FEASIBILITY REPORT
RESERVOIR DAM MODIFICATIONS
FOR HIGHER POND LEVELS
FIRST HERRING BROOK FISH PASSAGE IMPROVEMENTS

Prepared for
Mr. Albert Bangert, Director
Department of Public Works
Town of Scituate
Town Hall
600 Chief Justice Cushing Way
Scituate, MA 02061

Funded by
Massachusetts Department of Environmental Protection
Sustainable Watershed Management Initiative
MassDEP Project Number: BRP 2012-06- First Herring Brook

Prepared by
EA Engineering, Science, and Technology, Inc.
2374 Post Road, Suite 102
Warwick, Rhode Island 02886

26 June 2013
EA Project No. 62651.02

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Thomas C Cook — 6/26/13

Thomas C. Cook, P.E.
Senior Engineer

Date

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EXECUTIVE SUMMARY

EA Engineering, Science, and Technology, Inc. (EA) under contract to the Town of Scituate Department of Public Works (DPW) has investigated alternatives for improving fish passage at Reservoir Dam on First Herring Brook by utilizing the existing fishway and raising the normal pond level. This study was funded through a grant from the Sustainable Watershed Management Initiative (SWMI) through the Massachusetts Department of Environmental Protection (MassDEP). The goals of this study were to determine if greater storage capacities associated with higher reservoir levels would provide adequate flow for fish passage and stream habitat while meeting the Town's water demands and to determine the costs associated with the spillway, fishway, and infrastructure modifications.

Reservoir Dam has a three foot wide, pool and weir fishway. The fishway at Reservoir Dam is currently inoperable because the exit channel into the reservoir is at the same elevation as the spillway crest and normal pond (El. 40.0 ft National Geodetic Vertical Datum 1929 [NGVD 1929]). The fishway can only be used for upstream and downstream fish passage when water is discharged over the spillway which is a fixed crest, ogee-shaped, overflow concrete structure. The Scituate DPW is currently implementing an Interim Operational Plan (IOP) developed by the North and South Rivers Watershed Association (NSRWA) that utilizes storage below the spillway crest to meet downstream water supply demands and environmental flow releases at Old Oaken Bucket Pond. The IOP was developed using Water Evaluation and Planning (WEAP) model to simulate reservoir operation for various water demands and historical hydrologic conditions in the watershed. Ms. Margaret Kearns, formerly with the Massachusetts Department of Ecological Restoration (DER), was responsible for original IOP modeling and was contracted by NSRWA to update the model for the higher pond levels and water release schedules for this study.

Five options with various combinations of normal Reservoir Dam pond levels and fishway exit channel configurations were evaluated with the WEAP model. The options included: Option A – Pond El. 42.0 ft, Option B – Pond El. 42.5 ft, Option C – Pond El. 43.5 ft, Option D – Existing Pond El. 40.0 ft, and Option E – Pond El. 41.0 ft. Options A-C investigated fish passage viability with the existing fishway exit channel and a 6 inch deep, 18 inch wide notch in the exit channel. Options D-E modeled a lower fishway exit channel at El. 36.5 ft. Various outdoor water ban trigger elevations in the reservoir were investigated in all of the options. The results of the WEAP modeling suggested that several scenarios are feasible to meet fish passage requirements during the majority of both the spring in-migration and fall out-migration periods while minimizing the number of summer days when an outdoor watering ban is enforced.
An assessment of the infrastructure around Reservoir Dam and Tack Factory Pond was conducted to determine potential impacts of higher water levels and define mitigation measures

impacts to private property, homes, roads, water lines, sewer lines, gas lines, and stormwater structures from each alternative. Raising the reservoir level to El. 42.0 ft or higher would impact 21-27 private properties, and 7-10 houses on those properties. Dikes up to 1,000 ft long with 3-5 ft average heights would be necessary to minimize the impacts on private property for pond levels greater than El. 42.0 ft.

Three homes/properties would have to be raised and septic systems for 6-8 houses would require upgrades or sewer system connection at pond levels higher than El. 42.0 ft. Approximately 750 ft of Route 3A would need to be armored with a pond at El. 42.0 ft and raised 0.5-1.5 ft at higher water levels. Maintaining the current pond at El. 40.0 ft (Option D) or raising the normal level to El. 41.0 ft (Option E) would impact 21 properties, but would not affect any houses. At these pond levels, dikes to protect any properties and armoring or raising Route 3A would not be necessary. Three houses on Route 3A would require septic system upgrades or connection to the sewer system because of close proximity to the reservoir water level.

Various flow control mechanisms were evaluated for maintaining higher pond level at Reservoir Dam. These included flashboards, bottom hinged crest gates, and inflatable rubber dams. Budgetary quotations were obtained for the crest gates and inflatable dams. Conceptual designs of the spillway modifications were developed for each of these mechanisms to control water levels while preserving the existing spillway discharge capacity. Conceptual designs were also prepared for the modifications to the existing fishway and exit channel for five (5) alternatives, one for each pond level evaluated with the WEAP model. The alternatives represent the full range of options for spillway and fishway modifications, and infrastructure impact mitigation measures.

Construction costs were estimated for the five (5) pond level alternatives for the spillway and fishway modifications as well as implementation of mitigation measures needed to address impact on infrastructure. Costs ranged from $1,306,000 for Alternative 5 with flashboards and normal pond at El. 40.0 ft with the lower fishway exit channel at El. 36.5 ft up to $3,645,000 for Alternative 3 with an inflatable dam and normal pond at El. 43.5 ft with a 6 inch deep notch in the fishway exit channel. Infrastructure costs for Alternatives 1-3 with normal pond levels at El. 42.0 ft or higher were approximately 75% of the total project costs.

Modifications to the fishway to construct a lower exit channel for Alternatives 4 and 5 would cost approximately $450,000 with infrastructure costs reduced to $890,000. Because of the high fish passage success rate (Scenarios 4-6 Table 6, App. B) and the low watering ban frequency (Scenarios 4-6, Table 13, App. B), Alternative 5 with the fish exit channel lowered to El. 36.5 ft and one foot high flashboard creating a normal pond at El. 41.0 ft was selected as the most cost-effective solution with total costs estimated at $1,335,000.

INTRODUCTION

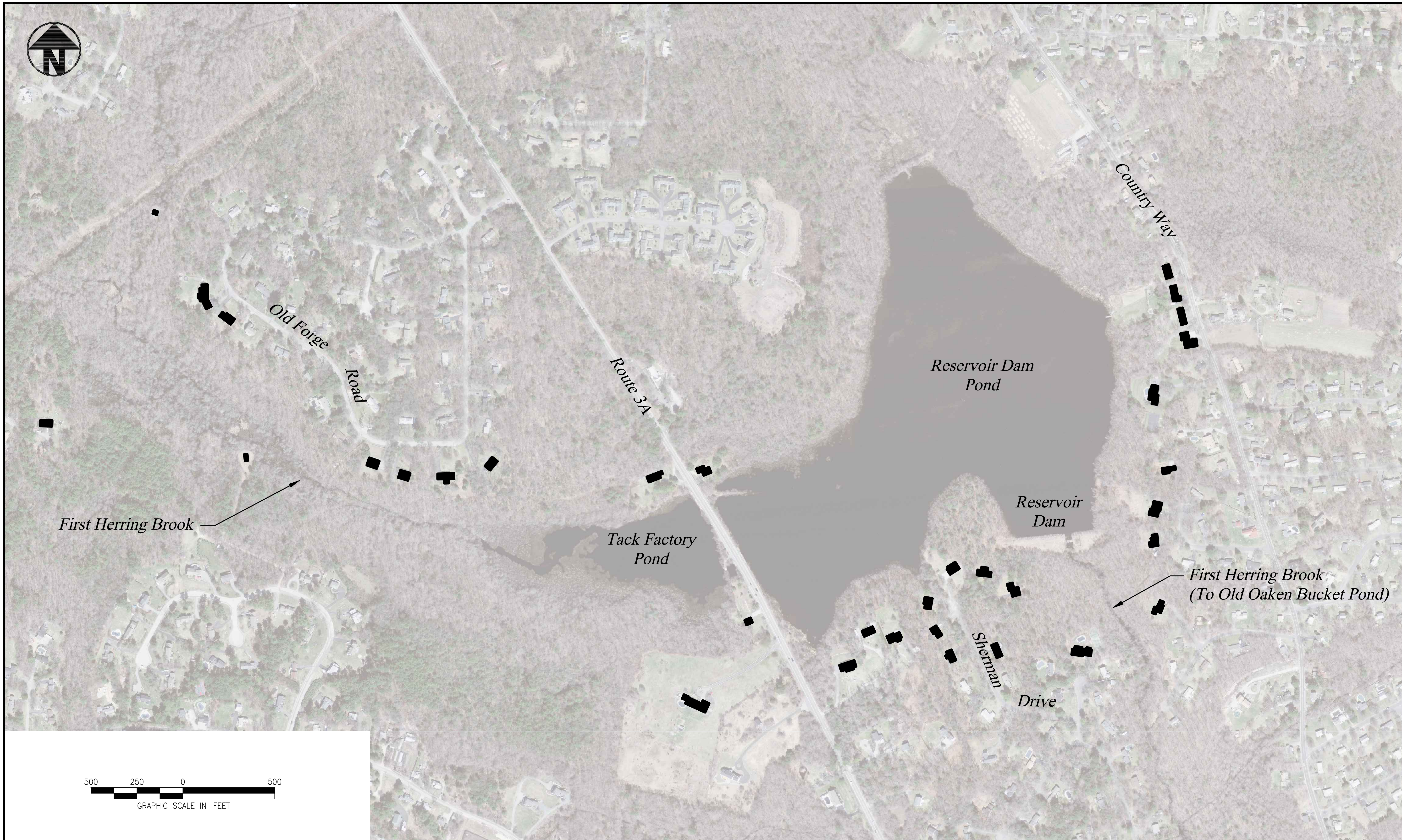
The Scituate Department of Public Works (DPW) has been partnering with the North and South Rivers Watershed Association (NSRWA), Massachusetts Bays Program (MBP), US Fish and Wildlife Service (USFWS), Massachusetts Division Ecological Restoration (MADER) and Massachusetts Division of Marine Fisheries (MADMF) to restore the river herring (alewife) run back to First Herring Brook and its impoundments. In the fall of 2012, the Town of Scituate, MA contracted EA Engineering, Science, and Technology, Inc. (EA) to conduct a preliminary assessment of fish passage improvements for Old Oaken Bucket Dam and Reservoir Dam. The results of that assessment indicated that providing more storage in the Reservoir by maintaining a higher normal pool level could allow the existing fishway to function during the spring upstream migration and fall out-migration periods. The 2012 assessment recommended a more detailed feasibility study of Reservoir Dam to further investigate options to restore fish passage to the Reservoir and evaluate potential impacts on the infrastructure around the Reservoir.

The Scituate DPW was awarded a grant by the Massachusetts Department of Environmental Protection (MassDEP) under the Sustainable Watershed Management Initiative (SWMI) and contracted EA to conduct a detailed feasibility study of alternatives available to improve fish passage utilizing the existing fishway at Reservoir Dam to the maximum extent possible by raising the normal pool levels. This report summarizes EA's detailed evaluation of these alternatives.

BACKGROUND

First Herring Brook Reservoir Dam has a three (3) foot wide pool and weir fishway, but does not currently have any downstream passage facilities except for the existing fishway. Normal pool levels in the Reservoir Dam impoundment are at the spillway crest, which is at El. 40.0 ft National Geodetic Vertical Datum 1929 (NGVD 1929) and is approximately the same elevation as the bottom of the fishway exit channel preventing downstream passage through the existing fishway. All elevations in this report reference NGVD 1929. Since blueback herring and alewife, collectively known as river herring, key on surface flow for late summer/fall out-migration, low-level outlets similar to the Reservoir Dam outlet are not effective for downstream passage.

The Scituate DPW is currently implementing an Interim Operational Plan (IOP) recommended by the NSRWA and its partners. The IOP utilizes reservoir storage below the spillway crest (El. 40.0 ft) to meet water supply demands and environmental flow releases needed to maintain the habitat in First Herring Brook between Reservoir Dam and Old Oaken Bucket Pond, as shown on Figure 1, and downstream of Old Oaken Bucket Dam.



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	DESIGNED BY HAH	DRAWN BY DPA	DATE MAY 2013	PROJECT NO. 62651.02	FILE NAME GEN. ARRANG.	FIRST HERRING BROOK SCITUATE, MASSACHUSETTS	RESERVOIR DAM GENERAL ARRANGEMENT FIGURE 1
	CHECKED BY TCC	PROJECT MGR. TCC	SCALE 1"=500'	DRAWING NO. 1 OF 1	FIGURE 1		

In addition, reservoir storage is used to provide flows for upstream and downstream passage at Old Oaken Bucket Dam through the existing fishway. Since the Reservoir Dam spillway does not have a gate, storage below the spillway crest is used to meet the water supply and environmental flow demand through operation of the low-level outlet. When Reservoir Dam pool levels drops to El. 32.0 ft (8 ft below the spillway crest), water is no longer released for environmental use, but is reserved for water supply according to the IOP.

In order to restore herring into Reservoir Dam, EA has explored the possibility of raising the normal pool in Reservoir Dam above the crest of the spillway to allow the existing fishway to be used for upstream and downstream fish passage. Installation of flow controls on the spillway would be necessary to achieve higher water levels and store as much water as possible during the spring for use later in the year, while maintaining the existing spillway discharge capacity for flood events.

HYDRAULIC ANALYSIS

In order to evaluate alternatives for increasing water storage in Reservoir Dam, EA reviewed the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Plymouth County and conducted an analysis of the reservoir, spillway, and existing fishway. A reservoir storage rating curve above El. 40.0 ft, a spillway discharge rating curve, and fishway flow estimates were prepared and used as input to the WEAP modeling of alternatives for increasing storage capacity for the environmental flow releases. The spillway design flood (SDF) for Reservoir Dam was calculated to identify spillway modifications that may be associated with higher Reservoir Dam Pond levels.

Reservoir Storage Rating Curve

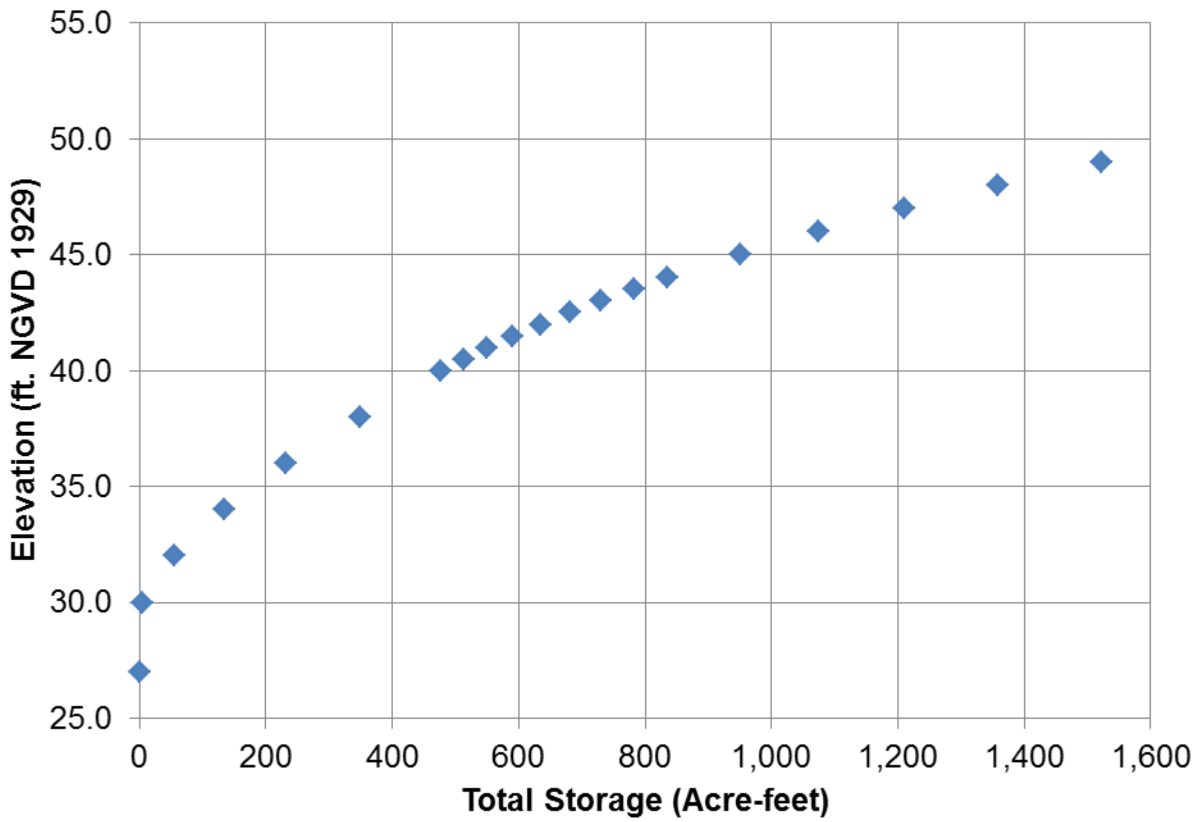
Light detection and ranging (LIDAR) topographic data (USGS 2011) was obtained by EA and used to develop a storage rating curve for Reservoir Dam Pond, including Tack Factory Pond Dam which is west of Route 3A, above the spillway crest El. 40.0 ft. At the time of the 2011 survey flyover, water levels in the Reservoir Dam impoundment were at approximately El. 40 ft, and no LIDAR topography below this level is included in the data. The LIDAR data, which has an accuracy of approximately ± 0.6 ft, was transposed into a computer aided drafting (CAD) file, areas measured for 0.5 ft contour intervals, and storage volumes calculated for the contour intervals.

The storage rating curve for Reservoir Dam is presented in Table 1 and illustrated in Figure 2.

Table 1 Reservoir Dam Storage Rating Curve Data

Reservoir Level (ft. NGVD 1929)	Total Storage (Acre-Ft)	Reservoir Level (ft. NGVD 1929)	Total Storage (Acre-Ft)
27.0	0.0	42.0	634.1
30.0	4.5	42.5	680.9
32.0	54.5	43.0	730.2
34.0	134.3	43.5	782.0
36.0	231.9	44.0	836.2
38.0	348.6	45.0	951.6
40.0	476.6	46.0	1075.4
40.5	512.3	47.0	1209.8
41.0	549.9	48.0	1359.2
41.5	590.3	49.0	1523.1

Figure 2 Reservoir Dam Storage Rating Curve



For pond levels at El. 40.0 ft and lower, EA used the reservoir storage rating curve presented in the 2003 Town of Scituate Drinking Water Supply and Demand Analysis (CEI 2003). This storage rating curve was also used for the 2012 Water Evaluation and Planning (WEAP) model (Kearns 2012).

Reservoir Dam has a storage volume of 476.6 ac-ft at the spillway crest El. 40.0 ft according to these data. The LIDAR data indicates that Reservoir Dam has a surface area of approximately 69.5 acres. Raising normal pond to El. 41.0 ft would increase the storage volume by 73.3 ac-ft to 549.9 ac-ft. Similarly, raising the storage elevation to EL 43.0 ft would increase the storage volume by 254.6 ac-ft (53%) to 730.2 ac-ft.

For pond levels at El. 40.0 ft and lower, EA used the reservoir storage rating curve presented in the 2003 Town of Scituate Drinking Water Supply and Demand Analysis (CEI 2003). This storage rating curve was also used for the 2012 Water Evaluation and Planning (WEAP) model (Kearns 2012). Reservoir Dam has a storage volume of 476.6 ac-ft at the spillway crest El. 40.0 ft according to these data. The LIDAR data indicates that Reservoir Dam has a surface area of approximately 69.5 acres. Raising normal pond to El. 41.0 ft would increase the storage volume by 73.3 ac-ft to 549.9 ac-ft. Similarly, raising the storage elevation to EL 43.0 ft would increase the storage volume by 254.6 ac-ft (53%) to 730.2 ac-ft.

Spillway Discharge Rating Curve

The existing spillway for Reservoir Dam is a 42 ft long concrete overflow structure with the crest at El. 40.0 ft. The ogee shaped spillway has a total discharge capacity of 2,300 cfs with the pond level at the top of dam El. 46.75 ft (Scituate DPW 2013). Discharge data and the rating curve for the spillway are presented on Table 2 and Figure 3, respectively. The rating curve assumes a constant 3.1 discharge coefficient over the entire range of flows.

FEMA Flood Study

Flood levels in First Herring Brook have been determined by the Federal Emergency Management Agency (FEMA) and reported in the 2012 Flood Insurance Study (FIS) for Plymouth County (FEMA 2012). The peak discharges in First Herring Brook 500 ft downstream from Old Oaken Bucket Dam range from 405 cfs for the 10-year storm (10-percent annual chance) up to 835 cfs for the 500-year storm (0.2-percent annual chance). At Grove Street, approximately 1.25 miles upstream of Reservoir Dam, peak discharges are 145 cfs, 197 cfs, 240 cfs, and 385 cfs for the 10-, 50-, 100-, and 500-year flood events, respectively.

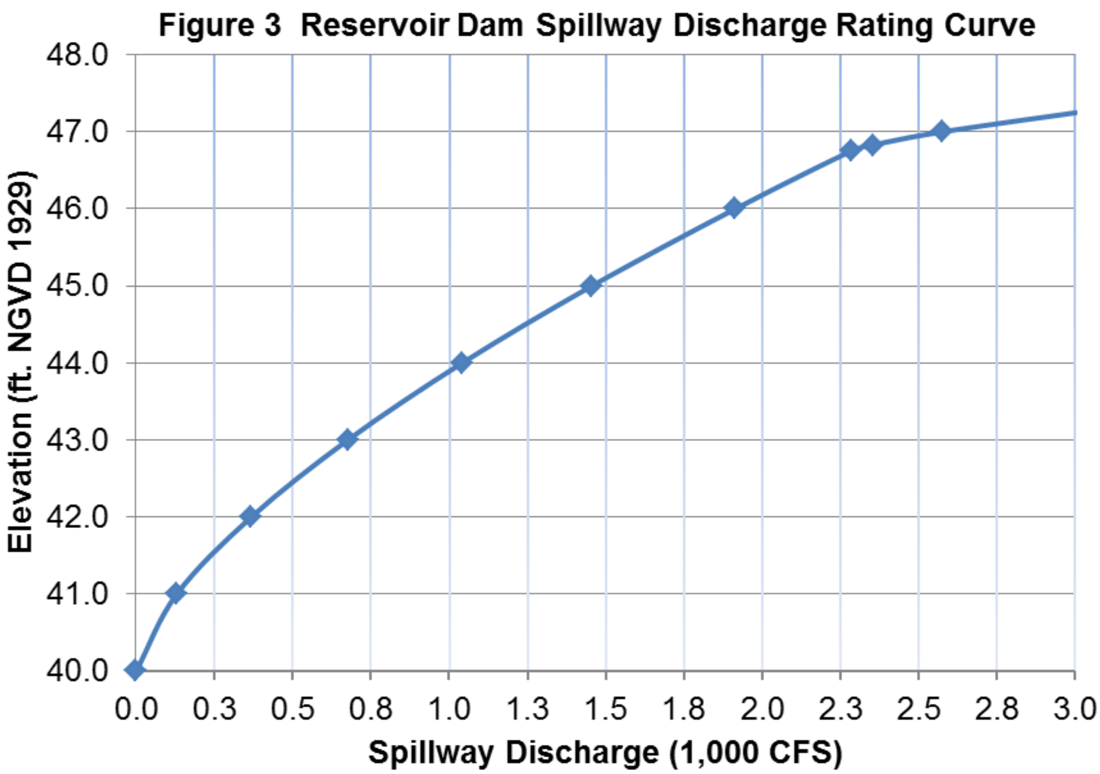


Table 2 Reservoir Dam Spillway Discharge Rating Curve Data

Reservoir Level (ft. NGVD 1929)	Discharge (CFS)
40.0	0
41.0	130
42.0	368
43.0	677
44.0	1,042
45.0	1,456
46.0	1,914
46.7	2,283
47.0	2,574
47.2	3,001

The FIS reports flood levels in Reservoir Dam range from approximately El. 41.0 ft for the 10-yr storm up to El. 42.5 ft for the 500-year storm event. Tack Factory Pond flood levels range from El. 43.0 ft for the 10-year event up to El. 44.8 ft for the 500-year flood. Route 3A would be overtopped at storms greater than the 50-year flood when water levels in Tack Factory Pond would be El. 43.5 ft or higher.

Spillway Design Flood

The Reservoir Dam is classified as an intermediate size and Class I high hazard dam (Scituate DPW 2013). This classification requires a spillway capacity at least equal to one-half of the Probable Maximum Flood (½ PMF). The PMF is the flood resulting from the most severe combination of meteorological and hydraulic conditions that can be expected for a watershed. The DPW's 2013 Dam inspection report indicates that 3,000 cfs is a reasonable value for the ½ PMF flood and that the spillway has adequate capacity for spillway design flood (SDF).

In order to identify potential spillway modifications that may be required to raise the normal pool level, EA computed the SDF for Reservoir Dam. The PMF was derived using probable maximum precipitation (PMP) values from "Design of Small Dams" published by the U.S. Department of the Interior (USDI-BR 1973), hydrologic runoff data from Natural Resources Conservation Service (NRCS) Technical Release No. 55 (TR-55) (Reference 7), soil data from the U.S. Department of Agriculture (USDA) Web Soil Survey (USDA 2013), and hydrograph development techniques from "Hydrology and Floodplain Analysis" by Bedient, et al (Bedient, et al 2013). A detailed description of the PMF analysis is provided in Appendix A.

The ½ PMF computations indicate that peak discharge at Reservoir Dam for a 6-hour storm is 2,021 cfs. The existing spillway has the capacity for this flow with approximately 0.5 ft of freeboard remaining before overtopping the dam embankment. Longer duration storms would have lower peak discharge rates.

The results of the analysis indicates that Reservoir Dam has an adequate design capacity and that modifications to the spillway and embankment would not be necessary for higher normal pond levels if the hydraulic capacity of the spillway is maintained during flood conditions. To achieve higher pond levels without reducing spillway capacity would require water level control mechanism which would be lowered to a level below the existing spillway crest during flood conditions.

Existing Fishway Flow

Reservoir Dam has a three (3) foot wide pool and weir fishway with a total height of 15.0 ft. There are twenty-one (21) pools each approximately 3 ft wide by 3 ft long by 1.5 ft deep.

Assuming a weir discharge coefficient of 3.1, fishway flow would be 2.50 cfs with a 5 inch water depth over the weirs and 5.06 cfs with an 8 inch water depth. These calculated flows are consistent with the flows used in the 2012 WEAP Model Report which was the basis for the 2011 IOP being implemented by the DPW.

Reductions in fishway flow with sufficient weir depth over the weirs could be achieved by shortening the weir crest length. The flow reduction with narrower weirs would be directly proportional to the length. A 1.5 ft weir width would have flow rates of 2.53 cfs with an 8 inch water depth. With a six (6) inch weir length, fishway flow would be 0.42 cfs with a 5 inch depth, similar to the notched weir installed in the summer of 2012 at the Old Oaken Bucket Fishway exit channel.

WEAP MODELING

The DPW is currently implementing the IOP for restoring stream flow for native aquatic and migratory species in First Herring Brook. The NSRWA developed the IOP in 2012 using the WEAP model for various operating scenarios. Ms. Margaret Kearns was contracted by NSRWA to update the model for evaluation of pond levels and water release schedules to improve fish passage at Reservoir Dam. Updates to the WEAP model included the Reservoir Dam storage rating curve discussed above, and modifications to the existing fishway at Reservoir Dam and changes in the fishway releases to reduce storage requirements while maintaining effective fish passage and habitat conditions in First Herring Brook. Streamflow guidelines in the 2012 IOP are summarized in Table 3.

The First Herring Brook IOP dictates that when the reservoir level drops more than five feet below the spillway to El. 35.0 ft, a total outdoor watering ban is declared. The total watering ban is conservatively modeled as reducing water use to average winter water use levels (1.31 mgd). During 2010, total watering outdoor watering ban actual water use dropped to 1.00 mgd.

The average recorded town water demand during 1999-2007, which was the basis of the WEAP modeling for the IOP, was 615 million gallons per year. The average pumping rate for the updated WEAP modeling in this study was 533 million gallons per year for 1999-2011. This water demand will need to be either met or reduced through enforcement of summer outdoor watering bans. A higher spillway level at Reservoir Dam is expected to improve the Town’s ability to meet local water demand while providing adequate fish passage and environmental flows.

Table 3 2011 IOP Streamflow Guidelines

Bioperiod	Eisenhower Lane (Downstream of Reservoir Dam)			Country Way (Downstream of Old Oaken Bucket Dam)	
	Water Supply (cfs)[2)]	Fishway (cfs)	River (cfs)	Fishway (cfs)	River (cfs)
March	0.61/0.31	0	2.56	0	3.78
April-May[1)]	0.98/0.64	0	2.56	5.20[3)]	3.78
June-August	1.23/0.82	0	0.22	0	0.39
September-October[1)]	0.82/0.48	0	0.25	2.56[3)]	0.45
November	0.53/0.28	0	0.25	0	0.45
December-February	0.36/0.27	0	2.13	0	3.15

1) April-May and September-October: manage releases over fishway weirs unless water is not available. If drought conditions are occurring, use staff gages to provide minimum river flow to maintain stream habitat.
2) First number represents average flow meeting 2011 IOP irrigation water ban trigger level. Second number represents one day per irrigation water limit implemented by the DPW in 2012. Complete outside water ban instituted when Reservoir Dam level drops to El. 35.0 ft. Streamflow guidelines discontinued when Reservoir Dam level drops to El. 32.0 ft.
3) An eight (8) inch water depth over the fishway weirs corresponds to 5.2 cfs; a five (5) inch water depth over the fishway weirs corresponds to 2.56 cfs. Because these flows exceed the river flow goals, all downstream releases during the migration season should be made through the fish ladder.

Streamflow guidelines in the 2011 IOP were selected to meet BioQ90 flows. BioQ90 flows are a minimum flow requirement that should be exceeded 90% of the time for each biological period. If flows fall below the BioQ90 flows, the low level outlet at the dam would be opened to provide the minimum flow. Under the 2011 IOP, BioQ90 flows are shutoff when Reservoir Pond levels drop below El. 32 ft. Under the existing IOP, no flows are provided for fish passage at Reservoir Dam and at Old Oaken Bucket Pond fish passage in spring is met 86 % of the time and only 17% of the time in the fall bioperiods.

A summary of the WEAP model input and results conducted to evaluate the effectiveness of four higher Reservoir Dam Pond level options are provided in the following sections. The model assumes that flow control mechanisms would be installed on the spillway crest to maintain the higher pond levels. An additional simulation for the existing reservoir level, but with a lower fishway exit channel, was completed for comparison to the higher pond level options. Operational guidelines and fishway modifications required for effective fish passage are described for each option. A detailed report of the WEAP modeling for this study is presented in Appendix B.

Option A – Pond El. 42.0 ft

The first option modeled a full pond of El. 42.0 ft and evaluated the existing fishway exit channel and an 18 inch wide, 6 inch deep notch in the fishway exit channel at Reservoir Dam. Full pond refers to target elevation at the beginning of April prior to the upstream fish migration period and is the maximum level that the DPW could control. This option was selected as a starting point since the 2011 WEAP modeling results indicated that there was generally sufficient storage to meet the IOP releases in the spring for the in-migration, but the summer water supply demand depleted the reservoir storage and there was insufficient water elevation for the fall out-migration.

Nine (9) different cases were simulated for Option A to evaluate various combinations of fishway flow, fishway exit elevation, and water ban target elevations. Input parameters for these cases are summarized in Table 4. Minimum water level for effective fish passage was set at El.40.5 ft with the existing fishway channel and El. 40.0 ft with a 6 inch deep notch in the fishway exit channel.

Results of the Option A WEAP model cases are presented in Appendix B, Tables 6 and 13. All of the cases would have fish ladder flows sufficient for fish passage at least 80% of the time during the spring in-migration and at least 40% of the time during the fall-out migration at both Reservoir Dam and Old Oaken Bucket. All of the cases with a watering ban trigger level at the 2011 IOP (El. 35.0 ft) indicated that a watering ban would be necessary less than 2 summer days (Cases 7-9). A trigger level at El. 41.0 ft would result in a water ban 34 summer days with the existing fishway exit channel and with a 6 inch deep notch in the exit channel (Case 13) and 34 summer days for the extended scenario (Case 11). Lowering the trigger point to El. 40.0 ft would reduce the water ban frequency to 14 summer days with both fishway exit channel configurations (Cases 10 and 12).

Table 4 WEAP Option A Model Input Parameters

Case	Normal Pond (El. ft NGVD 1929)	Fishway Exit Bottom (El. ft NGVD 1929)	Reservoir Dam Release Flow (cfs)		
			March-May Upstream Migration1)	June-August High Water Demand2)	September-October Downstream Migration3)
2011 IOP	El. 40.0 ft	El. 40.0 ft	5.20	0.22 (El. 35.0 ft)	0.25
7	El. 42.0 ft	El. 40.0 ft	5.20	0.22 (El. 35.0 ft)	0.45
8	El. 42.0 ft	El. 40.0 ft	2.60	0.22 (El. 35.0 ft)	0.45
9	El. 42.0 ft	El. 39.5 ft	5.20	0.22 (El. 35.0 ft)	0.45
10	El. 42.0 ft	El. 40.0 ft	2.60	0.22 (El. 40.0 ft)	0.45
11	El. 42.0 ft	El. 40.0 ft	2.60	0.22 (El. 41.0 ft)	0.45
12	El. 42.0 ft	El. 39.5 ft	2.60	0.22 (El. 40.0 ft)	0.45
13	El. 42.0 ft	El. 39.5 ft	2.60	0.22 (El. 41.0 ft)	0.45
14	El. 42.0 ft	El. 39.5 ft	2.60	0.22 (El. 35.0 ft/E)	0.45
15	El. 42.0 ft	El. 39.5 ft	2.60	0.22 (El. 40.0 ft/E)	0.45

1) A fishway flow of 5.20 cfs corresponds to an 8 inch water depth over a 3 ft wide weir; 2.6 cfs corresponds to a 5 inch depth over a 3 ft wide weir or an 8 inch depth over a 1.5 ft weir.
2) Elevations refer to Reservoir Dam water level at which a water ban is implemented. Water bans for all cases would be from Memorial Day through Labor Day except for Cases 14 and 15 which would be extended to include May and September as indicated by the letter E.
3) Downstream fish passage through the existing fishway accomplished with removable baffles on existing fishway weirs; 0.45 cfs corresponds to a 5 inch water depth through a 6 inch notch, similar to the removable baffles being installed at the Old Oaken Bucket Dam fishway.

Option B – Pond El. 42.5 ft

The second option modeled a full pond of El. 42.5 ft and evaluated the existing fishway exit channel and an 18 inch wide, 6 inch deep notch in the fishway exit channel at Reservoir Dam. Six different cases were simulated for Option B to evaluate various combinations of fishway flow, fishway exit elevation, and water ban target elevations. Input parameters for these cases are summarized in Table 5. Minimum water level for effective fish passage was set at El.40.5 ft with the existing fishway channel and El. 40.0 ft with a 6 inch deep notch in the fishway exit channel.

Table 5 WEAP Model Option B Input Parameters

Case	Normal Pond (El. ft NGVD 1929)	Fishway Exit Bottom (El. ft NGVD 1929)	Reservoir Dam Release Flow (cfs)		
			March-May Upstream Migration1)	June-August High Water Demand2)	September-October Downstream Migration3)
2011 IOP	El. 40.0 ft	El. 40.0 ft	5.20	0.22 (El. 35.0 ft)	0.25
16	El. 42.5 ft	El. 40.0 ft	2.60	0.22 (El. 42.0 ft)	0.45
17	El. 42.5 ft	El. 39.5 ft	2.60	0.22 (El. 41.0 ft)	0.45
18	El. 42.5 ft	El. 40.0 ft	2.60	0.22 (El. 35.0 ft)	0.45
19	El. 42.5 ft	El. 40.0 ft	2.60	0.22 (El. 40.0 ft)	0.45
20	El. 42.5 ft	El. 40.0 ft	2.60	0.22 (El. 41.0 ft)	0.45
21	El. 42.5 ft	El. 39.5 ft	2.60	0.22 (El. 40.0 ft)	0.45

1) A fishway flow of 5.20 cfs corresponds to an 8 inch water depth over a 3 ft wide weir. A fishway flow of 2.6 cfs corresponds to an 8 inch depth over a 1.5 ft weir.
2) Elevations refer to Reservoir Dam water level at which water ban is implemented. Water bans for all cases would be from Memorial Day through Labor Day.
3) Downstream fish passage through the existing fishway accomplished with removable baffles on existing fishway weirs; 0.45 cfs corresponds to a 5 inch water depth through a 6 inch notch, similar to the removable baffles being installed at the Old Oaken Bucket Dam fishway.

Fish ladder flows for all of the cases would occur more than 90% of the time during the spring in-migration and more than 60% of the time during the fall-out migration at both Reservoir Dam and Old Oaken Bucket (Appendix B, Tables 6 and 13). The case with a watering ban trigger level at the 2011 IOP (El. 35.0 ft) indicated that a watering ban would be necessary less than one summer day (Case 18). A trigger level at El. 41.0 ft would result in a water ban 20 of the summer days with the existing fishway exit channel and with a 6 inch deep notch in the exit channel (Cases 17 and 20). Lowering the trigger point to El. 40.0 ft would reduce the water ban frequency to 8 summer days with both fishway exit channel configurations (Cases 19 and 21).

Option C – Pond El. 43.5 ft

The third option modeled a full pond of El. 43.5 ft and evaluated the existing fishway exit channel and an 18 inch wide, 6 inch deep notch in the fishway exit channel at Reservoir Dam. Seven different cases were simulated for Option C to evaluate various combinations of fishway flow, fishway exit elevation, and water ban target elevations. Input parameters for these cases are summarized in Table 6. Minimum water level for effective fish passage was set at El.40.5 ft with the existing fishway channel and El. 40.0 ft with a 6 inch deep notch in the fishway exit channel.

Table 6 WEAP Model Option C Input Parameters

Case	Normal Pond (El. ft NGVD 1929)	Fishway Exit Bottom (El. ft NGVD 1929)	Reservoir Dam Release Flow (cfs)		
			March-May Upstream Migration 1)	June-August High Water Demand 2)	September-October Downstream Migration 3)
2011 IOP	El. 40.0 ft	El. 40.0 ft	5.20	0.22 (El. 35.0 ft)	0.25
22	El. 43.5 ft	El. 39.5 ft	2.60	0.22 (El. 41.0 ft)	0.45
23	El. 43.5 ft	El. 40.0 ft	5.20	0.22 (El. 35.0 ft)	0.45
24	El. 43.5 ft	El. 40.0 ft	2.60	0.22 (El. 35.0 ft)	0.45
25	El. 43.5 ft	El. 40.0 ft	2.60	0.22 (El. 40.0 ft)	0.45
26	El. 43.5 ft	El. 40.0 ft	2.60	0.22 (El. 41.0 ft)	0.45
27	El. 43.5 ft	El. 39.5 ft	2.60	0.22 (El. 40.0 ft)	0.45
28	El. 43.5 ft	El. 40.0 ft	2.60	0.22 (El. 42.0 ft)	0.45

1) A fishway flow of 5.20 cfs corresponds to an 8 inch water depth over a 3 ft wide weir; 2.6 cfs corresponds to a 5 inch depth over a 3 ft wide weir or an 8 inch depth over a 1.5 ft weir.
2) Elevations refer to Reservoir Dam water level at which water ban is implemented. Water bans for all cases would be from Memorial Day through Labor Day.
3) Downstream fish passage through the existing fishway accomplished with removable baffles on existing fishway weirs; 0.45 cfs corresponds to a 5 inch water depth through a 6 inch notch, similar to the removable baffles being installed at the Old Oaken Bucket Dam fishway.

For all of the Option C cases, fish ladder flows would occur more than 80% of the time during the spring in-migration and more than 50% of the time during the fall-out migration at both Reservoir Dam and Old Oaken Bucket (Appendix B, Tables 6 and 13). The case with a watering ban trigger level at the 2011 IOP (El. 35.0 ft) indicated that a watering ban would be necessary less than 2 summer days (Cases 23 and 24). A trigger level at El. 41.0 ft would result in a water ban 6 summer days with the existing fishway exit channel and with a 6 inch deep notch in the exit channel (Cases 22 and 26). Lowering the trigger point to El. 40.0 ft would reduce the water ban frequency to 3 summer days with both fishway exit channel configurations (Cases 25 and 27).

Option D – Pond El. 40.0 ft

Option D modeled a full pond El. 40.0 ft with the fishway exit channel lowered to El. 36.5 ft with no modifications to the spillway. This option would have the least impact on properties around the Reservoir, but the greatest extent of modifications to the existing fishway for effective fish passage. Input parameters for this case are summarized in Table 7. For this case, the water ban trigger water level was set at El. 37.0 ft or El. 38.0 ft.

Table 7 WEAP Model Option D Input Parameters

Case	Normal Pond (El. ft NGVD 1929)	Fishway Exit Bottom (El. ft NGVD 1929)	Reservoir Dam Release Flow (cfs)		
			March-May Upstream Migration[1)]	June-August High Water Demand[2)]	September-October Downstream Migration[3)]
2011 IOP	El. 40.0 ft	El. 40.0 ft	5.20	0.22 (El. 35.0 ft)	0.25
1	El. 40.0 ft	El. 36.5 ft	2.60	0.22 (El. 37.0 ft)	0.45
2	El. 40.0 ft	El. 36.5 ft	2.60	0.22 (El. 38.0 ft)	0.45
3	El. 40.0 ft	El. 36.5 ft	2.60	0.22 (El. 37.0 ft E)	0.45

1) A fishway flow of 5.20 cfs corresponds to an 8 inch water depth over a 3 ft wide weir; 2.6 cfs corresponds to a 5 inch depth over a 3 ft wide weir or an 8 inch depth over a 1.5 ft weir.
2) Elevations refer to Reservoir Dam water level at which water ban is implemented. Water bans for all cases would be from Memorial Day through Labor Day except for Cases 3 which would be extended to include May and September as indicated by the letter E.
3) Downstream fish passage through the existing fishway accomplished with removable baffles on existing fishway weirs; 0.45 cfs corresponds to a 5 inch water depth through a 6 inch notch, similar to the removable baffles being installed at the Old Oaken Bucket Dam fishway.

All of the Option D cases indicated that fish ladder flows would occur more than 95% of the time during the spring in-migration and more than 60% of the time during the fall-out migration at both Reservoir Dam and Old Oaken Bucket. The frequency of the water ban for this option was 11-22% of the summer days depending on the trigger point.

Option E – Pond El. 41.0 ft

Option E modeled full pond El. 41.0 ft with the fishway exit channel lowered to El. 36.5 ft with one foot high flashboards installed in the spillway. Like Option D, this option would have the minimal impact on properties around Reservoir, but the greatest extent of modifications to the existing fishway for effective fish passage. Input parameters for this case are summarized in Table 8. Water ban trigger levels at El. 38.0 ft, El 38.5 ft, and El. 39.0 ft were modeled for this option.

All of the Option E cases indicated that fish ladder flows would be greater than 95% of the time during the spring in-migration and greater than 70% of the time during the fall-out migration at both Reservoir Dam and Old Oaken Bucket. The frequency of the water ban for this option was 9-20% of the summer days depending on the trigger point.

Table 8 WEAP Model Option E Input Parameters

Case	Normal Pond (El. ft NGVD 1929)	Fishway Exit Bottom (El. ft NGVD 1929)	Reservoir Dam Release Flow (cfs)		
			March-May Upstream Migration[1)]	June-August High Water Demand[2)]	September-October Downstream Migration[3)]
2011 IOP	El. 40.0 ft	El. 40.0 ft	5.20	0.22 (El. 35.0 ft)	0.25
4	El. 41.0 ft	El 36.5 ft	2.60	0.22 (El. 38.0 ft)	0.45
5	El. 41.0 ft	El 36.5 ft	2.60	0.22 (El. 38.5 ft)	0.45
6	El. 41.0 ft	El. 36.5 ft	2.60	0.22 (El. 39.0 ft)	0.45

1) A fishway flow of 5.20 cfs corresponds to an 8 inch water depth over a 3 ft wide weir; 2.6 cfs corresponds to a 5 inch depth over a 3 ft wide weir or an 8 inch depth over a 1.5 ft weir.
2) Elevations refer to Reservoir Dam water level at which water ban is implemented. Water bans for all cases would be from Memorial Day through Labor Day.
3) Downstream fish passage through the existing fishway accomplished with removable baffles on existing fishway weirs; 0.45 cfs corresponds to a 5 inch water depth through a 6 inch notch, similar to the removable baffles being installed at the Old Oaken Bucket Dam fishway.

Options Recommended for Further Consideration

The results of the WEAP modeling suggest that several scenarios are feasible to meet fish passage requirements during the majority of both the spring in-migration and fall out-migration periods while minimizing the number of summer days where a watering ban is enforced. Six (6) options provide at least 95% fish ladder success during the in-migration period, 60% fish ladder success during the out-migration period, and a water ban in place on fewer than 14 summer days. Three of these cases have a normal pond at El. 43.5 ft (Cases 22, 26, and 27) with one case with normal pond at El. 42.5 ft (Case 21), one at El. 40.0 ft (Case 1), and one at El. 41.0 ft (Case 3) . Case 13 is the best pond El. 42.0 ft option with acceptable fish passage success rates, but would impose a water ban on 34 summer days on average.

Five (5) alternatives have been selected for detailed evaluation. These alternatives represent the full cost range of options for spillway and fishway modifications, and infrastructure impact mitigation measures (e.g. highway upgrades and septic system replacement). The alternatives are:

Alternative 1 (Case 13). Normal pond would be at El. 42.0 ft which would have the minimum amount of infrastructure impacts associated with higher pool levels, but would have the greatest number of water bans.

<u>Alternative 2 (Case 21).</u> Normal pond would be at El. 42.5 ft with substantially more infrastructure improvement, but a water ban frequency similar to the water ban frequency with the 2011 IOP.

<u>Alternative 3 (Case 27).</u> This alternative would have the greatest storage capacity with a normal pond at El. 43.5 ft, but would have the greatest impact on adjacent properties and Route 3A resulting in the greatest cost to address infrastructure impacts.

<u>Alternative 4 (Cases 1-3).</u> Alternative 4 would not have any impacts on infrastructure because there would be no modifications to the existing spillway and normal pond would remain at El. 40.0 ft. This alternative would have the greatest cost for fishway improvements, but the lowest overall cost.

<u>Alternative 5 (Cases 4-6).</u> Alternative 5 would be the same as alternative 4, but would include one foot high flashboards on the existing spillway approach apron – raising the normal pond to El. 41.0 ft. This alternative would have minimal infrastructure costs and would provide the greatest potential for meeting all of the water demands.

An assessment of the ecological benefits and the infrastructure impacts associated with these higher pond levels, a review of available flow control mechanism for maintaining higher pond elevations, and a detailed evaluation of these five (5) alternatives including cost estimates are provided in the following sections.

ECOLOGICAL BENEFITS

Modifying Reservoir Dam spillway and fishway to restore river herring passage will provide pond shoreline habitat for alewives and riverine habitat for blueback herring. The impoundment will also provide habitat for American eel. The current IOP was developed to assure environmental flows into Old Oaken Bucket Pond and was not developed with fish passage into Reservoir Dam in mind because of the water storage limitations. The existing fishway exit channel is at the same elevation as the spillway crest and the reservoir has no storage capability above the spillway.

Restoring fish passage at Reservoir Dam by keeping the reservoir at a more constant level will provide approximately 11,800 linear ft shoreline habitat – at El. 40.0 ft. Currently the reservoir is drawn down for water supply during the summer to 4-5 ft below the spillway crest. Shoreline habitat increases 30% to approximately 15,300 linear ft if normal pond level can be maintained at El. 41.0 ft and 37% to 16,200 linear ft with a normal pond at El. 44.0 ft.

Fish passage into Reservoir Dam Pond and Tack Factory Pond will restore approximately 70 acres of pond for American eels in addition to river herring. Based on median habitat carrying capacity estimates (Gibson and Myers 2003), this could result in a population of approximately 25,100 herring with reservoir levels remaining the same as current level (El. 40.0 ft). Raising the reservoir level would add between 3.8 and 17.8 acres of habitat (at El. 41.0 ft and El. 43.5 ft, respectively), resulting in gains to the potential population of 1,300-6,600 herring. Stream channel habitat upstream of Tack Factory Pond would be available for blueback herring spawning with higher water levels in Reservoir Dam Pond which would allow fish passage through the slide gate at Tack Factory Pond Dam.

ASSESSMENT OF IMPACTS ON EXISTING INFRASTRUCTURE

In order to assess the impacts of higher Reservoir Dam Pond levels on the infrastructure surrounding the Reservoir, EA prepared a base map of the immediate area using LIDAR obtained from the National Geospatial Technical Operations Center (USGS 2011). Approximate property line data were added to the base map with an aerial photograph to define the location of houses and structures around the pond. Figure 4 presents the base map with one foot contours colored coded from El. 40.0 ft (the spillway crest elevation) up to El. 49.0 ft.

EA reviewed available water, sewer, and stormwater to determine potential impacts of higher pond levels. Field verification of house locations, water and sewer lines, stormwater outfalls, and gas lines was conducted on May 14th and May 22nd. Infrastructure impacts are summarized in Table 9 for the water levels simulated in the WEAP model.

The following sections provide describe the impacts of higher pond levels on highways, properties, water and sewer lines, septic systems, and flood protection which are the basis for project costs estimated for the options selected for more detailed evaluation.

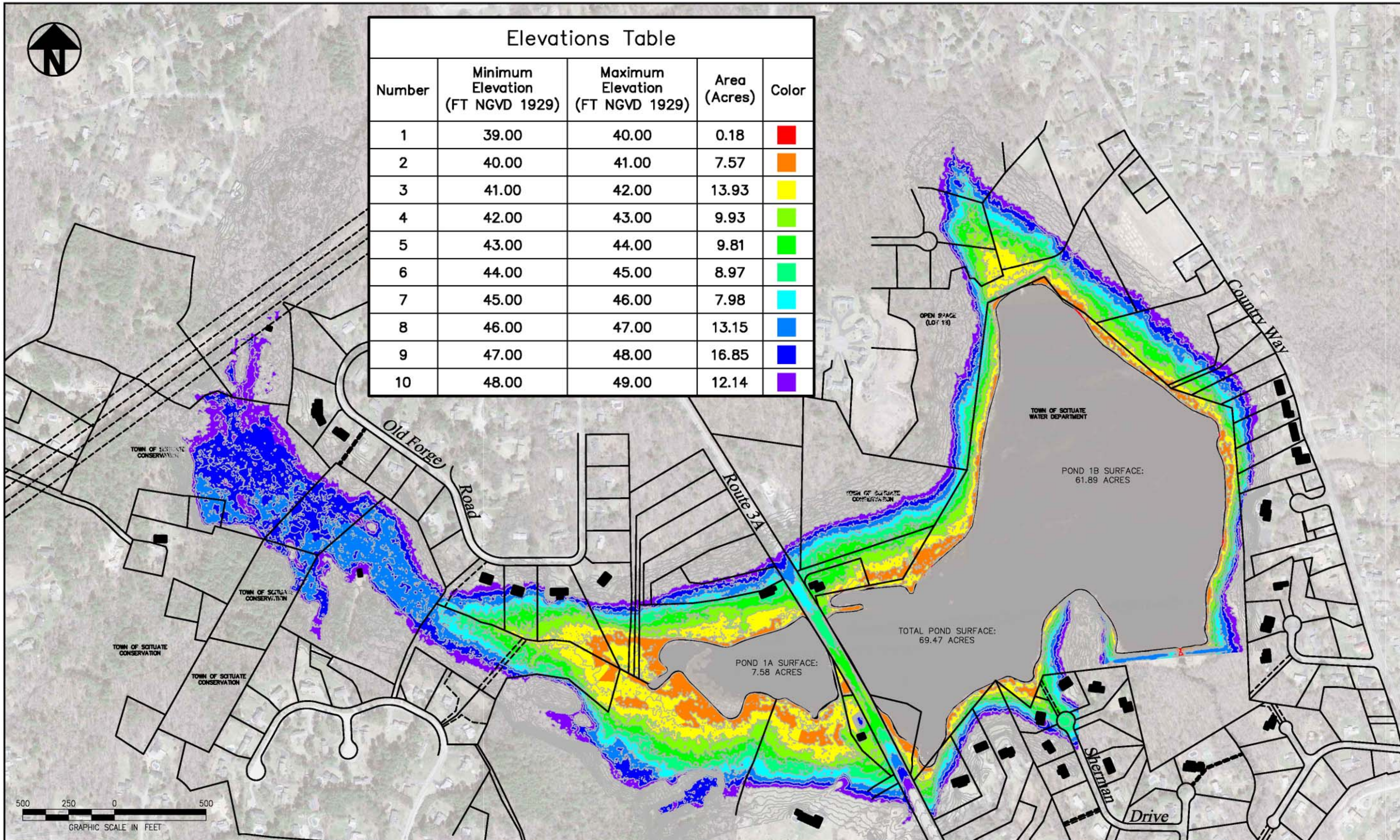
Highways

Route 3A is the only highway that would be impacted by higher reservoir levels. LIDAR data indicates that the lowest point in the road surface is approximately El. 43.5 ft at the south side of Reservoir Dam Pond sloping up to El. 46.0 ft within approximately 300 ft to the south and 500 ft to the north. The roadway embankment is vegetated with minimal riprap erosion protection. USGS benchmark L42 1978 is located on top of the concrete headwall on the east side of the highway culvert and is at El. 39.8 ft.

Higher Reservoir Dam Pond levels would require modification to Route 3A to raise the road surface and provide at least a one foot freeboard above normal water levels, and provide

Elevations Table

Number	Minimum Elevation (FT NGVD 1929)	Maximum Elevation (FT NGVD 1929)	Area (Acres)	Color
1	39.00	40.00	0.18	Red
2	40.00	41.00	7.57	Orange
3	41.00	42.00	13.93	Yellow
4	42.00	43.00	9.93	Yellow-green
5	43.00	44.00	9.81	Green
6	44.00	45.00	8.97	Sea green
7	45.00	46.00	7.98	Cyan
8	46.00	47.00	13.15	Light blue
9	47.00	48.00	16.85	Blue
10	48.00	49.00	12.14	Purple



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DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
HAH	DPA	MAY 2013	62651.02	IMPACT LOCAT.
CHECKED BY	**PROJECT MGR.**	**SCALE**	**DRAWING NO.**	**FIGURE**
TCC	TCC	1"=500'	1 OF 1	4

FIRST HERRING BROOK
SCITUATE, MASSACHUSETTS

IMPACTED SHORELINE AND PROPERTY LOCATIONS
FIGURE 4

Table 9 Impacts on Infrastructure

Infrastructure Parameter	2012 IOP/ OPTIONS D & E	OPTION A	OPTION B	OPTION C
Normal Pond (El. ft NGVD 1929	El. 40.0/41.0 ft	El. 42.0 ft	El. 42.5	El. 43.5 ft
Route 3A Improvements[1)] (Length/Height)	0 ft / 0 ft	750 ft / 0 ft	750 / 0.5 ft	750 / 1.5 ft
Private Property Shoreline[2)] (Number/Area)	21 / 0 ac	21 / 7.6 ac	27 / 9.9 ac	27 / 14.5 ac
Buffer Zone[3)] (Total Area)	52.6 ac	84.7 ac	90.4 ac	107.3 ac
Private Property Buffer Zone[3)] (Number/Area)	21 / 18.4 ac	21 / 29.7 ac	27 / 31.7 ac	27 / 37.5 ac
Number of Houses[4)] (Relocation/Flood Protection)	0 / 0	3 / 2	3 / 2	3 / 5
Flood Protection Dikes[5)] (Length/Height)	0 / 0	500 ft / 3 ft	500 ft / 3 ft	1,000 ft / 5 ft
Sewer Connections[6)] (Number/Feet)	3 / 2,500 ft	3 / 2,500 ft	3 / 2,500 ft	3 / 2,500 ft
Septic System Upgrades[7)] (Number)	0	3	3	5

1) Height represents the maximum height that roadway surface would be raised for the proposed normal pond level for each option. Riprap slope protection required on roadway embankment for all options including options not requiring roadway to be raised (0 ft height).
2) Total number of private properties adjacent to Reservoir Dam Pond and Tack Factory Pond, excluding Town owned water supply, conservation, or open space land, and approximate total area that would be impacted by higher pond level for each option.
3) Assumes a 200 ft buffer zone from the normal pool shoreline; private property impacted by buffer zone assumes 65% of the shoreline property is conservation land or open space controlled by the Town of Scituate.
4) Houses below the proposed normal pond level for each option would be relocated or raised to prevent flooding. Some houses could be protected with dikes and would not have to be raised or relocated. The total number of houses includes both categories.
5) The total length of dikes and the maximum height of the dikes are for the houses that would require flood protection.
6) There are three (3) houses below proposed normal pond level for each option which should be connected to the sewer system to protect the water supply. The linear feet of sewer connection is the maximum length of the sewer main line extension.
7) Houses with septic systems that would require septic system upgrades to provide proper separation from groundwater. These houses are different properties than the houses included in the previous row requiring sewer connection.

embankment erosion protection. If the normal pond level remains at El. 40.0 ft, no improvements to Route 3A would be needed for operation of the fishway.

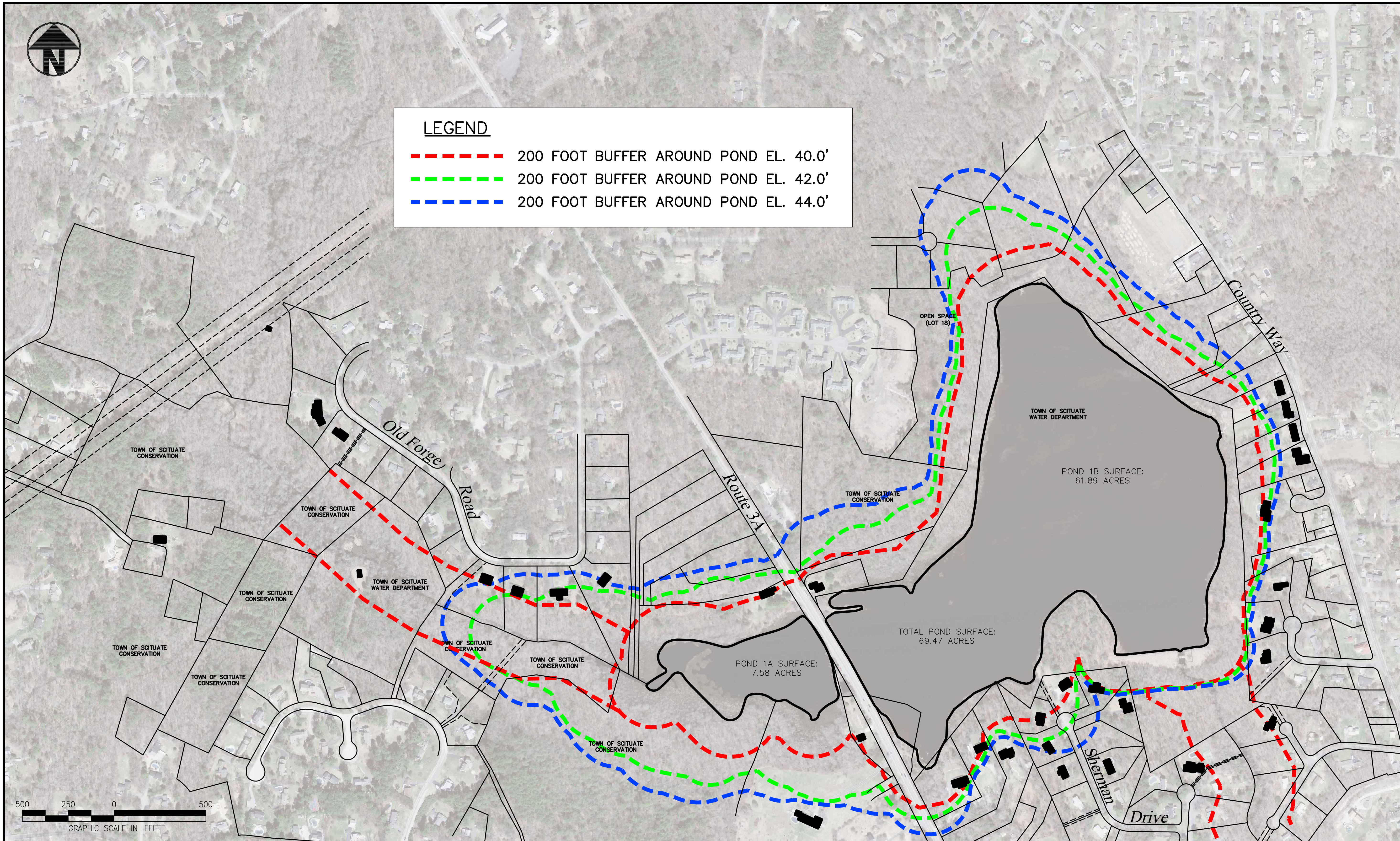
With pond levels of El. 41.0 ft and El. 42.0 ft, the highway would not have to be raised, but both embankments would need stone riprap from El. 40.0 ft up to El. 43.0 ft along 750 ft of the highway. The length of highway impacting by pond levels would also be approximately 750 ft with low point at the existing culvert for Tack Factory Pond. The low point in Route 3A would have to be raised approximately 0.5 ft for pond El. 42.5 ft and 1.5 ft for pond El. 43.5 ft to provide adequate freeboard for the roadway with 6 inches of flow over the spillway flow control mechanism. Pond levels higher than El. 42.0 ft would also require riprap slope protection on both sides of the highway embankment.

Private Property

The location of private property and houses abutting Reservoir Dam Pond and Tack Factory Pond are shown on Figure 3. Raising the spillway one foot to El. 41.0 ft or two feet to El. 42.0 ft would impact approximately 21 nearby private properties, excluding Town property. Raising the spillway to El. 42.5 ft or El. 43.5 ft would impact approximately 27 private properties surrounding Reservoir Dam Pond. The total area inundated by water levels at El. 41.0 ft, El. 42.0 ft, El. 42.5 ft, and El. 43.5 ft would be 7.8 acres, 21.7 acres, 28.3 acres, and 41.4 acres, respectively. Private property excluding the Town owned conservation land and open space that would be impacted by pond levels at El. 41.0 ft, El. 42.0 ft, El. 42.5 ft, and El. 43.5 ft would be 2.7 acres, 7.6 acres, 9.9 acres, and 14.5 acres, respectively.

Reservoir Dam Pond and First Herring Brook upstream of Reservoir Dam are characterized as a tributary to the Town's surface water supply and the area within 200 ft of the upper boundary of the bank is classified as a Zone A Surface Water Protection Area in accordance with the Massachusetts Department of Environmental Protection (MADEP) drinking water regulations (MADEP [a]). The Town's Water Resource Committee is currently preparing a water resource district bylaw incorporating the 200 ft buffer zone adjacent to the water supply tributaries.

Figure 5 illustrates the 200 ft buffer zone around Reservoir Dam Pond for the normal water level at El. 40.0 ft, El. 42.0 ft, and El. 44.0 ft. The total buffer zone area around Reservoir Dam Pond is 52.5 acres above normal pond El. 40.0 ft. 84.7 acres above El. 42.5 ft, and 107.3 acres above El. 43.5 ft. Deducting Town owned land from these acreages, private land impacted by this 200 ft buffer zone would be approximately 18.4 acres, 24.0 acres, 29.7 acres, 31.7 acres, and 37.5 acres for El. 40.0 ft, El. 41.0 ft, El. 42.0 ft, El. 42.5 ft, and El. 43.5 ft pond levels, respectively.



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DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
HAH	DPA	MAY 2013	62651.02	200FT BUFFER
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
TCC	TCC	1"=500'	1 OF 1	5

FIRST HERRING BROOK
SCITUATE, MASSACHUSETTS

SCITUATE WATER SUPPLY
PROPOSED 200 FOOT BUFFER ZONE
FIGURE 5

House Relocations/Modifications

There are three (3) houses off from Route 3A that are very close to the Reservoir and Tack Factory Pond (See Figure 1). Ground level around these houses is generally at El. 43.0 ft to El. 45.0 ft. Higher pond levels could increase groundwater level and the yards for these houses may have to be raised to provide some dry yard area for the owners.

For the purpose of estimating costs, this study assumes that each house would have one-half acre filled to an average depth of 1 ft, 2 ft, and 3 ft above the existing grade for Reservoir Dam Pond levels of El. 42.0 ft, El. 42.5 ft, and El. 43.5 ft. Each house would be raised and a new foundation constructed for the new grade. No property or house improvements would be necessary if normal pond level was increased only one foot to El. 41.0 ft.

Filling these properties was selected rather than flood protection dikes because the area behind dikes would be low and gravity drains would not be effective. Raising these yards would assure that the owners could use their property. This study assumes that these houses would be connected to the Town’s sewer system as discussed below.

Flood Protection Dikes

In addition to the properties identified above that would have shoreline impacts, there are five (5) houses that could be impacted by higher water levels in Reservoir Dam Pond and Tack Factory Pond. These houses, which are shown on Figure 6 and identified as #3, #4, #5, #9, and #10, could be protected by earthen dikes. The earthen dikes would be sized to prevent overtopping during normal conditions would assure that the property would be useable except during flood conditions. If normal pond level is limited to El. 41.0 ft or lower, no dikes would be required to protect these houses and property.

Assumptions relative to the extent and height of the dikes are provided in Table 9. The dikes would have an 8 ft top width and 3H:1V side slopes. The Reservoir Dam Pond side would have a 12 inch thick layer of stone riprap to prevent scour and erosion for wave action in the pond. The top and landward side of the dikes would have a grass surface. Trees and shrubbery plantings would not be allowed on the dikes.

Septic Systems and Sewer Lines

The Town’s sewer system services all houses on Country Way and extends north along Route 3A to Satuit Trail. All homes in the subdivision off from Satuit Trail including Sherman Drive

NOTES:

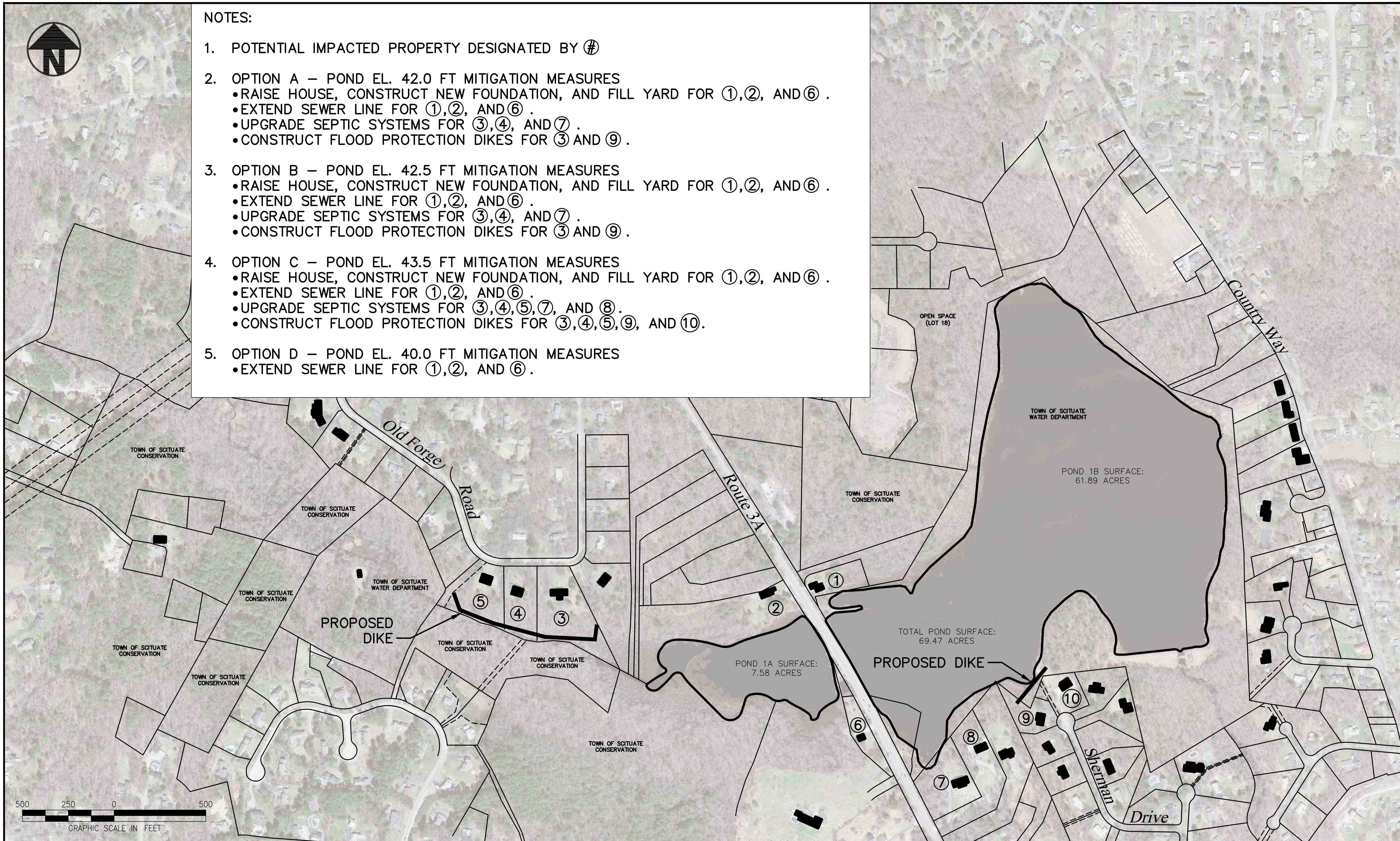
1. POTENTIAL IMPACTED PROPERTY DESIGNATED BY #

2. OPTION A – POND EL. 42.0 FT MITIGATION MEASURES
   - RAISE HOUSE, CONSTRUCT NEW FOUNDATION, AND FILL YARD FOR ①,②, AND ⑥.
   - EXTEND SEWER LINE FOR ①,②, AND ⑥.
   - UPGRADE SEPTIC SYSTEMS FOR ③,④, AND ⑦.
   - CONSTRUCT FLOOD PROTECTION DIKES FOR ③ AND ⑨.

3. OPTION B – POND EL. 42.5 FT MITIGATION MEASURES
   - RAISE HOUSE, CONSTRUCT NEW FOUNDATION, AND FILL YARD FOR ①,②, AND ⑥.
   - EXTEND SEWER LINE FOR ①,②, AND ⑥.
   - UPGRADE SEPTIC SYSTEMS FOR ③,④, AND ⑦.
   - CONSTRUCT FLOOD PROTECTION DIKES FOR ③ AND ⑨.

4. OPTION C – POND EL. 43.5 FT MITIGATION MEASURES
   - RAISE HOUSE, CONSTRUCT NEW FOUNDATION, AND FILL YARD FOR ①,②, AND ⑥.
   - EXTEND SEWER LINE FOR ①,②, AND ⑥.
   - UPGRADE SEPTIC SYSTEMS FOR ③,④,⑤,⑦, AND ⑧.
   - CONSTRUCT FLOOD PROTECTION DIKES FOR ③,④,⑤,⑨, AND ⑩.

5. OPTION D – POND EL. 40.0 FT MITIGATION MEASURES
   - EXTEND SEWER LINE FOR ①,②, AND ⑥.



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HAH	DPA	MAY 2013	62651.02	MIT. MEASURES
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
TCC	TCC	1"=500'	1 OF 1	6

FIRST HERRING BROOK
SCITUATE, MASSACHUSETTS

IMPACTED PROPERTY AND HOME MITIGATION MEASURES
FIGURE 6

are connected to the sewer system. The existing gravity sewer lines are all above the existing and proposed Reservoir Dam Pond levels being evaluated in this study and should not be affected by higher pond levels.

Properties located on Route 3A north of Satuit Trail, including Old Forge Road, have septic systems. Raising the pond level could impact septic systems and upgrades may be required to meet the MADEP Title V requirements for on-site septic systems (MADEP [b]). Upgrades to septic systems for eight (8) houses would be anticipated depending on the selected water surface elevation and are identified as #1-#8 on Figure 6. Because of the close proximity of houses #1, #2, and #6 to the pond normal water level (see Figure 1), this study assumes that the existing Town sewer system would be extended approximately 2,500 ft north of Satuit Trail along Route 3A for these houses at all pond normal levels.

Houses #3, #4, #5, #7, and #8 would require septic system upgrades depending on the normal pond level. Houses #3, #4, and #7 would require upgrades with pond El. 42.0 ft and El. 42.5 ft and all five would be upgraded with a normal pond at El. 43.5 ft. The upgrades to these systems would include installation of a new septic tank and leach field to raise the systems 3 ft and provide a 4 ft separation above groundwater which would be approximately the same elevation as the proposed pond levels. Upgrades to the septic systems for these five houses would not be necessary if normal pond remains unchanged at El. 40.0 ft or is only raised to El. 41.0 ft based on the assumption that the existing systems currently have adequate separation from groundwater.

Stormwater Collection Systems

All of the stormwater catch basins and collection systems for the roadways around Reservoir Dam Pond and Tack Factory Pond are well above pond water levels. Route 3A does not have a stormwater collection system. The Town's stormwater collection system map (CEI 2009) indicates that the stormwater collection system discharge points are above pond levels being evaluated in this study and should not be impacted by higher pond levels.

Utilities

All of the properties around Reservoir Dam Pond and Tack Factory Pond have Town water supply and have access to the National Grid gas distribution system. Water and gas lines located along Route 3A are currently below the reservoir level and should not be impacted by higher pond levels. All of the water and gas lines in other areas around the ponds are well above higher pond levels evaluated in this study and would not require any modification or upgrade for the higher pond levels.

SPILLWAY FLOW CONTROL ALTERNATIVES

Various flow control mechanism are available for retrofit on the spillway at Reservoir Dam to maintain higher reservoir levels while providing adequate discharge capacity during flood events. Flow control options include flashboards, bottom hinged crest gates, tainter gates, slide gates, roller gates, and inflatable dams.

Flashboards, bottom hinged crest gates, and inflatable dams have been selected as having the greatest potential for cost-effective application for the Reservoir Dam spillway geometry. These flow control methods all open downward and could be installed upstream of spillway crest with minimal modifications to the existing structure. Tainter, slide, and roller gates all open upward and would require major support structures and modifications to the existing spillway structure for the operating mechanisms. For that reason, these upward rising gates have been eliminated from further consideration.

A description of the spillway flow control mechanism selected for more detailed evaluation is provided in the following sections.

Flashboards

Flashboards are a non-permanent system typically installed on spillways to provide higher impoundment levels without reducing discharge capacity during flood events. Flashboards consist of wood timbers or sheeting supported by steel pins inserted into sockets in the spillway crest. The pins are either designed to fail or have shear pins that fail at specific overtopping heights, typically 1-2 ft above the flashboards depending on the spillway design. The boards are washed downstream following failure of the pins. The boards and pins are replaced after flood waters have subsided and personnel can access the spillway crest.

Sockets in the Reservoir Dam spillway crest were observed during inspection of the spillway at low reservoir levels. These sockets have a 1-3/4 inch inside dimension and are spaced at about 4 ft on-center approximately 4 ft from the upstream end of the 2 ft thick spillway apron. However, these sockets are not identified on the drawings of the dam (GAI 1984) and DPW personnel do not know the purpose of the sockets.

In order to assure that installation of flashboards does not jeopardize the structural integrity of the spillway, this study assumes that a new concrete support would be installed upstream of the existing spillway approach apron as shown on Figure 7. The new support would be 3 ft thick and 12 ft long spanning across the 42 ft spillway width. Flashboard sockets would be located at

4 ft on-center across the spillway. The pins and boards would be designed to fail at water levels one foot above the top of the boards.

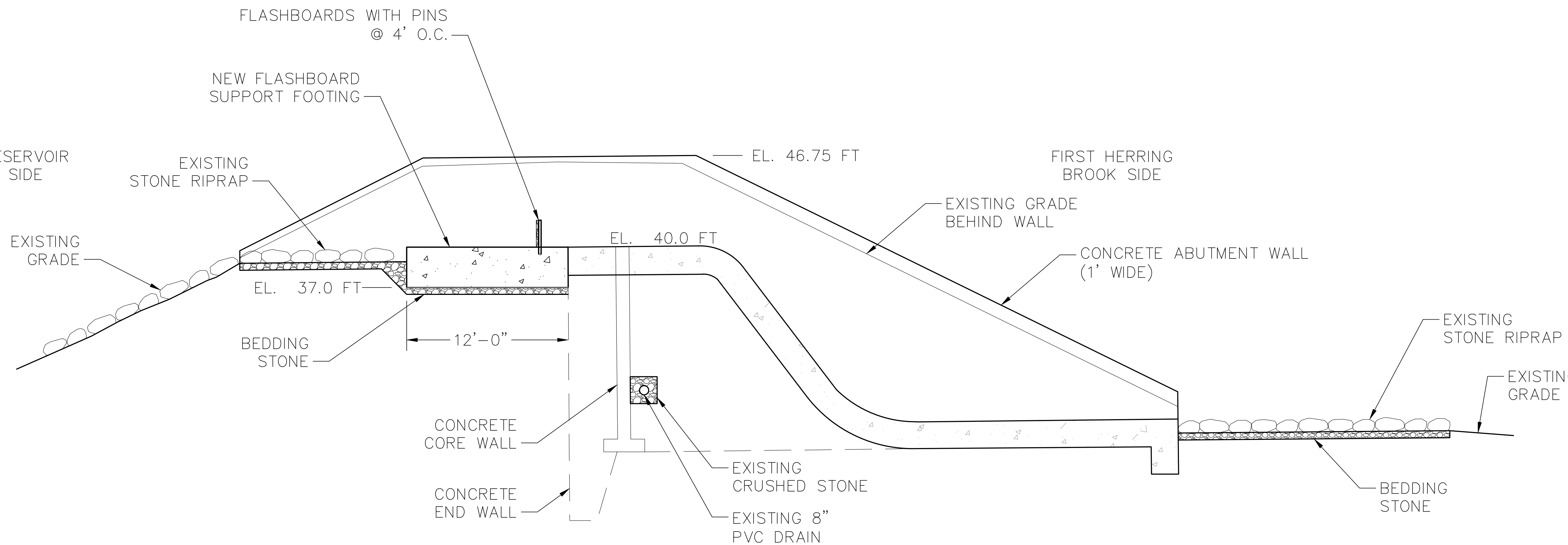
Routine inspection of the flashboards would be required following rainfall events to assure that the boards are in position to maximize storage. Inspections would be conducted by DPW personnel and would require approximately two hours per week. The boards and pins would have to be reinstalled following significant storms.

For this study, replacement of the flashboards would be necessary an average of four (4) times each year. Each time the flashboards fail, the storage lost while the flashboards are down would amount to 73.3 ac-ft with pond El. 41.0 ft, 157.5 ac-ft with pond El. 42.0 ft, and 305.4 ac-ft with pond El. 43.5 ft. This lost storage has not been accounted for in the WEAP model. The success rates for fish passage would be lower and the number of days for watering bans during the summer would be higher than simulated and presented in the earlier section of this report.

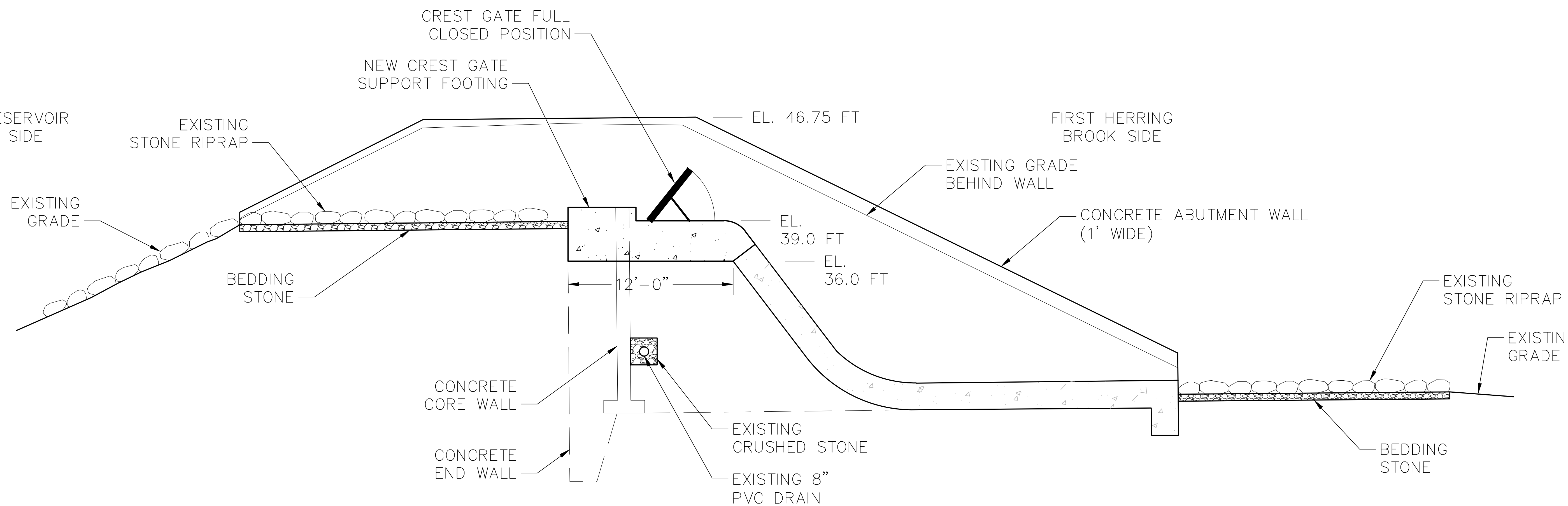
Crest Gates

Crest gates are bottom-hinged gates designed for spillways to accurately control water levels. The gates open downward and are typically positioned at the downstream end of the spillway crest. This location provides a self cleaning feature and assures debris does not prevent full opening of the gate. Crest gates can be manually operated with a hand wheel, or equipped with an electric motor operator or a hydraulic operating system. Hand wheels are typically geared for the load on the gate and require several hundred turns of the hand wheel. Motor and hydraulic operators allow automatic and remote operation controlled by water level sensor. Hydraulic operators can be design with a pressure relief valve to provide a fail-safe system for opening the gate during flood conditions and loss of power. A hydraulic system would be located in a small building adjacent to the spillway.

A bottom-hinged crest gate could be installed on the Reservoir Dam Spillway as shown on Figure 8. The spillway crest would have to be modified to incorporate a concrete footing sized to resist the hydrostatic forces on the gate without jeopardizing the stability of the spillway.



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	DESIGNED BY ---	DRAWN BY DPA	DATE JUNE 2013	PROJECT NO. 62651.02	FILE NAME FLASHBOARDS	FIRST HERRING BROOK SCITUATE, MASSACHUSETTS	SPILLWAY PROFILE WITH FLASHBOARDS FIGURE 7
	CHECKED BY ---	PROJECT MGR. TCC	SCALE 1/8"=1'	DRAWING NO. 1 OF 1	FIGURE 7		



EA ENGINEERING, SCIENCE, AND TECHNOLOGY

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
---	DPA	JUNE 2013	62651.02	CREST GATE
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
---	TCC	1/8"=1'	1 OF 1	8

FIRST HERRING BROOK
SCITUATE, MASSACHUSETTS

SPILLWAY PROFILE WITH CREST GATE
FIGURE 8

The new gate support would be doweled to the existing concrete core to eliminate a potential seepage flow path. The footing would be recessed such the face of the gate in the open position would be below the existing spillway crest to maintain the existing spillway discharge capacity. The actual gate height assumed for this study would be 6 inches higher than the height of the pond elevation above the spillway crest (i.e., a 2 ft increase in normal pond to El. 42.0 would require a 2.5 ft high crest gate.

The gate would have a single operator on the west side of the spillway to facilitate access by DPW personnel. The gate could have a manual, electric motor, or hydraulic operated. A motor or hydraulic operator would require the existing underground electric service to the low-level outlet control valve to be upgraded operated for the new electric load. An electric motor or hydraulic system would both have 5 HP motors. For this study, the power line on Sherman Drive has been assumed to be adequate for the additional load and the underground cable would only be changed out from the Sherman Drive cul-de-sac.

Steel-Fab, Inc. and Rodney Hunt, Inc. are two local crest gate manufacturers in Massachusetts. Steel-Fab provided budgetary quotations and a typical crest gate installation drawing which is provided in Appendix C. Budgetary costs for fabrication and delivery of three crest gate sizes are provided in Table 10. Costs for a crest gate sized for pond El. 41.0 ft would be comparable to the costs for the crest gate sized for pond El. 42.0 ft.

Table 10 Crest Gate Fabrication Costs

Option	Pond El. 42.0 ft	Pond El. 42.5 ft	Pond El. 43.5 ft
Manual Operator	$162,000	$174,000	$181,000
Electric Motor Operator	$170,000	$182,000	$189,000
Hydraulic Operator	$177,000	$200,000	$212,000

Inflatable Rubber Dams

Inflatable dams are constructed of a multilayer fabric with a nylon core and rubberized coating. Inflatable dams are anchored to the spillway crest and typically inflated with air to a low pressure of approximately 1 to 10 PSI to achieve the desired crest elevation. A low-pressure compressor would be used to inflate the dam and could be operated manually or equipped with an automatic control system to maintain a constant water level. The air supply system would be located in a small building adjacent to the spillway.

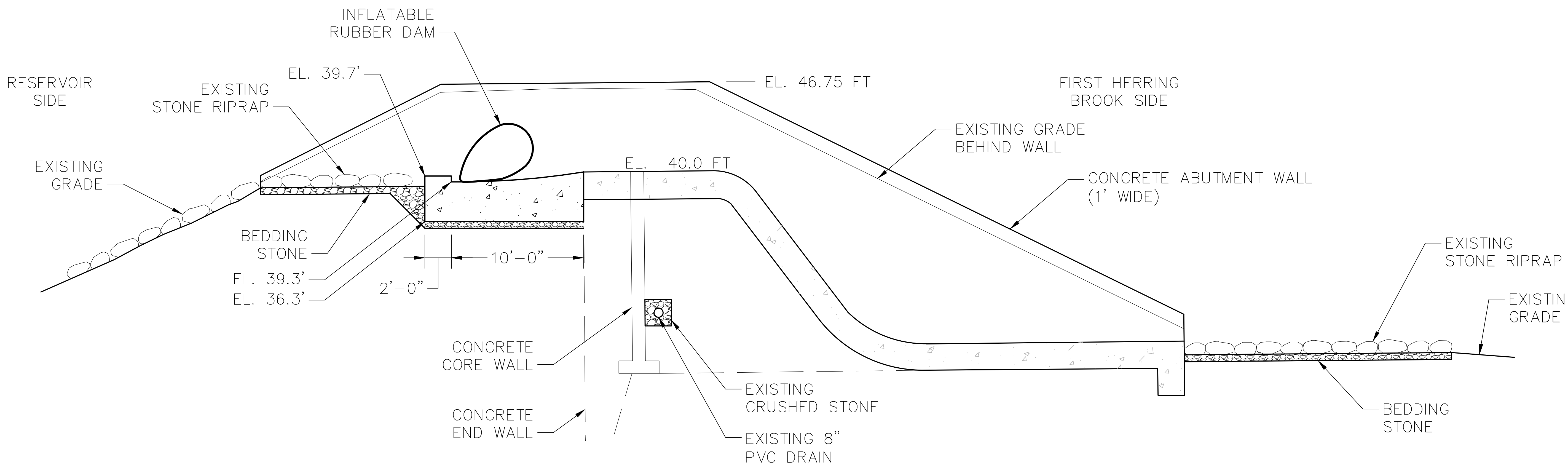
An inflatable rubber dam could be installed on the Reservoir Dam Spillway as shown on Figure 9. The spillway crest would be modified to incorporate a concrete footing sized to resist the hydrostatic forces on the inflatable dam without jeopardizing the stability of the spillway. The inflatable dam footing would be similar to the flashboard footing, but could be similar to the crest gate footing. The actual inflated dam height would be 6 inches higher than the height of the pond elevation above the spillway crest similar to the crest gate option.

The air supply system would require the existing underground electric service to the low-level outlet control valve to be upgraded operated for the new electric load similar to the crest gate. The power line on Sherman Drive has been assumed to be adequate for the additional load and the underground cable would only changed out from the Sherman Drive cul-de-sac to power the 5 HP compressor motors.

Dyrhoff, Inc., Obermeyer Hydro, Inc., and Quigdao Hua Chen Industrial Technology Co. Ltd are manufacturers of air inflatable rubber dams. Hua Chen also has a water filled inflatable dam. Atlantic Fluid Technology, Inc., a manufacturer’s representative for Dyrhoff Inc., provided budgetary quotations and a typical inflatable dam installation drawing (see Appendix D). Budgetary costs for fabrication and delivery of three inflatable rubber dam sizes are provided in Table 11. Costs for an inflatable dam sized for pond El. 41.0 ft would be comparable to the costs for the inflatable dam sized for pond El. 42.0 ft.

Table 11 Inflatable Rubber Dam Fabrication Costs

Option	Pond El. 42.0 ft	Pond El. 42.5 ft	Pond El. 43.5 ft
Inflatable Rubber Dam	$87,000	$94,000	$102,000
Air control System	$62,000	$62,000	$62,000



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	DESIGNED BY ---	DRAWN BY DPA	DATE JUNE 2013	PROJECT NO. 62651.02	FILE NAME INFLAT. DAM	FIRST HERRING BROOK SCITUATE, MASSACHUSETTS	SPILLWAY PROFILE WITH FLASHBOARDS FIGURE 9
	CHECKED BY ---	PROJECT MGR. TCC	SCALE 1/8"=1'	DRAWING NO. 1 OF 1	FIGURE 9		

DETAILED EVALUATION OF SELECTED ALTERNATIVES

Five (5) alternatives representing the different normal pond levels simulated with the WEAP model have been evaluated to identify engineering, construction, and operational issues. The alternatives were selected to represent the range of implementation costs associated with the spillway and fishway modifications, potential infrastructure costs, and annual operating and maintenance (O&M) costs.

Alternative 1 – Normal Pond El. 42.0 ft

Alternative 1 would provide additional water storage in Reservoir Dam Pond by raising the normal pool level to El. 42.0 ft with flashboards and modifying the existing fishway exit channel to incorporate a 6 inch deep notch. A new concrete footing would be installed upstream of the existing spillway approach apron to support the flashboard pins (Figure 7). The flashboards would be timber planks with pins designed to fail at pond El. 43.0 ft. The fishway exit channel notch would be 1.5 ft wide with the bottom at El. 39.5 ft. The notch would have slot for removable baffles which would be used at higher water levels. In addition, guides would be installed in the exit channel for six (6) removable baffles and for an isolation slide gate. The existing fishway weirs would be modified with removable baffles to reduce the fishway flow for effective upstream and downstream passage.

<u>Engineering Considerations.</u> The spillway flashboards would fail at stream flows of approximately 130 cfs when Reservoir Dam Pond reaches El. 43.0 ft. El. 43.0 ft is comparable to the 10-year flood level in Tack Factory Pond, but is 0.5 ft higher than Reservoir Dam Pond levels for the 500-year flood (FEMA 2012). As discussed in the section above on impacts on existing infrastructure, improvements to houses and properties upstream of Reservoir Dam would be necessary for higher normal pond levels (see Table 9). Preliminary design of a flashboard system would have to include a detailed analysis of the flood wave resulting from failure of the flashboards to determine impacts on downstream properties and identify potential mitigation measures. Even though the flood wave would be less than three feet high following failure of the flashboards, the analysis would be provide documentation for approval of the modifications by the Executive Office of Energy and Environmental Affairs (EOEEA), Office of Dam Safety (ODS).

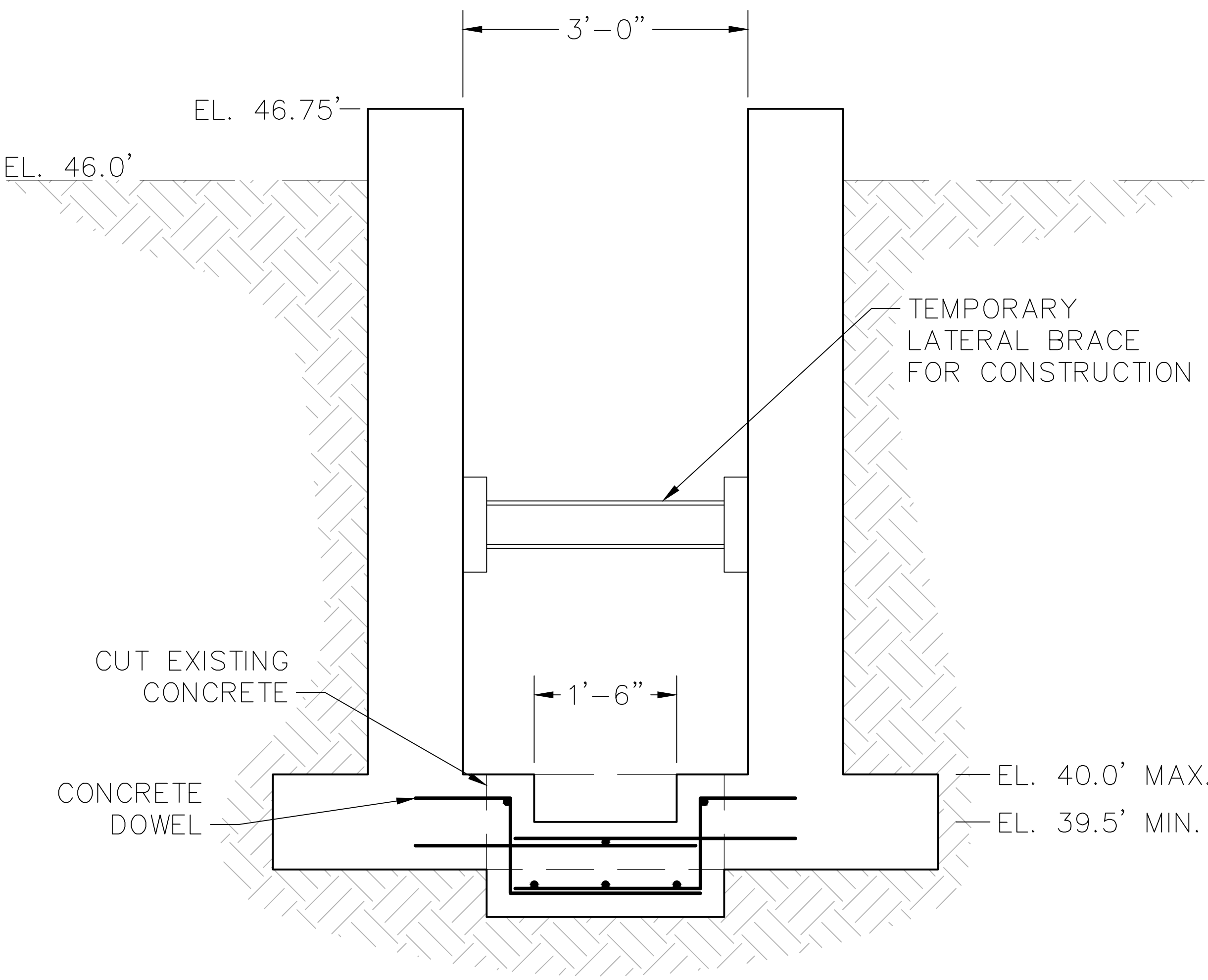
The new flashboard support footing would be designed to provide adequate factors of safety against overturning and sliding with the maximum pressure on the flashboards. The support footing would be designed to be independent of the existing spillway structure and would not impart any additional load on the approach apron or core seepage wall under the spillway.

The fishway exit channel would be modified to incorporate a 6 inch deep, 18 inch wide notch in the concrete bottom as shown on Figure 10. The modifications could be completed without excavation of dam embankment; however, lateral braces between exit channel walls would have to be installed with sawcutting of the exit channel bottom slab completed around the braces. The construction contractor would be required to submit a stability analysis of the fishway walls during construction of the notch prior to initiating any the work. The analysis should be stamped by a licensed Geotechnical Engineer.

Seven (7) Removable weirs as shown on Figure 11 would be installed in the existing fishway exit channel to meet USFWS criteria for upstream and downstream fish passage (USFWS 2010). The removable weirs would extend the operating range for the fishway from El. 40.0 ft up to El. 43.0 ft with the notches ranging between El. 39.5 ft up to El. 42.0 ft. Aluminum angles would be installed on the fishway exit walls to form support slots for the removable weirs. Slots would be incorporated in the channel bottom notch to support stoplogs in the notch at pond levels higher than El. 40.5 ft. The removable weirs would extend to El. 43.5 ft (6 inches above the maximum pond level with the spillway flashboards in place) and would have an 18 inch wide notch for upstream passage. A second set of removable weirs would have a 6 inch wide notch for downstream passage similar to the removable weirs installed at the Old Oaken Bucket Dam fishway. In addition, the removable weirs at the Old Oaken Bucket fishway would be retrofitted with new notched weirs matching the Reservoir Dam fishway weirs to reduce fishway flow during the spring migration.

A 1.5 ft wide by 4.5 ft high slide gate would be installed at the upstream end of the fishway exit channel. The slide gate frame would fit in the 3 ft wide fishway exit channel and would be anchored to the walls with concrete expansion bolt. The gate would have a manual operator with a hand wheel located at El. 50.0 ft. A walkway bridge would be installed over the spillway and the fishway exit channel to allow DPW personnel to access the isolation gate. The spillway bridge would be a pre-fabricated steel footbridge anchored to the spillway concrete abutment walls. The fishway footbridge would be a fabricated steel structure supporting grating with handrails.

The existing fishway weirs at Reservoir Dam would be modified to incorporate removable weirs similar to the Old Oaken Bucket removable weirs as shown on Figure 12. The removable weirs would reduce the fishway flow with an 18 inch notch width providing an 8 inch minimum depth during the upstream migration period and a 6 inch notch width with a 5 inch minimum depth during the downstream migration period. In addition, removable weirs with an 18 inch notch would be installed in the Old Oaken Bucket Fishway for upstream passage.



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FISHWAY MODIFICATIONS FOR EXIT CHANNEL NOTCH
FIGURE 10

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
TCC	–	DPA	–	1/2"=1'	JUNE 2013	62651.02	10

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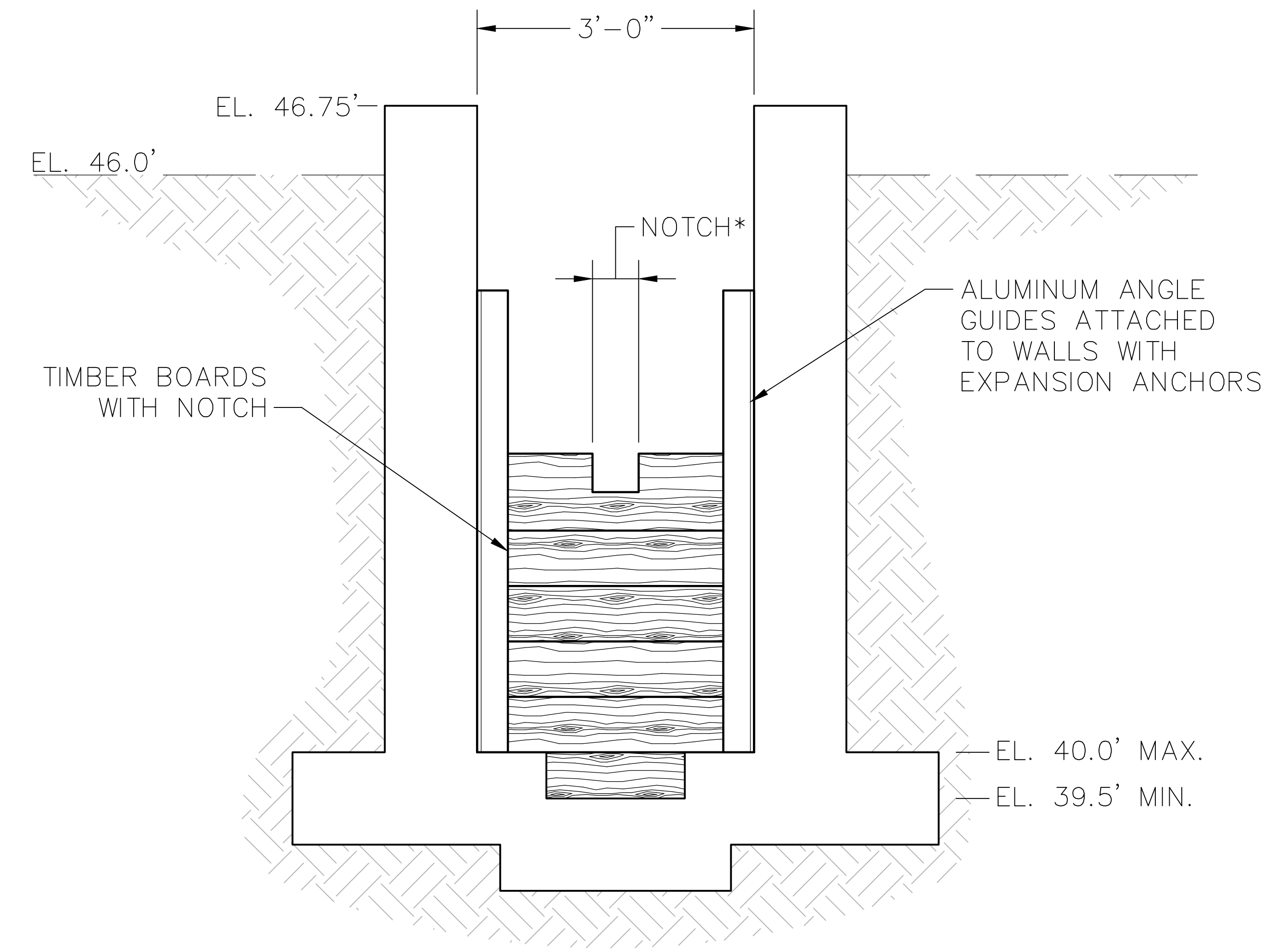

*NOTCH NOTE:
6" WIDE X 5" DEEP NOTCH
FOR DOWNSTREAM PASSAGE

18" WIDE X 8" DEEP NOTCH
FOR UPSTREAM PASSAGE

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FISHWAY MODIFICATIONS FOR
EXIT CHANNEL REMOVABLE WEIRS
FIGURE 11

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
TCC	–	DPA	–	1/2"=1'	JUNE 2013	62651.02	11

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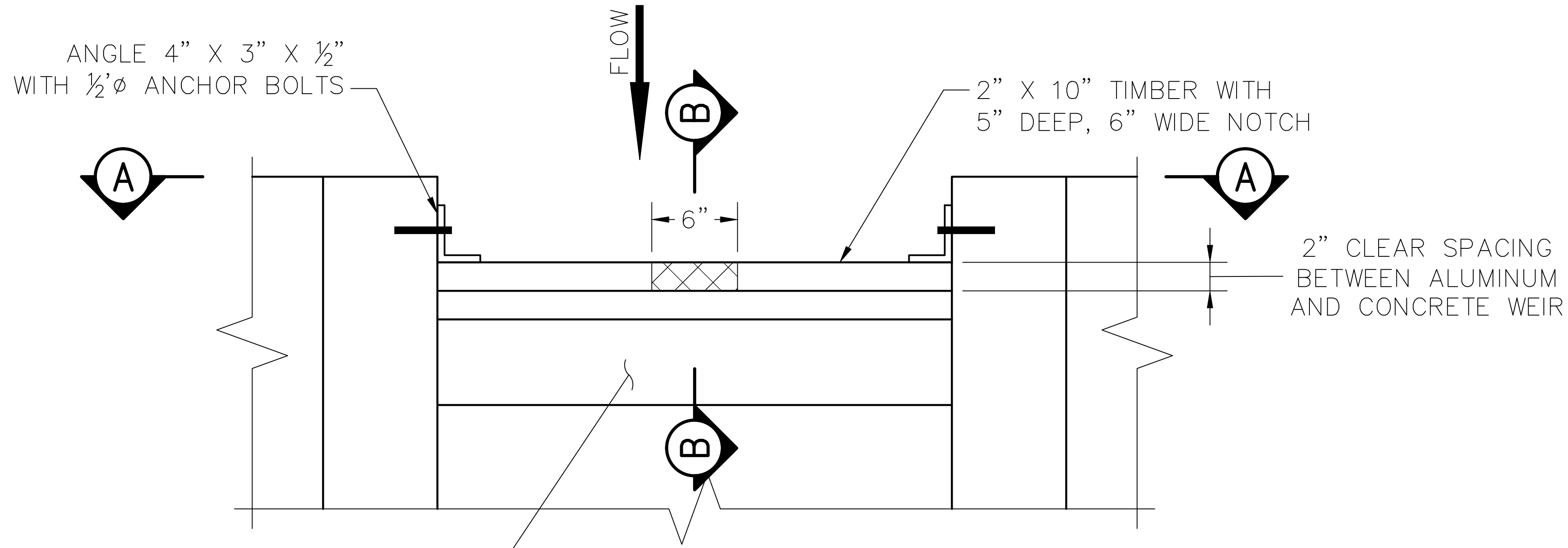
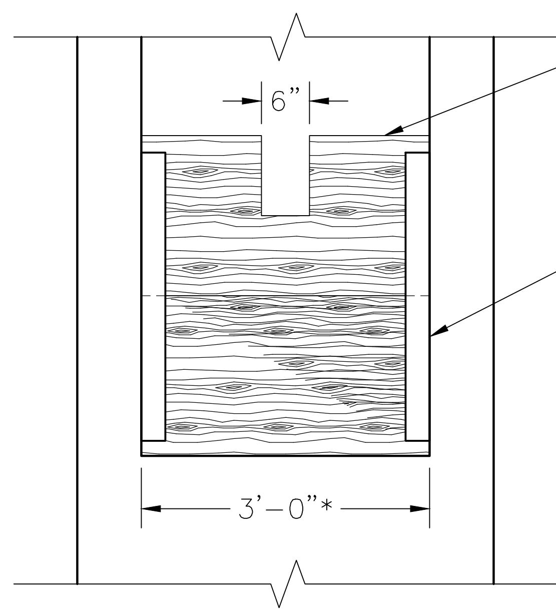


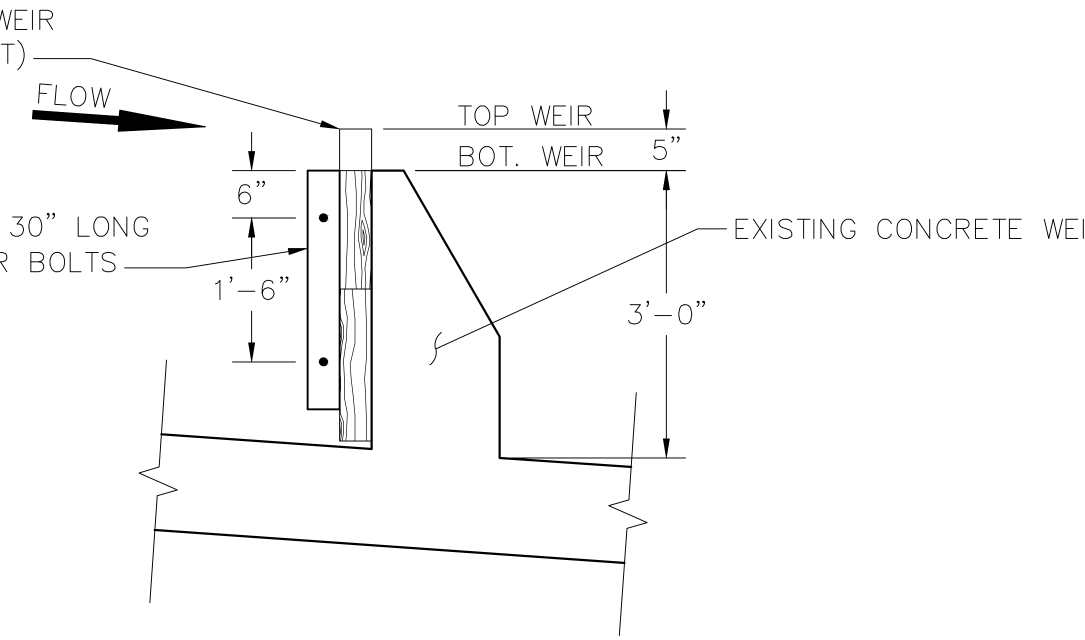
WEIR PLAN

SCALE: 1" = 1'-0"



SECTION A–A

SCALE: 1/2" = 1'-0"



SECTION B–B

SCALE: 1/2" = 1'-0"

NOTES:

1. ALL 4"X3"X½" ANGLES TO BE MARINE GRADE ALUMINUM.
2. ALL TIMBER TO BE PRESSURE TREATED, #2 OR BETTER.
3. ALL ANCHOR BOLTS TO BE STAINLESS STEEL.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	DESIGNED BY ---	DRAWN BY DPA	DATE JUNE 2013	PROJECT NO. 62651.02	FILE NAME WEIR DETAILS	OLD OAKEN BUCKET DAM FISHWAY SCITUATE, MASSACHUSETTS	TYPICAL FISHWAY CONCRETE WEIR MODIFICATIONS FIGURE 12
	CHECKED BY ---	PROJECT MGR. TCC	SCALE AS SHOWN	DRAWING NO. 1 OF 1	FIGURE 12		

The stream channel downstream of the Reservoir Dam fishway entrance would be reconfigured to create acceptable hydraulic conditions for fish to reach the fishway entrance and the proper water depth in the fishway entrance. The approach channel would be a roughened rock ramp with stone weirs creating several pools (Figure 13). Existing stones in the stream would be used to create channel velocities less than 5 ft/sec and pools with a vertical height through low flow notches of less than 8 inches.

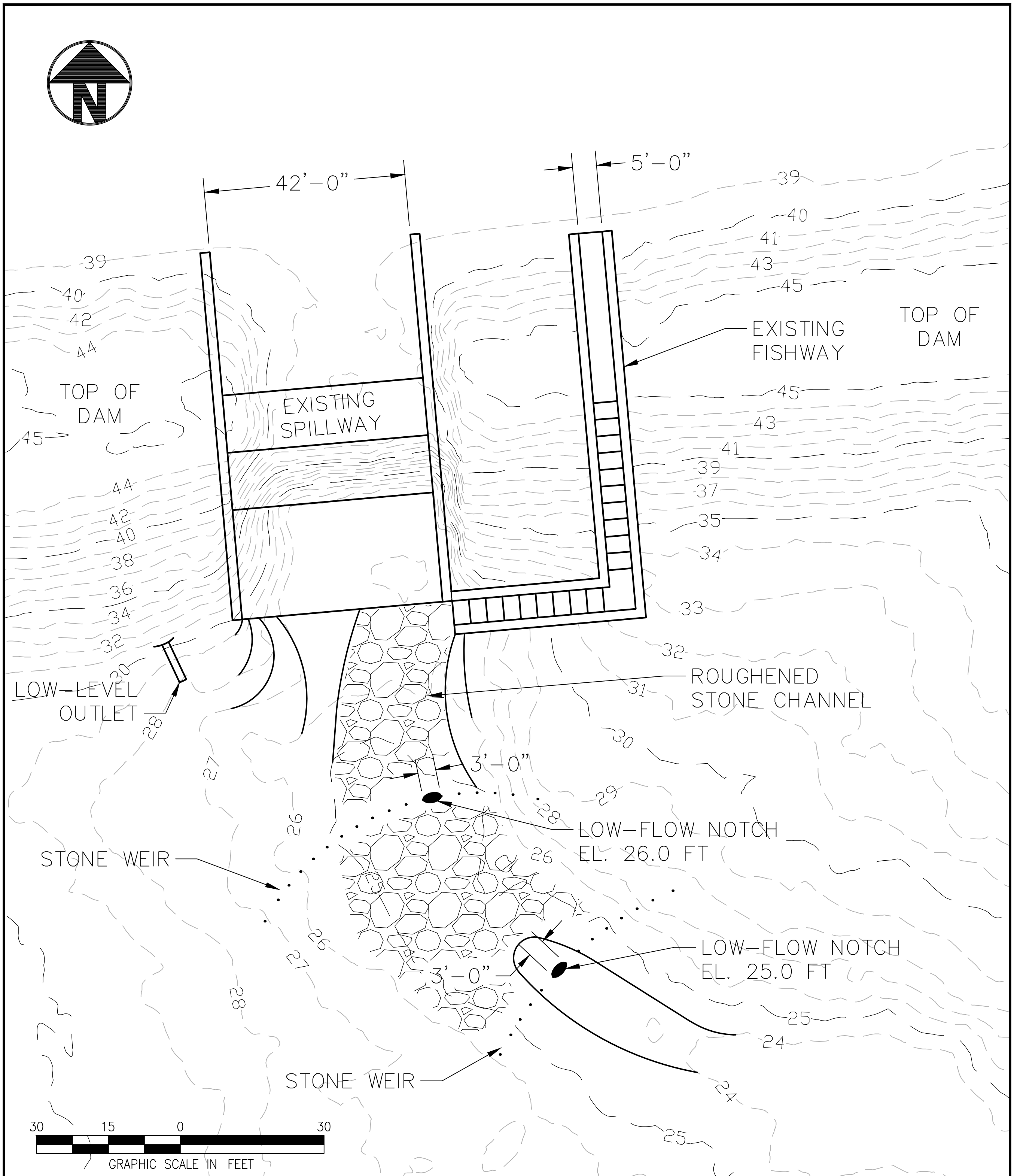
Modification to the dam, spillway, and fishway would require the following permits:

- US Army Corps of Engineers (USACE) Section 404 General Permit
- Massachusetts Section 401 Water Quality Certification
- National Heritage Endangered Species Program (NHESP) and US Fish and Wildlife Service Section 7 consultation
- Massachusetts Historical Commission National Historical Preservation Act (NHPA) Section 106 consultation
- Massachusetts Wetlands Protection Act Order of Conditions from Scituate Conservation Commission
- Massachusetts Chapter 253 Dam Safety Permit
- Massachusetts Endangered Species Act (MESA) consultation with Massachusetts Division of Marine Fisheries (DMF) and Division of Fisheries and Wildlife (DFW).

A Massachusetts Chapter 91 Waterway Permit is not anticipated since the proposed changes would not impact any jurisdictional areas identified in 310 CMR 9.04.

Construction Considerations. Access to the Reservoir Dam spillway would be through the Town's easement from Sherman Drive. Construction staging and material stockpiling areas would be located downstream of the dam embankment. A temporary chain link security fence would be installed around the staging/stockpile areas. A temporary gravel road surface would be installed between Sherman Drive and staging/stockpile areas. A temporary travel surface would also be installed along the top of the earthen dam for equipment to access the spillway. A temporary stone bed crossing the stream would be installed to access the fishway entrance. Silt fence would be installed along the wetlands downstream of the dam and a turbidity curtain installed across the stream to minimize impacts on water quality during construction.

Approximately two weeks would be required to prepare the site and install the temporary construction components. All temporary facilities would be removed at the completion of construction and the site restored to the pre-construction conditions. Site cleanup and restoration would require a two week period.



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FISHWAY ENTRANCE APPROACH CHANNEL MODIFICATIONS
FIGURE 13

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
TCC	-	DPA	-	1"=30'	JUNE 2013	62651.02	13

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All work on the spillway and the fishway would be completed during a low flow period with reservoir lowered to El. 35.0 ft. Construction would be scheduled for the late summer and fall period when flows are normally low. Lowering of the pond for construction of the spillway and fishway modifications would have minimal impact on the fisheries in Reservoir Dam Pond since the water levels are currently drawing down with the IOP. The low-level outlet would be used to maintain the pond at a low level eliminating the need for cofferdams. Flow releases through the low-level outlet would also maintain the stream habitat downstream from Reservoir Dam. The low-level outlet is located above the reservoir bottom and sediment transport through the low-level outlet would be minimal and similar to the current operation.

Approximately 6 weeks would be required to remove the stone approach apron to the spillway and construct the flashboard support footing. Modifications to the fishway exit channel would be scheduled to coincide with the spillway modifications to minimize the construction period and allow refilling of the pond as soon as possible. The flashboards and fishway weirs would be installed after the new concrete support has cured 14 days, but hydrostatic loads would not be allowed for another 14 days until the concrete has reached design strength. The overall construction period would be approximately 12 weeks.

<u>Operational Considerations.</u> During the spring and fall fish migration periods, all flow would be conveyed through the modified fishway at pond levels between El. 40.0 ft and El. 43.0 ft. At pond levels below El. 40.0 ft, DPW personnel would operate the low-level outlet valve to provide the water demand and environmental flow agreed upon for First Herring Brook downstream of Reservoir Dam. During rainfall events when the pond rises to El. 43.0 ft, the flashboards would fail restoring the spillway to its original design capacity. DPW personnel would have to install replacement flashboards and pins after storm flows recede and water levels drop to the existing spillway crest level and conditions are safe for work on the spillway crest. For this study, failure of the flashboards has been assumed to average four times each year requiring a two person crew and one day to prepare and install replacement boards each time.

During non-migration periods, the fishway isolation gate would be closed and the low-level outlet operated for all water supply and environmental releases. Prior to the spring migration period and opening of the isolation gate, the fishway would have to be inspected for damage and the 18 inch wide notched removable weirs installed in the exit channel and pool and weir sections of the fishway. The removable weirs in the fishway exit would have to be installed and removed during April and May to follow the pond level in 0.5 ft increments. Monitoring of the pond levels would initially be conducted on a daily basis. As DPW personnel gain knowledge of the new operational guidelines, water level monitoring would be adjusted to a frequency consistent with the monitoring effort currently being implemented for the IOP. For this study, adjustment of the removable weirs would be necessary on a weekly basis on average and would require a two person crew 2 hours to adjust and inspect the weirs each time.

In June, the isolation gate would be closed and the 6 inch wide notch weirs installed in the exit channel and fishway weirs. At the beginning of September, the isolation gate would be opened and the removable weirs adjusted to track changes in Reservoir Dam Pond levels and conserve as much water as possible. Weekly adjustment of the removable weirs has also been assumed during September-October out-migration period, but would be dependent on hydrologic conditions. In November after out-migration, the isolation gate would be closed and all releases would be controlled through the low-level outlets.

Alternative 2 – Normal Pond El. 42.5 ft

Alternative 2 would consist of installing a hydraulic operated crest gate on the existing spillway to raise the normal pool level to El. 42.5 ft and modifying the existing fishway exit channel to incorporate ad 6 inch deep notch. The existing spillway would be modified to incorporate a new concrete footing for the gate (Figure 8). The top of the gate in the full open position would be El. 39.5 ft. The hydraulic actuator would be controlled by a water level sensor to maintain the pond level at the top of the gate. The fishway exit channel notch and removable baffles would be similar to Alternative 1 except six (6) removable baffles would be required for the higher pond level and the El. 40.0 ft to El. 42.5 ft fishway operating range.

Engineering Considerations. The fishway and/or the low-level outlet would be used to discharge water for irrigation demand and environmental flows at pond levels below El. 42.5 ft when spillway crest gate would fully closed. The hydraulic actuator would automatically position the gate to maintain a constant pond level at the top of the gate with a level sensor. When stream flows exceed the low-level outlet and fishway capacity, the gate would begin to open to maintain the pond at El. 42.5 ft. With the gate in the full open position, the current spillway discharge capacity would remain unchanged. The gate could be remotely lowered from the Water Department’s office in anticipation of significant rainfall to provide flood storage. As flood flows recede, the gate would be automatically close to store as much water as possible.

Normal pond El. 42.5 ft is comparable to the 500-year flood level in Reservoir Dam Pond, but is 0.5 ft higher than Tack Factory Pond levels for the 10-year flood (FEMA 2012). Improvements to houses and properties upstream of Reservoir Dam would be necessary for higher normal pond levels (see Table 9). A detailed analysis of downstream flooding with opening of the gate would not be necessary since gate operation would allow controlled releases and would not change the existing spillway outflow hydrograph.

The new crest gate support foundation would be designed to provide adequate factors of safety against overturning and sliding with the maximum pressure on the gate. The location of the gate would require the support footing to be designed as an integral part of the existing spillway structure. Preliminary design would require a detailed stability analysis to document acceptable factors of safety. Approval by ODS would be required for any modifications to the spillway and dam.

Fishway exit channel modifications and removable weir, existing fishway weir modifications, channel improvements at the fishway entrance, and permitting considerations for Alternative 2 would be similar to the modifications for Alternative 1.

Construction Considerations. Construction access, staging/stockpile area, and erosion and sediment control measures for Alternative 2 would be similar to Alternative 1. All work on the spillway and the fishway would be completed during a low flow period with reservoir lowered to El. 35.0 ft with all water demand released through the low-level outlet. Approximately 8 weeks would be required to remove the top portion of the spillway and construct the new gate support structure including the first two weeks of concrete curing time. An additional two weeks would be required to install the gate and hydraulic control system. A truck-mounted crane positioned on the dam would lift the crest gate into position on the new spillway crest.

Fishway modifications would be scheduled to coincide with the spillway modifications minimizing the construction period. Pond levels would remain below the gate until all concrete has cured and reached the 28 day design strength. The overall construction period would be approximately 14 weeks.

Operational Considerations. Operation of the fishway with the crest gate would be the same as described for Alternative 1. During the spring and fall fish migration periods, all flow would be conveyed through the modified fishway at pond levels between El. 40.0 ft and El. 42.5 ft. At pond levels below El. 40.0 ft, DPW personnel would operate the low-level outlet valve to provide the water demand and environmental flow agreed upon for First Herring Brook downstream of Reservoir Dam. During rainfall events when the pond rises to El. 42.5 ft, the crest gate would be opened as needed to maintain pond El. 42.5 ft. The crest gate would be remotely operated from DPW's office. Water level sensors would monitor the pond elevation and would interface with the crest gate control system. DPW personnel would also have the ability to lower the gate in anticipation of flood conditions.

Routine inspection and maintenance of the crest gate would be necessary to assure acceptable operation. Weekly inspection of the gate and hydraulic actuator system would require a two person DPW crew 2 hours per week (200 hours per year).

Alternative 3 – Normal Pond El. 43.5 ft

Alternative 3 would consist of installing inflatable rubber dam hydraulic operated crest gate on the existing spillway to raise the normal pool level to El. 43.5 ft and modifying the existing fishway exit channel to incorporate ad 6 inch deep notch. The existing spillway would be modified to incorporate a new concrete footing for the gate (Figure 9). The top of the gate in the full open position would be El. 39.5 ft. The air supply system would be controlled by a water level sensor to maintain the pond level at the top of the rubber dam. The fishway exit channel notch and removable baffles would be similar to Alternative 2 except eight (8) removable baffles would be required for the higher pond level and the El. 40.0 ft to El. 43.5 ft fishway operating range.

Engineering Considerations. The inflatable rubber dam would be used to maintain the normal pond at El. 43.5 ft. The fishway and/or the low-level outlet would be used to discharge water for irrigation demand and environmental flows at pond levels below El. 42.5 ft when spillway rubber dam would be fully inflated in the full closed position. When stream flows exceed the low-level outlet and fishway capacity with a full pond, the air supply system would deflate the rubber dam to maintain the pond at El. 42.5 ft. With the rubber dam fully deflated, the current spillway discharge capacity would remain unchanged. The inflated rubber dam gate could be remotely lowered from the Water Department's office in anticipation of significant rainfall to provide flood storage. As flood flows recede, the gate would be automatically close to store as much water as possible.

Normal pond El. 43.5 ft is 1 ft higher than the 500-year flood level in Reservoir Dam Pond, but is comparable to the 50-year flood level in Tack Factory Pond levels (FEMA 2012). Improvements to houses and properties upstream of Reservoir Dam would be necessary for higher normal pond levels (see Table 9). A detailed analysis of downstream flooding with opening of the gate would not be necessary since inflatable rubber dam operation would allow controlled releases and would not change the existing spillway outflow hydrograph.

The inflatable rubber dam design consideration would to similar to the crest gate alternative. A support foundation would be constructed upstream of the existing spillway approach apron similar to the flashboard Alternative 1. Spillway modifications would have to be approved by ODS.

Fishway exit channel modifications and removable weir, existing fishway weir modifications, channel improvements at the fishway entrance, and permitting considerations for Alternative 3 would be similar to the modifications for Alternative 1.

Construction Considerations. Installation of the inflatable rubber dam and modifications to the fishway would be similar to the Alternative 2 Crest Gate.

Operational Considerations. Operation of the inflatable rubber and fishway would be identical to operation of the Alternative 2 crest gate and fishway.

Alternative 4 – Normal Pond El. 40.0 ft

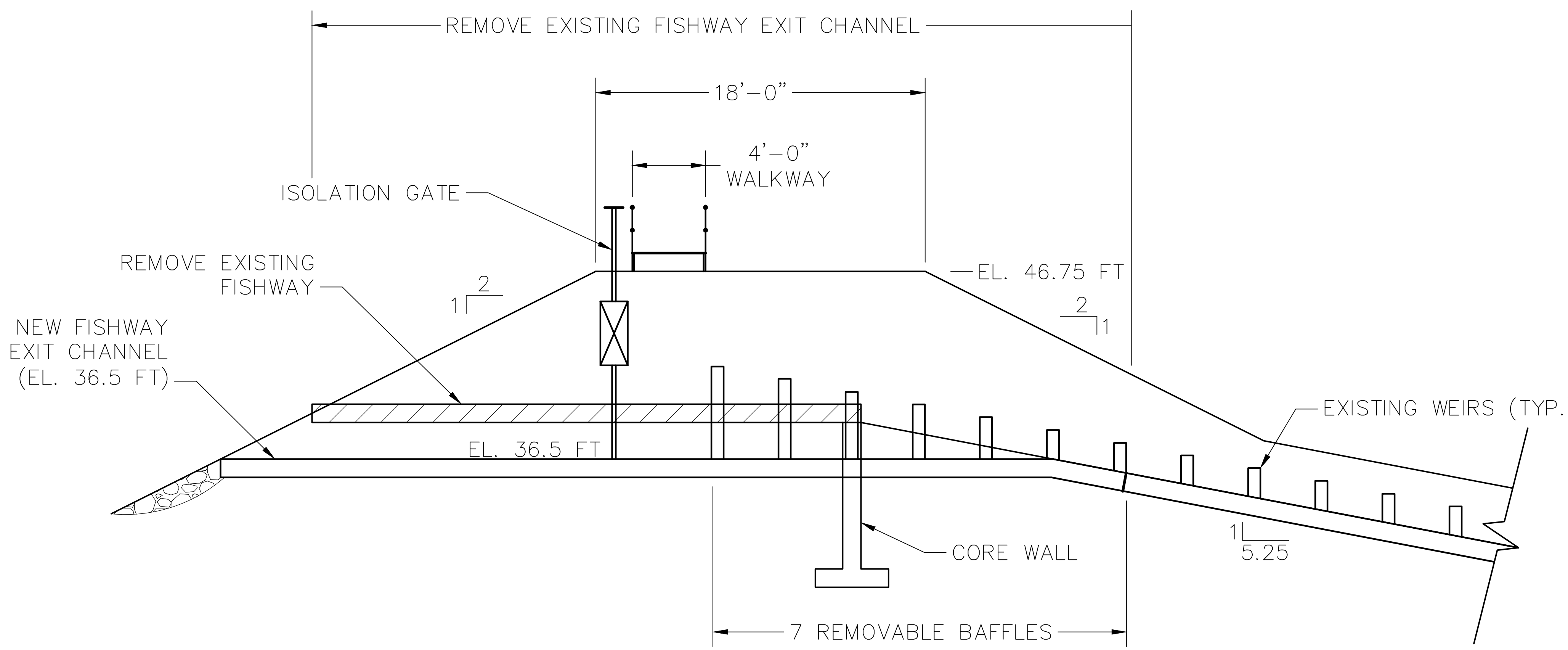
Alternative 4 would not require any spillway modifications, but would consist of reconstructing the fishway exit channel with the bottom at El. 36.5 ft. As shown on Figure 14, three of the existing fishway concrete weirs would be removed for the lower exit channel elevation and replaced by seven (7) removable weirs in the new exit channel to provide fish passage at pond levels ranging from El. 37.0 ft up to El. 40.0 ft. The remainder of the existing fishway concrete weirs would be retrofitted with removable weirs and the fishway entrance approach channel modified similar to Alternatives 1-3.

Engineering Considerations. Maintaining the normal pond El. 40.0 ft at Reservoir Dam eliminates all modifications to the spillway and all impacts on the houses, properties, and infrastructure around Reservoir Dam Pond. DPW would use the fishway and/or the low-level outlet to discharge water for irrigation demand and environmental flows at pond levels below the spillway crest El. 40.0 ft similar to the current operations. There would be no change in flood levels for this alternative.

Modification to the fishway exit channel would require removal of the dam embankment down to El. 34.5 ft on each side of the fishway and complete removal of the fishway exit channel and top three pools (Figure 13). The existing concrete core would be sawcut to El. 35.5 ft.

A 12 inch thick layer of bedding material would be placed on the existing dam material and a new concrete slab poured for the fishway exit channel with a finished grade at El. 36.5 ft. The new fishway concrete walls would be constructed with removable weir guide slots. The earthen dam would then be reconstructed to the existing top grade, riprap erosion protection installed on the upstream face, and the top and downstream slope seeded.

The new fishway exit channel would have removable weirs, an isolation gate, and a walkway bridge similar to the previous alternatives. A new walkway bridge across the spillway would be installed to facilitate access to the fishway isolation gate and installation of removable weirs.



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	DESIGNED BY ---	DRAWN BY DPA	DATE JUNE 2013	PROJECT NO. 62651.02	FILE NAME EXIT CHANNEL	FIRST HERRING BROOK SCITUATE, MASSACHUSETTS	NEW FISHWAY EXIT CHANNEL WITH BAFFLES FIGURE 14
	CHECKED BY ---	PROJECT MGR. TCC	SCALE 1/8"=1'	DRAWING NO. 1 OF 1	FIGURE 14		

The remaining concrete weirs in the existing fishway and the stream channel modifications at the fishway entrance would be similar to Alternatives 1-3. Permits for only modifying the fishway would be similar to the previous alternatives although the level of effort to complete the applications and consultations would not be as extensive as Alternatives 1-3 with the spillway modifications.

Construction Considerations. Access to the Reservoir Dam spillway would through the Town's easement from Sherman Drive. Construction staging and material stockpiling areas would be located downstream of the dam embankment and existing fishway and would have a temporary security fence. A gravel access road would be constructed from Sherman Drive and a temporary stone bed crossing the stream installed to access the fishway. Silt fence would be installed along the entire access road and construction area with a turbidity curtain installed across the stream to minimize impacts on water quality.

Approximately two weeks would be required to prepare the site and install the temporary construction components. All temporary facilities would be removed at the completion of construction and the site restored to the pre-construction conditions. Site cleanup and restoration would require a two week period.

All work on the fishway would be completed during a low flow period with reservoir lowered to El. 35.0 ft similar to Alternatives 1-4. Approximately 10 weeks would be required to excavate the earthen embankment and construct new fishway exit channel including a 28 day curing period for the concrete to reach design strength. Modifications to the existing concrete weirs and the stream channel at the fishway entrance would be completed while the concrete was curing. Reconstructing the earthen embankment, placing the stone riprap on the upstream face, seeding the embankment would require an additional two (2) weeks resulting in a 14 week construction period.

Operational Considerations. Operation of the fishway with the lower exit channel would be similar to the previous alternatives. Weekly inspection and adjustment of the weirs would be necessary by DPW personnel.

Alternative 5 – Normal Pond El. 41.0 ft

Alternative 5 would consist of installation of one foot high flashboards on the existing spillway and reconstructing the fishway exit channel with the bottom at El. 36.5 ft similar to Alternative 4 and shown on Figure 14. The fishway concrete weir and entrance approach channel modifications would be similar to the previous alternatives. Ten (10) removable weirs would be installed in the new fishway exit channel for fish passage at pond levels between El. 37.0 ft and El. 42.0 ft.

Engineering Considerations. The existing spillway concrete apron at Reservoir Dam would be adequate to support one foot high flashboards eliminating the need for any structural modifications to the spillway. The existing 1-3/4 inch sockets on the spillway approach apron, which are spaced at 4 ft on center, would be used for pins to support the flashboards. A normal pond at El. 41.0 ft for Reservoir Dam would not have any impact on houses, properties, and infrastructure around Reservoir Dam Pond (see Table 9). DPW would use the fishway and/or the low-level outlet to discharge water for irrigation demand and environmental flows at pond levels below the spillway crest El. 40.0 ft similar to the current operations.

Normal pond El. 41.0 ft would be comparable to the 10-year flood level in Reservoir Dam Pond, but 2.0 ft lower than Tack Factory Pond 10-year flood levels (Reference 5). The flashboards would be designed to fail at pond El. 42.0 ft. Preliminary design of a flashboard system would have to include a detailed analysis of the flood wave resulting from failure of the flashboards to determine impacts on downstream properties and document that failure of the flashboards would not increase flooding hazards to downstream properties.

Modification to the fishway exit channel, fishway weirs, and fishway entrance approach channel would be identical to Alternative 4.

Construction Considerations. Construction techniques and sequencing for modifying the fishway exit channel would be identical to Alternative 4. Installation of the flashboards would coincide with the fishway modifications.

Operational Considerations. Operation of the fishway with the lower exit channel and one foot high flashboards would be identical to Alternative 4 similar to the previous alternatives. Weekly inspection and adjustment of the removable weirs would be necessary during the upstream and downstream migration periods. Replacement of the flashboards subsequent to significant rainfall has been assumed to average four times each year similar to Alternative 1.

IMPLEMENTATION COSTS

Probable construction costs for implementing the preferred alternatives evaluated above have been estimated using construction industry and comparable project cost data. The costs are considered order of magnitude estimates suitable for identifying a cost-effective plan to improve fish passage on First Herring Brook and for budgetary planning purposes. The costs include modifications to the spillway and fishway at Reservoir Dam and improvements to the infrastructure components impacted by higher reservoir levels.

Table 12 presents the estimated cost for construction, engineering, permitting, and annual operating and maintenance (O&M) associated with the alternatives selected for detailed evaluation of Reservoir Dam Pond levels at El. 42.0 ft, El. 42.5 ft, and El. 43.5 ft. Table 13 presents the same costs for alternatives with El. 40.0 ft and El. 41.0 ft. A detailed cost breakdown is provided in Appendix E.

The costs reflect the project features described above for each of the alternatives. The costs assume fully-contracted rates by General Contractor for construction of all components associated with each alternative for the DPW. A 25% contingency factor has been added to the construction costs to account for uncertainties at this level of design. The contingency factor reflects a 10% allowance for indeterminants for items that are known to exist, but are not included in the estimate, and a 15% contingency for unforeseeable events that may affect the construction cost. Annual O&M costs are based on the amount of labor to complete the routine inspections and maintenance expected for each alternative.

Table 12 Estimated Costs for Implementation of Selected Alternatives

Cost Item	Alternative		
	1 Pond Level El. 42.0 ft	**2 Pond Level El. 42.5 ft**	**3 Pond Level El. 43.5 ft**
Mobilization/Demobilization	**$132,000**	**$187,000**	**$235,000**
Temporary Construction Facilities	**$27,000**	**$27,000**	**$34,000**
Spillway Modifications			
Flashboard/Crest Gate/Inflatable Dam Support	$14,000	$77,000	$14,000
Flashboard/Crest Gate/Inflatable Dam	$11.000	$237,000	$201,000
Subtotal	**$25,000**	**$314,000**	**$215,000**
Fishway Modifications			
Exit Channel Notch	$23,000	$23,000	$23,000
Exit Channel Removable Baffles	$26,000	$34,000	$48,000
Exit Channel Isolation Slide Gate	$71,000	$71,000	$71,000
Weir Modifications	$26,000	$26,000	$19,000
Entrance Channel Improvement	$13,000	$13,000	$13,000
Subtotal	**$159,000**	**$167,000**	**$174,000**
Infrastructure Improvements			
Route 3A	$88,000	$213,000	$374,000
Sewer Extension	$572,000	$572,000	$572,000
Septic System Upgrades	$192,000	$192,000	$320,000
Property Protection Dikes	$37,000	$37,000	$189,000
Structure Modifications	$223,000	$345,000	$467,000
Property Compensation	$0	$0	$0
Subtotal	**$1,112,000**	**$1,359,000**	**$1,922,000**
Total Construction Costs	**$1,455,000**	**$2,054,000**	**$2,580,000**
Contingency (25%)	**$364,000**	**$514,000**	**$645,000**
Subtotal Probable Construction Costs	**$1,821,000**	**$2,568,000**	**$3,225,000**
Engineering, Design, and Permitting Costs (8%)	**$146,000**	**$205,000**	**$259,000**
Construction Management (5%)	**$91,000**	**$128,000**	**$161,000**
Total Project Cost	**$2,058,000**	**$2,901,000**	**$3,645,000**
Annual O&M Costs	**$20,000**	**$15,000**	**$15,000**

Table 13 Estimated Costs for Implementation of Selected Alternatives

Cost Item	Alternative	
	4 Pond Level El. 40.0 ft	**5 Pond Level El. 41.0 ft**
Mobilization/Demobilization	**$84,000**	**$86,000**
Temporary Construction Facilities	**$27,000**	**$27,000**
Spillway Modifications		
Flashboard/Crest Gate/Inflatable Dam Support	$0	$0
Flashboard/Crest Gate/Inflatable Dam	$0	$7,000
Subtotal	**$0**	**$7,000**
Fishway Modifications		
Exit Channel Notch	$107,000	$107,000
Exit Channel Removable Baffles	$26,000	$38,000
Exit Channel Isolation Slide Gate	$71,000	$71,000
Weir Modifications	$24,000	$24,000
Entrance Channel Improvement	$13,000	$13,000
Subtotal	**$241,000**	**$253,000**
Infrastructure Improvements		
Route 3A	$0	$0
Sewer Extension	$572,000	$572,000
Septic System Upgrades	$0	$0
Property Protection Dikes	$0	$0
Structure Modifications	$0	$0
Property Compensation	$0	$0
Subtotal	**$572,000**	**$572,000**
Total Construction Costs	**$924,000**	**$945,000**
Contingency (25%)	**$231,000**	**$236,000**
Subtotal Probable Construction Costs	**$1,155,000**	**$1,181,000**
Engineering, Design, and Permitting Costs (8%)	**$93,000**	**$95,000**
Construction Management (5%)	**$58,000**	**$59,000**
Total Project Cost	**$1,306,000**	**$1,335,000**
Annual O&M Costs	**$10,000**	**$15,000**

RECOMMENDATIONS

Comparison of the fish passage success and the estimated costs for the five (5) alternatives evaluated for each of the pond levels and fishway configurations indicate that Alternative 5 with lower fishway exit channel at El. 36.5 ft and one foot high flashboards is most cost-effective option with the least impact on infrastructure. All of the alternatives have good fish passage success with water ban trigger points providing watering restrictions consistent with the existing IOP. The Scituate DPW should prepare a preliminary design of the fishway modifications to lower the exit channel to El. 36.5 ft and improve the existing pools and weirs.

The phased approach described below is recommended for restoring fish passage at Reservoir Dam:

1) Implementation of the water protection district bylaw defining the buffer zone around the tributary to the Old Oaken Bucket Zone A surface water supply. This bylaw will dictate the costs associated with mitigation measures associated with properties adjacent to Reservoir Dam Pond.

2) Discuss the study results with DMF and finalize acceptable fish passage criteria for design of the lower fishway exit channel and the pool and weir modifications.

3) Discuss fishway modifications with ODS and develop design criteria for the dam modifications. Calculations should be prepared to finalize and document:
    - ½ PMF design storm.
    - Adequate spillway capacity and freeboard with the design storm.
    - Stability analysis of spillway with one foot high flashboards
    - Lower fishway exit channel stability analysis.
    - Lower fishway exit channel structural calculations

4) Meet with the private property owners around Reservoir Dam Pond and Tack Factory Pond to discuss the project and obtain their input.

5) Conduct a public meeting to present the plan to the entire Town.

6) Prepare a preliminary design of fishway modifications at Reservoir Dam with a lower exit channel to refine the cost estimate and seek funding for implementing the fishway and spillway modifications. Preliminary design should include:
    - Detailed survey of dam embankment, fishway, spillway, and downstream approach channel to fishway entrance.
    - A preliminary design drawing package showing plans, profiles, and typical sections for modification to the spillway, fishway, and stream channel modifications.
    - Revised cost estimate for the fishway and spillway modifications.

The preliminary design should also address flow control and personnel access to change the removable notched weirs at the Old Oaken Bucket fishway for the upstream and downstream migration periods.

7) Obtain funding sources to finance the project design and construction

8) Prepare detailed design, construction drawings, and specifications for the lower fishway exit channel and fishway modifications.

9) Prepare and file permit applications for the proposed project.

All of these tasks could be sequenced to meet available funding sources.

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APPENDIX A

½ PMF DERIVATION

APPENDIX A
PROBABLE MAXIMUM FLOOD COMPUTATION

Methodology

The probable maximum flood (PMF) for a watershed is defined as the flood which occurs during the probable maximum precipitation (PMP) event. "Design of Small Dams", published by U.S. Department of the Interior, Bureau of Reclamation, defines this precipitation amount to be approximately 23.5 inches near Scituate, MA for the 6-hour storm event. Precipitation values can be adjusted for longer storm durations (12-hour, 24-hour, etc.) using appropriate figures in Design of Small Dams.

The Natural Resources Conservation Service (NRCS) hydrologic curve number (CN) method, as outlined in Technical Release 55 (TR-55), and Hydrology and Floodplain Analysis (Bedient 2013) was used to calculate the PMF given the PMP.

The peak flow for 1 inch of rainfall excess is defined as:

$$Q_p = \frac{484A_m}{T_R}$$

where A_m = area of the watershed (sq mi)
T_R = time of rise (hr)

The time of rise is calculated with the following equation:

$$T_R = \frac{D}{2} + t_p$$

where: D = storm duration (hr)
t_p = lag time from centroid of rainfall to Q_p (hr)

The lag time is computed with the following equation:

$$t_p = \frac{L^{0.8}(S+1)^{0.7}}{1900\sqrt{y}}$$

where: L = length to divide (ft) or watershed length
y = average watershed slope (in percent)
S = potential abstraction (inches)

The potential abstraction is based on the weighted curve number of the watershed:

$$S = \frac{1000}{CN} - 10$$

The curve number for the watershed was calculated using NRCS TR-55, aerial maps, and the NRCS web soil survey (U.S. Department of Agriculture) to derive the following assumptions:

- Approximately 60% of the watershed is wooded. Half of these soils are Hydrologic Soil Group C, and half are Hydrologic Soil Group D.
- About 40% of the watershed consists of ½-ac residential neighborhoods. Twenty percent of these soils are Hydrologic Soil Group B and 80% are Hydrologic Soil Group C.

The length and slope of the watershed were estimated with topographic maps. The watershed area was assumed to be 4.4 square miles (DPW 2013).

Once the peak flow Q_p was obtained, this flow is computed to a unit peak discharge by dividing by the watershed area.

$$q_u = \frac{Q_p}{A_m}$$

The unit peak discharge was then used as an input to the TR-55 equation for peak flow, or in this case, the probable maximum flood. This equation can be used for any rainfall amount, whereas the original peak flow (Q_p) is defined for 1 inch of rainfall.

$PMF = q_u A_m Q F_p$ where q_u = unit peak discharge (cfs/sq mi/inch)
A_m = area of the watershed (sq mi)
Q = direct runoff (inches)
F_p = adjustment factor for pond and swamp areas

The direct runoff is calculated with the following equation:

$Q = \frac{(P-0.2S)^2}{(P+0.8S)}$ where P = probable maximum precipitation (inches)
S = potential abstraction (inches)

EA conservatively assumed that 1% of the watershed consists of ponded/swampy areas, which according to the TR-55 produces an adjustment factor F_p of 0.87.

Input parameters for the PMF calculation are presented in Table A-1.

Table A-1 Input Parameters for Probable Maximum Flood Analysis

Runoff CN	Watershed Length, L (ft)	Watershed slope, y (%)	Watershed Area, A_m (sq. mi.)	Ponding Adjustment Factor, F_p
77	17,200	0.29	4.4	0.87

Results

Estimates of the PMF peak discharge for 6-hr, 12-hr, and 24-hr precipitation duration are summarized in Table A-2. The Spillway Design Flood (SDF) for Reservoir Dam is the ½ PMF flow which is also shown in Table A-2.

Table A-2 Probable Maximum Flood for 6-hr, 12-hr, and 24-hr Precipitation Events

Storm Duration, D (hr)	Probable Maximum Rainfall, P (in)	PMF (cfs)	½ PMF (cfs)
6	23.5	4,042	2,021
12	25.9	3,405	1,703
24	28.2	2,524	1,262

Reservoir Dam would have approximately 0.5 ft of freeboard and would not be overtopped during a 6-hour ½ PMF SDF. Longer duration storms would have lower peak discharges and more freeboard.

References

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APPENDIX B

WEAP MODEL RESULTS

Improving Fish Passage and Environmental Stream Flows in First Herring Brook, Scituate, MA

Prepared for the North and South Rivers Watershed Association
by Margaret Kearns, Instar Ecology
June 2013
Waltham, MA

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EXECUTIVE SUMMARY

This report is the fifth in a series of reports that provide detailed analyses of alternative scenarios for restoring stream flow and aquatic habitat to First Herring Brook in Scituate, MA, while maintaining the reliability of the Town's water supply. The previous reports identified strategies that improved stream flow conditions but still resulted in minimal ability to provide adequate water over both fish ladders to support the restoration of a herring run in First Herring Brook. The current analysis uses the Water Evaluation and Planning (WEAP) integrated water resources planning tool (Stockholm Environment Institute, Medford, MA, v. 3.11, 2011) to evaluate the effects of four new potential structural and operational changes in an effort to improve the predicted success of fish ladder flows at the Reservoir and Old Oaken Bucket Pond:

1) Raising the full elevation of the Reservoir,

2) Reducing the flow through both fish ladders,

3) Lowering the fish ladder exit elevation at the Reservoir dam, and

4) Adjusting the trigger elevation for the outdoor water ban.

All of the new scenarios met the Town's water needs without reservoir failure, and in many cases the minimum Reservoir water level elevation over the period of record was significantly higher than the reference condition (i.e., 2008), providing the Town with additional resilience to extreme drought conditions.

Several of the new scenarios had moderate to good fish ladder flow success at 40.0, 41.0, 42.0, 42.5 and 43.5 ft. spillway elevations (scenario numbers 2, 4-6, 11, 13, 16-17, 20-22 and 26-28). Lowering the fish ladder exit elevation at the Reservoir generally improved fall fish ladder success. At Old Oaken Bucket Pond, many scenarios still have moderately low fish ladder success, and an adaptive management plan for pulsing flows over the fish ladder may help to maximize the Town's ability to support a viable herring run if one of these options is selected. In addition, when November water levels are adequate in Old Oaken Bucket Pond, the fall BioQ90 flow may be provided over the fish ladder to increase the ability of late migrating herring to exit the system.

All of the new scenarios eliminated zero flow days, supported continuous BioQ90 bioperiod minimum flows (except for 2 days in scenarios 7 and 9) and provided adequate Reservoir habitat for herring spawning and juvenile growth in spring and summer. The bioperiod median flow goals for most scenarios were adequately met during the winter and spring bioperiods, but remained a challenge to meet during summer and fall.

Among the scenarios with moderate to good fish ladder success, water bans occurred an average of 3-37% of summer days over the period of record (1962-2000), often with higher monthly

values from August to October. In general, greater fish ladder success was correlated with higher outdoor water ban trigger elevations, which resulted in a greater number of days with outdoor water bans.

Suggested criteria for many of the statistics discussed in this report are provided to support the decision-making process.

1 BACKGROUND

This report is the fifth in a series of reports that provide detailed analyses of alternative scenarios for restoring stream flow and aquatic habitat to First Herring Brook in Scituate, MA, while maintaining the reliability of the Town's water supply. The analysis uses the Water Evaluation and Planning (WEAP) integrated water resources planning tool to evaluate the effects of specific management options on environmental and water system objectives. Four new management options are evaluated in this report in an effort to improve the predicted success of fish ladder flows at the Reservoir and Old Oaken Bucket Pond:

1) Raising the full elevation of the Reservoir,

2) Reducing the flow through both fish ladders,

3) Lowering the fish ladder exit elevation at the Reservoir dam, and

4) Adjusting the trigger elevation for the outdoor water ban.

This work was funded by a Sustainable Watershed Management Initiative grant from the MA Department of Environmental Protection to the North and South Rivers Watershed Association and the Town of Scituate, MA. The funded project also included a preliminary engineering feasibility and cost assessment for raising the full elevation of the Reservoir and reducing the fish ladder exit elevation (EA Engineering, Science, and Technology, Inc., 2013).

2 SCENARIO COMPONENTS

2.1 Reference Scenario (REF)

The Reference scenario (REF) was developed to represent current conditions at the time the project began in 2008. This scenario included the town's average water use at that time, including a water ban that was triggered when the water level in the Reservoir reached 35 ft. elevation. It did not include the BioQ90 minimum seasonal flows to the river, the operation of either fish ladder, the 2010-2011 system updates or the effects of the 2010 irrigation system restriction. Results from this scenario are provided for comparative purposes.

2.2 Interim Operating Plan Scenario (IOP)

The base scenario for the 2013 WEAP modeling effort was the scenario labeled "Irrigation Restriction" in the 2012 report (Kearns, 2012). This scenario was an updated version of the

"Interim 4" scenario that was being used to manage bioperiod river flows and Old Oaken Bucket Pond fish ladder flows according to the Interim Operational Plan (Kearns, 2011), and is thus labeled "IOP" (Interim Operational Plan) in this report. In addition to the assumptions included in the Interim Operational Plan (i.e., BioQ90 river flows, 32 ft. Reservoir elevation BioQ90 shut off trigger, 35 ft. elevation outdoor water ban trigger, irrigation system restriction and operation of the fish ladder at Old Oaken Bucket Pond), the IOP scenario incorporated a demand reduction of 0.22 million gallons per day (mgd) based on the 2010-2011 water system updates (well rehabilitation and leak repairs) and a revised 0.31 mgd reduction in summer demand based on the outdoor irrigation system restriction that was adopted by the Town in 2010. The IOP scenario did not include operation of the Reservoir fish ladder due to its inability to operate efficiently at the current spillway elevation.

Thus, IOP represents the current operating conditions in spring of 2013. All of the new scenarios that were modeled for this report include the system upgrades and watering restriction assumptions common to the IOP scenario; however, both fish ladders were assumed to be operational in all of the new scenarios.

2.3 Spillway elevation

Five different Reservoir spillway elevations were modeled over a range from the current spillway elevation to the lowest point on Route 3A adjacent to the Reservoir: 40.0 (the current elevation), 41.0, 42.0, 42.5 and 43.5 ft. Note that although these elevations are referred to in this report as "spillway elevations", in reality, the current spillway would remain intact and additional structures would be added to hold back water to a higher level in the Reservoir while maintaining the current flood elevations (for further details, see EA Engineering, Science, and Technology, Inc. (2013)).

2.4 Fish Ladder Flow

The existing pool and weir fish ladders at both the Reservoir and Old Oaken Bucket Pond were retained in the model for all of the new scenarios, with some modifications (Table 1). The required water depths in the fish ladders were the same for all of the new scenarios: 8 inches for the spring upstream migration and 6 inches for the fall juvenile downstream migration. In all of the scenarios, fish ladder flows were only provided when adequate head was available (i.e., when the water elevation in the reservoir or pond was high enough to provide the proper depth of flow).

Adjustments to the fish ladder flow goals were made by reducing the width of the weirs while maintaining the same depths. The existing fish ladders are approximately 36 inches wide and require 5.2 cubic feet per second (cfs) to provide 8 inches of water depth in the spring. In the fall, this flow was reduced in the new scenarios by decreasing the width of the weir to 6 inches, which resulted in a flow of 0.45 cfs. These flows are denoted as "Full" in the tables in this report.

"Reduced" flows were incorporated in many of the new scenarios and represent an 18 inch weir width in the spring that requires only 2.56 cfs to provide the same 8 inches of water depth. The same flow and weir dimensions were assumed for the fall juvenile out-migration season for both the "Full" and "Reduced" scenario components. Note that the fall out-migration flow of 0.45 cfs is less than the 2.62 cfs that was assumed for the Old Oaken Bucket Pond fish ladder in the Interim Operational Plan and is also the same flow that is required for the fall BioQ90 minimum flow downstream of Old Oaken Bucket Pond.

2.5 Fish Ladder Exit Elevation

The ability to provide water down the fish ladders is dependent not only on the availability of water in the reservoir but also on the head, or elevation of the water above the fish ladder exit. The head can be managed by inserting or removing a series of boards across the width of the weir down to a minimum elevation that is determined by the fish ladder exit structure. The fish ladder exit elevation at the Reservoir was modeled at three different levels: 40.0 (current), 39.5 and 36.5 ft. (Table 2). At Old Oaken Bucket Pond, the existing fish ladder invert (18.34 ft.) was used for all scenarios. See EA Engineering, Science, and Technology, Inc. (2013) for further details of the engineering assumptions for the fish ladders.

2.6 Outdoor Water Ban Trigger Elevation

Currently, a total outdoor water ban is triggered when the water level in the Reservoir falls below 35 ft. elevation. When the spillway elevation of the Reservoir is increased, this water level is less frequently encountered; therefore, the water ban trigger elevations were adjusted. Several water ban triggers for each spillway elevation were modeled to provide the Town with information about the frequency, timing and duration of total outdoor water bans as well as their effects on fall fish ladder flows. The water ban triggers ranged from 35 (current) to 42 ft.

2.7 Irrigation System Restriction Season

The Town's current irrigation system restriction, which limits the operation of irrigation systems to one day a week, is effective from Memorial Day to Labor Day. During this time period, a reduction in demand of 0.31 mgd was assumed in the model based on the difference in average summer water use from 2007-2010 versus 2011, the first year of the irrigation system restriction. In several scenarios, the season was extended to May 1 through September 30 in an attempt to improve fall fish ladder flows (Table 3).

A total of 28 new scenarios were modeled in this report using various combinations of the model components described above (Table 4).

3 RESULTS

3.1 Water Supply

All of the new scenarios were able to meet the Town's water supply demands without draining the Reservoir. The amount of water supply that was delivered varied only slightly based on the number of days under a total water ban and the length of the irrigation restriction season, ranging from an annual average of 1.32 – 1.38 mgd (Table 5). The average summer (June-August) water supply delivered ranged from 1.48-1.64 mgd. These values are significantly reduced from the REF scenario (2008 conditions), which delivered an annual average of 1.62 mgd and a summer average of 2.15 mgd, but similar to the IOP scenario, which delivered an annual average of 1.36 mgd and a summer average of 1.59 mgd.

3.2 Fish Ladder Success

Fish ladder success was evaluated with the percent of days during each migration period that the water depth and flow were adequate to pass fish (Table 6). Overall, the new scenarios provided greatly improved fish ladder success, particularly during the fall migration period, and scenarios with good and/or moderate fish ladder success were identified at each spillway elevation.

At the Reservoir, spring fish passage increased from 0% in the REF and IOP scenarios to 82-98% in the new scenarios, and fall passage increased from 0% to 46-95%. At Old Oaken Bucket Pond, the Reference scenario had 0% success, while the IOP scenario had 63% spring success and 26% fall success and the new scenarios ranged from 89-98% spring success and 58-95% fall success.

In addition to the average percent of successful days over the period of record, the number of effective and ineffective years was assessed to help evaluate of the number of years that may experience a year-class failure (i.e., a high level of juvenile herring mortality) due to inadequate in- or out-migration fish ladder flows (Table 6). Following the methods of the 2010 report (The Nature Conservancy et al., 2010), effective years were classified as years with >50 days of adequate flow out of the 61-day period, and ineffective years were classified as years with < 30 days of adequate flow out of the 61-day period. For the Reservoir fish ladder, most of the new scenarios resulted in >90% effective years and <15% ineffective years in the spring and 41-97% effective years and 8-56% ineffective years in the fall. Results from the Old Oaken Bucket Pond ladder were also variable, with 82-100% effective and 3-56% ineffective years in the spring and 51-95% effective and 3-38% ineffective years in the fall.

3.3 River Stream Flow Goals

In all of the new scenarios, zero flow days in First Herring Brook downstream of both the Reservoir and Old Oaken Bucket Pond were eliminated, with the exception of 2 days in scenarios 7 and 9 (Table 7). For comparison, in the REF scenario, 13-88% of days per bioperiod had zero flow downstream of Old Oaken Bucket Pond and 1-18% had zero flow downstream of the Reservoir. Thus, any of the new scenarios described in this report represent a significant improvement in the ability to provide continuous flow for the entire aquatic community in First Herring Brook.

The minimum "BioQ90" stream flow goals, based on the 10th percentile (low flow) statistic for natural stream flow in First Herring Brook (Table 8), were also regularly met in all of the new scenarios (Table 9). By definition, the BioQ90 flow occurs for 90% of each bioperiod. In the REF scenario, the BioQ90 was only met for 18% of the fall bioperiod downstream of Old Oaken Bucket Pond and 62-70% of the other bioperiods. The IOP scenario provided near-normal (85-100%) BioQ90 flows for both sites in all bioperiods, except spring and winter downstream of the Reservoir, which met the BioQ90 conditions less frequently (44-53%) than in the REF scenario. Downstream of the Reservoir, both the REF and IOP scenarios, along with all of the new scenarios, exceeded the natural low flow condition in the summer due to the transfer of water downstream for water supply. In all of the new scenarios, the BioQ90 low flow was achieved within 10% of the natural condition. Note that the fall BioQ90 flow downstream of Old Oaken Bucket Pond is the same as the required fish ladder flow (0.45 cfs); thus if the water level in Old Oaken Bucket Pond is adequate, the new scenarios could be managed to provide the BioQ90 in November over the fish ladder to extend the opportunity for late migrating juvenile herring to exit the system.

Median environmental flow goals for First Herring Brook were developed in 2010 (The Nature Conservancy et al., 2010) and were based on median values for specific months or bioperiods at specific locations on the brook (Table 10). Consequently, these goals are more challenging to meet in a system that is heavily used for water supply than the low flow goals. Downstream of the Reservoir, flows were generally within approximately 10% of the natural condition, with some scenarios providing more flow than natural during the spring and summer bioperiods (Table 11). However, during the September-November bioperiods downstream of the Reservoir, there were varying results among scenarios, with 5-38% of days meeting the goals (vs. 50% in the natural scenario). Downstream of Old Oaken Bucket Pond, the May and summer goals were not met very often (13-21% vs. 50% for the natural flow regime). In the fall, greater fish ladder success provided some improvement in median flows downstream of Old Oaken Bucket Pond compared to the REF scenario; the fall median flow goals were achieved 34-41% of the time in the new scenarios and only 20% of the time in the REF scenario, versus 50% of the time under natural conditions. Overall, the new scenarios continue to fall short of meeting the summer median environmental flow goals downstream of the Old Oaken Bucket Pond and fall goals downstream of the Reservoir, with better success during the other bioperiods.

3.4 Reservoir Water Levels

Minimum water levels in the Reservoir for the entire model period from 1962-2000 are listed in Table 12 for each scenario and range from 31.95 - 39.63 ft. Note that in the REF scenario, the minimum water level is 27.0 ft., which is the elevation of the low level intake pipe and indicates a failure of the Reservoir and an inability to meet the Town's demand for water. The minimum Reservoir elevation in the IOP scenario was 31.95 ft., and the BioQ90 stream flow shut off trigger of 32.0 feet was triggered for 70 days over the model period.

In general, raising the spillway elevation and the water ban trigger elevation both significantly increased the minimum Reservoir water level during the drought of record, providing additional drought resilience for the Town's water supply. None of the new scenarios triggered the BioQ90 minimum flow shut off trigger of 32.0 feet, except for two days in scenarios 7 and 9.

3.5 Water Bans & Irrigation Restriction Season

The successful operation of the fish ladder, particularly during the fall outmigration season, was sensitive to the trigger level that was chosen for the total outdoor water ban. Triggers that were 1-5 ft. below the spillway elevation were tested in different scenarios and resulted in water bans that occurred for 1-48% of summer days over the period of record (Table 13). Among the scenarios that provided moderate or good fish ladder success, water bans occurred for 3-37% of the summer period. As a point of reference, the total outdoor water ban occurred for 9% of summer days in the REF scenario and 11% of summer days in the IOP scenario.

Monthly values for the percent of days per month below the water ban trigger are also provided in Table 13. August, September and October tended to have the greatest number of days with water bans; however, water bans in late September and October may be of less concern for the public because many residents have already reduced their lawn irrigation efforts and are expecting their lawns to turn brown for the fall and winter. Not surprisingly, the scenarios with the best fish ladder success and lowest percent of days under a water ban were those with the highest spillway elevation.

Extending the irrigation system restriction season from June-August to May-September had a minor effect on both the environmental indicators and the number of days under an outdoor water ban. Fish ladder success was generally slightly improved (5-7%), with up to a 10% reduction in ineffective years and up to a 13% increase in effective years. Extending the irrigation restriction season only increased the number of restricted days per year by approximately 3, saving just 0.83 mg per year (2,273 gallons per day (gpd)). Similarly, it only decreased the number of days under an outdoor water ban by a maximum of approximately 1.5 days per month during the summer season.

3.6 Reservoir Habitat

Habitat goals for herring spawning and juvenile development were developed in 2010 based on water level elevations in the Reservoir during different bioperiods and were based on a review of bathymetric maps and alewife habitat needs (Table 14) (The Nature Conservancy, et al., 2010). For the summer and fall bioperiods, the goals were split into wet years (top 25%), normal years (middle 50%) and dry years (lowest 25%). Note that these goals were based on a Reservoir spillway elevation of 40 ft., and different habitat conditions, particularly edge habitat, may exist when the spillway is raised. In general, raising the spillway elevation will provide additional area and edge habitat for herring spawning and juvenile growth. The rate at which these edge habitats become desiccated in the late spring and early summer depends on the bathymetry of the impoundment; to the extent that this bathymetry is represented in the storage-elevation data that are incorporated into the WEAP model, these rates can be calculated if necessary.

All of the new scenarios resulted in adequate water levels to meet the existing Reservoir habitat goals for all bioperiods (Table 15). This is a significant improvement over both the REF and IOP scenarios, which did not meet the summer/fall bioperiod goals for years with normal precipitation. The new scenarios that included the "very low" fish ladder exit elevation improved the least but still provided adequate water levels for 56-59% of the summer and fall bioperiods in years with normal precipitation.

4 DISCUSSION

All of the new scenarios met the Town's water needs without reservoir failure, and in many cases the minimum Reservoir elevation over the period of record was significantly higher than the REF and IOP scenarios, providing the Town with additional resilience to extreme drought conditions. There were several new scenarios with moderate to good fish ladder flow success at 40.0, 41.0, 42.0, 42.5 and 43.5 ft. spillway elevations (scenario numbers 2, 4-6, 11, 13, 16-17, 20-22 and 26-28). Among these scenarios, water bans occurred on average for 3-44% of over the period of record (1962-2000), often with higher monthly values from August to October. In general, greater fish ladder success was correlated with higher water ban trigger elevations, which resulted in a greater number of days with water bans.

The structural changes that were modeled resulted in many new scenarios with environmental conditions that were greatly improved from both the REF and IOP scenarios. Zero flow days, which were common in the REF condition, were eliminated in all of the new scenarios, and the minimum seasonal BioQ90 flows were continuously met, with the exception of 2 days in scenarios 7 and 9. The Reservoir water level elevation habitat goals that were developed in 2010 to ensure the hatching success and juvenile development of alewife in the Reservoir were also achieved in all of the new scenarios. Note, however, that these goals may need to be adjusted for scenarios with higher spillway elevations to reflect the different habitat conditions at higher elevations. The median stream flow goals were generally met within 15% of the natural condition during the winter and spring bioperiods, although summer and fall median flows were still significantly less common in most of the new scenarios.

Lowering the Reservoir's fish ladder exit elevation substantially (i.e., to 36.5 ft.) improved the Reservoir's fish ladder success rate, especially in the fall, and reduced the number of ineffective years by up to 18%. The success of the Old Oaken Bucket Pond fish ladder was unaffected or slightly improved in scenarios with the lower fish ladder exit at the Reservoir. Also note that when the water level in Old Oaken Bucket Pond is high enough to run the fish ladder, the flow required for fall fish ladder success is exactly the same as the fall BioQ90 flow (0.45 cfs) and could be provided over the fish ladder to allow late migrating juvenile herring to exit the system. This additional benefit could be quantified using the model results if a scenario with lower fish ladder success at Old Oaken Bucket Pond is seriously considered.

4.1 Suggested Criteria for Decision-Making

In selecting the best option to pursue, environmental, operational and cost considerations will all be important factors. Based on previous discussions with fisheries experts and best professional judgment, the following criteria are suggested to help guide discussions of the environmental and operational parameters (Table 16). Cost information is discussed in the attached EA Engineering, Science, and Technology, Inc. report (2013).

1. *Provide continuous BioQ90 flows; minimize the number of days that the BioQ90 stream flow shut off trigger is activated (32 ft. Reservoir elevation).* The BioQ90 minimum stream flows represent the 90th percentile low flow for each bioperiod and are critically important for sustaining the entire aquatic community. If necessary, adaptive management protocols, such as pulsed fish ladder flows or adjusted water ban triggers, should be developed to ensure that the BioQ90 shut off trigger is not reached. Notably, all of the new scenarios in this report have adequate BioQ90 exceedance values.

2. *Maximize the successful operation of fish ladders. The best options have >80% successful days for both fish ladders and migration seasons. Options with 70-80% success (or less) may be considered as part of an adaptive management plan, but are less optimal for the longterm viability of a herring population.* Because juvenile herring will congregate in impoundments until the proper flow and environmental conditions occur, managing fish ladder flow to provide pulses over the course of the season may be a viable option, particularly for the fall out-migration season.

3. *Minimize the number of years of ineffective fish passage. The best options have <20% ineffective years at both fish ladders during both seasons. Scenarios with 20-40% ineffective years may be adequate with a carefully considered adaptive management plan*. Herring live for approximately 6-7 years and first spawn at age 2 (Bozeman et al., 2010). Thus, they have 5-6 years of active reproduction. Given the myriad of other environmental factors that may cause low reproductive success or year-class failure, it is prudent to limit the number of ineffective years of fish ladder flow to a maximum of once per reproductive lifetime (i.e., 1 in 5-6 years, or 15-20% of years) or at most, twice (i.e., 2 in 5-6 years, or 33-40%). Although the percentages of ineffective years are moderately high for the fall outmigration season at Old Oaken Bucket Pond for many of the new scenarios, the definition of an "ineffective year" is also ecologically conservative: less than 30 out of 61 days of effective flow during the migration period. If a scenario is chosen with a moderate or high percentage of ineffective years, more care should be taken to develop an adaptive management plan for pulsed flows that ensures the longterm viability of the herring population.

4. *Develop targets for water ban frequency and timing based on the perceived willingness of the community to comply, and use these targets to select a water level elevation to trigger the water ban.*

5 BENEFITS OF THE PROJECT

5.1 Historical Perspective

When the original project began in 2008, the Town's average annual water demand was 1.62 mgd, and neither fish ladder was operational. In addition, as water was shuttled from the Reservoir to Old Oaken Bucket Pond to meet the Town's water supply needs, periods of no flow commonly occurred in the stretch of river between the two reservoirs, particularly during the summer and early fall. Despite the lack of year-round flow to the river and seasonal flow in the fish ladders, the water ban was still triggered for 11 % of summer days, averaged over the period of record.

Based on the Town's work with the stakeholder group, efforts to improve the efficiency of the system, manage demand and operate the fish ladder at Old Oaken Bucket Pond have improved both the environmental conditions and the reliability of the water system for human use. The implementation of the irrigation restriction and repairs of leaks have reduced the town’s average annual water demand for the past two years by 0.22 mgd, resulting in an annual average water use of 1.36 mgd and a summer average use of 1.59 mgd (Table 5, IOP scenario). The IOP scenario provides adequate water supply to meet the Town's needs with a watering ban occurring for 10% of summer days (Kearns, 2012). The significant drawback to this base scenario is the complete inoperability of the fish ladder at the Reservoir and the low success rate of the Old Oaken Bucket Pond fish ladder, which is only operational for 26% of fall days (8% effective years and 77% ineffective years) and 63% of spring days (36% effective years and 31% ineffective years) (Kearns, 2012).

5.2 Potential Project Benefits

The potential benefits of increasing the Reservoir's full elevation, lowering the fish ladder exit elevation and/or changing the trigger elevation for a total outdoor water ban include improved drought resiliency for water supply, seasonal flows in First Herring Brook, operational fish ladders to support herring migration and possible water quality improvements. The level of benefits that is achieved will depend on the specific scenario that is chosen.

5.2.1 Drought Resilience

In combination with the system improvements and irrigation system restrictions that have already been implemented by the Town, increasing the capacity of the Reservoir by raising the spillway elevation and water ban trigger result in fewer instances of extremely low Reservoir water level elevations that threaten the safety, availability and water quality of the public water supply. Most of the lowest Reservoir water level elevations in the new scenarios remained 6-9 ft.

above the intake pipe, which is located at elevation 27 ft. Even during the drought of record (1964-66), only 2 of the new scenarios dropped below 32 ft., the BioQ90 stream flow shut off trigger, and only for 2 days. This condition is a significant improvement over the REF scenario, which averaged 25 days per year below 32 ft. and 88% zero flow days downstream of Old Oaken Bucket Pond in the summer bioperiod (Table 7). The IOP scenario had only an average 1 day per year of water levels below 32 ft. This increased resilience to drought conditions is especially important in light of general climate change predictions for New England, which include earlier snowmelt and more frequent summer droughts (Hodgkins et al., 2006).

5.2.2 River Flow

The purpose of this effort was to determine the feasibility of restoring more natural stream flows to First Herring Brook. All of the new scenarios described in this report provided continuous flow (no zero flow days) and adequate minimum seasonal flows (BioQ90), although median flow goals in the summer and fall were still a challenge to meet. These improvements provide continuous aquatic habitat in First Herring Brook that will support a diverse community of aquatic species.

5.2.3 Fish Ladder Operation

The main goal of this report was to test several new management options for increasing the success of the fish ladders, particularly in the fall bioperiod. Many of the scenarios modeled in this report provide moderate to good flows for successful fish ladder operation.

5.2.4 Reservoir Habitat for Herring Reproduction and Growth

At 77 acres (with a 40 ft. elevation spillway), the Reservoir offers the largest area of suitable habitat for alewife spawning and juvenile development in the First Herring Brook system, but only if adequate water levels are maintained. In the spring, water levels must remain high enough to inundate herring eggs that are adhered to emergent vegetation until they hatch. Over the course of the summer, the water quality, which is affected by the water level, must remain adequate to support the growth of juvenile herring. All of the new scenarios result in water levels that meet the Reservoir habitat goals for all bioperiods.

5.2.5 Water Quality

In addition to the benefits that can be quantified with the WEAP model outputs, many of the new scenarios have the potential to improve water quality in both the Reservoir and Old Oaken Bucket Pond. Old Oaken Bucket Pond exhibits symptoms of severe eutrophication (nutrient overload) and is listed as an impaired water due to phosphorous enrichment and the presence of non-native plants by the MA Department of Environmental Protection (Massachusetts

Department of Environmental Protection, Division of Watershed Management, 2006). While the Reservoir itself was not assessed, Tack Factory Pond just upstream of Route 3A was listed as impaired due to turbidity and exotic species, with moderate total phosphorous levels noted, although these were considered to be naturally occurring. Recent habitat monitoring by the North and South Rivers Watershed Association also revealed that the Reservoir impoundment experiences high pH during very low water conditions (North and South Rivers Watershed Association anadromous fish habitat monitoring data, 2007-2009, Norwell, MA).

Scenarios that provide continuous minimum stream flow and fish ladder flows, increased Reservoir volume and sewering for homes around the Reservoir could all contribute to water quality improvements. Seasonal minimum flows will help to increase circulation through both the Reservoir and Old Oaken Bucket Pond and minimize stagnation, which can contribute to low oxygen or hypoxic conditions that are harmful to many aquatic organisms. Increasing the spillway elevation of the Reservoir will increase its volume and, thus, its capacity to dilute nutrients and other pollutants. Maintaining a larger volume of water (i.e., higher Reservoir water level) during stressful summer and drought conditions is also likely to provide additional thermal refuges for aquatic organisms because deeper areas will remain cooler. Sewering homes within the buffer area of the Reservoir would result in a permanent reduction in the nutrient load to the Reservoir and Old Oaken Bucket Pond, which, as noted above, exhibit signs of nutrient overload and eutrophication. Thus, although this benefit is unquantified, the scenarios described in this report have the potential to improve water quality through increased circulation, greater dilution capacity, and reduced summer temperatures and nutrient loads.

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TABLES

Table 1. Fish Ladder Flow Requirements (cfs)

Fish Ladder Location	Spring		Fall	
	Full	Reduced	Full	Reduced
Reservoir	5.2	2.56	0.45	0.45
Old Oaken Bucket Pond	5.2	2.56	0.45	0.45

Table 2. Fish Ladder Exit Elevations

Fish Ladder Exit Elevation	Elevation (ft)
Current	40.0
Lower	39.5
Very Low	36.5

Table 3. Irrigation Restriction Seasons

Irrigation Restriction Season Extension	Season
No	May 31 – September 4
Yes	May 1 – September 30

Table 4. Scenarios

Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders).
Blue shading indicates moderate success (70-80% for some seasons & ladders).

Scenario	Reservoir Spillway Elevation	Fish Ladder Flow	Fish Ladder Elevation	Water Ban Trigger Elevation	Irrigation Restriction Season Extension
#	feet	Fall 0.44 cfs Spring Full: 5.2 cfs Spring Reduced: 2.56 cfs	Current: 40 ft Lower: 39.5 ft Very Low: 36.5 ft	feet	Yes: May 1 - Sep 30 No: May 31 - Sep 4
REF	40	(None)	(Inoperable)	35	None
IOP	40	Full (2.61 Fall)	Current	35	No
1	40	Reduced	Very Low	37	No
2	40	Reduced	Very Low	38	No
3	40	Reduced	Very Low	37	Yes
4	41	Reduced	Very Low	38	No
5	41	Reduced	Very Low	38.5	No
6	41	Reduced	Very Low	39	No
7	42	Full	Current	35	No
8	42	Reduced	Current	35	No
9	42	Full	Lower	35	No
10	42	Reduced	Current	40	No
11	42	Reduced	Current	41	No
12	42	Reduced	Lower	40	No
13	42	Reduced	Lower	41	No
14	42	Reduced	Lower	35	Yes
15	42	Reduced	Lower	40	Yes
16	42.5	Reduced	Current	42	No
17	42.5	Reduced	Lower	41	No
18	42.5	Reduced	Current	35	No
19	42.5	Reduced	Current	40	No
20	42.5	Reduced	Current	41	No
21	42.5	Reduced	Lower	40	No
22	43.5	Reduced	Lower	41	No
23	43.5	Full	Current	35	No
24	43.5	Reduced	Current	35	No
25	43.5	Reduced	Current	40	No
26	43.5	Reduced	Current	41	No
27	43.5	Reduced	Lower	40	No
28	43.5	Reduced	Current	42	No

Table 5. Water Supply Delivered (mgd)

Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders).
Blue shading indicates moderate success (70-80% for some seasons & ladders).

Scenario	Annual Average (mgd)	Summer Average (June - August) (mgd)
REF	1.62	2.15
IOP	1.36	1.59
1	1.36	1.60
2	1.34	1.55
3	1.32	1.61
4	1.36	1.60
5	1.35	1.59
6	1.34	1.56
7	1.37	1.63
8	1.38	1.64
9	1.37	1.63
10	1.35	1.57
11	1.32	1.48
12	1.35	1.57
13	1.32	1.48
14	1.33	1.64
15	1.32	1.59
16	1.30	1.43
17	1.34	1.55
18	1.38	1.64
19	1.36	1.60
20	1.34	1.55
21	1.36	1.60
22	1.36	1.61
23	1.38	1.63
24	1.38	1.64
25	1.37	1.63
26	1.36	1.61
27	1.37	1.63
28	1.34	1.56

Table 6. Fish Ladder Success (continued on p. 18)

Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders).
Blue shading indicates moderate fish ladder success (70-80% for some seasons & ladders).

Scenario #	Reservoir						Old Oaken Bucket					
	Spring Fish Ladder Success (%)	Fall Fish Ladder Success (%)	Effective Years (%) (>50 effective days in the 61 day season)		Ineffective Years (%) (<30 effective days in the 61 day period)		Spring Fish Ladder Success (%)	Fall Fish Ladder Success (%)	Effective Years (%) (>50 effective days in the 61 day season)		Ineffective Years (%) (<30 effective days in the 61 day period)	
			Spring	Fall	Spring	Fall			Spring	Fall	Spring	Fall
REF	0%	0%	0%	0%	100%	100%	0%	0%	0%	0%	100%	100%
IOP	0%	0%	0%	0%	100%	100%	63%	26%	36%	8%	31%	77%
1	96%	74%	97%	72%	3%	26%	96%	61%	97%	51%	3%	38%
2	97%	85%	97%	82%	3%	13%	97%	75%	97%	72%	0%	23%
3	97%	77%	97%	77%	3%	18%	96%	68%	97%	64%	3%	28%
4	97%	92%	97%	95%	0%	5%	98%	71%	100%	64%	0%	28%
5	98%	94%	97%	95%	0%	3%	98%	75%	100%	67%	0%	23%
6	98%	95%	100%	97%	0%	3%	98%	82%	100%	74%	0%	15%
7	82%	46%	72%	41%	13%	56%	89%	58%	82%	51%	3%	38%
8	96%	52%	97%	44%	3%	46%	96%	74%	97%	72%	3%	23%
9	87%	51%	74%	46%	5%	49%	89%	58%	82%	51%	3%	38%
10	96%	54%	97%	46%	3%	44%	97%	83%	97%	82%	3%	18%
11	97%	70%	97%	69%	3%	28%	97%	92%	97%	95%	0%	5%
12	97%	64%	97%	59%	3%	36%	97%	83%	97%	82%	3%	18%
13	97%	81%	97%	82%	3%	18%	97%	92%	97%	95%	0%	5%
14	96%	67%	97%	62%	3%	28%	96%	77%	97%	77%	3%	21%
15	97%	69%	97%	64%	3%	28%	97%	84%	97%	82%	3%	15%

Table 6. Fish Ladder Success (continued)

Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders).
Blue shading indicates moderate fish ladder success (70-80% for some seasons & ladders).

Scenario	Reservoir						Old Oaken Bucket					
	Spring Fish Ladder Success (%)	Fall Fish Ladder Success (%)	Effective Years (%) (>50 effective days in the 61 day season)		Ineffective Years (%) (<30 effective days in the 61 day period)		Spring Fish Ladder Success (%)	Fall Fish Ladder Success (%)	Effective Years (%) (>50 effective days in the 61 day season)		Ineffective Years (%) (<30 effective days in the 61 day period)	
#			Spring	Fall	Spring	Fall			Spring	Fall	Spring	Fall
16	97%	89%	97%	92%	0%	8%	98%	93%	97%	95%	0%	5%
17	97%	87%	97%	85%	0%	10%	98%	91%	100%	92%	0%	5%
18	96%	64%	97%	54%	3%	33%	96%	76%	97%	74%	3%	23%
19	96%	64%	97%	54%	3%	33%	97%	79%	97%	77%	3%	18%
20	97%	75%	97%	74%	3%	23%	97%	92%	97%	92%	0%	5%
21	97%	74%	97%	72%	3%	23%	97%	79%	97%	77%	3%	18%
22	97%	88%	97%	87%	0%	8%	98%	94%	97%	95%	0%	3%
23	89%	52%	79%	46%	3%	46%	92%	64%	87%	56%	3%	33%
24	96%	63%	97%	54%	3%	33%	96%	80%	97%	79%	3%	18%
25	96%	63%	97%	54%	3%	33%	97%	88%	97%	85%	3%	8%
26	97%	75%	97%	72%	3%	23%	98%	94%	97%	95%	0%	3%
27	97%	74%	97%	72%	3%	23%	97%	88%	97%	85%	0%	8%
28	98%	95%	100%	97%	0%	3%	98%	90%	100%	90%	0%	5%

Table 7. Percent Zero Flow Days

Scenario	Downstream of the Reservoir				Downstream of Old Oaken Bucket Pond			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
REF	1	1	18	13	13	88	79	18
IOP	0	0	0	0	0	0	0	1
All Others (1-28)	0	0	0	0	0	0	0	0

Table 8. BioQ90 Stream Flow Goals

Bioperiod	Downstream of the Reservoir	Downstream of Old Oaken Bucket Pond
	cfs	cfs
Mar-May	2.56	3.78
Jun-Aug	0.22	0.39
Sep - Nov	0.25	0.45
Dec - Feb	3.15	3.15

Table 9. BioQ90 Exceedance

Percent of bioperiod that exceeds the BioQ90

Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders).

Blue shading indicates moderate fish ladder success (70-80% for some seasons & ladders).

	Downstream of the Reservoir				Downstream of Old Oaken Bucket Pond			
Scenario	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Natural	90	90	90	90	90	90	90	90
REF	77	98	70	69	70	11	18	62
IOP	44	100	98	53	86	88	88	85
1	98	100	100	92	86	88	88	85
2	98	100	100	92	86	88	88	85
3	98	100	100	92	86	88	88	85
4	98	100	100	92	86	88	88	85
5	98	100	100	92	86	88	88	85
6	98	100	100	92	86	88	88	85
7	98	100	100	92	86	88	88	85
8	96	100	100	92	93	88	88	85
9	98	100	100	92	86	88	88	85
10	98	100	100	92	86	88	88	85
11	98	100	100	92	86	88	88	85
12	98	100	100	92	86	88	88	85
13	98	100	100	92	86	88	88	85
14	96	100	100	92	93	88	88	85
15	98	100	100	92	86	88	88	85
16	95	100	100	92	86	88	88	85
17	97	100	100	92	86	88	88	85
18	98	100	100	92	86	88	88	85
19	98	100	100	92	86	88	88	85
20	97	100	100	92	86	88	88	85
21	97	100	100	92	86	88	88	85
22	97	100	100	92	86	88	88	85
23	97	100	100	92	86	88	88	85
24	97	100	100	91	96	88	88	85
25	98	100	100	92	86	88	88	85
26	97	100	100	92	86	88	88	85
27	97	100	100	92	86	88	88	85
28	97	100	100	92	86	88	88	85

Table 10. Median Flow Goals

	Downstream of the Reservoir		Downstream of Old Oaken Bucket Pond	
Bioperiod	cfs	Statistic	cfs	Statistic
Mar-May	4.03	May median	10.41	March-April median
			5.90	May median
Jun-Aug	0.83 - 1.95	monthly medians	1.83	bioperiod median
Sep - Nov	0.80	September median	2.63	bioperiod median
	1.56 - 3.5	monthly medians		
Dec - Feb	5.31	bioperiod median	7.76	bioperiod median

Table 11. Median Flow Goal Achievement

Percent of bioperiod achieving environmental flow goals. Natural scenario is a point of reference.
Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders).
Blue shading indicates moderate fish ladder success (70-80% for some seasons & ladders).

	Downstream of the Reservoir					Downstream of Old Oaken Bucket Pond				
Scenario	Spring	Summer	Sep	Oct-Nov	Winter	Mar-Apr	May	Summer	Fall	Winter
Natural	72	63	50	67	50	50	50	50	50	50
REF	61	97	25	16	36	29	10	13	20	41
IOP	34	77	26	38	26	42	19	13	39	47
1	60	72	19	24	37	32	13	20	38	48
2	60	62	14	25	37	32	13	20	39	48
3	60	75	5	25	37	32	16	20	40	48
4	61	73	20	24	39	35	13	20	38	51
5	61	69	18	25	39	35	13	20	38	51
6	61	64	14	25	39	35	13	20	39	51
7	62	50	13	27	41	36	14	20	41	53
8	85	75	23	21	38	35	14	17	34	50
9	62	79	24	24	40	36	14	20	38	51
10	62	67	16	25	40	36	14	20	39	52
11	62	50	13	27	41	36	14	20	41	53
12	62	81	6	26	40	36	16	20	40	52
13	62	71	6	26	40	36	16	20	41	52
14	85	75	23	21	38	35	14	17	34	50
15	62	67	16	25	40	36	14	20	39	52
16	62	41	12	28	41	36	14	21	43	53
17	62	62	14	26	41	36	14	20	40	53
18	62	80	24	24	40	36	14	20	38	52
19	62	73	20	25	40	36	14	20	39	52
20	62	62	14	26	41	36	14	20	40	53
21	62	73	20	25	40	36	14	20	39	52
22	63	64	14	27	42	36	14	20	41	54
23	63	74	20	25	41	36	14	20	39	53
24	89	74	24	22	39	36	14	17	35	51
25	63	80	25	25	41	36	14	20	39	53
26	63	77	22	25	41	36	14	20	39	53
27	63	74	20	25	41	36	14	20	39	53
28	63	77	22	25	41	36	14	20	39	53

Table 12. Minimum Reservoir Water Level Elevations (ft.)

Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders).
Blue shading indicates moderate fish ladder success (70-80% for some seasons & ladders).

Scenario	Minimum Reservoir Elevation (ft)
REF	27.00
IOP	31.95
1	33.37
2	34.35
3	33.64
4	34.99
5	35.39
6	35.77
7	31.96
8	33.92
9	31.95
10	37.14
11	37.67
12	37.14
13	37.67
14	34.48
15	37.30
16	38.38
17	38.15
18	34.26
19	37.45
20	38.15
21	37.45
22	38.81
23	33.05
24	34.86
25	38.13
26	38.83
27	38.13
28	39.63

Table 13. Water Ban Frequency

Water Ban Frequency is the number or percent of days during the summer or specified month that the Town of Scituate would experience an outdoor watering ban, averaged over the entire period of record from 1961 – 2000. Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders). Blue shading indicates moderate fish ladder success (70-80% for some seasons & ladders).

#	# of Summer Days per year (Jun-Aug; extended scenarios: May-Sep)	% of Days in Month											
		J	F	M	A	M	J	J	A	S	O	N	D
REF	10	5	5	0	0	0	0	1	31	50	41	28	8
IOP	11	5	5	0	0	2	3	11	21	23	25	11	6
1	10	5	5	0	1	3	3	10	19	23	25	12	6
2	20	5	5	0	2	3	9	21	34	41	34	16	6
3	14	5	4	0	1	3	3	7	15	19	22	10	5
4	8	5	5	0	1	3	3	8	16	21	24	11	5
5	12	5	5	0	1	3	3	13	22	28	31	14	6
6	18	5	5	0	2	3	7	19	32	39	34	16	6
7	2	3	3	0	0	2	3	3	3	7	8	3	3
8	1	0	2	1	0	0	0	0	2	3	3	2	0
9	2	3	3	0	0	2	2	3	3	7	8	3	3
10	14	5	5	0	1	3	4	16	27	34	33	15	6
11	34	6	5	1	2	6	19	35	56	48	35	18	8
12	14	5	5	0	1	3	4	16	27	34	33	15	6
13	34	6	5	1	2	6	19	35	56	48	35	18	8
14	1	0	0	0	0	0	0	0	2	3	2	0	0
15	21	5	5	0	1	3	3	12	24	29	29	14	6
16	44	6	7	3	3	15	29	54	61	54	39	19	7
17	20	6	5	0	1	3	8	21	37	43	34	16	6
18	1	0	0	0	0	0	0	0	3	3	2	0	0
19	8	5	4	0	0	3	3	8	17	22	24	12	5
20	20	6	5	0	1	3	8	21	37	43	34	16	6
21	8	5	4	0	1	3	3	8	17	22	24	12	5
22	6	6	4	0	0	3	3	5	13	18	21	9	4
23	2	3	2	0	0	1	0	3	3	3	3	0	2
24	0	0	0	0	0	0	0	0	0	0	1	0	0
25	3	4	3	0	0	2	3	3	5	11	10	3	3
26	6	6	4	0	0	3	3	5	13	18	21	9	4
27	3	4	3	0	0	2	3	3	5	11	10	3	3
28	17	6	5	0	1	3	5	18	32	39	34	15	6

Table 14. Reservoir Habitat Goals

Bioperiod	Reservoir Elevation (ft)
March – May	>39
June - August	Wet >40 Normal 36-40 Dry >36
September – November	Wet >40 Normal 36-40 Dry >36
December - February	>39

Table 15. Reservoir Habitat Goal Achievement

Average % of bioperiod that meets Reservoir habitat goals. Orange text indicates a moderate problem. Red text indicates a serious problem. Pink shading indicates best scenarios for fish ladder success (>80% for all seasons & ladders). Blue shading indicates moderate fish ladder success (70-80% for some seasons & ladders).

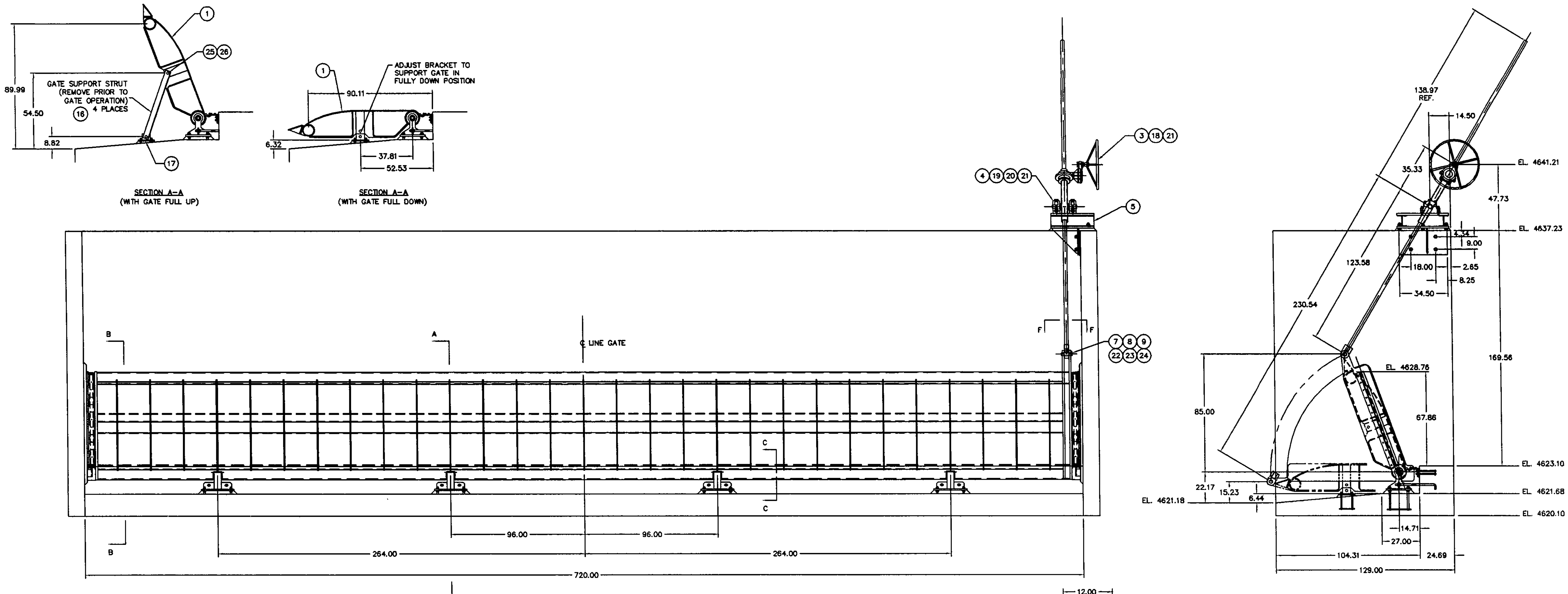
Scenario	March - May: 39 ft	June - November: Normal 39 ft	June - November: Wet 40 ft	June - November: Dry 34 ft	December - February: 39 ft
REF	99%	38%	20%	82%	86%
IOP	50%	24%	12%	97%	86%
1	95%	56%	30%	100%	92%
2	95%	58%	31%	100%	93%
3	96%	59%	33%	100%	92%
4	98%	72%	58%	100%	94%
5	98%	73%	58%	100%	94%
6	98%	75%	59%	100%	95%
7	96%	70%	60%	99%	92%
8	97%	88%	77%	100%	91%
9	96%	70%	60%	99%	92%
10	100%	96%	79%	100%	97%
11	100%	98%	91%	100%	98%
12	100%	96%	79%	100%	97%
13	100%	98%	91%	100%	98%
14	98%	90%	80%	100%	95%
15	100%	97%	82%	100%	97%
16	100%	100%	97%	100%	99%
17	100%	100%	94%	100%	99%
18	98%	91%	85%	100%	94%
19	100%	98%	86%	100%	98%
20	100%	100%	95%	100%	99%
21	100%	98%	86%	100%	98%
22	100%	100%	99%	100%	100%
23	97%	88%	80%	99%	94%
24	100%	97%	93%	100%	97%
25	100%	99%	94%	100%	99%
26	100%	100%	99%	100%	100%
27	100%	99%	94%	100%	99%
28	100%	100%	100%	100%	100%

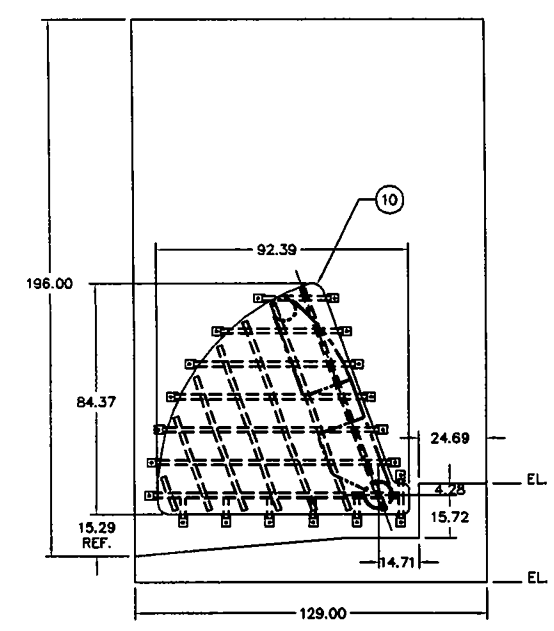
Table 16. Suggested Criteria

Criteria	Best	Moderate	Other
Fish Ladder Success	> 80%	70-80%	< 70%
Fish Ladder Effective Years	> 80%	70-80%	< 70%
Fish Ladder Ineffective Years	< 20%	20-40%	> 40%
Minimum Reservoir Elevation (ft)	35	32	< 32
Water ban (% summer days)	< 20%	20-33%	> 33%
Water ban (% August days)	< 33%	25-33%	> 33%
% Bioperiod meeting Reservoir Habitat Goals	(see Table 14)		
Zero Flow Days	0	0	> 0
BioQ90 Exceedance (within x % of natural)	10%	15%	> 15%
Median Flow Goal Exceedance (within x% of natural)	10%	20%	> 20%

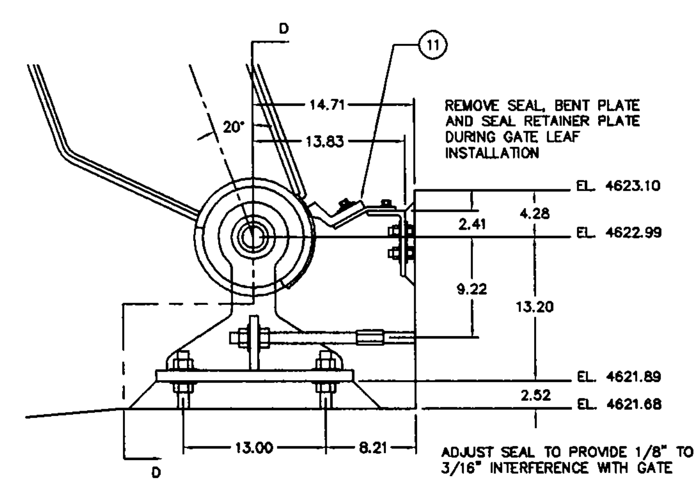
APPENDIX C

REPRESENTATIVE SPILLWAY CREST GATE INSTALLATION

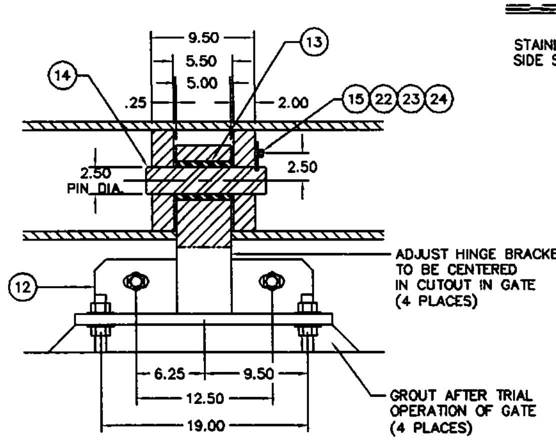




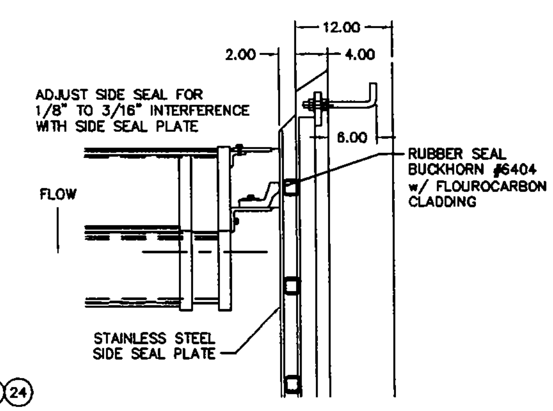
SECTION B-B
GATE LEAF NOT SHOWN FOR CLARITY



SECTION C-C



SECTION D-D



SECTION F-F

PART #	QUANTITY	MATERIAL / DRAWING #	DESCRIPTION
26	8	18-8 SS	HEX NUT 1 1/2"-UNC
25	8	18-8 SS	HEX HEAD CAP SCREW 1 1/2"-UNC x 4" LG
24	10	18-8 SS	SPLIT LOCK WASHER 3/8"
23	10	18-8 SS	FLAT WASHER 3/8"
22	10	18-8 SS	HEX HEAD CAP SCREW 3/8"-UNC x 1" LG
21	8	18-8 SS	SPLIT LOCK WASHER 3/4"
20	4	18-8 SS	FLAT WASHER 3/4"
19	4	18-8 SS	HEX HEAD CAP SCREW 3/4"-UNC x 5 1/2" LG
18	4	18-8 SS	SOCKET HEAD CAP SCREW 3/4"-UNC x 2" LG
17	4	CRG-01165-316	SUPPORT BRACKET
16	4	CRG-01165-316	SUPPORT STRUT ASSEMBLY
15	4	304 SS	KEEPER PLATE 1/4" x 2 1/2" x 3 1/2"
14	4	A564 Gr. 1075 SS	HINGE PIN ø2 1/2" x 11" LG
13	4	BRONZE	SLEEVE BUSHING 3" OD x 2 1/2" ID x 5" LG
12	4	CRG-01165-312	HINGE BRACKET
11	1	CRG-01165-311	HORIZONTAL SEAL ASSMBLY
10	2	CRG-01165-310	SIDE SEAL PLATE ASSEMBLY
9	1	BRONZE	SLEEVE BUSHING 2 1/2" OD x 2" ID x 3" LG
8	1	304 SS	KEEPER PLATE 1/4" x 1 1/2" x 3 1/2"
7	1	18-8 SS	GATE ATTACHMENT PIN ø2" x 8" LG
6	1	CRG-01165-306	SCREW STEM/ROD EYE
5	1	CRG-01165-305	SCREW STEM BRACKET
4	2	---	SPECIAL DUTY PILLOW BLOCK (2 BOLT BASE) FOR ø2 5/8" SHAFT, DODGE P/N 066262
3	1	---	EXEECO BEVEL GEAR MANUAL OPERATOR I88/AS5 w/ 16:1 RATIO & 36" HANDWHEEL
2	1	CRG-01165-302	MANUAL OPERATOR MOUNTING BRACKET
1	1	CRG-01165-300	GATE LEAF ASSEMBLY

DESCRIPTION	DATE	BY	REV
PART #13 WAS 3 1/2" OD, IS NOW 3" OD	9/13/01	EEN	C
ADDED PARTS # 25 & 26	8/28/01	EEN	B
REVISED DESCRIPTION OF PART #3	8/10/01	EEN	A

DRAWN BY:	DATE:
CHECKED BY:	DATE:
CAD FILE:	
SCALE:	

GENERAL TOLERANCES: (UNLESS OTHERWISE NOTED)

DECIMAL PLACES	FABRICATION & STRUCTURAL	MACHINING
X.X	+/- 0.240	+/- 0.040
X.XX	+/- 0.120	+/- 0.020
X.XXX	+/- 0.060	+/- 0.001
ANGLE	+/- 1 DEG	+/- .5 DEG

CITY OF GREELEY
WATER AND SEWER DEPARTMENT
GREELEY, COLORADO 80631

7' x 60' (APPROX. 84" x 720")
MANUALLY OPERATED CREST GATE

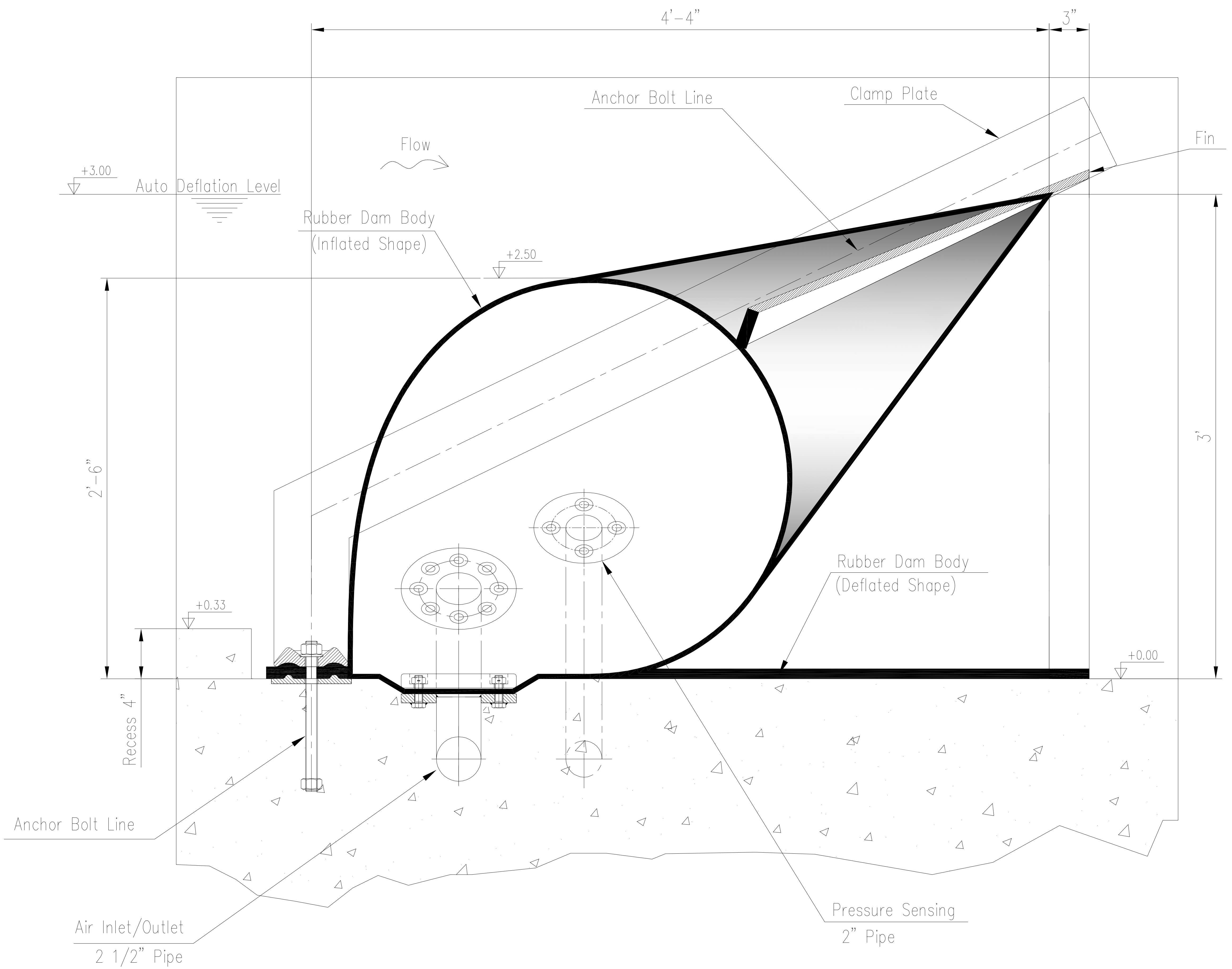
STEEL - FAB, inc
FITCHBURG, MASSACHUSETTS 01420

TITLE: CREST GATE INSTALLATION

DWG. NO. CRG-01165-102 REV. C

APPENDIX D

INFLATABLE RUBBER DAM INSTALLATION SCHEMATIC



DRAWN BY	APPROVED BY	DATE	REV.	REV. DESCRIPTION	DRAWING DESCRIPTION		All dimensions: mm	SCALE 1:8
A Osinska		23.05.2013			AIR INFLATABLE RUBBER DAM RUBBER DAM CROSS SECTION A–A 2.5ft high rubber dam	Dyrhoff Inc. 354 WEST BOYLSTON RD, SUITE 221 WEST BOYLSTON, MA 01583-2373 TEL: 508 755 0440 FAX: 508 755 9589 DYRHOFF	Drawing Method	JOB; *Preliminary Design* *Inflatable Rubber Dam* *Scituate MA, USA*
								DRG NO 13164–101

APPENDIX E

PROBABLE CONSTRUCTION COST ESTIMATES

Item	Alternative 1 - Pond El. 42.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Mobilization/demobilization	LS	1	132,412	$132,412
Temporary Construction Facilities				
Silt Fences	LF	1,000	3.50	$3,500
Prepare Staging Areas	AC	1.4	6,875	$9,625
Security Fencing	LF	250	16	$4,001
Access Road Improvements	LS	1	5,000	$5,000
Site Restoration	LS	1	5,000	$5,000
Subtotal Temporary Construction Facilities				**$27,126**
Spillway Modifications				
Flashboard Support Foundation				
Remove Riprap and Embankment Material	CY	100	19	$1,870
Geotextile Fabric	SY	100	2.4	$238
Foundation Stone	CY	25	57	$1,422
Concrete	CY	60	61	$3,630
Rebar (epoxy coated)	TN	3	1,749	$5,247
Formwork	SF	130	13	$1,716
Subtotal				**$14,122**
Flashboards				
Flashboards and Pins	LS	1	3,300	$3,300
Installation of Pins and Boards	HRS	100	75	$7,500
Control System (not required)	LS	0	0	$0
Powerline Upgrade (1/0 in existing conduit)	LF	0	0	$0
Electrical and Control System Installation	HRS	0	0	$0
Crane	Days	0	0	$0
Subtotal				**$10,800**
Subtotal Spillway Modifications				**$24,922**
Fishway Modifications				
Exit Channel Notch				
Temporary Steel Bracing of Wall	TN	1.8	7,006	$12,611
Concrete Demolition (sawcut and disposal)	CY	5	1,444	$7,222
Foundation Stone	CY	2	569	$1,137
Concrete	CY	5	61	$303
Rebar	TN	0.50	2,602	$1,301
Formwork	SF	50	13	$660
Subtotal				**$23,234**
Exit Channel Removable Baffles (7 Weirs)				
Aluminum Guides	TN	1.2	13,530	$16,236
Wooden Weirs (2 sets)	SF	110	91	$10,043
Subtotal				**$26,279**
Exit Channel Isolation Slide Gate				
Procure and Deliver Gate with Guides and Manual Operator	LS	1	17,655	$17,655
Procure and Deliver Gate Motor Operator (5 HP)	LS	1	3,500	$3,500
Install Guides and Gates	HRS	40	75	$3,000
Fishway Footbridge	LF	8	1,200	$9,600
Spillway Footbridge	LF	46	800	$36,800
Subtotal				**$70,555**

Item	Alternative 1 - Pond El. 42.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Weir Modifications				
Cut Notch in Concrete Weir	HRS	168	75	$12,600
Install Aluminum Guides for Removable Notched Weir Boards	EA	21	400	$8,400
Fabricate and Install Weir Boards	EA	21	240	$5,040
Subtotal				**$26,040**
Entrance Channel Improvement				
Clean Concrete Fishway Entrance	HRS	8	55	$440
Construct Rock Ramp Channel up to Fishway Entrance	TNS	400	32	$12,980
Subtotal				**$13,420**
Subtotal Fishway Modifications				**$159,528**
Infrastructure Improvements				
Route 3A				
Clear and Grub	AC	0.34	6,875	$2,338
Pavement Removal	SY	0	10	$0
Remove Guardrail	LF	0	6	$0
Excavation	CY	0	19	$0
Geotextile Fabric	SY	0	2.4	$0
Foundation Material	CY	0	57	$0
Riprap Slope Protection	TNS	1,836	46	$84,456
Asphalt Base and Top Course (3 inch each)	SY	0	29	$0
Install Guardrail	LF	0	28	$0
Lane Painting	LF	0	0.3	$0
Signage	EA	2	374	$748
Subtotal				**$87,542**
Sewer Extension (3 house connections)				
Trenching	LF	2,500	50	$125,000
Dewatering	Day	20	250	$5,000
Bedding Material	CY	600	39	$23,562
Pipe (18 inch Dia.)	LF	2,500	25	$63,250
Backfill and Compaction	CY	1,800	50	$90,486
Lift Station (100,000 gpd)	EA	1	150,000	$150,000
Highway Resurfacing	SY	850	80	$68,000
Abandon Septic Systems	EA	3	4,483	$13,448
House Connections (6 inch Dia. 150 ft length)	LF	450	75	$33,750
Subtotal				**$572,496**
Septic System Upgrades (3 houses)				
Clear and Grub	AC	0.7	6,875	$4,813
Excavation	CY	1,275	19	$23,843
Tank and Leach Field Sand Fill	CY	570	39	$22,384
Septic Tank (5,000 gal)	EA	3.0	13,530	$40,590
Leach Field Piping (4 inch Dia.)	LF	1,500	13	$19,223
Backfill	CY	2,225	30	$67,796
Top Soil	CY	290	40	$11,600
Seeding (Slope Mix with Hydroseeder)	SF	16,000.0	0.09	$1,434
Subtotal				**$191,682**

Item	Alternative 1 - Pond El. 42.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Property Protection Dikes (500 ft Length, 3 Maximum Height)				
Clear and Grub	AC	0.08	6,875	$550
Top Soil Excavation	CY	60	19	$1,140
Embankment Fill	CY	440	50	$22,119
Geotextile Fabric	SY	840	2.4	$1,996
Riprap Stabilization	TNS	200	45	$9,000
Top Soil	CY	60	40	$2,400
Seeding (Slope Mix with Hydroseeder)	SF	3,250	0.09	$291
Subtotal				**$37,496**
Structure Modifications				
Jack Structure	EA	3	12,320	$36,960
New Foundation	CY	180	61	$10,890
Backfill	CY	2,420	50	$121,653
Top Soil	CY	1,200	40	$48,000
Seeding (Slope Mix with Hydroseeder)	SF	65,000	0.09	$5,827
Subtotal				**$223,331**
Property Compensation				
Higher Shoreline	AC	7.6	0	$0
Buffer Zone	AC	29.7	0	$0
Conservation Land	AC	0	0	$0
Subtotal				**$0**
Subtotal Infrastructure Improvements				**$1,112,545**
Total Construction Costs				**$1,456,534**
Contingency (25%)			0.25	**$364,133**
Subtotal Probable Construction Costs				**$1,820,667**
Engineering, Design, and Permitting Costs (8%)			0.08	**$145,653**
Construction Management and Administration (5%)			0.05	**$91,033**
Total Project Cost				**$2,057,354**

Item	Alternative 2 - Pond El. 42.5 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Mobilization/demobilization	LS	1	186,799	$186,799
Temporary Construction Facilities				
Silt Fences	LF	1,000	3.50	$3,500
Prepare Staging Areas	AC	1.4	6,875	$9,625
Security Fencing	LF	250	16	$4,001
Access Road Improvements	LS	1	5,000	$5,000
Site Restoration	LS	1	5,000	$5,000
Subtotal Temporary Construction Facilities				**$27,126**
Spillway Modifications				
Crest Gate Support				
Remove Riprap and Concrete Demolition	CY	65	864	$56,160
Geotextile Fabric	SY	100	2.4	$238
Foundation Stone	CY	25	57	$1,422
Concrete	CY	100	61	$6,050
Rebar (epoxy coated)	TN	5	1,749	$8,745
Formwork	SF	300	13	$3,960
Subtotal				**$76,574**
Crest Gate				
Procure and Deliver Gate and Control System	LS	1	174,000	$174,000
Mechanical Installation of Gate	HRS	200	75	$15,000
Control System (hydraulic)	LS	1	26,000	$26,000
Powerline Upgrade (1/0 in existing conduit)	LF	700	7	$5,159
Electrical and Control System Installation	HRS	120	75	$9,000
Crane	Days	2	3,939	$7,878
Subtotal				**$237,037**
Subtotal Spillway Modifications				**$313,612**
Fishway Modifications				
Exit Channel Notch				
Temporary Steel Bracing of Wall	TN	1.8	7,006	$12,611
Concrete Demolition (sawcut and disposal)	CY	5	1,444	$7,222
Foundation Stone	CY	2	569	$1,137
Concrete	CY	5	61	$303
Rebar	TN	1	2,602	$1,301
Formwork	SF	50	13	$660
Subtotal				**$23,234**
Exit Channel Removable Baffles				
Aluminum Guides	TN	1.5	13,530	$20,295
Wooden Weirs (2 sets)	SF	150	91	$13,695
Subtotal				**$33,990**
Exit Channel Isolation Slide Gate				
Procure and Deliver Gate with Guides and Manual Operator	LS	1	17,655	$17,655
Procure and Deliver Gate Motor Operator (5 HP)	LS	1	3,500	$3,500
Install Guides and Gates	HRS	40	75	$3,000
Fishway Footbridge	LF	8	1,200	$9,600
Spillway Footbridge	LF	46	800	$36,800
Subtotal				**$70,555**

Item	Alternative 2 - Pond El. 42.5 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Weir Modifications				
Cut Notch in Concrete Weir	CY	168	75	$12,600
Install Aluminum Guides for Removable Notched Weir Boards	LS	21	400	$8,400
Fabricate and Install Weir Boards	SF	21	240	$5,040
Subtotal				**$26,040**
Entrance Channel Improvement				
Clean Concrete Fishway Entrance	HRS	8	59	$475
Construct Rock Ramp Channel up to Fishway Entrance	TNS	400	32	$12,980
Subtotal				**$13,455**
Subtotal Fishway Modifications				**$167,274**
Infrastructure Improvements				
Route 3A				
Clear and Grub	AC	0.34	6,875	$2,338
Pavement Removal	SY	1,500	10	$14,603
Remove Guardrail	LF	800	6	$4,800
Excavation	CY	260	19	$4,862
Geotextile Fabric	SY	3,200	2.4	$7,603
Foundation Material	CY	475	57	$27,013
Riprap Slope Protection	TNS	1,836	46	$84,456
Asphalt Base and Top Course (3 inch each)	SY	1,500	29	$44,138
Install Guardrail	LF	800	28	$22,000
Lane Painting	LF	2,400	0.3	$766
Signage	EA	2	374	$748
Subtotal				**$213,326**
Sewer Extension (3 house connections)				
Trenching	LF	2,500	50	$125,000
Dewatering	Day	20	250	$5,000
Bedding Material	CY	600	39	$23,562
Pipe (18 inch Dia.)	LF	2,500	25	$63,250
Backfill and Compaction	CY	1,800	50	$90,486
Lift Station (100,000 gpd)	EA	1	150,000	$150,000
Highway Resurfacing	SY	850	80	$68,000
Abandon Septic Systems	EA	3	4,483	$13,448
House Connections (6 inch Dia. 75 ft length)	LF	450	75.0	$33,750
Subtotal				**$572,496**
Septic System Upgrades (3 houses)				
Clear and Grub	AC	0.7	6,875	$4,813
Excavation	CY	1,275	19	$23,843
Tank and Leach Field Sand Fill	CY	570.0	39	$22,384
Septic Tank (5,000 gal)	EA	3.0	13,530	$40,590
Leach Field Piping (4 inch Dia.)	LF	1,500.0	13	$19,223
Backfill	CY	2,225.0	30	$67,796
Top Soil	CY	290.0	40	$11,600
Seeding (Slope Mix with Hydroseeder)	SF	16,000	0.09	$1,434
Subtotal				**$191,682**

Item	Alternative 2 - Pond El. 42.5 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Property Protection Dikes (500 ft Length, 3 Maximum Height)				
Clear and Grub	AC	0.08	6,875	$550
Top Soil Excavation	CY	60	19	$1,140
Embankment Fill	CY	440	50	$22,119
Geotextile Fabric	SY	840	2.4	$1,996
Riprap Stabilization	TNS	200	45	$9,000
Top Soil	CY	60	40	$2,400
Seeding (Slope Mix with Hydroseeder)	SF	3,250	0.09	$291
Subtotal				**$37,496**
Structure Modifications				
Jack Structure	EA	3	12,320	$36,960
New Foundation	CY	180	61	$10,890
Backfill	CY	4,840	50	$243,307
Top Soil	CY	1,200	40	$48,000
Seeding (Slope Mix with Hydroseeder)	SF	65,000	0.09	$5,827
Subtotal				**$344,984**
Property Compensation				
Higher Shoreline	AC	10	0	$0
Buffer Zone	AC	13.8	0	$0
Conservation Land	AC	0	0	$0
Subtotal				**$0**
Subtotal Infrastructure Improvements				**$1,359,983**
Total Construction Costs				**$2,054,794**
Contingency (25%)			0.25	**$513,698**
Subtotal Probable Construction Costs				**$2,568,492**
Engineering, Design, and Permitting Costs (8%)			0.08	**$205,479**
Construction Management and Administration (5%)			0.05	**$128,425**
Total Project Cost				**$2,902,396**

Item	Alternative 3 - Pond El. 43.5 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Mobilization/demobilization	LS	1	234,542	$234,542
Temporary Construction Facilities				
Silt Fences	LF	1,000	3.50	$3,500
Prepare Staging Areas	AC	1.4	6,875	$9,625
Security Fencing	LF	250	45	$11,275
Access Road Improvements	LS	1	5,000	$5,000
Site Restoration	LS	1	5,000	$5,000
Subtotal Temporary Construction Facilities				**$34,400**
Spillway Modifications				
Inflatable Dam Support				
Remove Riprap and Embankment Material	CY	100	19	$1,870
Geotextile Fabric	SY	100	2.4	$238
Foundation Stone	CY	25	57	$1,422
Concrete	CY	60	61	$3,630
Rebar (epoxy coated)	TN	3	1,749	$5,247
Formwork	SF	130	13	$1,716
Subtotal				**$14,122**
Inflatable Dam				
Procure and Deliver Rubber Dam and Control System	LS	1	102,000	$102,000
Mechanical Installation of Rubber Dam	HRS	200	75	$15,000
Control System (Air Compressors and regulators)	LS	1	62,000	$62,000
Powerline Upgrade (1/0 in existing conduit)	LF	700	7	$5,159
Electrical and Control System Installation	HRS	120	75	$9,000
Crane	Days	2	3,939	$7,878
Subtotal				**$201,037**
Subtotal Spillway Modifications				**$215,160**
Fishway Modifications				
Exit Channel Notch				
Temporary Steel Bracing of Wall	TN	1.8	7,006	$12,611
Concrete Demolition (sawcut and disposal)	CY	5	1,444	$7,222
Foundation Stone	CY	2	569	$1,137
Concrete	CY	5	61	$303
Rebar	TN	1	2,602	$1,301
Formwork	SF	50	13	$660
Subtotal				**$23,234**
Exit Channel Removable Baffles				
Aluminum Guides	TN	2.1	13,530	$28,413
Wooden Weirs	SF	210	91	$19,173
Subtotal				**$47,586**
Exit Channel Isolation Slide Gate				
Procure and Deliver Gate with Guides and Manual Operator	LS	1	17,655	$17,655
Procure and Deliver Gate Motor Operator (5 HP)	LS	1	3,500	$3,500
Install Guides and Gates	HRS	40	75	$3,000
Fishway Footbridge	LF	8	1,200	$9,600
Spillway Footbridge	LF	46	800	$36,800
Subtotal				**$70,555**

Item	Alternative 3 - Pond El. 43.5 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Weir Modifications				
Cut Notch in Concrete Weir	CY	80.0	75.00	$6,000
Install Aluminum Guides for Removable Notched Weir Boards	LS	21	400	$8,400
Fabricate and Install Weir Boards	SF	21	240	$5,040
Subtotal				**$19,440**
Entrance Channel Improvement				
Clean Concrete Fishway Entrance	HRS	8	59	$475
Construct Rock Ramp Channel up to Fishway Entrance	TNS	400	32	$12,980
Subtotal				**$13,455**
Subtotal Fishway Modifications				**$174,270**
Infrastructure Improvements				
Route 3A				
Clear and Grub	AC	0.34	6,875	$2,338
Pavement Removal	SY	3,000	10	$29,205
Remove Guardrail	LF	1,500	6	$9,000
Excavation	CY	490	19	$9,163
Geotextile Fabric	SY	4,667	2.4	$11,089
Foundation Material	CY	1,700	57	$96,679
Riprap Slope Protection	TNS	1,836	46	$84,456
Asphalt Base and Top Course (3 inch each)	SY	3,000	29	$88,275
Install Guardrail	LF	1,500	28	$41,250
Lane Painting	LF	4,500	0.3	$1,436
Signage	EA	2	374	$748
Subtotal				**$373,638**
Sewer Extension (3 house connections)				
Trenching	LF	2,500	50	$125,000
Dewatering	Day	20	250	$5,000
Bedding Material	CY	600	39	$23,562
Pipe (18 inch Dia.)	LF	2,500	25	$63,250
Backfill and Compaction	CY	1,800	50	$90,486
Lift Station (100,000 gpd)	EA	1	150,000	$150,000
Highway Resurfacing	SY	850	80	$68,000
Abandon Septic Systems	EA	3	4,483	$13,448
House Connections (6 inch Dia. 75 ft length)	LF	450	75.0	$33,750
Subtotal				**$572,496**
Septic System Upgrades (5 houses)				
Clear and Grub	AC	1.2	6,875	$8,021
Excavation	CY	2,125.0	19	$39,738
Tank and Leach Field Sand Fill	CY	950.0	39	$37,307
Septic Tank (5,000 gal)	EA	5.0	13,530	$67,650
Leach Field Piping (4 inch Dia.)	LF	2,500.0	13	$32,038
Backfill	CY	3,708.3	30	$112,993
Top Soil	CY	483.3	40	$19,333
Seeding (Slope Mix with Hydroseeder)	SF	26,666.7	0.09	$2,391
Subtotal				**$319,469**

Item	Alternative 3 - Pond El. 43.5 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Property Protection Dikes (1,000 ft Length, 5 Max Height)				
Clear and Grub	AC	0.2	6,875	$1,650
Top Soil Excavation	CY	288	19	$5,472
Embankment Fill	CY	2,560	50	$128,691
Geotextile Fabric	SY	2,800	2.4	$6,653
Riprap Stabilization	TNS	768	45	$34,560
Top Soil	CY	288	40	$11,520
Seeding (Slope Mix with Hydroseeder)	SF	9,000	0.09	$807
Subtotal				**$189,353**
Structure Modifications				
Jack Structure	EA	3	12,320	$36,960
New Foundation	CY	180	61	$10,890
Backfill	CY	7,260	50	$364,960
Top Soil	CY	1,200	40	$48,000
Seeding (Slope Mix with Hydroseeder)	SF	65,000	0.09	$5,827
Subtotal				**$466,637**
Property Compensation				
Higher Shoreline	AC	14.5	0	$0
Buffer Zone	AC	19	0	$0
Conservation Land	AC	0	0	$0
Subtotal				**$0**
Subtotal Infrastructure Improvements				**$1,921,593**
Total Construction Costs				**$2,579,965**
Contingency (25%)			0.25	**$644,991**
Subtotal Probable Construction Costs				**$3,224,956**
Engineering, Design, and Permitting Costs (8%)			0.08	**$257,996**
Construction Management and Administration (5%)			0.05	**$161,248**
Total Project Cost				**$3,644,200**

Item	Alternative 4 - Pond El. 40.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Mobilization/demobilization	LS	1	84,139	$84,139
Temporary Construction Facilities				
Silt Fences	LF	1,000	3.50	$3,500
Prepare Staging Areas	AC	1.4	6,875	$9,625
Security Fencing	LF	250	16	$4,001
Access Road Improvements	LS	1	5,000	$5,000
Site Restoration	LS	1	5,000	$5,000
Subtotal Temporary Construction Facilities				**$27,126**
Spillway Modifications				
Crest Gate/Inflatable Dam Support				
Remove Riprap and Embankment Material	CY	0	0	$0
Geotextile Fabric	SY	0	0	$0
Foundation Stone	CY	0	0	$0
Concrete	CY	0	0	$0
Rebar (epoxy coated)	TN	0	0	$0
Formwork	SF	0	0	$0
Subtotal				**$0**
Crest Gate/Inflatable Dam				
Procure and Deliver Gate and Control System	LS	0	0	$0
Mechanical Installation of Gate	HRS	0	0	$0
Control System (hydraulic or air)	LS	0	0	$0
Powerline Upgrade (1/0 in existing conduit)	LF	0	0	$0
Electrical and Control System Installation	HRS	0	0	$0
Crane	Days	0	0	$0
				$0
Subtotal Spillway Modifications				**$0**
Fishway Modifications				
Exit Channel				
Temporary Steel Bracing of Wall	TN	0.0	0	$0
Embankment Excavation	CY	525.0	19	$9,818
Concrete Demolition (sawcut and disposal)	CY	25	1,444	$36,110
Foundation Stone	CY	15	569	$8,531
Geotextile Fabric	SY	200	2.4	$475
Concrete	CY	40	61	$2,420
Rebar	TN	2	2,602	$5,203
Concrete Dowels in Existing Dam Cutoff Wall	EA	8	200	$1,600
Formwork	SF	1,500	13	$19,800
Embankment Fill (placement and compaction	CY	420	50	$21,113
Riprap Slope Protection	TNS	65	32	$2,109
Seeding	SF	2,000	0.09	$179
Subtotal				**$107,358**
Exit Channel Removable Baffles (7 Weirs)				
Aluminum Guides	TN	1.2	13,530	$16,236
Wooden Weirs	SF	110	91	$10,043
Subtotal				**$26,279**

Item	Alternative 4 - Pond El. 40.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Exit Channel Isolation Slide Gate				
Procure and Deliver Gate with Guides and Manual Operator	LS	1	17,655	$17,655
Procure and Deliver Gate Motor Operator (5 HP)	LS	1	3,500	$3,500
Install Guides and Gates	HRS	40	75	$3,000
Fishway Footbridge	LF	8	1,200	$9,600
Spillway Footbridge	LF	46	800	$36,800
Subtotal				**$70,555**
Weir Modifications				
Cut Notch in Concrete Weir	HRS	168.0	75	$12,600
Install Aluminum Guides for Removable Notched Weir Boards	EA	18	400	$7,200
Fabricate and Install Weir Boards	EA	18	240	$4,320
Subtotal				**$24,120**
Entrance Channel Improvement				
Clean Concrete Fishway Entrance	HRS	8	59	$475
Construct Rock Ramp Channel up to Fishway Entrance	TNS	400	32	$12,980
Subtotal				**$13,455**
Subtotal Fishway Modifications				**$241,768**
Infrastructure Improvements (Not Applicable)				
Route 3A				
Clear and Grub	AC	0	0	$0
Pavement Removal	SY	0	0	$0
Remove Guardrail	LF	0	0	$0
Excavation	CY	0	0	$0
Geotextile Fabric	SY	0	0	$0
Foundation Material	CY	0	0	$0
Riprap Slope Protection	TNS	0	0	$0
Asphalt Base and Top Course (3 inch each)	SY	0	0	$0
Install Guardrail	LF	0	0	$0
Lane Painting	LF	0	0	$0
Signage	EA	0	0	$0
Subtotal				**$0**
Sewer Extension (3 house connections)				
Trenching	LF	2,500	50	$125,000
Dewatering	Day	20	250	$5,000
Bedding Material	CY	600	39	$23,562
Pipe (18 inch Dia.)	LF	2,500	25	$63,250
Backfill and Compaction	CY	1,800	50	$90,486
Lift Station (100,000 gpd)	EA	1	150,000	$150,000
Highway Resurfacing	SY	850	80	$68,000
Abandon Septic Systems	EA	3	4,483	$13,448
House Connections (6 inch Dia. 75 ft length)	LF	450	75.0	$33,750
Subtotal				**$572,496**

Item	Alternative 4 - Pond El. 40.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Septic System Upgrades (Not Applicable)				
Clear and Grub	AC	0	0	$0
Excavation	CY	0	0	$0
Tank and Leach Field Sand Fill	CY	0	0	$0
Septic Tank (5,000 gal)	EA	0	0	$0
Leach Field Piping (4 inch Dia.)	LF	0	0	$0
Backfill	CY	0	0	$0
Top Soil	CY	0	0	$0
Seeding (Slope Mix with Hydroseeder)	SF	0	0	$0
Subtotal				**$0**
Property Protection Dikes (Not Applicable)				
Clear and Grub	AC	0	0	$0
Top Soil Excavation	CY	0	0	$0
Embankment Fill	CY	0	0	$0
Geotextile Fabric	SY	0	0	$0
Riprap Stabilization	TNS	0	0	$0
Top Soil	CY	0	0	$0
Seeding (Slope Mix with Hydroseeder)	SF	0	0	$0
Subtotal				**$0**
Structure Modifications (Not Applicable)				
Jack Structure	EA	0	0	$0
New Foundation	CY	0	0	$0
Backfill	CY	0	0	$0
Top Soil	CY	0	0	$0
Seeding (Slope Mix with Hydroseeder)	SF	0	0	$0
Subtotal				**$0**
Property Compensation				
Higher Shoreline	AC		0	$0
Buffer Zone	AC		0	$0
Conservation Land	AC		0	$0
Subtotal				**$0**
Subtotal Infrastructure Improvements				**$572,496**
Total Construction Costs				**$925,528**
Contingency (25%)			0.25	**$231,382**
Subtotal Probable Construction Costs				**$1,156,910**
Engineering, Design, and Permitting Costs (8%)			0.08	**$92,553**
Construction Management and Administration (5%)			0.05	**$57,846**
Total Project Cost				**$1,307,309**

Item	Alternative 5 - Pond El. 41.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Mobilization/demobilization	LS	1	85,970	$85,970
Temporary Construction Facilities				
Silt Fences	LF	1,000	3.50	$3,500
Prepare Staging Areas	AC	1.4	6,875	$9,625
Security Fencing	LF	250	16	$4,001
Access Road Improvements	LS	1	5,000	$5,000
Site Restoration	LS	1	5,000	$5,000
Subtotal Temporary Construction Facilities				**$27,126**
Spillway Modifications (Not Applicable)				
Crest Gate/Inflatable Dam Support				
Remove Riprap and Embankment Material	CY	0	0	$0
Geotextile Fabric	SY	0	0	$0
Foundation Stone	CY	0	0	$0
Concrete	CY	0	0	$0
Rebar (epoxy coated)	TN	0	0	$0
Formwork	SF	0	0	$0
Subtotal				**$0**
Flashboards				
Flashboards and Pins	LS	1	3,300	$3,300
Mechanical Installation of Gate	HRS	50	75	$3,750
Control System (hydraulic, reduce by 75% for handwheel)	LS	0	0	$0
Powerline Upgrade (1/0 in existing conduit)	LF	0	0	$0
Electrical and Control System Installation	HRS	0	0	$0
Crane	Days	0	0	$0
				$7,050
Subtotal Spillway Modifications				**$7,050**
Fishway Modifications				
Exit Channel				
Temporary Steel Bracing of Wall	TN	0.0	0	$0
Embankment Excavation	CY	525.0	19	$9,818
Concrete Demolition (sawcut and disposal)	CY	25	1,444	$36,110
Foundation Stone	CY	15	569	$8,531
Geotextile Fabric	SY	200	2.4	$475
Concrete	CY	40	61	$2,420
Rebar	TN	2	2,602	$5,203
Concrete Dowels in Existing Dam Cutoff Wall	EA	8	200	$1,600
Formwork	SF	1,500	13	$19,800
Embankment Fill (placement and compaction	CY	420	50	$21,113
Riprap Slope Protection	TNS	65	32	$2,109
Seeding	SF	2,000	0.09	$179
Subtotal				**$107,358**
Exit Channel Removable Baffles (10 weirs)				
Aluminum Guides	TN	1.7	13,530	$23,194
Wooden Weirs	SF	157	91	$14,347
Subtotal				**$37,541**

Item	Alternative 5 - Pond El. 41.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Exit Channel Isolation Slide Gate				
Procure and Deliver Gate with Guides and Manual Operator	LS	1	17,655	$17,655
Procure and Deliver Gate Motor Operator (5 HP)	LS	1	3,500	$3,500
Install Guides and Gates	HRS	40	75	$3,000
Fishway Footbridge	LF	8	1,200	$9,600
Spillway Footbridge	LF	46	800	$36,800
Subtotal				**$70,555**
Weir Modifications				
Cut Notch in Concrete Weir	HRS	168.0	75.00	$12,600
Install Aluminum Guides for Removable Notched Weir Boards	EA	18	400	$7,200
Fabricate and Install Weir Boards	EA	18	240	$4,320
Subtotal				**$24,120**
Entrance Channel Improvement				
Clean Concrete Fishway Entrance	HRS	8	59	$475
Construct Rock Ramp Channel up to Fishway Entrance	TNS	400	32	$12,980
Subtotal				**$13,455**
Subtotal Fishway Modifications				**$253,030**
Infrastructure Improvements				
Route 3A (Not Applicable)				
Clear and Grub	AC	0	0	$0
Pavement Removal	SY	0	0	$0
Remove Guardrail	LF	0	0	$0
Excavation	CY	0	0	$0
Geotextile Fabric	SY	0	0	$0
Foundation Material	CY	0	0	$0
Riprap Slope Protection	TNS	0	0	$0
Asphalt Base and Top Course (3 inch each)	SY	0	0	$0
Install Guardrail	LF	0	0	$0
Lane Painting	LF	0	0	$0
Signage	EA	0	0	$0
Subtotal				**$0**
Sewer Extension (3 house connections)				
Trenching	LF	2,500	50	$125,000
Dewatering	Day	20	250	$5,000
Bedding Material	CY	600	39	$23,562
Pipe (18 inch Dia.)	LF	2,500	25	$63,250
Backfill and Compaction	CY	1,800	50	$90,486
Lift Station (100,000 gpd)	EA	1	150,000	$150,000
Highway Resurfacing	SY	850	80	$68,000
Abandon Septic Systems	EA	3	4,483	$13,448
House Connections (6 inch Dia. 75 ft length)	LF	450	75.0	$33,750
Subtotal				**$572,496**

Item	Alternative 5 - Pond El. 41.0 ft			
	Unit	Quantity	Unit Price ($/Unit)	Cost ($)
Septic System Upgrades (Not Applicable)				
Clear and Grub	AC	0	0	$0
Excavation	CY	0	0	$0
Tank and Leach Field Sand Fill	CY	0	0	$0
Septic Tank (5,000 gal)	EA	0	0	$0
Leach Field Piping (4 inch Dia.)	LF	0	0	$0
Backfill	CY	0	0	$0
Top Soil	CY	0	0	$0
Seeding (Slope Mix with Hydroseeder)	SF	0	0	$0
Subtotal				**$0**
Property Protection Dikes (Not Applicable)				
Clear and Grub	AC	0	0	$0
Top Soil Excavation	CY	0	0	$0
Embankment Fill	CY	0	0	$0
Geotextile Fabric	SY	0	0	$0
Riprap Stabilization	TNS	0	0	$0
Top Soil	CY	0	0	$0
Seeding (Slope Mix with Hydroseeder)	SF	0	0	$0
Subtotal				**$0**
Structure Modifications (Not Applicable)				
Jack Structure	EA	0	0	$0
New Foundation	CY	0	0	$0
Backfill	CY	0	0	$0
Top Soil	CY	0	0	$0
Seeding (Slope Mix with Hydroseeder)	SF	0	0	$0
Subtotal				**$0**
Property Compensation				
Higher Shoreline	AC	0	0	$0
Buffer Zone	AC	0	0	$0
Conservation Land	AC	0	0	$0
Subtotal				**$0**
Subtotal Infrastructure Improvements				**$572,496**
Total Construction Costs				**$945,672**
Contingency (25%)			0.25	**$236,418**
Subtotal Probable Construction Costs				**$1,182,090**
Engineering, Design, and Permitting Costs (8%)			0.08	**$94,567**
Construction Management and Administration (5%)			0.05	**$59,104**
Total Project Cost				**$1,335,762**