

APPENDIX C RESERVOIR LEVEL FREQUENCY STUDY

June 3, 2019

TECHNICAL MEMORANDUM

TO: Scituate Department of Public Works (DPW)
Mr. Kevin Cafferty, Director Scituate DPW

CC: Mr. Dan Smith, Engineering Department, Scituate DPW
Mr. Sean McCarthy, Supervisor, Engineering Department, Scituate DPW
Mr. Sean Anderson, Supervisor Water Division, Scituate DPW

FROM: Mr. Thomas C. Cook, PE, Project Manager, Tetra Tech, Inc. (Tetra Tech)

**SUBJECT: DEIR Appendix C - Reservoir Level Frequency Study
Reservoir Dam – NID # MA 000478
Reservoir Dam Water Storage and Fish Passage Improvement Project**

INTRODUCTION

The Certificate of the Secretary of Executive Office of Energy and Environmental Affairs (EOEEA #15711) for the Reservoir Dam Water Storage and Fish Passage Improvement Project (EOEEA 2017) requires the Draft Environmental Impact Report (DEIR) for Reservoir Dam Water Storage and Fish Passage Improvement Project to address the impacts of the proposed higher reservoir levels on adjacent wetlands, private properties, and Chief Justice Cushing Highway (CJCH). This Technical Memorandum presents the results of the Water Level Frequency Study which evaluates the frequency of Reservoir Dam and Tack Factory Dam water levels with the existing spillway and the proposed spillway operation. Impacts on the wetlands are discussed in the DEIR Appendix D. Coordination with the Massachusetts Department of Transportation (MassDOT) and filing of the MassDOT Non-Vehicular Access Permit Application will be completed after approval of the Final Environmental Impact Statement (FEIR).

EXISTING PROJECT FEATURES

Reservoir Dam is an earthen embankment with an ogee-shaped concrete spillway, a low-level outlet, and a pool and weir fishway. The dam height is 21 ft and has a high hazard potential classification as discussed in DEIR Appendix B. The low-level outlet is a 12-inch diameter pipe through the dam with an inlet structure at the bottom of the reservoir and a flow control valve on the downstream side of the dam. The low-level outlet flow control valve has an electric motor and is operated through a supervisory control and data acquisition (SCADA) system. The fishway has 21 weirs approximately 3 feet (ft.) wide creating pools that are approximately 3.5 ft.

long. The invert of the existing fishway exit channel is at the same elevation as the spillway crest and does not function at Reservoir Dam water levels lower than the spillway crest.

The existing spillway has a 37.5 ft. minimum length with the crest at El. 38.9 ft. North American Vertical Datum 1988 (NAVD88). The discharge rating curve data for the surveyed spillway from the 2014 Preliminary Design Memorandum (Tetra Tech 2014) for the Reservoir Dam Fish Passage Project is presented in Table C-1. The existing spillway has a total discharge capacity of 1,751 cubic feet per second (cfs) at the top of dam El. 45.0 ft. NAVD88.

Table C-1. Reservoir Dam Existing Spillway Discharge Data

Reservoir Level (ft. NAVD88)	Spillway Discharge (cfs)
38.9	0
39.9	116
40.9	329
41.9	604
42.9	930
43.9	1,300
45.0	1,751
45.4	2,306
46.8	5,814

Tack Factory Pond Dam is located west of the Reservoir Dam impoundment and Chief Justice Cushing Highway (CJCH). First Herring Brook has a 4.5 ft high by 10.5 ft wide concrete box that is 75 ft long crossing CJCH. The invert of the culvert outlet into Reservoir Dam invert is at El. 32.8 ft.

Tack Factory Pond Dam is an earthen embankment with a concrete outlet structure located upstream of the First Herring Brook culvert under CJCH. The dam is an earthen embankment less than 5 ft high and approximately 250 ft long extending from CJCH on the left abutment (looking downstream) to natural ground on the right abutment. The embankment top is at El. 41.0 ft. First Herring Brook passes through a 5.25 ft high by 9.5 ft wide concrete box culvert approximately 13.25 ft long in the dam. The invert of the box culvert is at El. 34.6 ft with crown at El. 39.8 ft and top at El. 40.7 ft.

A concrete weir structure is located 6.75 ft upstream of dam and box culvert. The weir structure is approximately 18 ft wide with two 4.3 ft wide by 3 ft high slide gates. The slide gates have double operator stems for manual opening. The top of the weir and gates are at El. 39.3 ft. The gates are typically closed to retain storage in Tack Factory Pond for emergency water supply during droughts. Concrete side walls transition between the weir and culvert through the dam. The discharge rating data for the Tack Factory Pond weir is shown in Table C-2. The entire dam

is overtopped at 139 cfs. The CJCH culvert controls flow up to 750 cfs when the roadway is overtopped.

Table C-2. Tack Factory Pond Existing Dam and Weir Discharge Data

Tack Factory Pond Level (ft. NAVD88)	Discharge (cfs)
39.3	0
40.0	30
40.7	86
41.0	139
41.5	441
42.0	1,143
42.3	1,803
43.0	4,166
44.0	5,574

The storage rating curve data for the Reservoir Dam and Tack Factory Pond are presented in Table C-3. The reservoir impoundment including Tack Factory Pond has 422.1 ac-ft. of useable storage between the existing normal pool (El. 38.9 ft. NAVD88) and the low level at which the current streamflow guidelines are discontinued (El. 30.9 ft. NAVD88). Tack Factory Pond has slide gates that are normally closed and maintain the water level at El. 39.3 ft NAVD88. Opening the gates provides an additional 5.0 ac-ft of useable storage between El. 39.3 ft and El. 38.9 ft NAVD88 water levels in Tack Factory Pond.

Table C-3. Reservoir Dam and Tack Factory Pond Storage Capacity Data

Reservoir Level (ft. NAVD88)	Reservoir Dam Storage (Ac.-ft.)	Tack Factory Pond Storage (Ac.-ft.)	Total Storage (Ac.-ft.)	Useable Storage with Tack Factory Pond Gates Closed (Ac.-ft.)
26.9	0.0	0.0	0.0	0.0
28.9	4.5	0.0	4.5	4.5
30.9	54.5	0.0	54.5	54.5
32.9	134.3	0.0	134.3	134.3
34.9	231.9	2.3	234.2	231.9
36.9	348.6	18.1	348.6	348.6
38.9	476.6	30.8	507.4	476.6
40.0	549.3	46.2	595.5	559.1
42.0	700.9	96.5	797.4	761.0
44.0	872.8	162.9	1,035.7	999.3
46.0	1,071.5	255.4	1,326.9	1,290.5

PROPOSED PROJECT FEATURES

Reservoir Dam is categorized as a High Hazard Potential dam in accordance with both Massachusetts General Law c.253, Section 46 and 301 Code of Massachusetts Regulations (CMR) 10.00. CMR 10.06 requires spillways for High Hazard Potential dams to have a discharge capacity at least equal to the One-half Probable Maximum Flood (½ PMF). Modifications to a High Hazard Potential dam, including the spillway and fishway, must also conform to the dam safety regulations, and must be approved by the Department of Conservation and Recreation (DCR) Office of Dam Safety (ODS) as discussed in DEIR Appendix B.

The proposed project will include spillway modifications designed to pass the SDF, installation of a bottom-hinged spillway gate to maintain a 1.5 ft. higher maximum normal pool (El. 40.4 ft. NAVD88) providing additional water supply storage, and fishway modifications to allow upstream and downstream passage of river herring. The bottom hinged crest gate would be remotely operated from the DPW’s Water Treatment Plant. The electric motor operator control system would automatically open or close the gate base on the Reservoir level. As Reservoir levels increase above El. 40.4 ft NAVD88 normal pool, the gate would open to maintain the normal pool. In the fully opened position, the top of the gate would be at a maximum El. 36.4 ft. to pass the ½ Probable Maximum Flood with acceptable freeboard on the dam embankment. When Reservoir levels fall below El. 40.4 ft, the gate would close eliminating spillway discharges and storing water. Table C-4 presents the proposed spillway gate discharge capacity

Table C-4. Reservoir Dam Proposed Spillway Discharge Data

Reservoir Level (ft. NAVD88)	Spillway Discharge Gate Full Open (cfs)	Spillway Discharge Normal Gate Operation (cfs)
36.4	0	0
37.5	131	0
38.9	447	0
39.9	741	0
40.4	905	0
40.6	974	974
40.9	1,080	1,080
41.5	1,303	1,303
41.9	1,459	1,459
42.4	1,663	1,663
42.9	1,875	1,875
43.5	2,141	2,141
43.9	2,324	2,324
44.4	2,560	2,560
44.9	2,804	2,804

data with the proposed gate full open and with normal operation to maintain Reservoir level at normal pool El. 40.4 ft.

The proposed project will not include any modifications to the Task Factory Pond weir except for improvements for fish passage at the weir. These improvements will not significantly change the discharge rating curve for the Tack Factory Pond weir (see Table C-2). The proposed low-flow notch will add approximately 0.5 cfs to the discharge values at Tack Factory Pond water levels above El. 39.3 ft.

2017 RESERVOIR WATER LEVEL ANALYSIS

The sixty-percent permit level design prepared in 2017 (Tetra Tech 2017) included an evaluation of water level durations for the existing and proposed Reservoir Dam operations based on the 2011 through 2016 Monthly Precipitation Reports from the Town of Scituate DPW (2018). The monthly precipitation reports provide daily data in inches of the Reservoir Dam water levels relative to the spillway crest. The measured values were averaged daily, then adjusted to the NAVD 1988 vertical datum for the existing spillway crest level. Using the elevation obtained from these measurements and the reservoir storage curve provided in the 2017 Sixty Percent Design and Initial Permitting Report the storage values for each day from 2011 through 2016 were obtained and water levels estimated with the proposed higher normal level. These estimates with the proposed dam modifications assume that the IOP, precipitation, and water supply demand would be the same as those in 2011 through 2016. The proposed water level of El. 40.4 ft. NAVD88 was used as the maximum height. The daily difference between the storage for the measured water levels was used to calculate the proposed water level elevation for each day with the proposed higher maximum pool.

Water level duration curves for the existing conditions and proposed conditions are provided for each year (2011-2016) on Figures C-1 and C-2. A comparison of the two conditions indicated that the proposed water levels would be lower than the existing water levels approximately 50% of the time, and that 50% of the time the water levels will be approximately 1 ft. higher than existing conditions (Tetra Tech 2017).

2019 WEAP MODEL WATER LEVELS

The Water Evaluation and Planning (WEAP) model utilized for previous phases of the Reservoir Dam Water Storage and Fish Passage Improvement Project was updated in 2018 to reflect updated water supply operational data and proposed final operational plans. The primary changes to the WEAP model in 2018 included routing Well 17A through Old Oaken Bucket for the baseline condition and redirecting Well 17A through Tack Factory Pond, additional water demand for ice pigging, and adjustment of stream flow cutoff threshold for proposed condition. The 2018 WEAP modeling results are presented in the DEIR Appendix A.

The updated model results of the proposed operating conditions for the 1961-2016 period were compared to the 2011-2016 period. The comparison shown on Figure C-3 indicates that the 2011-2016 period is representative of the entire modeled period.

The updated model results of the proposed operating conditions were compared to the Scituate Water Department measurements for the 2011-2016 period to assess impacts of the 1.5 ft higher normal pool level on adjacent property and wetlands. Differences in the proposed and existing water levels in Tack Factory Pond and Reservoir Dam are shown on Figure C-4. The WEAP model results with the existing spillway and project operations indicate that water levels will be at El. 38.9 ft more than 74% of the time in Reservoir Dam and El. 39.3 ft more than 66% of the time in Tack Factory Pond. Water levels in Reservoir Dam and Tack Factory Pond are summarized in Table C-5 with current spillway and project operations and Table C-6 for the proposed spillway modifications and operations.

Table C-5. Reservoir Levels with Existing Project Operation

Condition	Reservoir Dam Level (ft. NAVD88)	Tack Factory Pond Level (ft. NAVD88)
Mean Annual Low Flow (DPW)	31.2	39.3
Mean Annual Flow (DPW)	37.6	39.3
Mean Annual High Flow (DPW)	39.9	39.9
100-year Flood (HEC-HMS)	42.9	42.9
100-year Flood (FEMA)	42.0	44.0
½ PMF (HEC-HMS)	45.4	45.4

Table C-6. Reservoir Levels with Proposed Project Operation

Condition	Reservoir Dam Level (ft. NAVD88)	Tack Factory Pond Level (ft. NAVD88)
Mean Annual Low Flow (WEAP)	34.9	39.3
Mean Annual Flow (WEAP)	39.3	39.8
Mean Annual High Flow (WEAP)	40.4	40.4
100-year Flood (HEC-HMS)	40.4	41.9
100-year Flood (FEMA)	42.0	44.0
½ PMF (HEC-HMS)	43.6	43.6

Figure C-4 shows how water levels at Reservoir Dam under the proposed conditions are consistently higher than those under current conditions.

WATER LEVELS DURING WETLANDS VEGETATION GROWING SEASON

In order to assess impacts on wetlands vegetation resulting from the higher reservoir levels with the proposed spillway operation, water level frequency curves were developed for the April 18th-

October 30th wetlands vegetation growing season as discussed in DEIR Appendix D. Water level frequency curves for the existing conditions using the DPW daily measurements and WEAP model results for the 2011-2016 period, and for the proposed conditions using the WEAP model results for the same period. Comparisons of the Reservoir Dam and Tack Factory Pond water levels with the existing spillway and proposed spillway operations during the vegetation growing season are presented on Figure C-5 and C-6, respectively. Frequency data for each month during the growing season is provided in DEIR Appendix D.

The proposed reservoir operations would increase average water levels during the growing season by 1.2 ft in Reservoir Dam and 0.5 ft in Tack Factory Pond, and maximum levels during the growing season water would increase by 0.5 ft. in both areas.

WATER LEVELS AT CJCH

Reservoir Dam water levels at CJCH have historically ranged from El. 40.0 ft down to El. 32.0 ft. The proposed spillway modifications and project operations will increase the normal water level to El. 40.4 ft on both sides of CJCH and El. 40.4 ft in Tack Factory Pond on the west side of CJCH. The low point in CJCH is El. 42.4 ft NAVD88 (see DEIR Appendix F, Drawing C-101) and there would 2 ft of freeboard at normal pool level. The proposed project operations will increase the typical low water levels east of CJCH to El. 36.4 ft while typical low water levels in Tack Factory Pond will remain the same as the existing conditions at El. 39.3 ft.

The 100-year flood level with the proposed project operation will be El. 40.4 ft east of CJCH and El. 40.5 ft in Tack Factory pond west of CJCH. These levels are lower than the FEMA 100-year flood levels.

WATER LEVELS AT ADJACENT PROPERTIES

The proposed higher normal pool in Reservoir Dam would be contained within Town owned land except for 2.48 acres. Figure C-7 shows the location of the 12 private properties with topography lower than the proposed normal pool. All of the private property impacted areas are within the 200 ft Water Supply Protection District in areas classified as bordering vegetative wetlands (BVW), except for land below the Mean Annual Flood Level (MAFL) which defines the lower limit of BVW. Potential impacts of the 1.5 ft higher normal pool level on groundwater are discussed in DEIR Appendix E.

CONCLUSIONS

The results of the Reservoir Level Frequency Study indicate that:

- 1) Reservoir Dam high water levels typically attain El. 39.5 ft and are frequently as high as El. 40.0 ft with the existing spillway and current reservoir operations.

- 2) Reservoir Dam water levels with the proposed spillway modifications and project operation would result in water levels ranging from El. 34.9 ft. to El. 40.4 ft compared to a range of El 31.3 ft to El. 40.0 ft for the existing conditions.
- 3) Proposed water levels in Reservoir Dam would be 1.0 ft higher than existing conditions 50% of the time and 1.3 ft higher 25% of the time primarily in the winter and early spring.
- 4) The proposed reservoir operations would increase average water levels by 0.6 ft higher than existing conditions in Tack Factory Pond 50% of the time and 1.0 ft higher 25% of the time winter and early spring.
- 5) Maximum growing season water levels would increase by 0.5 in both Reservoir Dam and Tack Factory Pond.
- 6) Minimum growing season water levels would increase 3.8 ft in Reservoir Dam and remain the same in Tack Factory Pond due to the existing weir structure that maintains a minimum water level of El. 39.3 ft.
- 7) Proposed water levels on both sides of CJCH would have a maximum of normal El. 40.4 ft. Water levels on the Tack Factory Pond side of the highway are generally above or equal to water levels at Reservoir Dam with average water levels of El. 39.8 ft. on both sides of CJCH.

REFERENCES

Secretary of Executive Office of Energy and Environmental Affairs (EOEEA), Commonwealth of Massachusetts. (2017). Certificate #15711 on the Environmental Notification Form (ENF). June 7.

Tetra Tech, Inc. (Tetra Tech). (2014). Final Preliminary Design Memorandum for Reservoir Dam Water Storage and Fish Passage Improvement Project. June 28.

Tetra Tech, Inc. 2017. Final Sixty Percent Design and Initial Permitting for Reservoir Dam Water Storage and Fish Passage Improvement Project. June 27.

LIST OF FIGURES

- C-1 Reservoir Dam Existing Water Level Frequency Curves for 2011-2016 DPW Measurements
- C-2 Reservoir Dam Proposed Water Level Frequency Curves for 2011-2016 WEAP Model Results
- C-3 Comparison of Water Level Frequency Curves for 2011-2016 WEAP Model Results to 1966-2016 WEAP Model Results with Proposed Project
- C-4 Comparison of Proposed Reservoir Dam Water Level Frequency Curves WEAP Model Results to DPW Measurements for 2011-2016
- C-5 Comparison of Existing and Proposed Reservoir Dam Water Level Frequency Curves for 2011-2016 Wetland Vegetation Growing Season WEAP Model Results
- C-6 Comparison of Existing and Proposed Tack Factory Pond Water Level Frequency Curves for 2011-2016 Wetland Vegetation Growing Season 2018 WEAP Model Results
- C-7 Proposed Normal Pool Impacts on Private Property

Figure C-1
Reservoir Dam Existing Water Level Frequency Curves for 2011-2016 DPW
Measurements

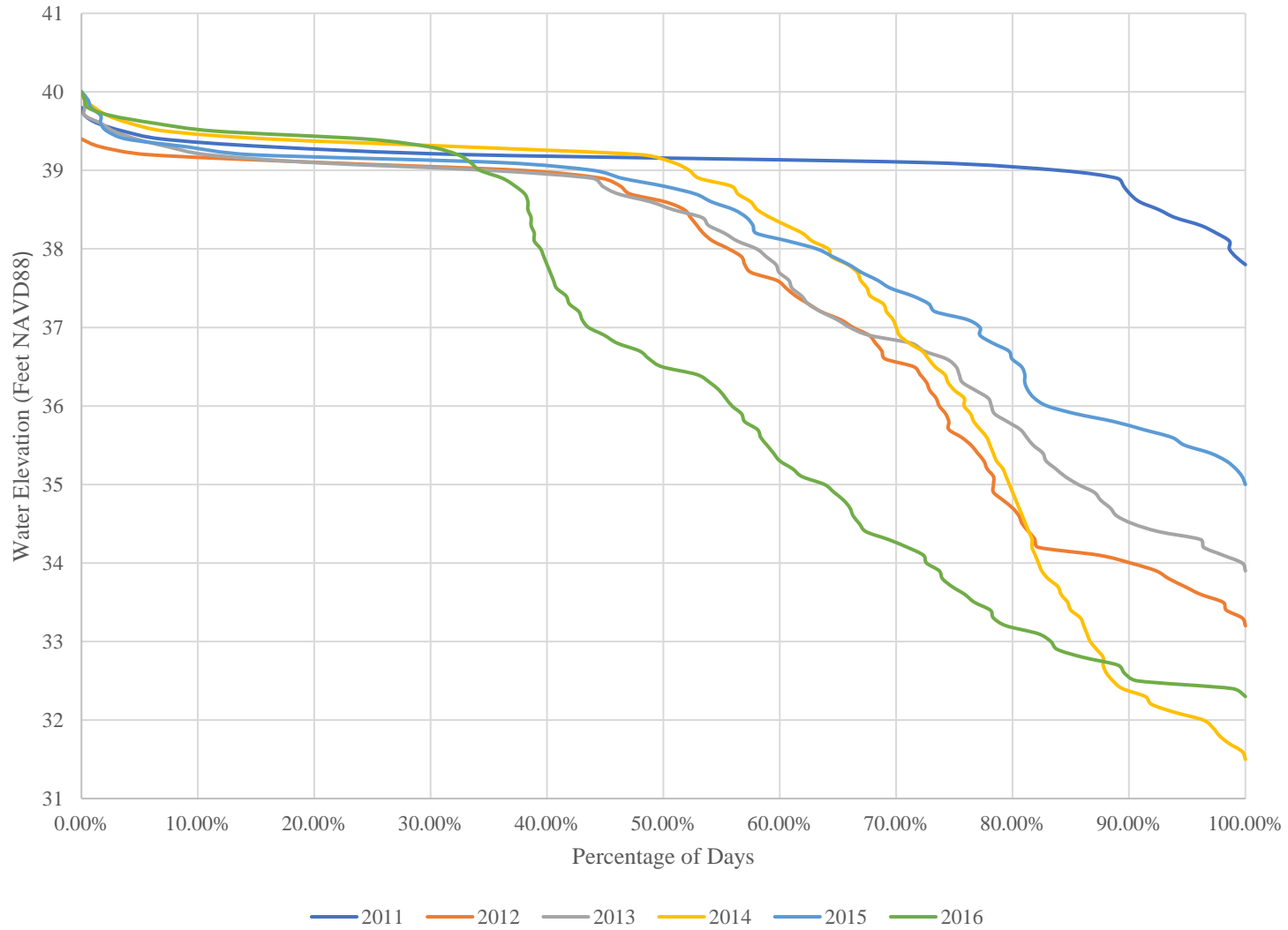


Figure C-2.
Reservoir Dam Proposed Water Level Frequency Curves for 2011-2016 WEAP Model
Results

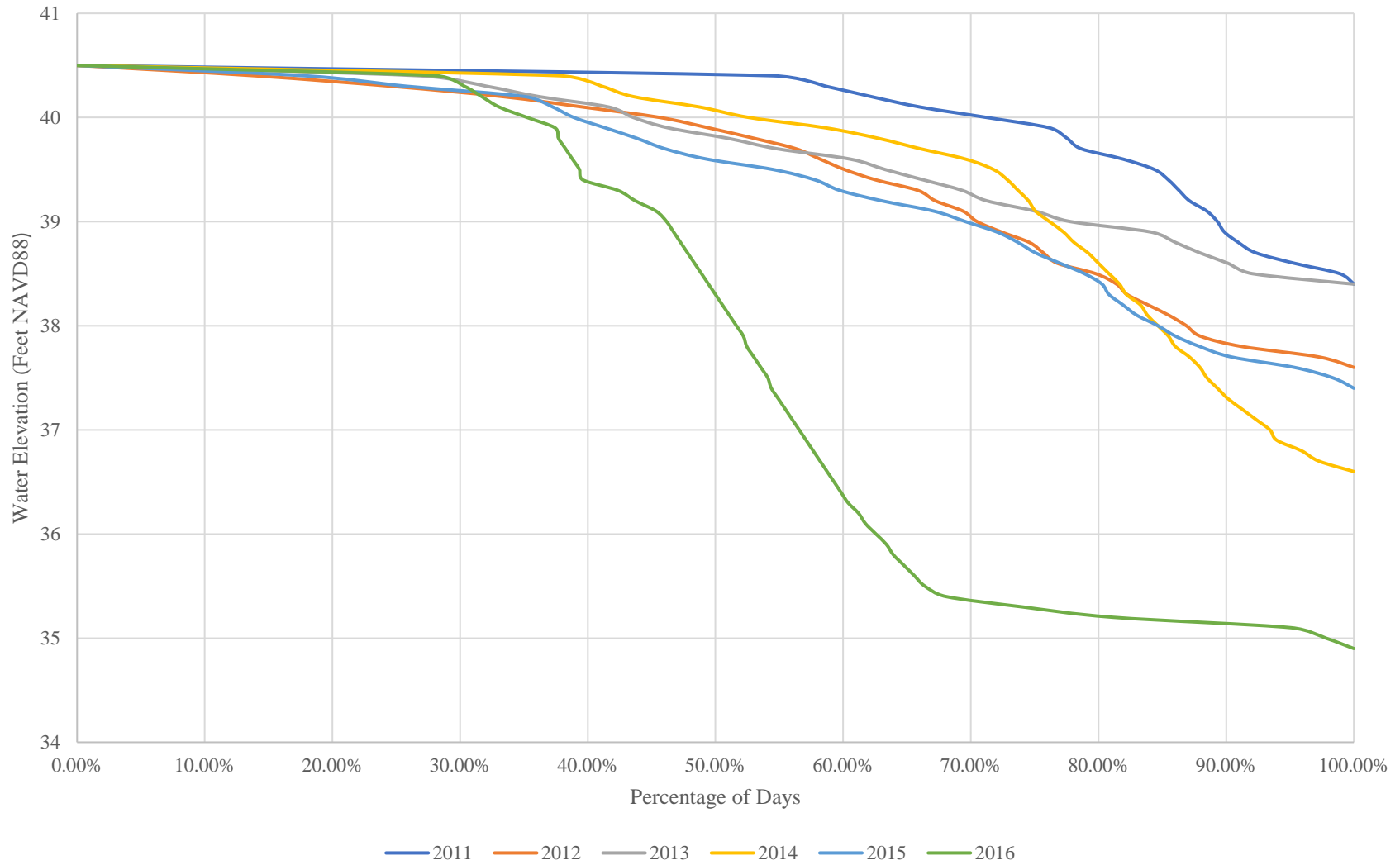
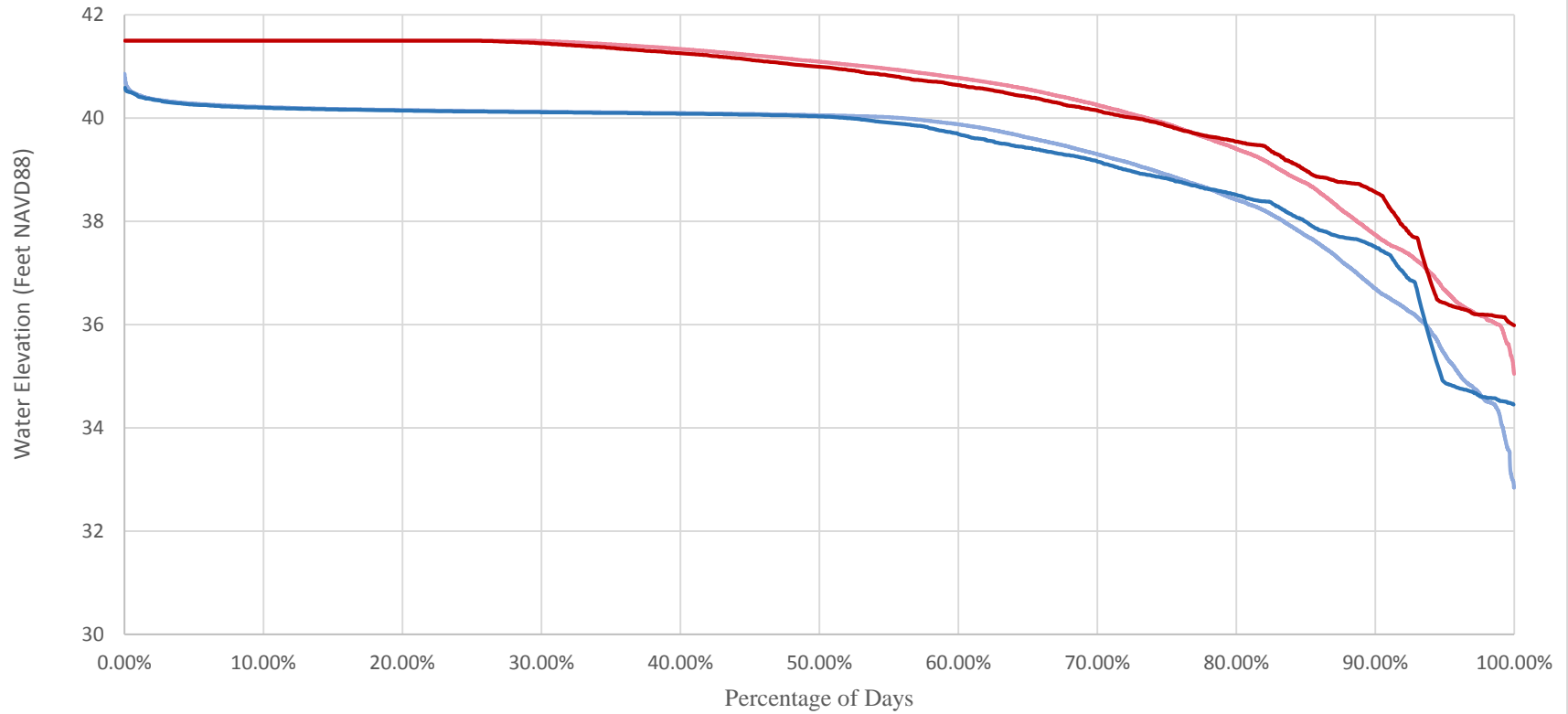


Figure C-3
 Comparison of Water Level Frequency Curves for 2011-2016 WEAP Model Results to
 1966-2016 WEAP Model Results with Proposed Project



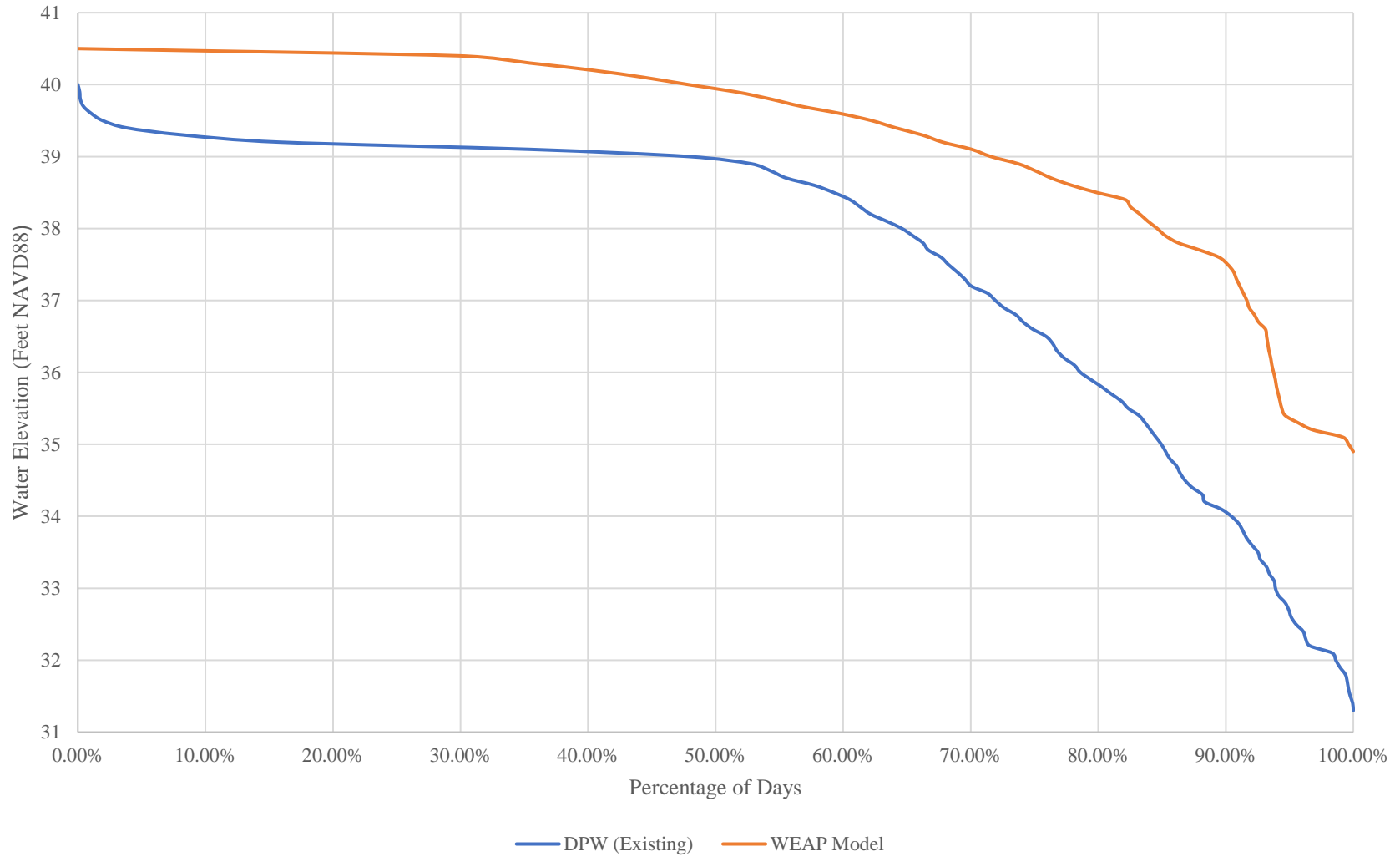
— 2019 Final Baseline with OOB Aug rule (1961-2016)

— 2019 Final Baseline with OOB Aug rule (2011-2016)

— 2019 Future Baseline 36.2 (1961-2016)

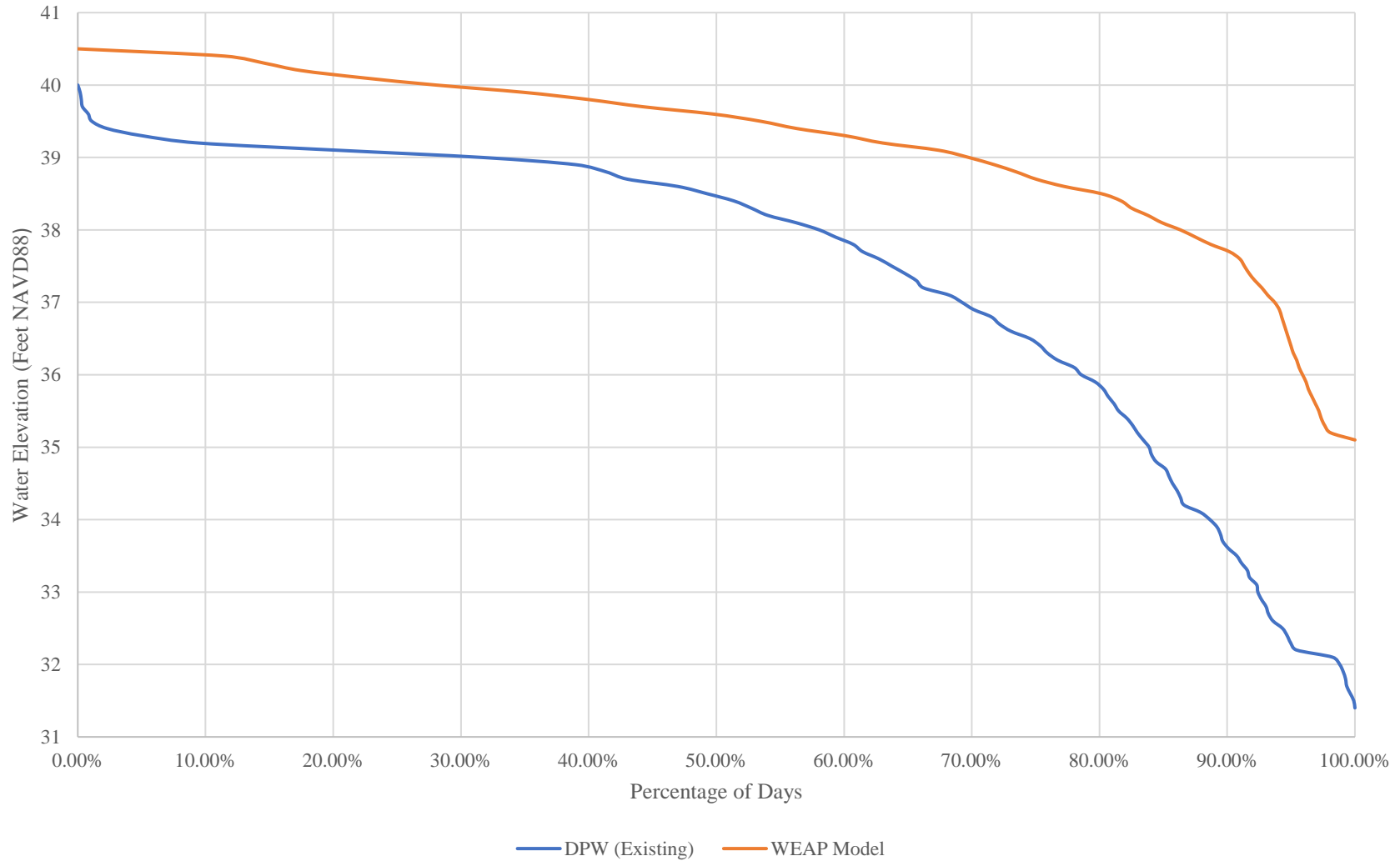
— 2019 Future Baseline 36.2 (2011-2016)

Figure C-4
Comparison of Proposed Reservoir Dam Water Level Frequency Curves WEAP Model
Results to DPW Measurements for 2011-2016



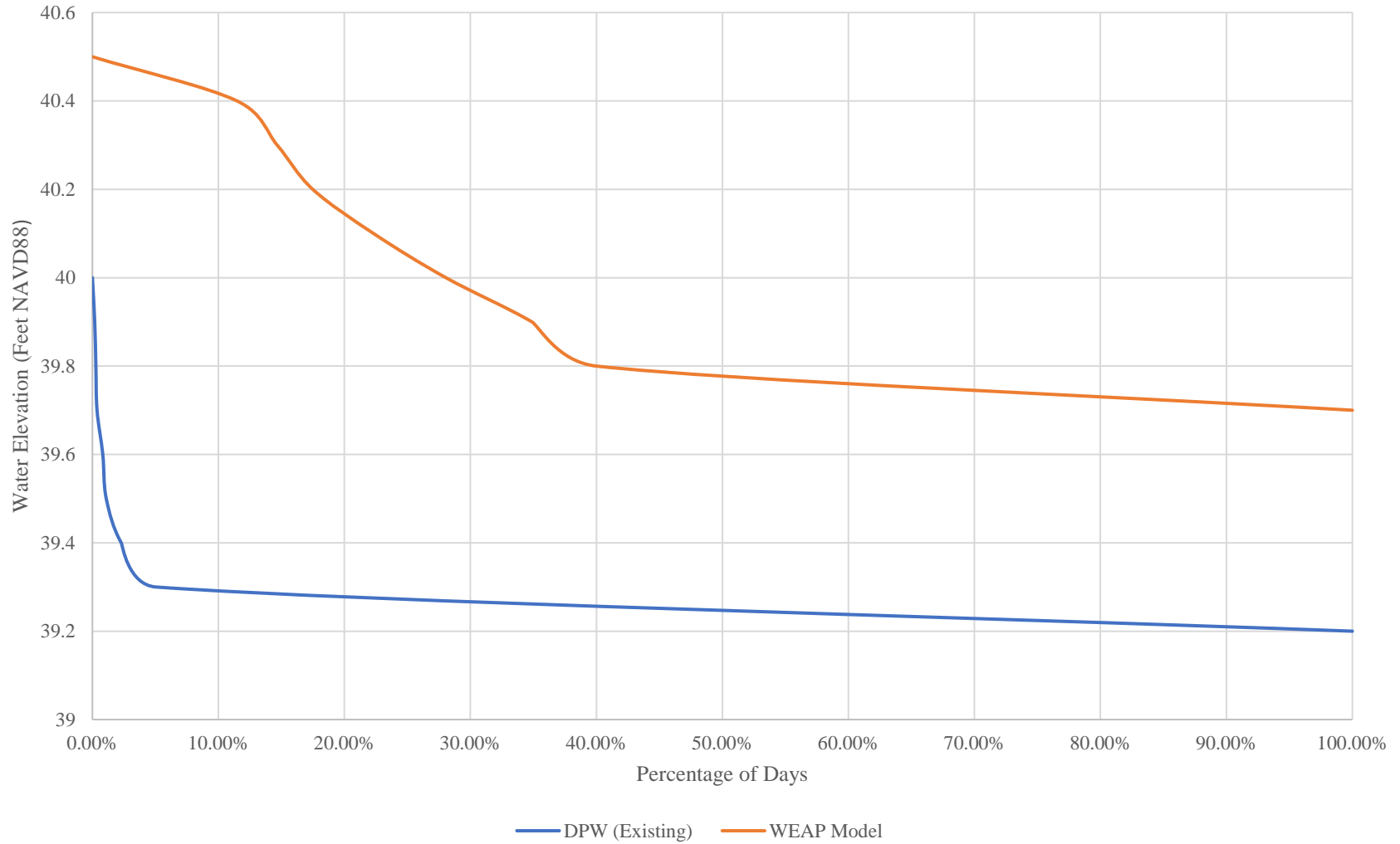
C-5

Comparison of Existing and Proposed Reservoir Dam Water Level Frequency Curves for 2011-2016 Wetland Vegetation Growing Season WEAP Model Results



C-6

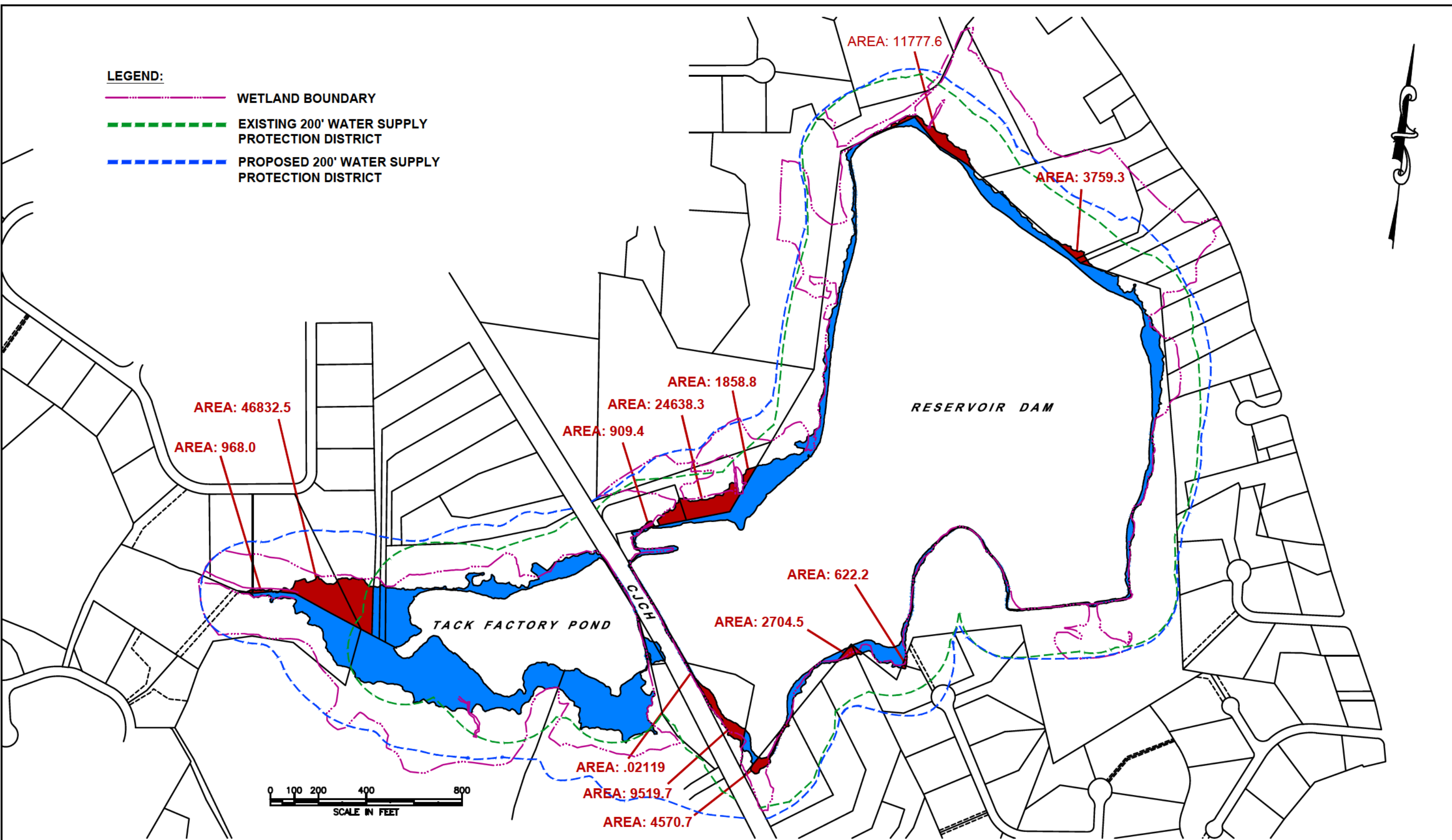
Comparison of Existing and Proposed Factory Pond Water Level Frequency Curves for 2011-2016 Wetland Vegetation Growing Season 2018 WEAP Model Results



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LEGEND:

- WETLAND BOUNDARY
- - - EXISTING 200' WATER SUPPLY PROTECTION DISTRICT
- - - PROPOSED 200' WATER SUPPLY PROTECTION DISTRICT



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MARK	DATE	DESCRIPTION	BY

Reservoir Dam Water Storage and Fish Passage Improvement Project
Scituate, Plymouth County, Massachusetts

PROPOSED NORMAL POOL IMPACTS ON PRIVATE PROPERTY

Date: 05/22/2019
Project No.: 194-8444
Designed by: FGM
Drawn by: FGM
Checked by: TC

Figure C-7