the manufacturer in the shop drawings.
- Drawing showing the datum and all elevations recorded.
- A summary of data, results and observations.

Attachment A. Pump Test Form

Project: *MWRA Alewife Brook Pump Station*
Subject: *Dry Weather Pump Test*
Test Date:

Pump Manufacturer:
Pump Tag Number:
Model Number:
Serial Number:
Impeller Diameter:
Rating Point: gpm at feet
Motor hp: hp
Motor Speed, rpm: rpm



Datum	Vacuum Readings			Suction Pipe, in
Pump Centerline	**hs**	**hd**	**A**	
			0.00	24
	Pressure Readings			**Discharge Pipe, in**
	hs	**hd**	**B**	
		0.00	0.00	24

Time:	12:05:00 PM	12:15:00 PM	12:10:00 PM	12:20:00 PM	12:00:00 PM	
Speed (RPM / %):	Setting No.1	Setting No.2	Setting No.3	Setting No.4	Setting No.5	Setting No.6
Operating Condition/RPM:	Shutoff Head	1/4 Open	1/2 Open	3/4 Open	Full Open	
Suction Condition:	Pressure	Pressure	Pressure	Vacuum	Vacuum	Pressure
Discharge Gauge (Pd), psi:	50.00	40.00	35.00	30.00	20.00	20.00
Discharge Gauge (Ps), psi:	10.00	10.00	10.00	10.00	10.00	10.00
Flow, gpm:	0	1,000	2,000	3,000	4,000	4,000
Static Correction:						
Suction Velocity Head:						
Discharge Velocity Head:						
Velocity Correction:						
Total Head, feet:						
Voltage:						
Amps:						

EXAMPLE FOR FIELD. USE ONLY ONE SPEED CONDITION PER TEST SET

Project: MWRA Alewife Brook Pump Station
Subject: Dry Weather Pump Test
Test Date:

Time:						
Speed (RPM / %):	Setting No.1	Setting No.2	Setting No.3	Setting No.4	Setting No.5	Setting No.6
Operating Condition/RPM:						
Suction Condition:						
Discharge Gauge (Pd), psi:						
Suction Gauge (Ps), psi:						
Flow, gpm:						
Static Correction:						
Suction Velocity Head:						
Discharge Velocity Head:						
Velocity Correction:						
Total Head, feet:						
Voltage:						
Amps:						

Time:						
Speed (RPM / %):	Setting No.1	Setting No.2	Setting No.3	Setting No.4	Setting No.5	Setting No.6
Operating Condition/RPM:						
Suction Condition:						
Discharge Gauge (Pd), psi:						
Suction Gauge (Ps), psi:						
Flow, gpm:						
Static Correction:						
Suction Velocity Head:						
Discharge Velocity Head:						
Velocity Correction:						
Total Head, feet:						
Voltage:						
Amps:						

Time:						
Speed (RPM / %):	Setting No.1	Setting No.2	Setting No.3	Setting No.4	Setting No.5	Setting No.6
Operating Condition/RPM:						
Suction Condition:						
Discharge Gauge (Pd), psi:						
Suction Gauge (Ps), psi:						
Flow, gpm:						
Static Correction:						
Suction Velocity Head:						
Discharge Velocity Head:						
Velocity Correction:						
Total Head, feet:						
Voltage:						
Amps:						

Time:						
Speed (RPM / %):	Setting No.1	Setting No.2	Setting No.3	Setting No.4	Setting No.5	Setting No.6
Operating Condition/RPM:						
Suction Condition:						
Discharge Gauge (Pd), psi:						
Suction Gauge (Ps), psi:						
Flow, gpm:						
Static Correction:						
Suction Velocity Head:						
Discharge Velocity Head:						
Velocity Correction:						
Total Head, feet:						
Voltage:						
Amps:						

Testing Performed By: ______________________________ Date:

Testing Witnessed By: ______________________________ Date:

AECOM

AECOM

Project: *MWRA Alewife Brook Pump Station*
Subject: *Dry Weather Pump Test*
Test Date:

WET WELL LEVEL TEST FORM						
Description:						
Speed/RPM:						
Start Time:						
End Time:						
Data Reading Time:						
Wet Well Level:						
Discharge Gauge (Pd), psi:						
Suction Gauge (Ps), psi:						
Flow, gpm:						
Notes: (Notes discuss sounds/sites as wet well level is drawn down)						
Description:						
Speed/RPM:						
Start Time:						
End Time:						
Data Reading Time:						
Wet Well Level:						
Discharge Gauge (Pd), psi:						
Suction Gauge (Ps), psi:						
Flow, gpm:						
Notes: (Notes discuss sounds/sites as wet well level is drawn down)						
Description:						
Speed/RPM:						
Start Time:						
End Time:						
Data Reading Time:						
Wet Well Level:						
Discharge Gauge (Pd), psi:						
Suction Gauge (Ps), psi:						
Flow, gpm:						
Notes: (Notes discuss sounds/sites as wet well level is drawn down)						

Testing Performed By: ______________________ *Date:*

Testing Witnessed By: ______________________ *Date:*

Attachment B. Flowserve Factory Performance Test

Rating Point: 10415 gpm
24 feet

AECOM

Dry Weather Pump - Pump 4
Pump Factory Test Data S/N: 0705MS004248 1
Speed (RPM) 510

Flow, gpm	0	2,427	4,630	6,846	9,040	10,420	11,330	12,016	12,822	13,299	13,888
Head, ft	37.41	36.94	35.29	32.5	27.31	24.3	21.96	19.7	16.8	15.64	13.35

Dry Weather Pump - Pump 4
Pump Factory Test Data S/N: 0705MS004248 1
Speed (RPM) 473

Flow, gpm	0	2,276	4,474	6,383	8,434	9,718	10,577	11,267	12,055	12,580	12,995
Head, ft	32.41	31.69	30.18	28.04	23.37	21.05	18.97	17.1	14.43	12.53	11.39

Dry Weather Pump - Pump 4
Pump Factory Test Data S/N: 0705MS004248 1
Speed (RPM) 436

Flow, gpm	0	2,475	4,501	5,555	6,383	7,915	9,014	9,670	10,532	11,045	11,808
Head, ft	27.07	26.9	25.13	24.37	22.27	19.53	17.66	15.73	14.13	12.99	10.4

FLOWSERVE
PUMP DIVISION

HYDROSTATIC TEST CERTIFICATION

Customer: EL WATERMAN
Customer Order: MWRA ALEWIFE BROOK
Pump Model: 20MNF24
TT Order: S-004248-000

Part No.	Part Name:	Qty
COMP.PUMP	Complete Pump	1
		0
		0
		0

Pressure: 50
Hold Time: 10 MINUTES
Gauge ID # 200-1

Procedure#: 8.2.4.526 - 10 Min hold time

Pressure Gauge Loads:

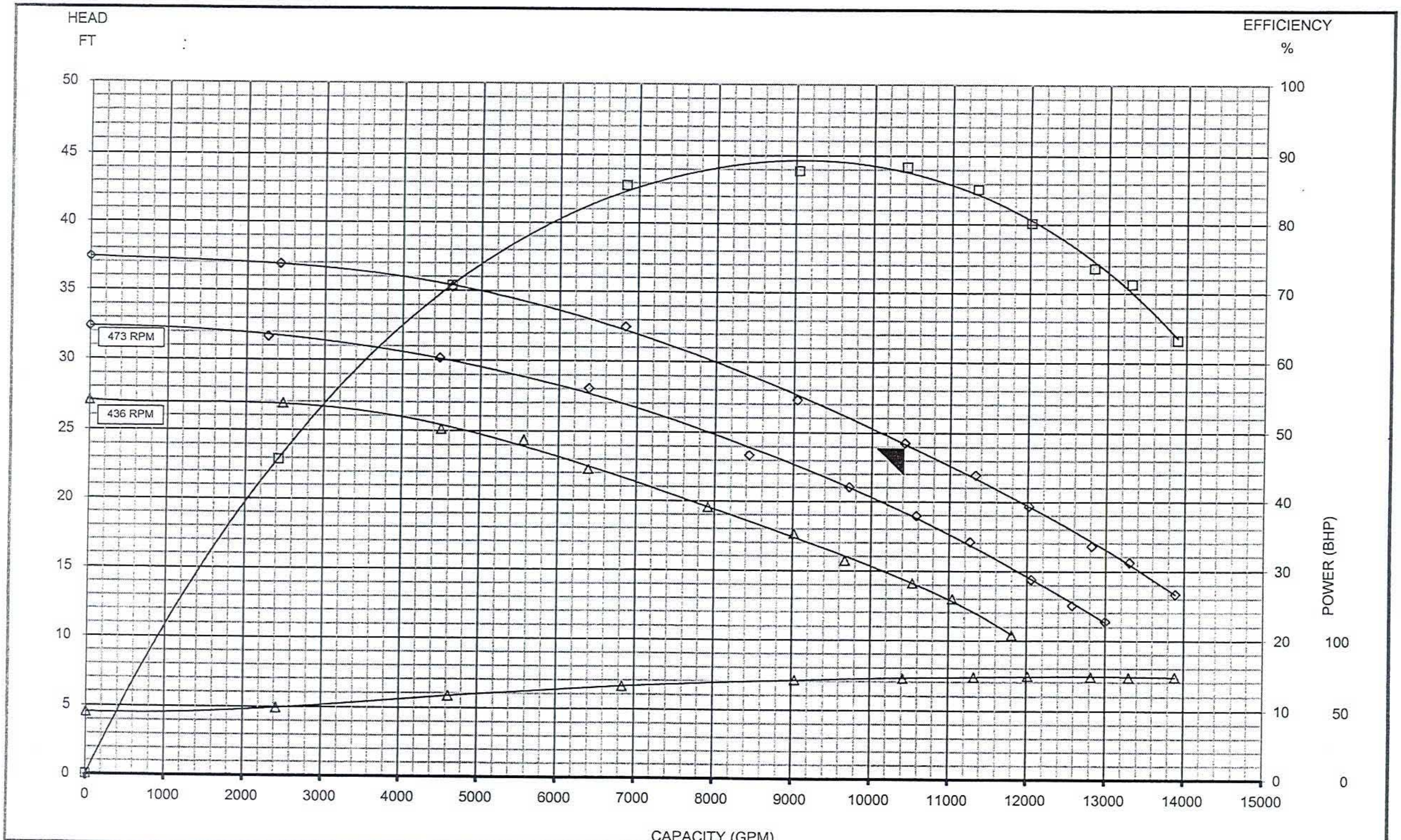
Pre-Test		Post-Test	
Dead	Actual	Dead	Actual
40	40	40	40
60	60	60	60

Comments: HYDROED BY DON SCRIMA

Flowserve Pump Division hereby certifies that the material furnished on the above subject order was satisfactorily hydro tested per the above pressure and hold time.

Tester: Greg Short Date: 5/15/2007
Witness: Michael Jones PM Date: 5/15/07
Professional Engineer: Date:

Form #8.2.4.707 Rev. 07 Date: 3/10/05



0705MS004248-1	S4248-1	20MNF24	1	MAIN WELL	PUMP	JOB	4 MAG	05/14/07	1B
SERIAL NO.	ORDER NO.	MODEL	STAGES	TEST LOOP	TYPE OF TEST	TEST MOTOR	FLOW METER	DATE TESTED	CURVE NO

CASING DATA	IMPELLER DATA		CONDITIONS OF SERVICE	
CAST IRON MATERIAL	STAINLESS STEEL MATERIAL	1A FINISH	10415 GPM FLOW	24 FT HEAD
1A FINISH	22.50 DIAMETER		1 SG	510 RPM SPEED
N/A TONGUE	DEBURR TIP			84 TEMP. (F)

I CERTIFY THAT WITHIN THE ACCURACY OF THE TEST INSTRUMENTATION, THIS TEST REPRESENTS THE PERFORMANCE OF 0705MS004248-1

FLOWSERVE

FLOWSERVE

FLOWSERVE PUMP DIVISION
Taneytown

PERFORMANCE TEST RESULTS

ORDER NUMBER: S4248-1
SERIAL NUMBER: 0705MS004248-1
MODEL: 20MNF24 -1
TEST DATE: 05/14/07

DATA CORRECTED TO 510 RPM AND 1 S.G.

	FLOW GPM	HEAD FT	POWER BHP	EFFICIENCY %	NPSHA FT
	0.0	37.41	45.63	0.00	30.81
	2426.5	36.94	49.40	45.82	28.72
	4629.5	35.29	58.28	70.78	28.57
	6846.0	32.50	65.66	85.57	28.68
510	9040.2	27.31	71.00	87.80	28.91
RPM	10419.9	24.30	72.37	88.36	29.08
	11329.5	21.96	73.79	85.14	29.13
	12015.5	19.70	74.56	80.16	29.19
	12821.5	16.80	73.91	73.58	29.20
	13299.4	15.64	73.63	71.32	29.19
	13888.4	13.35	73.99	63.27	29.12
	0.0	32.41	34.69	0.00	35.72
	2276.3	31.69	39.53	46.09	33.55
	4474.3	30.18	46.81	72.85	33.49
	6383.1	28.04	52.52	86.07	33.40
	8433.6	23.37	57.40	86.73	33.70
473	9718.1	21.05	58.11	88.91	33.84
RPM	10576.9	18.97	59.58	85.03	33.91
	11266.9	17.10	59.80	81.35	33.97
	12054.6	14.43	58.86	74.62	33.97
	12580.4	12.53	59.24	67.18	34.00
	12994.8	11.39	58.30	64.10	33.93
	0.0	27.07	27.23	0.00	41.83
	2474.6	26.90	31.66	53.09	39.57
	4500.5	25.13	37.65	75.85	39.65
	5554.5	24.37	40.17	85.09	39.71
	6383.1	22.27	42.29	84.90	39.70
436	7915.0	19.53	44.81	87.13	39.84
	9014.1	17.66	45.61	88.12	40.01
RPM	9669.6	15.73	46.27	83.02	40.03
	10532.3	14.13	47.20	79.62	40.17
	11045.3	12.99	46.78	77.45	40.16
	11807.9	10.40	46.65	66.50	40.03

FLOWSERVE PUMP DIVISION
Taneytown

TEST DATA

ORDER NUMBER:	S4248-1
SERIAL NUMBER:	0705MS004248-1
MODEL:	20MNF24 -1
TEST DATE:	05/14/07

BAROM	DISCHARGE DIA. (IN)	SUCTION DIA. (IN)	GAUGE DATUM (IN)	Z DATUM (IN)
30.30	20.00	20.00	72	-57.25

FLOW HG (IN)	FLOW GPM	POWER KW	Discharge Pressure PSI	Suction Pressure PSI	Speed RPM
0	0	34.03	14.81	1.25	512
0.25	2426.50491	36.84	13.61	0.25	511
0.91	4629.47631	43.46	12.72	0.07	511
1.99	6846.01282	48.96	11.39	-0.05	511
3.47	9040.15563	52.94	8.95	-0.25	510
4.61	10419.854	53.97	7.54	-0.36	510
5.45	11329.4655	55.02	6.41	-0.48	510
6.13	12015.4878	55.60	5.35	-0.56	510
6.98	12821.5013	55.12	3.96	-0.70	510
7.51	13299.3721	54.90	3.37	-0.79	510
8.19	13888.4289	55.18	2.24	-0.93	510
0	0	25.87	12.51	1.11	473
0.22	2276.26337	29.48	11.36	0.27	473
0.85	4474.25398	34.91	10.58	0.14	473
1.73	6383.13782	39.16	9.48	-0.04	473
3.02	8433.6319	42.80	7.36	-0.14	473
4.01	9718.14459	43.33	6.25	-0.25	473
4.75	10576.8897	44.43	5.25	-0.35	473
5.39	11266.9289	44.59	4.36	-0.43	473
6.17	12054.6263	43.89	3.08	-0.56	473
6.72	12580.4393	44.17	2.18	-0.64	473
7.17	12994.8344	43.47	1.59	-0.74	473
0	0	20.31	10.14	1.04	436
0.26	2474.55918	23.61	9.31	0.28	436
0.86	4500.49616	28.07	8.47	0.21	436
1.31	5554.52362	29.96	8.09	0.16	436
1.73	6383.13782	31.53	7.11	0.08	436
2.66	7915.01948	33.42	5.82	-0.02	436
3.45	9014.06567	34.01	4.93	-0.10	436
3.97	9669.55356	34.50	4.02	-0.18	436
4.71	10532.2613	35.20	3.25	-0.26	436
5.18	11045.2627	34.89	2.68	-0.34	436
5.92	11807.8825	34.78	1.40	-0.50	436

Appendix B: Wet Weather Pump Test Report

AECOM Imagine it. Delivered.

AECOM
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To:
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Lisa Bina, MWRA

CC:
Brian Kubaska, MWRA
Jeremy Hall, MWRA
Erika Casarano
Evelyn Grainger
Larry Soucie
Don Walker

Project name:
Massachusetts Water Resource Authority – Alewife Brook Pump Station Evaluation and Optimization

Project ref:
60559027

From:
Daniel Braz
Paul Moulton

Date:
November 2, 2020

Pump Test Report

Subject: **MWRA – Task 8.1 ABPS Wet Weather Pump Test Report**

The pump test for wet weather pumps 1 and 3 at the Alewife Brook Pump Station (ABPS) was performed and completed on Tuesday, October 13th, 2020. One test was performed as stated in the AECOM-developed pump test plan. The goal of the test was to assess the minimum wet well operating level below which the pump may experience physical phenomena that could reduce its performance and/or cause damage to the pump.

Results of the test suggest that the wet weather pumps can operate at 100% speed down to a wet well level of at least 95.6 feet (the wet weather pumps' centerline elevation), a level much lower than the current operational controls OFF level of 97.50 feet.

SCADA data for the ABPS was provided by MWRA in order to correlate data taken in the field with the recorded station data.

Attachment A provides the AECOM-developed pump test plan.

1. Personnel and Procedure Summary

In addition to the MWRA staff onsite to support the various tasks required for the pump test, the lead personnel for MWRA and AECOM were as follows:

MWRA:
- Pat Hardy, Pump Station Operations Lead
- Kristen Hall, Pump Station Operations and Engineering

AECOM:
- Daniel Braz, Engineering
- Tyler Brinson, Engineering
- Evelyn Grainger, Engineering

A summary of the day is provided for information:
- AECOM personnel arrived onsite at 10:00 am
- Due to surface scum buildup in the wet well, the test was delayed as MWRA decided on how best to proceed with the day's plan. It was then decided that the wet well would not be drawn down lower than the wet weather pump centerline of 95.6 feet in order to reduce the potential for surface scum to be pulled through the pump
- Following a tailgate and safety meeting, MWRA staff guided AECOM on a walk-through of the pump station
- At approximately 11:00 am, AECOM briefed MWRA personnel on the pump test plan and its general procedure
- Before beginning the first pump test, all pumps were shut off to allow the wet well level to rise to approximately 98.5 feet
- The first pump test, which began at approximately 11:10 am and concluded at approximately 11:12 am, had wet weather pump 1, set at 100% speed, draw the wet well level down to 96 feet.
- At approximately 12:05 pm, the test was repeated for wet weather pump 3 set at 100% speed, again drawing the wet well level down to 96 feet
    - It was noted that the feedback from the SCADA system indicated a pump speed of low to mid 90s. It is not known if the SCADA system had a misreading or if the pump was truly not operating at 100% speed
- At approximately 12:14 pm, the test was repeated for wet weather pump 3 set to 60% speed, after an initial draw down to 98 feet, the wet well level began to rise indicating that there was an inrush of water greater than the pump capacity at 60% speed or that at 60% speed the pumped flow is insufficient to handle wet weather inflow rates
    - It was noted that at 60% speed, the check valve on the pump discharge piping was not fully open even at the higher initial wet well level of 98.5 feet.
- The pump speed was raised to 80% and the wet well was drawn down to 96.5 feet at which point the pump speed was lowered to 60% to continue drawing the wet well level down to 95.6 feet. Again, the wet well level rose at the 60% pump speed. The pump speed raised to 80% and the wet well was drawn down to 95.7 feet. This test concluded at approximately 12:32 pm
- The final test of the day was a repeat of the 100% speed draw down test simply to get more SCADA data points for the station effluent meter for a constant pump speed at varying wet well levels
- AECOM personnel left the site at 1:00 pm

2. Wet Well Level Test Results

A general discussion of the performed tests is provided in the above summary section.

The following qualitative observations were noted during the test:
- No crackling, popping or other noises typically associated with cavitation or other similar phenomena were heard emanating from the tested wet weather pumps
- The wet well showed no obvious signs of surface vortex formation (e.g., an obvious depression in the water surface)
- At pump speeds of 80% and 100% the check valve on the pump discharge piping was fully open
- At a pump speed of 60% the check valve on the pump discharge piping was partially open showing small oscillations in position

Figure 1, below, provides a curve of flow vs minimum wet well level based on ANSI HI-9.8 hand calculations. These calculations provide a first estimate of the minimum allowable wet well level at which a pump should operate in order to minimize the potential for surface vortex formation and pump damage. Two points are included on this figure indicating the minimum wet well level for the wet weather pump's rated design flow at 100% speed and its 60% speed pump flow calculated from the pump affinity law that states ideal pump flow is linearly proportional to pump speed. At the 100% speed design flow of 37.5 mgd, the ANSI HI-9.8 plot indicates that the minimum wet well level for pump operation is approximately 95.7 feet, 0.1 feet above the pump centerline. If the wet well level falls below the blue plot for this same pump flow then the potential for surface vortex formation increases. However, as the pump flow decreases the recommend minimum wet well level for pump operation drops, such as at the 60% pump speed with a corresponding pump flow of 22.5 mgd and a resulting minimum recommended wet well level of 94.8 feet.

The goal of these pump tests was to assess the validity of the ANSI HI-9.8 hand calculations when applied to ABPS (i.e., too conservative or not conservative enough).

Due to the buildup of scum and concern of pulling this potentially damaging material through the pumps, the testing was limited to a minimum wet well level of 95.6 feet. However, based on the test results, which showed a lack of any qualitative indicators of poor pump operation, the ANSI HI-9.8 calculations can be considered a reasonable benchmark for defining alternative wet weather pump operational setpoints.

Figure 2, below, presents a scatter plot of MWRA-provided SCADA PI data taken during the tests. The Station Effluent Meter FT-1422 data is plotted against Wet Well Level LT-1400-1 data. Three data sets are presented for bands of pump operating speeds: the red scatter data for pump speeds greater than or equal to 90%, the blue scatter data for pump speeds less than 90% and greater than or equal to 65%, and the yellow scatter data for pump speeds less than 65 percent. Despite the outliers, the wet weather pump's flow for the yellow and blue operating bands exhibit decent linear trends. The spread of data points in the red operating band make it difficult to separate trends from noise, however the data suggests that near full speed the pumps produce flows greater than their 37.5 mgd design point. These data can assist in determining the minimum recommended wet well level for pump operation at a given speed.

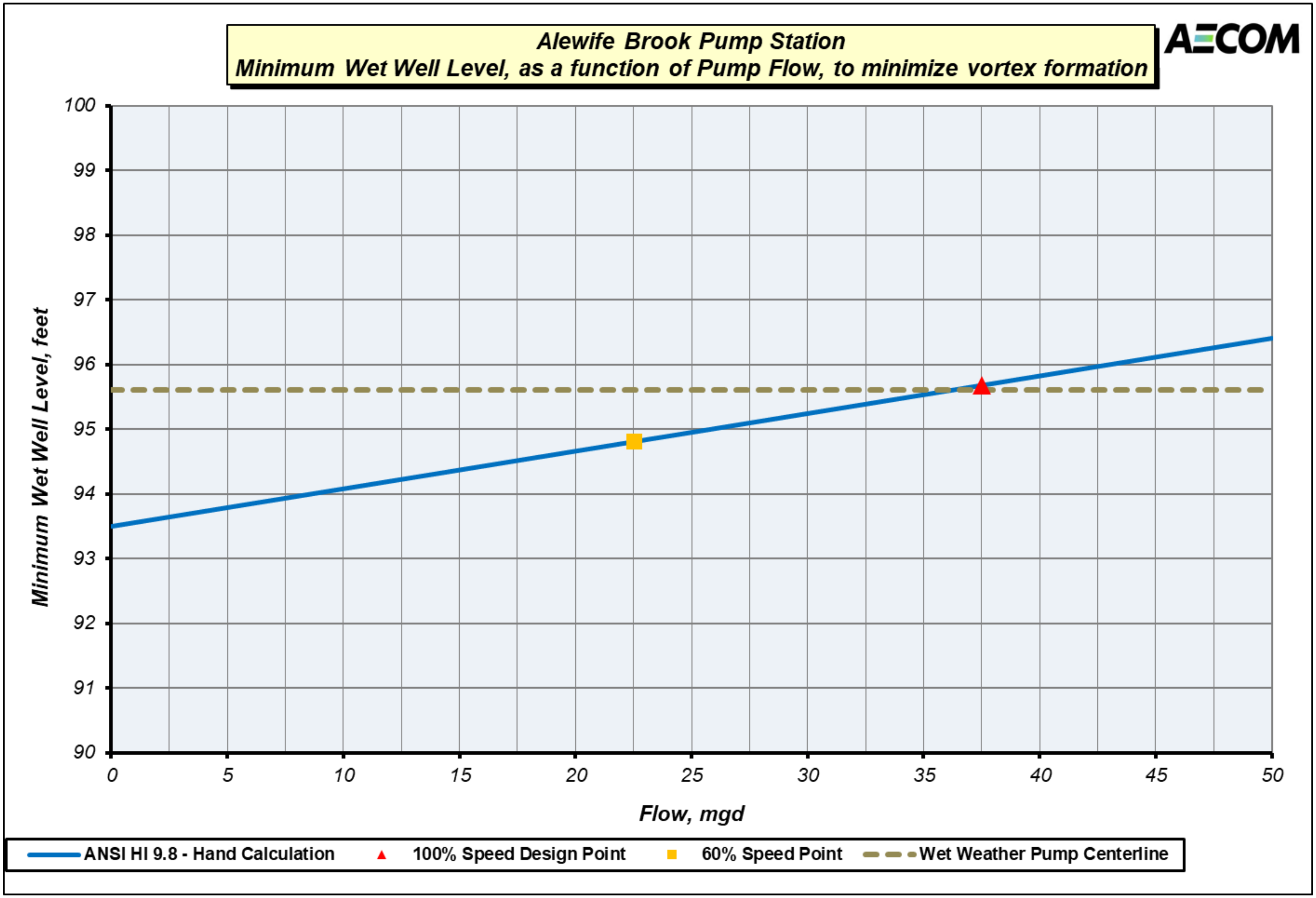

Figure 1: ANSI HI-9.8 hand calculation plot of minimum wet well level as a function of pump flow.

Figure 2: Field performance data taken from MWRA-provided SCADA data from the pump test date, October 13, 2020

3. Conclusion

The wet weather pump tests indicate that the pumps can operate at 100% speed down to a wet well level of 96 feet and at 80% speed down to a wet well level of 95.7 feet without observed indications of cavitation or vortex formation in the wet well. Additionally, at a pump speed of 60% the wet weather pump was unable to maintain or reduce the wet well level below 98 feet. This indicates that the wet weather pumps' OFF setpoints could be set lower than the current operating setpoint to minimize pump cycling during brief pauses in wet weather events.

Attachment A. ABPS Wet Weather Pump Test Plan

AECOM
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To:
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Lisa Bina, MWRA

CC:
Brian Kubaska, MWRA
Jeremy Hall, MWRA
Erika Casarano
Evelyn Grainger
Larry Soucie
Don Walker

Project name:
Massachusetts Water Resource Authority – Alewife Brook Pump Station Evaluation and Optimization

Project ref:
60559027

From:
Daniel Braz
Paul Moulton

Date:
September 28, 2020

Pump Test Plan

Subject: MWRA – ABPS Wet Weather Pump Test Plan

The test procedure for the wet weather pumps, pumps 1, 2, and 3, at the Alewife Brook Pump Station (ABPS) is provided.

The test to be performed is an observational drawdown test to assess the minimum acceptable wet well level for pump operation for a variety of pump speeds.

The tests should be performed during a wet weather event that would result in sufficient ABPS influent flow to support sustained use of at least one wet weather pump operating at 100% speed.

Attachment A provides the field testing form and worksheet that will be used and filled out during the pump test.

1. General

The following is the recommended procedure for field performance testing of dry pit pumps.

1. Review the job specifications, drawings and shop drawings prior to any field trip to the job site.

2. Check with the Project Manager and/or Resident Engineer to confirm that the pumps, motors and controls are installed, functioning, and ready for testing. Confirm that the gauges, level instrumentation and flowmeters are installed, functioning and calibrated.

3. Once at the jobsite:
   - safety plans should be reviewed with personnel assigned to specific safety tasks
   - walk down the facility to familiarize all parties with access and building exit locations
   - review test procedure and work plan
   - test communication methods

4. The following data must be recorded for the pump of interest:
   - Pump nameplate data

- Motor nameplate data
- Flowmeter data
- Distance between centerline of suction and discharge gauges for static correction
- Distance from pump centerline to pump floor
- Size of piping at suction and discharge gauge locations for velocity corrections

Input the above data into the testing worksheet, provided in Attachment A.

2. Testing Procedure

The wet weather pumps will be subject to drawdown tests to assess the minimum acceptable wet well level for pump operation for a variety of pump speeds. These tests will not include amp draw and will therefore not require an electrician for test support.

The tests should be performed during a wet weather event that would result in sufficient ABPS influent flow to support sustained use of at least one wet weather pump operating at 100% speed.

The following MWRA staff, operators, and MWRA-provided equipment are required for testing:

- Pump operator
- Operator to open and supervise wet well hatches
- Face shield for pressure gauge and pump case venting
- Work lights to allow for clear viewing of wet well water surface

Address the following items prior to testing:

- All items in the General section of this plan have been completed
- Check and set all discharge valves to 100% open
- Check datum for wet well level readings
- Setup wet well access location to support visual monitoring
- Wet weather and dry weather pump operation set to manual
- Dry weather pump to remain off unless needed to control wet well level
- Override local low wet well level controls that could initiate wet weather pump shutdown
- Allow wet well level to rise to at least 100 feet
- Record initial wet well levels
- Run wet weather pump at minimum speed (60%) to provide a warmup period and establish steady state flow conditions
- Vent pump casing and pressure gauge lines of all air
- Ensure flowmeter, pump speed, and wet well level readouts are readily available for recording from the control room

2.1 Wet Well Level Testing

Prior to the testing, confirm responsibilities and procedure with personnel.

All data should be recorded in the worksheet provided in Attachment A.

Confirm test speeds and target wet well levels based on ANSI HI 9.8 submergence to minimize surface vortices calculations.

Testing procedure:

- Set the pump speed to 100%
- Draw down the wet well level. Take pressure gauge and flowmeter readings throughout the testing period. At a minimum the readings should be captured at the start and finish for a given pump speed
- As wet well level drops record descriptions of any pump/system noise, vibration and visual condition of wet well water surface. Any vortices that form on the wet well surface indicate possibility of air entrainment in the pump. Note behavior of pump discharge check valve
- Repeat this test for the mid speed and 60% pump speed

Following conclusion of the wet well level testing, reset all controls for wet weather and dry weather pumps to resume normal operating procedures.

2.2 Wet Weather Requirements

As stated, the tests should be performed during a wet weather event that would result in enough ABPS influent flow to support sustained use of at least one wet weather pump operating at 100% speed. It is estimated that a predicted storm with a total ½ inch rainfall depth and 24-hour duration would be sufficient to support testing. Due to reliance on wet weather, MWRA and AECOM will monitor weather forecasts and reports in order to pinpoint potential storms as they approach. All personnel should be prepared with the proper PPE and supplies to mobilize to the ABPS as soon as possible once a sufficient storm event is predicted. Currently, mobilization will only occur during normal business hours.

2.3 SCADA Data

The following time stamped SCADA data should be requested from MWRA, covering the time span in which the above testing occurred:

- Wet well level: LIT1400-1, LIT1400-2
- Pump 1 flowmeter: FIT 1467-1
- Pump 2 flowmeter: FIT 1467-2
- Pump 3 flowmeter: FIT 1467-3
- Station effluent flowmeter: FIT 1469-1
- Pump 1 speed
- Pump 2 speed
- Pump 3 speed

3. Test Results and Formalization

A memorandum will be written containing the following:

- Date of testing
- All people present for the test
- Data recorded during the testing, test results and observations
- Plots of the test results
- Drawing showing the datum and all elevations recorded
- A summary of data, results and observations

Attachment A. Pump Test Form

Project: MWRA Alewife Brook Pump Station
Subject: Wet Weather Pump Test
Test Date:

WET WELL LEVEL TEST FORM						
Description:	Wet Weather Pump Drawdown Test					
Speed/RPM:						
Start Time:						
End Time:						
Data Reading Time:						
Wet Well Level:						
Discharge Gauge (Pd), psi:						
Suction Gauge (Ps), in Hg:						
Flow, gpm:						
Notes: (Notes: discuss sounds/sites as wet well level is drawn down)						

Appendix C: Baseline Model Regulator and Interceptor HGL Profiles for the October 23rd and August 18th Typical Year Storm Events

Hydraulic profile figures through the regulators to the interceptor for the updated baseline model are provided. The figures present the peak HGL for the 10/23/92 and 8/18/92 storm events – the largest and third largest storms, respectively, in the Typical Year based on CSO volume discharged to Alewife Brook. Figures are provided for the five regulator structures shown in Figure C-1. Additionally, the peak HGL in the ABC from the dry weather flow connection at SOM001A to the ABPS wet well is provided for both storm events. Figure C-2 through C-9 provide the hydraulic profiles for the 10/23/92 storm event. Figures C-10 through C-17 provide the hydraulic profiles for the 8/18/92 storm event. The figures are presented in order from downstream to upstream, (i.e., from the ABPS to SOM001A…to CAM401A).

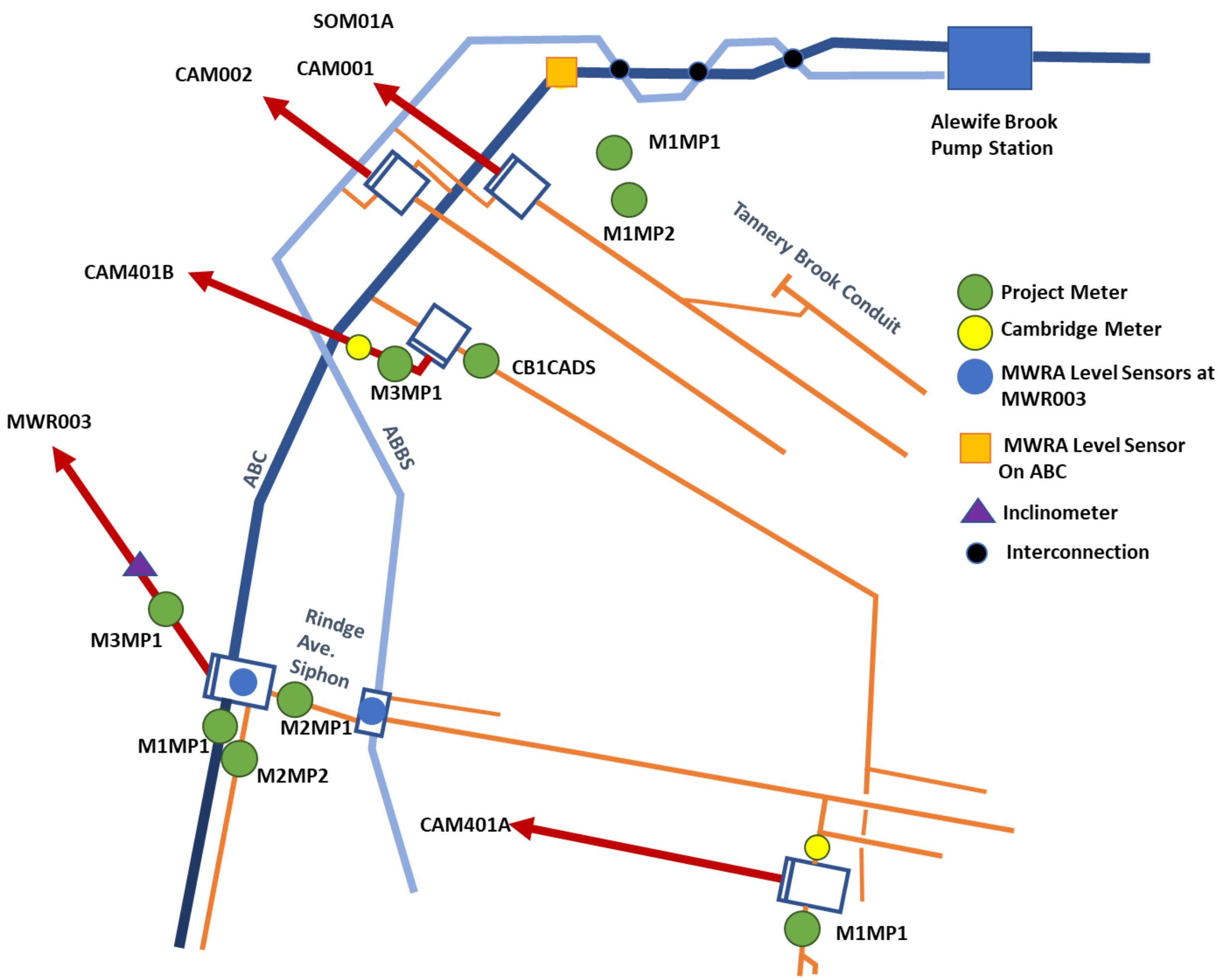


Figure C-1: Alewife Brook System Schematic

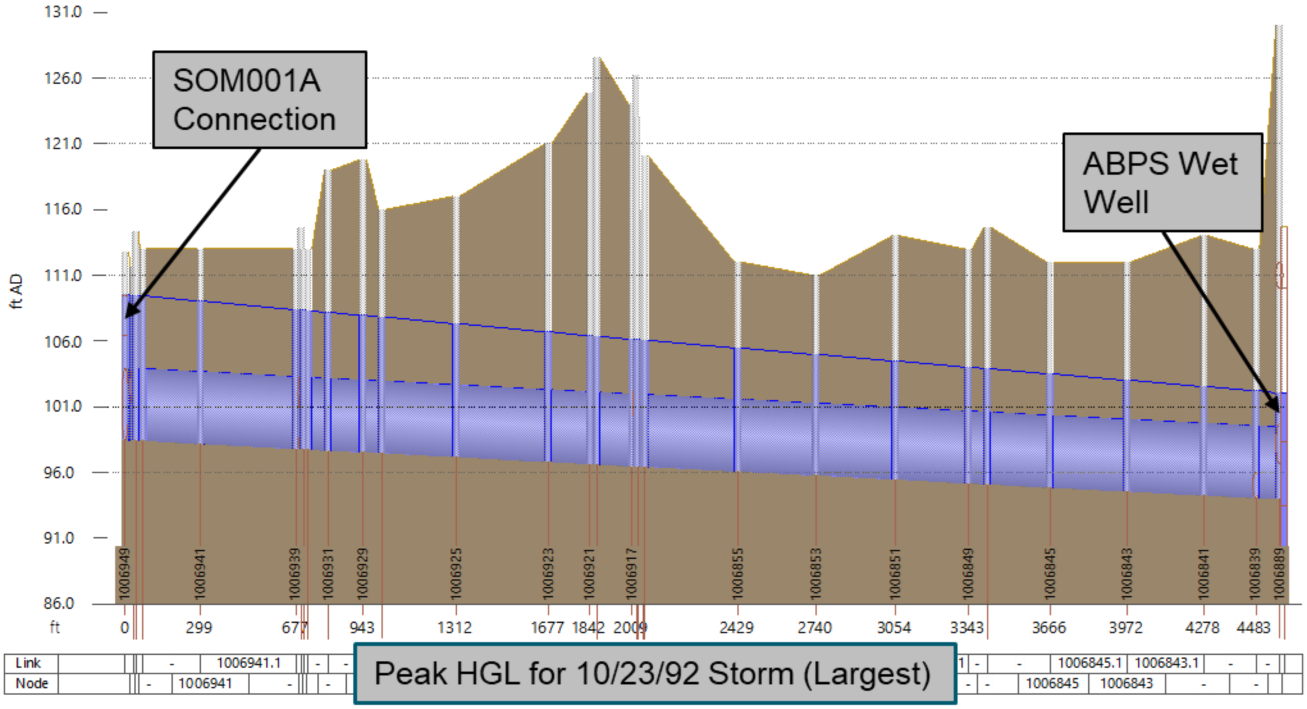


Figure C-2. ABC Interceptor Profile for the 10/23/1992

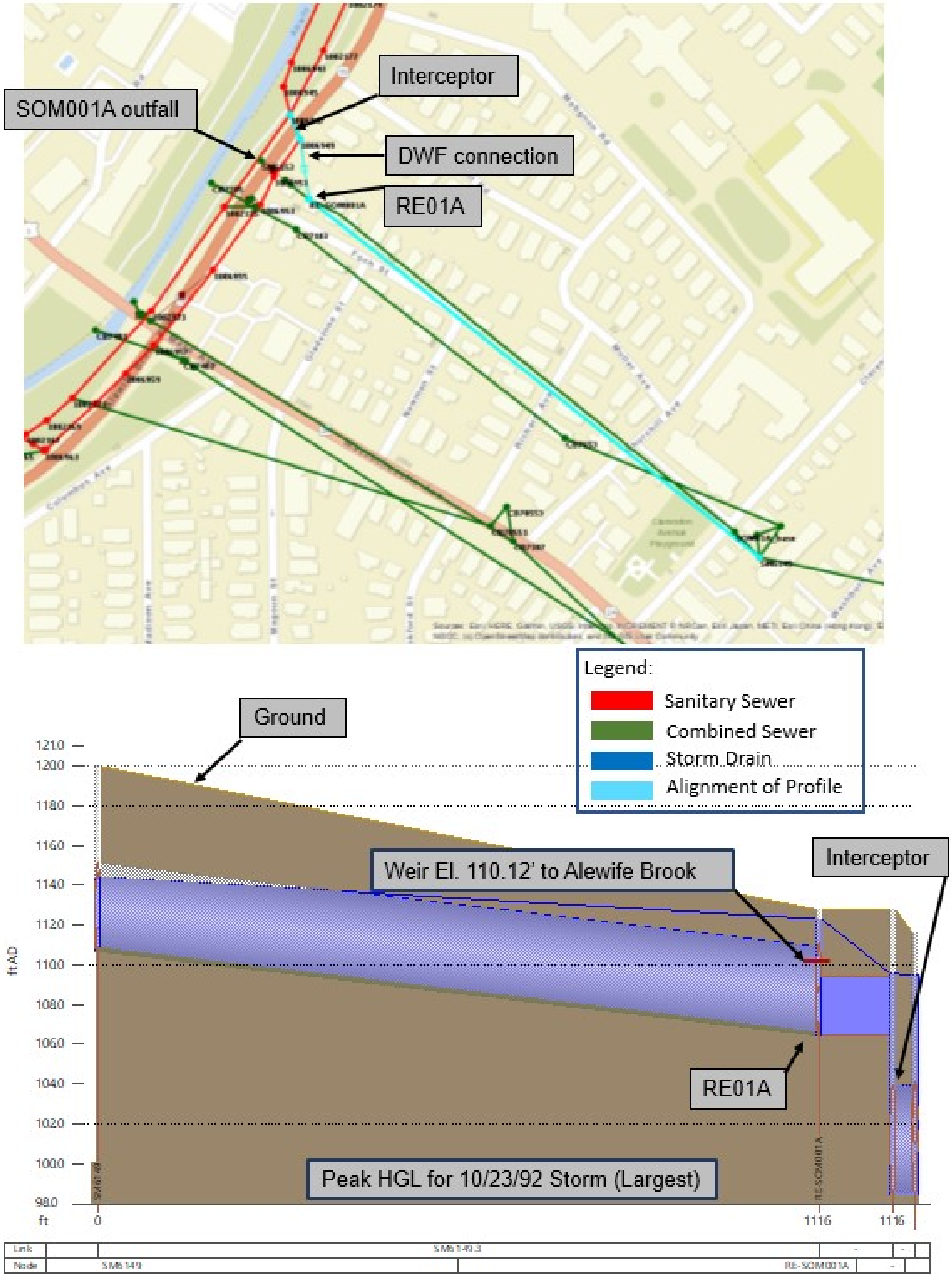


Figure C-3. Regulator Profile at SOM001A for the 10/23/1992 storm event

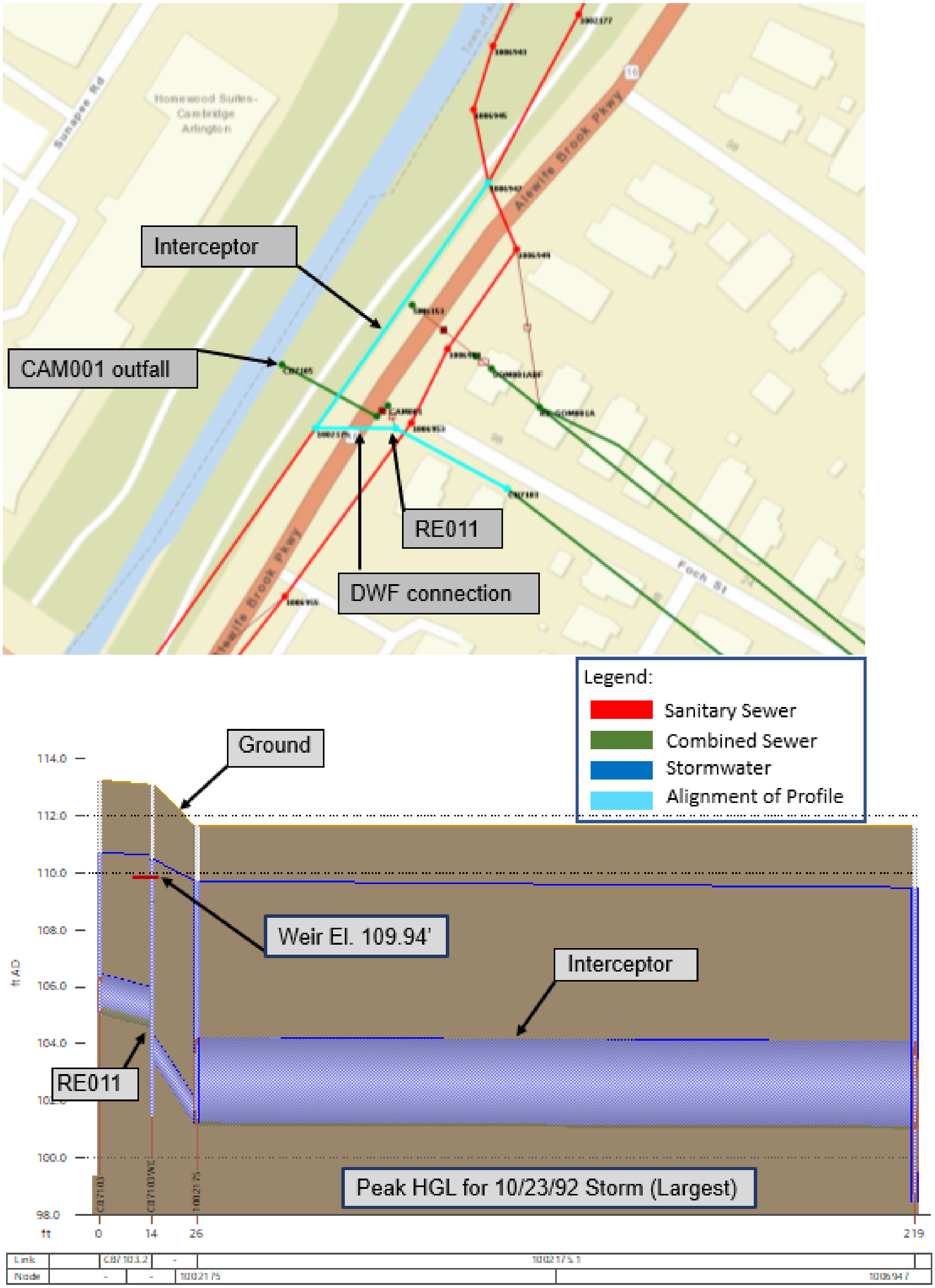


Figure C-4. Regulator Profile at CAM001 for the 10/23/1992 storm event

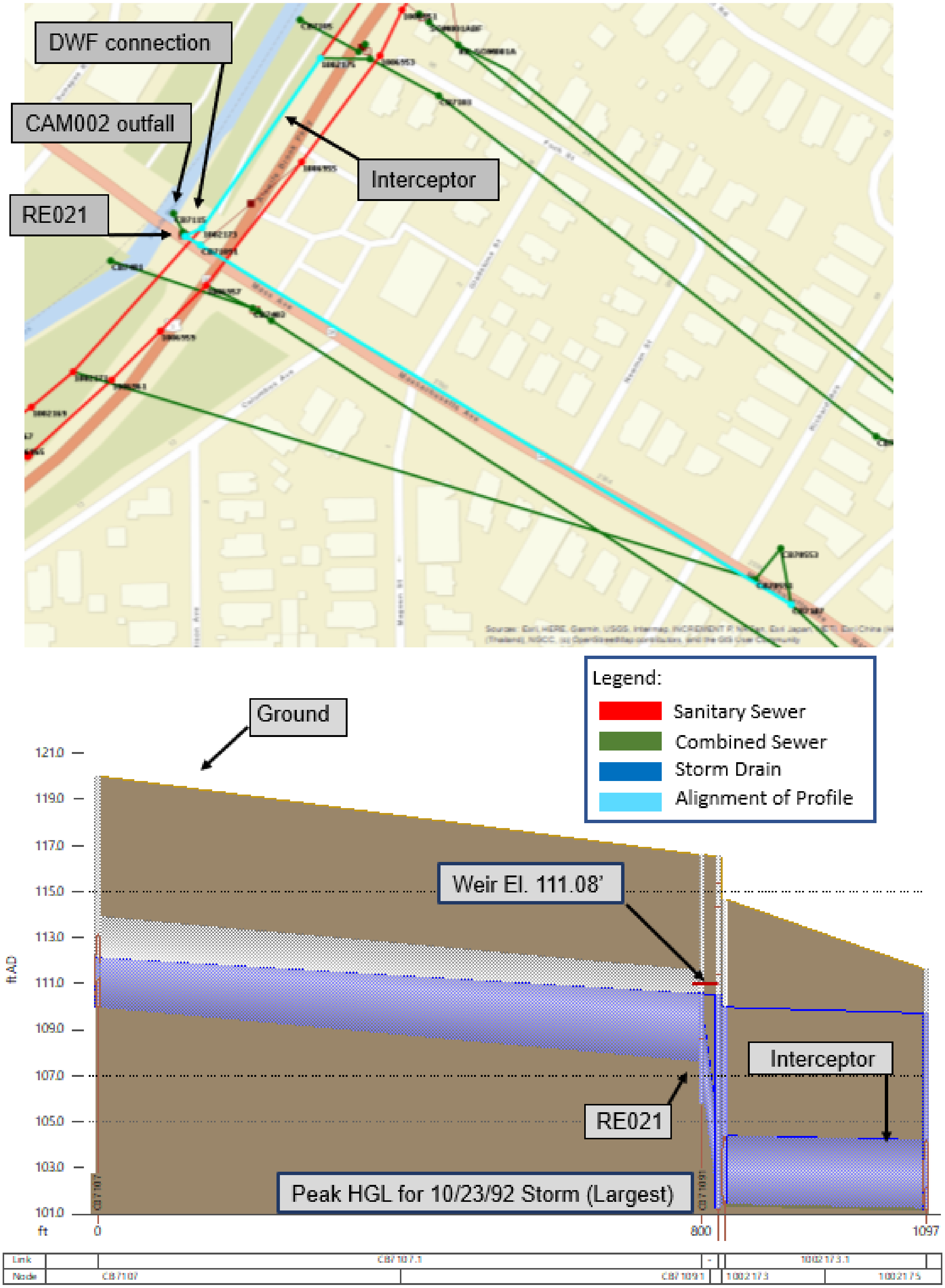


Figure C-5. Regulator Profile at CAM002 to ABBS for the 10/23/1992 storm event

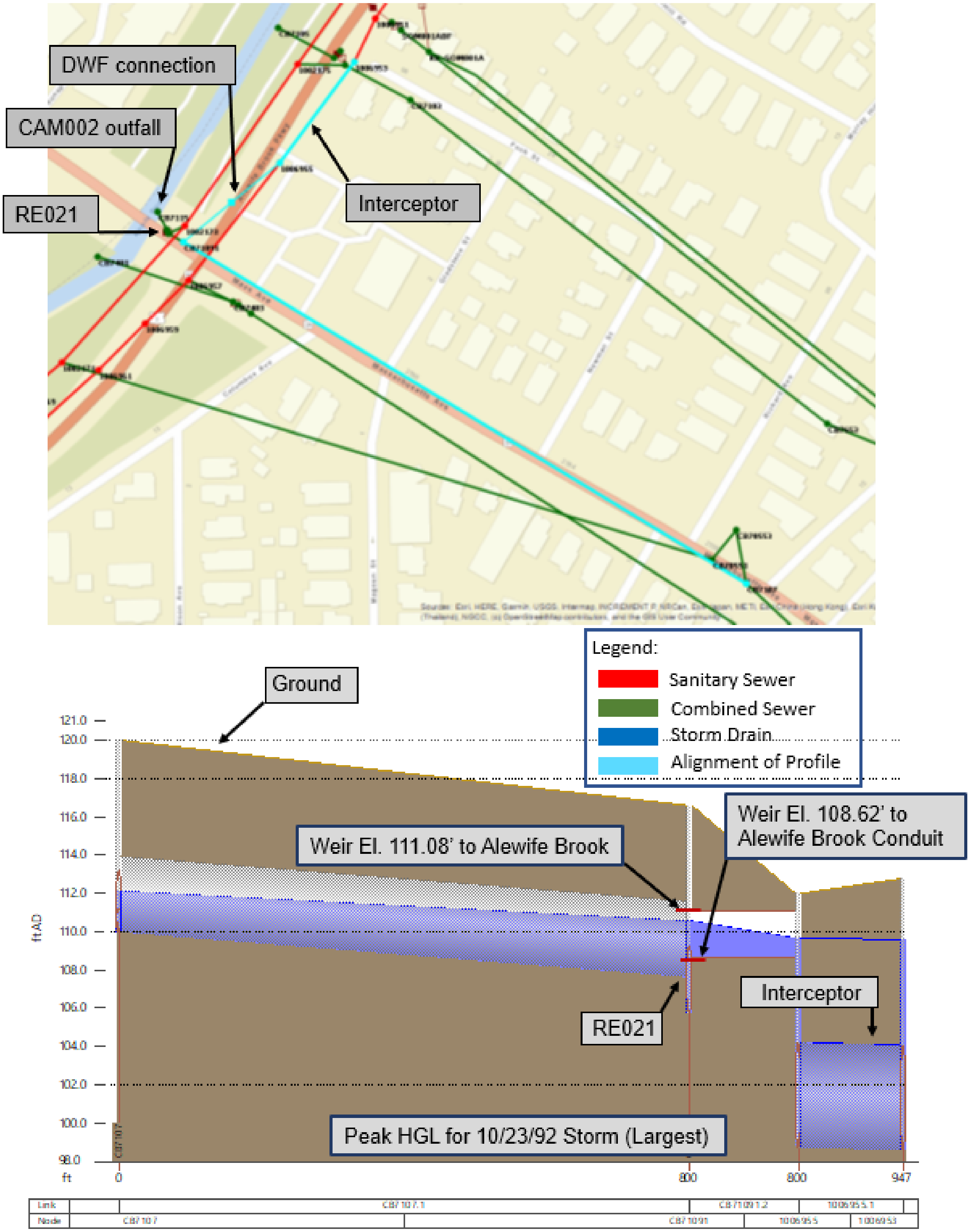


Figure C-6. Regulator Profile at CAM002 to ABC for the 10/23/1992 storm event

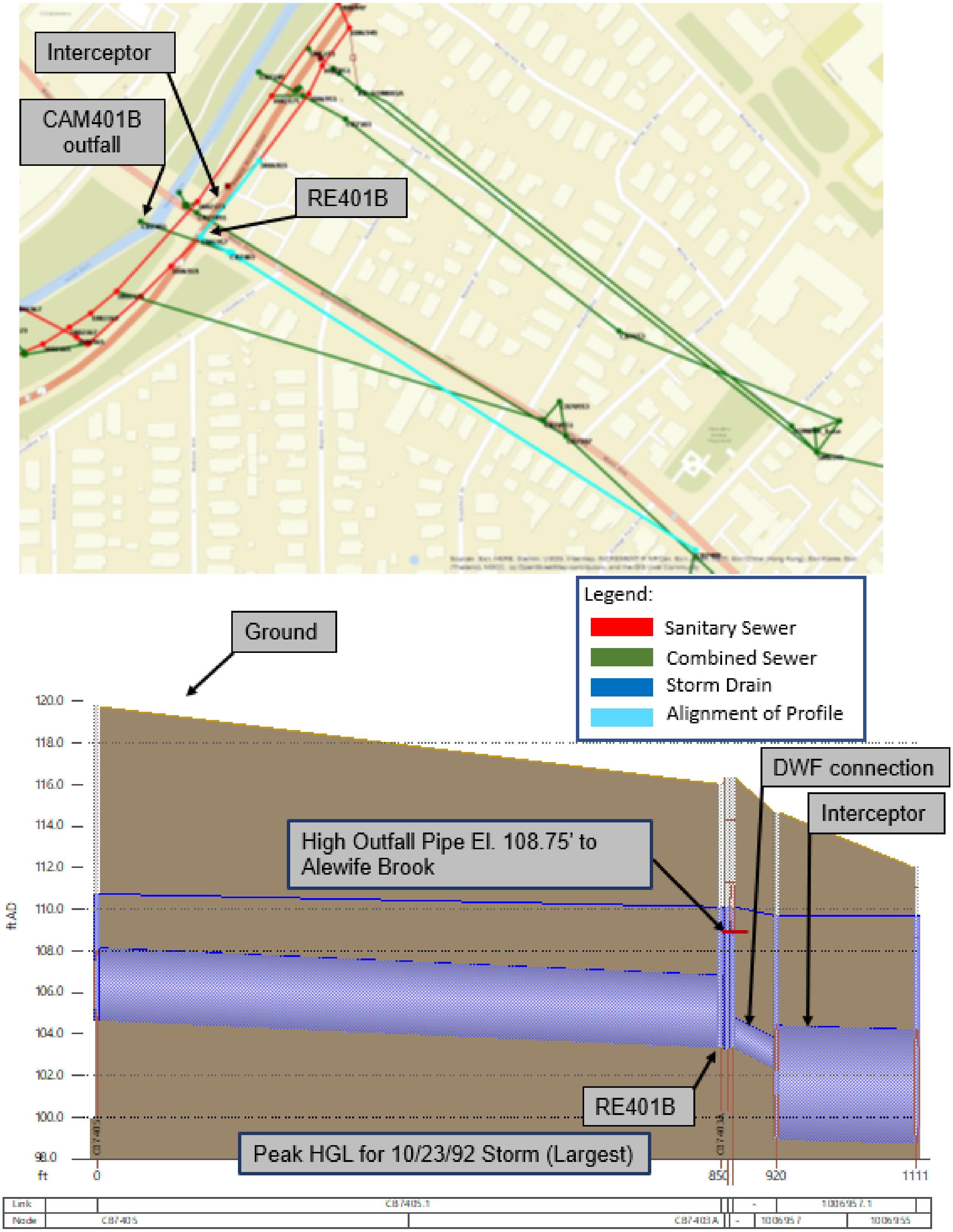


Figure C-7. Regulator Profile at CAM401B for the 10/23/1992 storm event

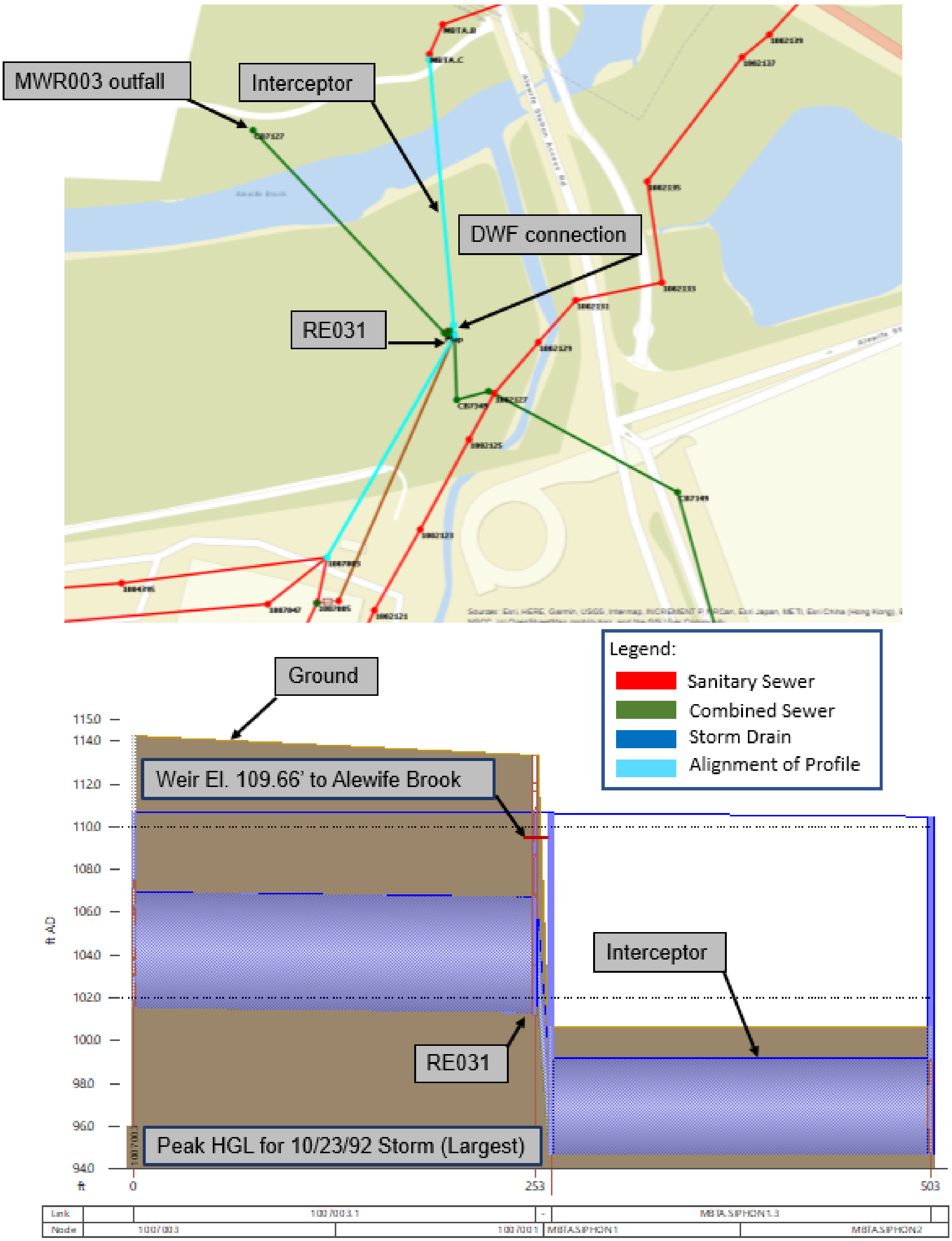


Figure C-8. Regulator Profile at MWR003 for the 10/23/1992 storm event

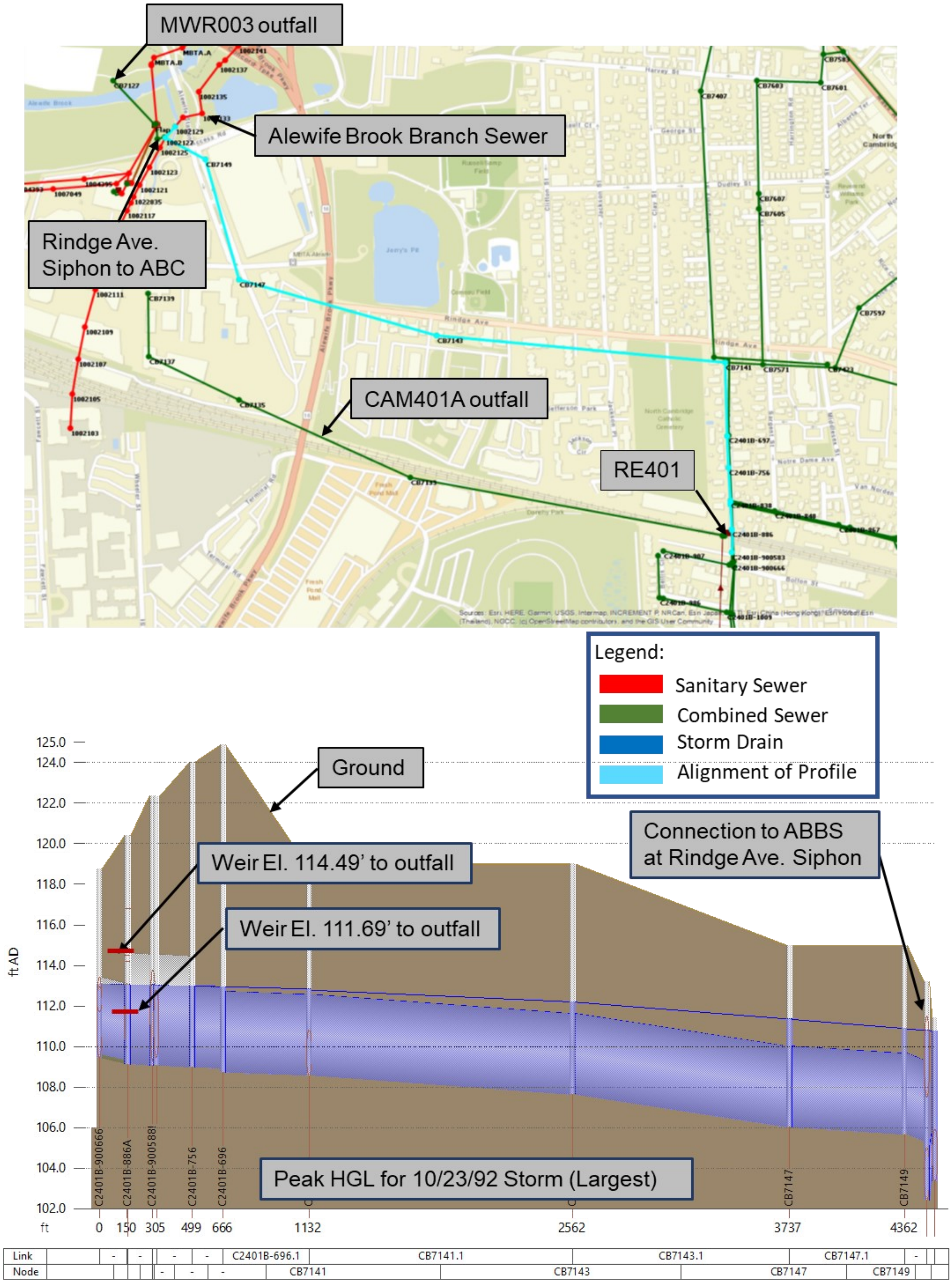


Figure C-9. Regulator Profile at CAM401A for the 10/23/1992 storm event

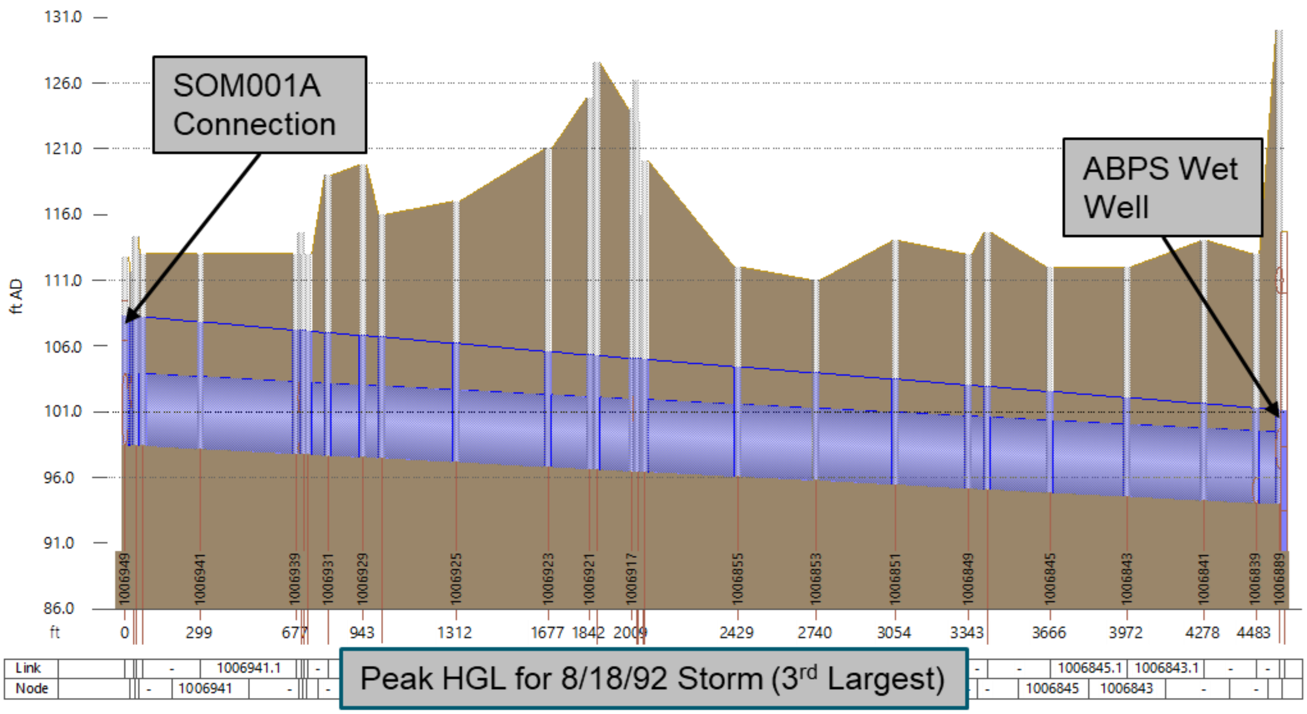


Figure C-10. ABC Interceptor Profile for the 8/18/1992

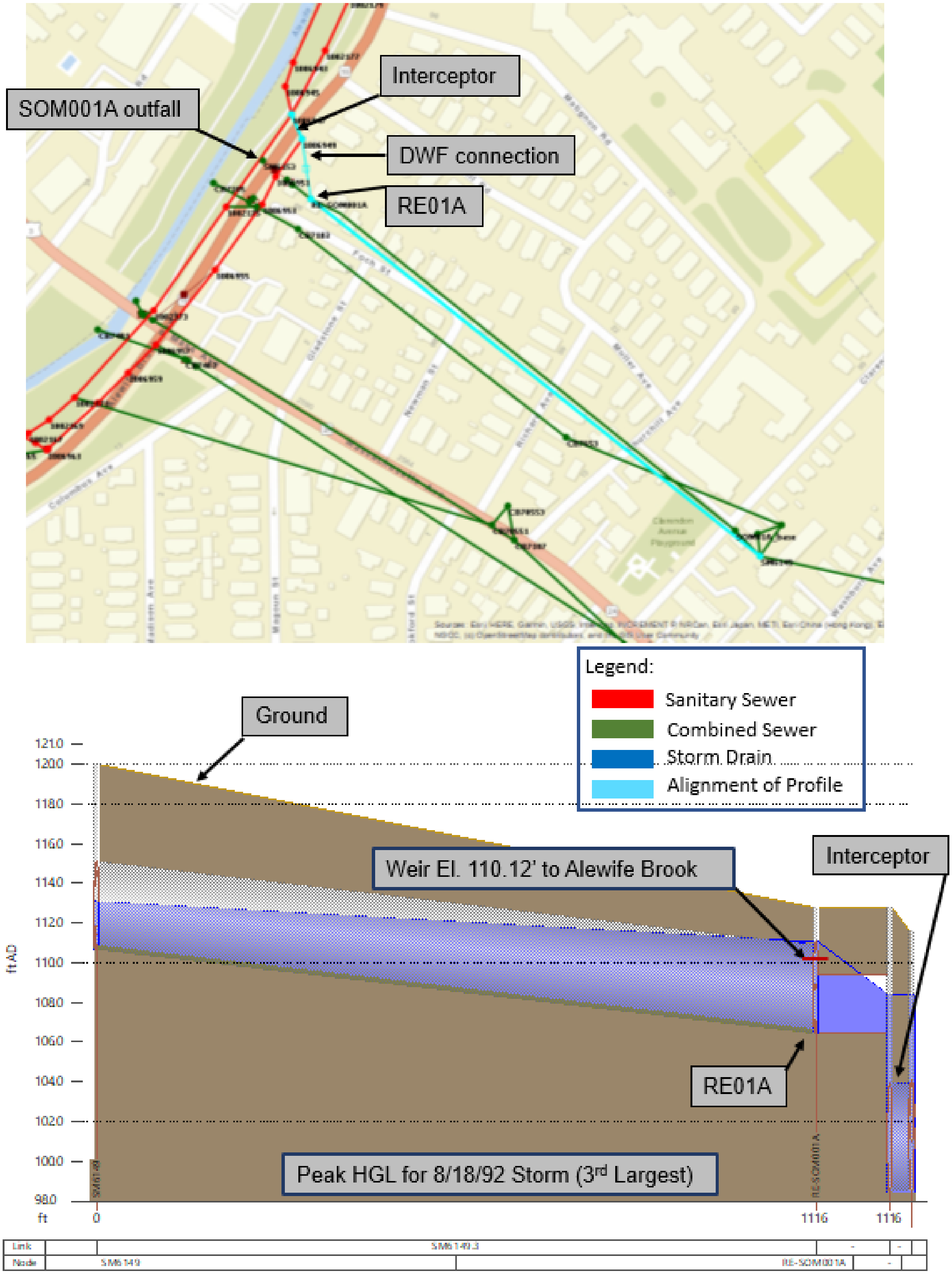


Figure C-11. Regulator Profile at SOM001A for the 8/18/1992 storm event

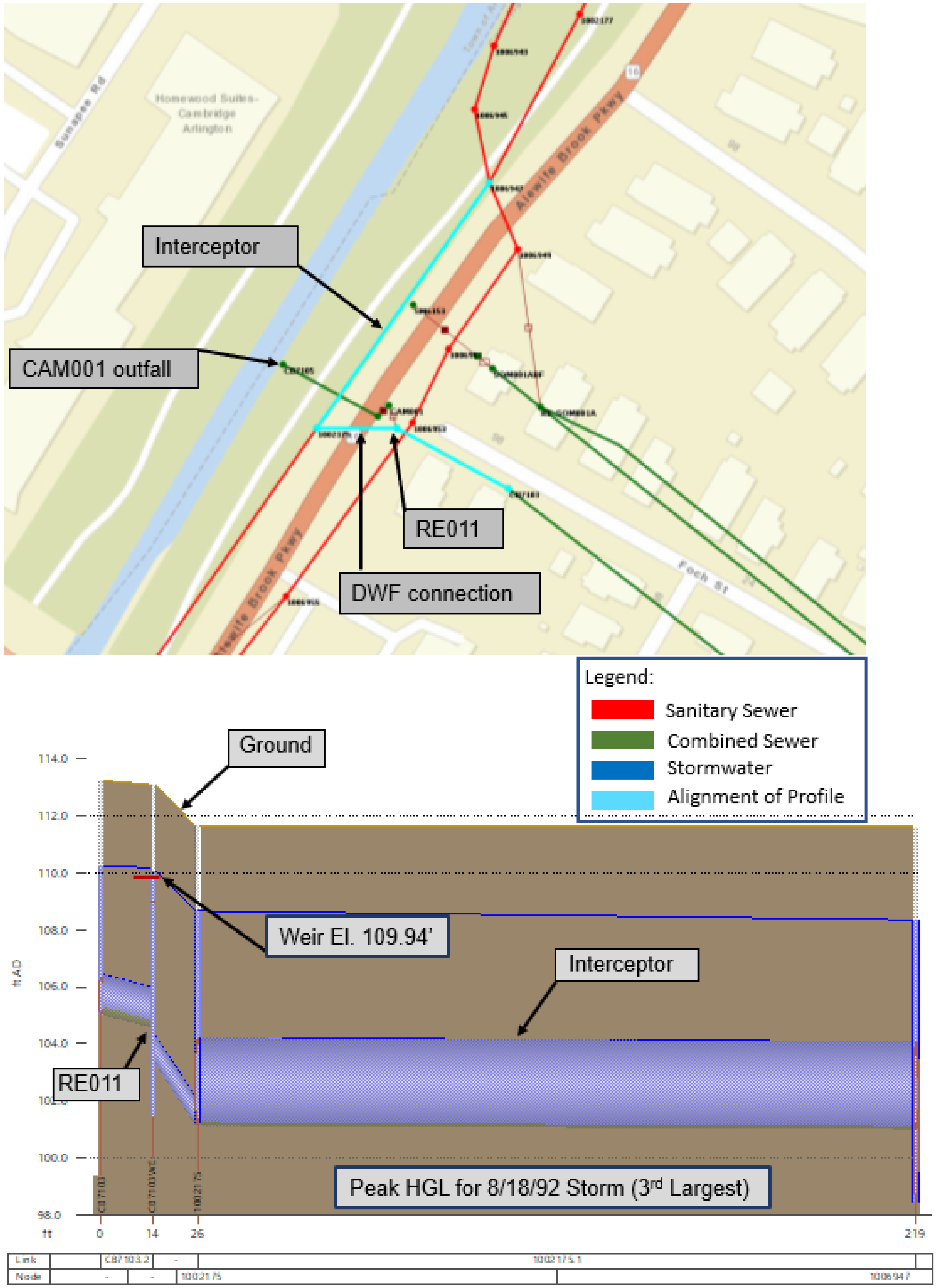
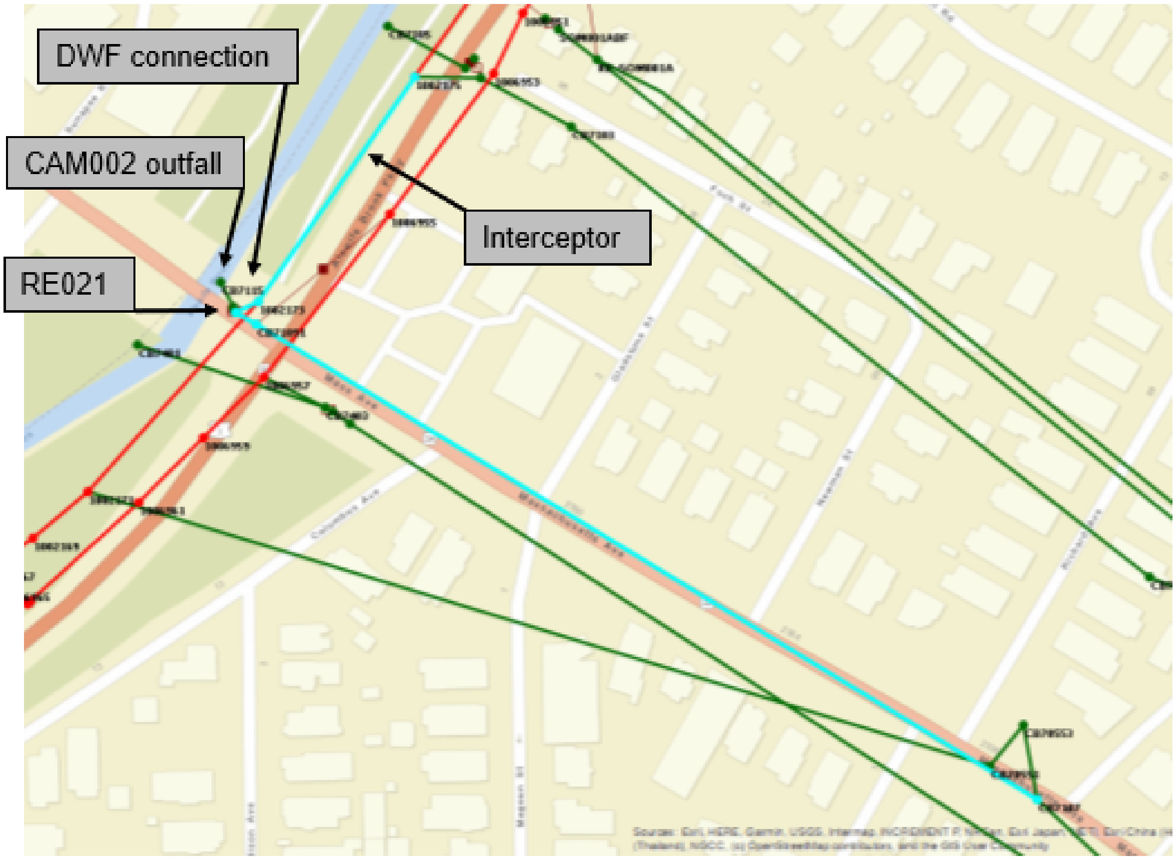


Figure C-12. Regulator Profile at CAM001 for the 8/18/1992 storm event



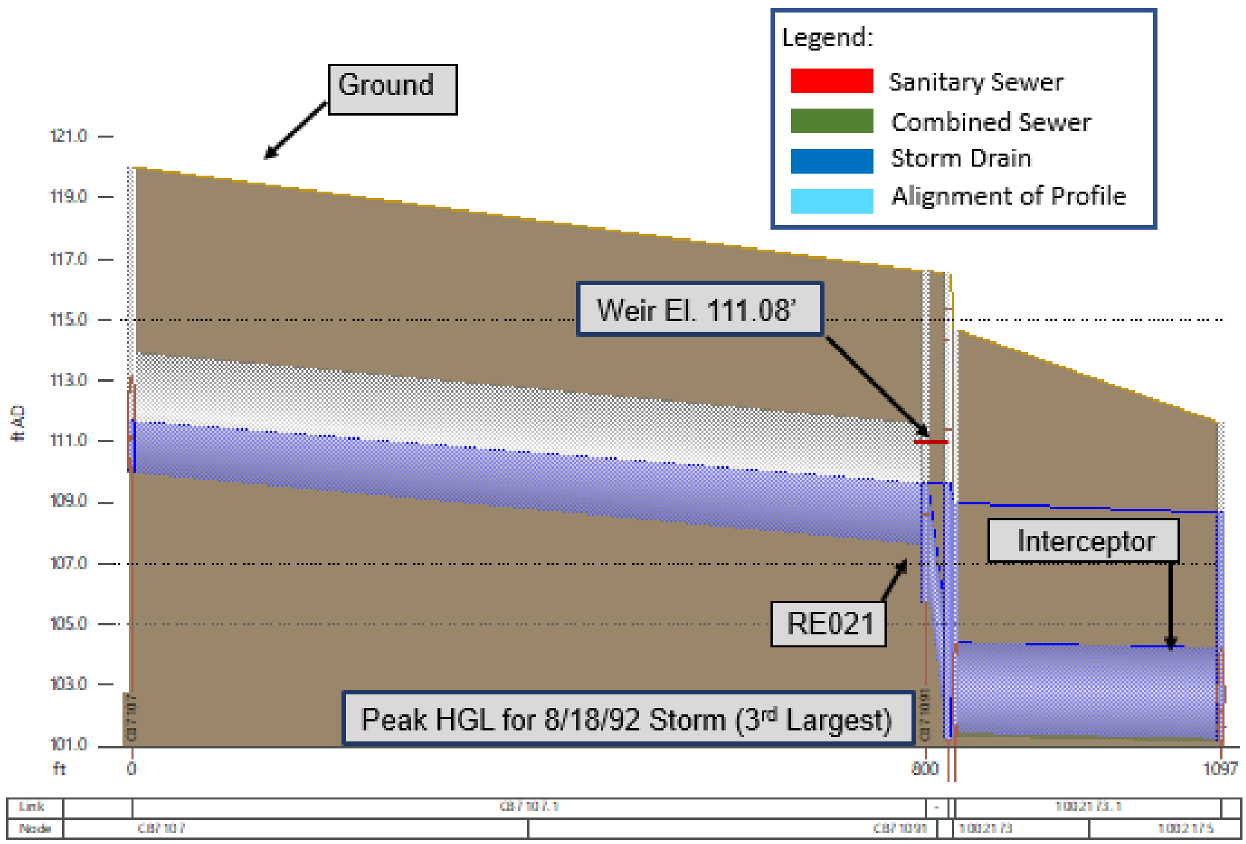


Figure C-13. Regulator Profile at CAM002 to ABBS for the 8/18/1992 storm event

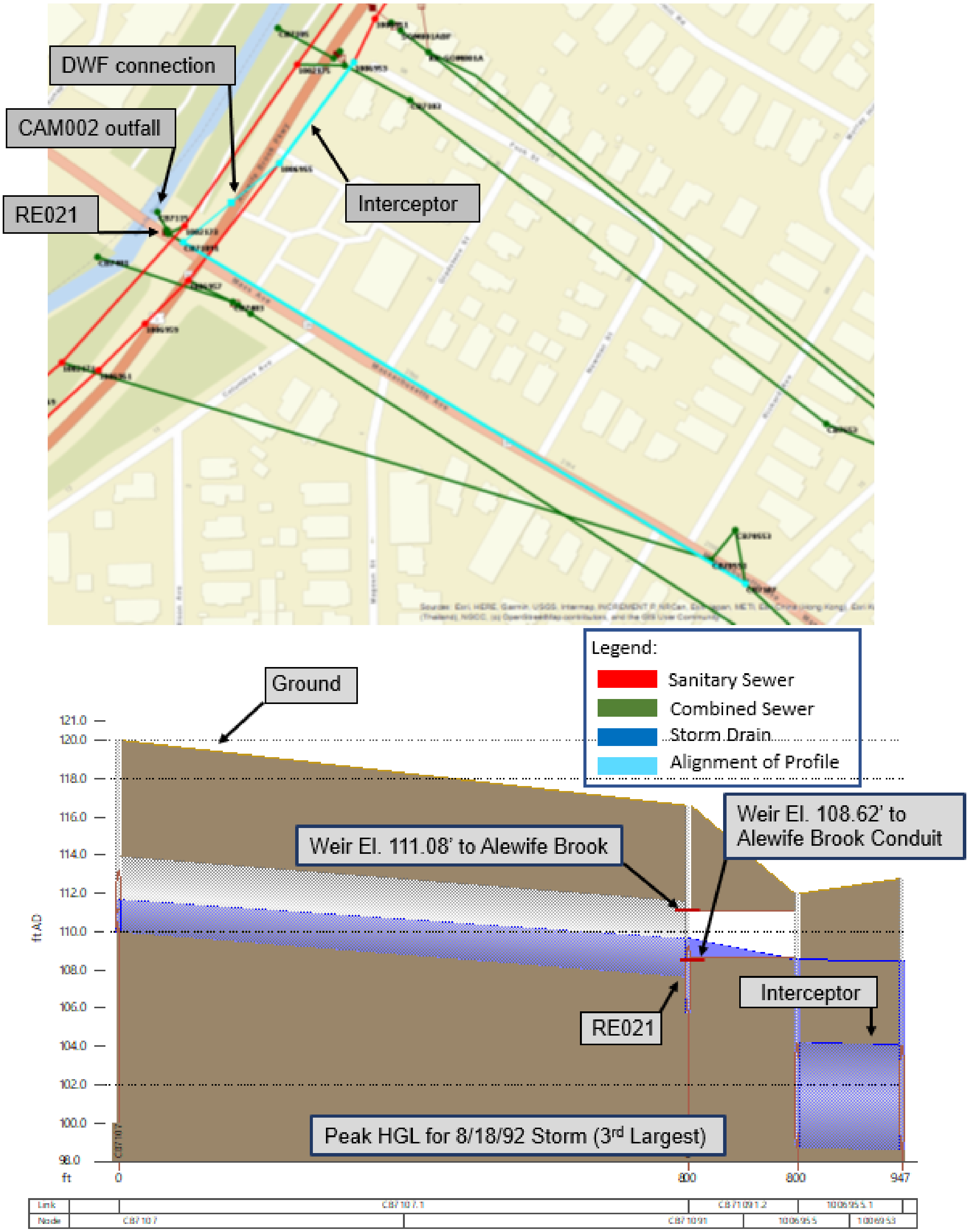


Figure C-14. Regulator Profile at CAM002 to ABC for the 8/18/1992 storm event

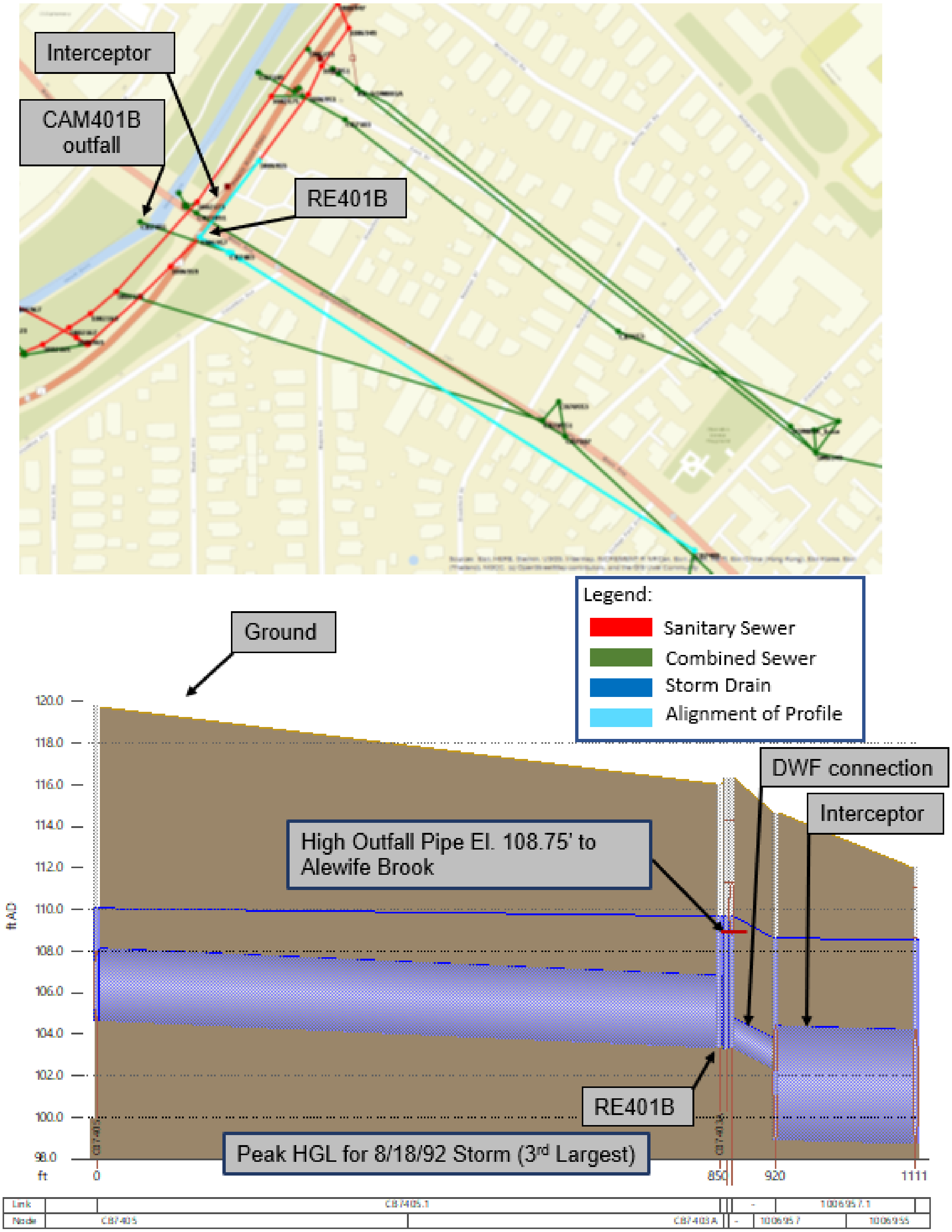


Figure C-15. Regulator Profile at CAM401B for the 8/18/1992 storm event

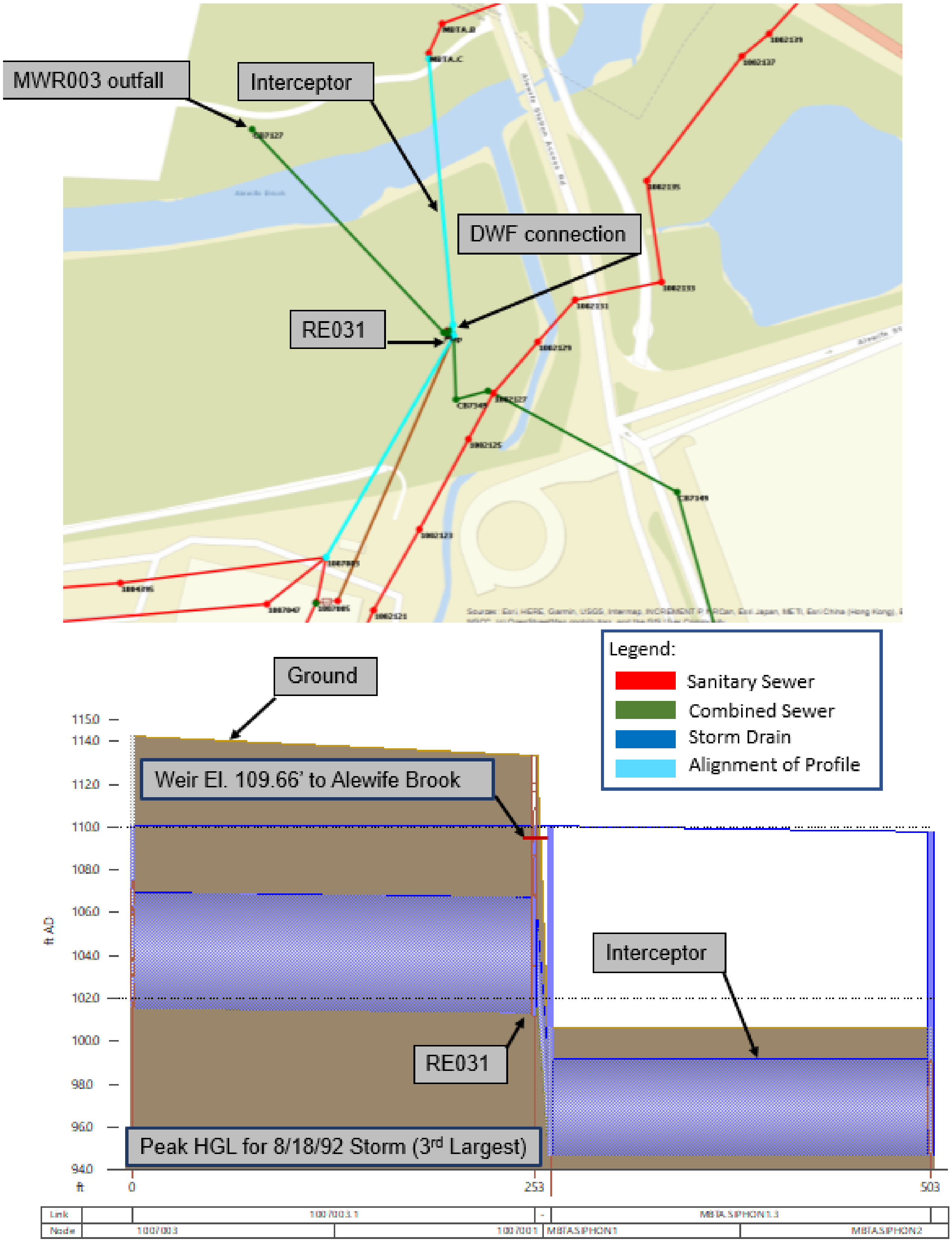


Figure C-16. Regulator Profile at MWR003 for the 8/18/1992 storm event

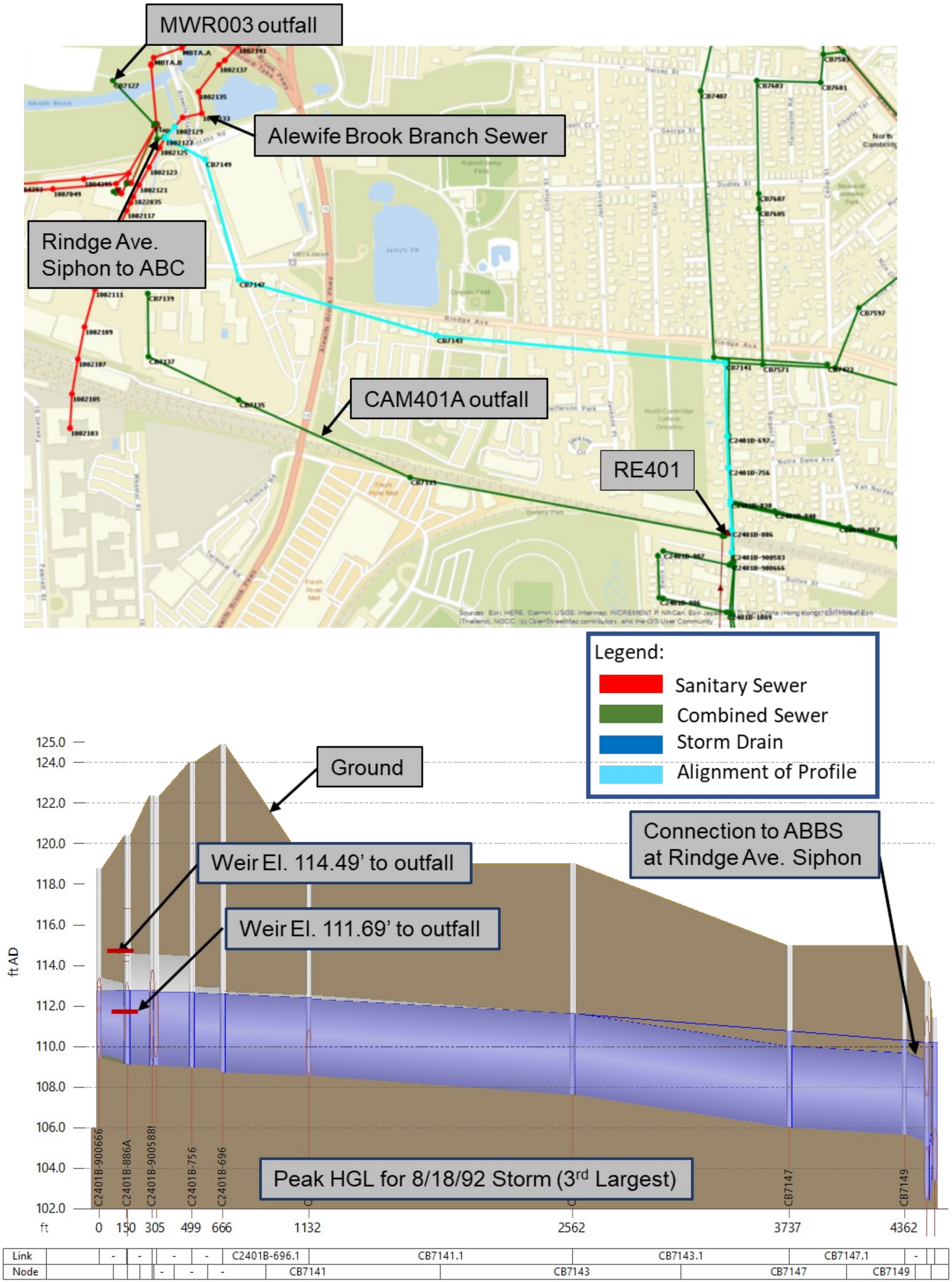


Figure C-17. Regulator Profile at CAM401A for the 8/18/1992 storm event