Fishway Assessment and Cost Analysis Report

ROYAL RIVER, YARMOUTH ME

PREPARED FOR THE NATURE CONSERVANCY
FINAL – JULY 2017, REVISED JANUARY 2018

INTER-FLUVE
P.O. BOX 236
DAMARISCOTTA, ME 04543

Partially funded via the Environmental Protection Agency, CFDA Number under Casco Bay Estuary Partnership EPA Year 18, Grant Number CE 96173101-0

Executive Summary

This study provides a detailed assessment of the fish passage potential at the Bridge Street and East Elm Street dams on the Royal River in the town of Yarmouth, Maine. The study also identifies four alternative approaches to enhance fish passage at each dam, and summarizes analyses to compare the relative costs of the identified alternatives at each site. The target native fish community identified for the study included alewife, American eel, American shad, blueback herring, sea-run brook trout, rainbow smelt, sea lamprey, and striped bass.

At the time of the assessment, the fishway at the Bridge Street dam was functioning hydraulically, but was found to have fair to poor ability to attract fish to the entrance of the fishway, with geometry and slope that are likely to discourage usage by American shad. The operational limits for the existing fishway are constrained by its size. The proportion of flow available for attraction was found to be within limits established by the U.S. Fish and Wildlife (USFWS; 2016) for the lower 75 percent of the fish passage flows, but is below the established criteria for the upper 25 percent of the fish passage flows. Available guidance from NOAA suggests that the available attraction flow is less than recommended for attraction of upstream migrating fish. Resting areas within the fishway were found to be inadequate when compared to prevailing criteria (USFWS 2016). There are no provisions for upstream passage of juvenile eels, and there is notable potential for injury to downstream outmigrating fish. Overall, it can be concluded that the fishway at the Bridge Street dam is a likely constraint on the long-term restoration of bi-directional passage for the full target diadromous fish community.

At the time of the assessment, the fishway at the East Elm Street dam was not functioning and was in disrepair. If the fishway were restored to fully operational status, it would exhibit nearly identical trends to those summarized above for the Bridge Street fishway. Thus, it can also be concluded that the fishway at the East Elm Street dam is also a likely constraint on the long-term restoration of bi-directional passage for the full target diadromous fish community.

For the four alternatives (no action, retrofit/rebuild technical fishway, nature-like fishway, and dam removal) identified to enhance fish passage potential at each site, their relative costs were analyzed in terms of initial project costs, life span costs (operation, maintenance and repair) over a 30-year planning horizon, and eventual replacement costs. The lowest cost alternative in economic terms at each site was the no action alternative. However, based on the results summarized above, it can be concluded that this alternative would not achieve the stated goal of restoring long-term bi-directional passage for the target native diadromous fish community.

Of the remaining alternatives that enhance fish passage at the Bridge Street site, the dam removal option had the lowest initial and total costs, followed by the nature-like fishway alternative. The technical fishway retrofit/rebuild alternative had the highest estimated initial and total costs at the Bridge Street site.

Of the remaining alternatives that enhance fish passage at the East Elm Street site, the nature-like fishway option had the lowest initial and total project costs, followed by the technical fishway retrofit/rebuild alternative. The dam removal alternative at the East Elm Street site had the highest estimated costs, primarily due to the potential need for proactive management of the potentially mobile sediment stored behind the dam, and the potential for mitigation associated with critical infrastructure resulting from dam removal.

Table of Contents

1. Introduction 1
1.1 Fisheries Overview 1
1.2 Scope of Work 3
2. Project Area 4
2.1 Royal River watershed 4
2.2 Project Reach Description 6
2.2.1 Bridge Street Dam 6
2.2.2 East Elm Street Dam 8
3. Fishway Assessment 9
3.1 Fish Utilization 9
3.2 Fish Passage Criteria, Standards and Assessment Methods 10
3.3 Fish Passage Hydrology 14
3.4 Bridge Street Dam fishway 16
3.4.1 Bridge Street - Physical Description and Qualitative Assessment 16
3.4.2 Bridge Street – Quantitative Assessment 18
3.4.3 Bridge Street - Assessment Summary 22
3.5 East Elm Street Dam Fishway 24
3.5.1 East Elm Street - Physical Description and Qualitative Assessment 24
3.5.2 East Elm Street – Quantitative Assessment 27
3.5.3 East Elm Street - Assessment Summary 29
4. Fish Passage Alternatives 31
4.1 Bridge Street dam 31
4.1.1 No Action 31
4.1.2 Fishway Retrofit/Rebuild 31
4.1.3 Nature-like Fishway 33
4.1.4 Dam Removal 36
4.2 East Elm street dam 38
4.2.1 No Action 38
4.2.2 Fishway Retrofit/Rebuild 38
4.2.3 Nature-like Fishway 39
4.2.4 Dam Removal 42
4.3 Summary of Fish Passage Alternatives 44
5. Cost Analysis 45
5.1 Assumptions 45
5.2 Cost Analysis Summary 51
6. Summary and Conclusions 52
7. References 54

8. Appendix A: Bridge Street Fishway Inspection Form and Photographs 57

9. Appendix B: East Elm Street Fishway Inspection Form and Photographs 64

10. Appendix C: Flow Partitioning Calculations 71

10.1 Bridge Street Dam Analyses 71

10.2 East Elm Street Dam Analyses 74

11. Appendix D: Detailed Cost Analysis Tables 78

11.1 Bridge Street Dam Detailed Cost Analyses 79

11.2 East Elm Street Dam Detailed Cost Analyses 84

List of Figures

Figure 1: Normalized time series of abundance indices for five species of the target fish community. 2

Figure 2: Royal River watershed boundaries, study reach and study sites. 5

Figure 3: Overlays of assessment sites and FEMA flood risk delineations of the Yarmouth Cascades section of the Royal River. 6

Figure 4: View looking upstream at Bridge Street Dam. 7

Figure 5: View looking upstream at East Elm Street Dam. 8

Figure 6: Flow-duration curves during target fish migration period. 15

Figure 7: Site map of the Bridge Street site indicating key decision points for upstream migrating fish. 17

Figure 8: Site map of the Bridge Street site indicating primary flow vectors. 17

Figure 9: Site map of the East Elm Street site indicating key decision points for upstream migrating fish. 26

Figure 10: Site map of the East Elm Street site indicating primary flow vectors. 26

Figure 11: Possible Bridge Street dam site alignment and dimensions of new Denil fishway to meet USFWS criteria (Table 4). 33

Figure 12: Potential alignment options for the nature-like fishway alternative at the Bridge Street dam Location. 35

Figure 13: Probable post-dam-removal fish passage channels at the Bridge Street Dam site. 37

Figure 14: Location and dimensions of proposed retrofit of existing East Elm Street Denil fishway to meet USFWS criteria (Table 4). 39

Figure 15: Potential alignment options for the nature-like fishway alternative at the East Elm Street dam site. 41

Figure 16: Probable post-dam-removal fish passage channels at the East Elm Street dam site. 43

Figure 17: Selection of photos of Bridge Street Dam Fishway 63

Figure 18: Selection of photos of East Elm Street Dam Fishway. 70

List of Tables

Table 1: Dates of capture on the Royal River between 1983 and 1989, and estimated bioperiods for upstream migration of target diadromous and resident fish species on the Royal River, using sampling efforts conducted on the Saco, Kennebec and Penobscot Rivers (Wippelhauser, 2016). 9

Table 2: General criteria for the design and operation of technical fishways (USFWS 2016). 11

Table 3: General criteria for the design and operation of technical fishways, with emphasis on Denil fishways (USFWS 2016). 12

Table 4: Select design criteria adapted from Nature-like and Weir-type fish passage design guidance (Turek et al. 2016). 12

Table 5: Average and median monthly flows on the Royal River. 14

Table 6: Flow duration exceedance percentiles during target migration periods derived from USGS gage 01060000 Royal River at Yarmouth, Maine. 14

Table 7: Bridge St. dam flow partitioning between Denil fishway and dam spillway over the fish passage operational range, if flow is constrained to these two pathways. 19

Table 8: Bridge St. dam flow partitioning between Denil fishway, stop log weir, and dam spillway over the fish passage operational range. 20

Table 9: Comparison of estimated mean water column velocities in the central plane of the fully developed flow portions of the Bridge St. fishway, to recent (Turek et al. 2016) critical velocity design criteria over the fish passage operational range. 21

Table 10: East Elm St. dam flow partitioning between Denil fishway, foundry channel, and dam spillway over the fish passage operational range if flow is constrained to these three pathways. 28

Table 11: East Elm St. dam flow partitioning between Denil fishway, foundry channel, stop log weir, and dam spillway over the fish passage operational range. 28

Table 12: Slopes and channel lengths associated with the potential nature-like fishway alignments shown in Figure 12. 35

Table 13: Slopes and lengths of probable post-Bridge-Street-dam-removal fish passage channels shown in Figure 12. 37

Table 14: Slopes and channel lengths associated with the potential nature-like fishway alignments at the East Elm Street dam site shown in Figure 14. 41

Table 15: Slopes and lengths of probable post-East-Elm-Street-dam-removal fish passage channels shown in Figure 15. 43

Table 16: Preliminary estimates of proportion of total flow routed through fish passage facilities associated with the alternative fish passage approaches. 44

Table 17: Repair recommendations of HDR based on visual inspection (2009). 47

Table 18: Repair recommendations of FERC based on their 2015 safety inspection as indicated in their letter (FERC 2015) which was issued subsequent to the inspection. 48

Table 19: Summary of cost analysis, rounded to nearest $1,000......51

1. Introduction

The Royal River has been the focus of multiple studies investigating the current functionality and proposed future of two dams within the developed portion of this watershed in the town of Yarmouth, Maine. These studies were initiated after these two dams, the East Elm Street Dam and the Bridge Street Dam, were identified as high priority candidates for restoration by collaborative efforts including the Gulf of Maine Council on the Environment, the Nature Conservancy's (TNC) Northeast Connectivity Project, and the former State Planning Office. Restoration of fish passage at the East Elm Street and Bridge Street Dams was ranked in the top 5% of 14,000 dams throughout the northeast analyzed by TNC.

In response to this high ranking, the Town of Yarmouth began a restoration planning process that initiated in early 2008 with the *Royal River Corridor Study* which resulted in the *Royal River Corridor Master Plan* (Royal River Study Committee 2008). Development of the master plan was followed by the *Royal River Fisheries and Aquatic Habitat Feasibility Study* (Stantec 2010) and the associated *Phase II Analysis and Reporting* (Stantec 2013), and the *Royal River Recreational Study* (Maine Rivers 2013).

Initiated by TNC and their partners (Maine Rivers and Casco Bay Estuary Partnership), this fishway assessment and cost analysis is a continuation of the effort to provide safe, timely and effective passage for diadromous and resident fish upstream and downstream of the two Yarmouth dams. The assessment portion of this report aims to provide detailed information on the performance of the current fishways. The alternatives portion of this report aims to describe four fish passage modification alternatives (no action, retrofit/rebuild, nature-like ramp/bypass, dam removal) at a level of detail to support comparative cost analysis for each site. The intent for the cost analyses is to facilitate comparison of the relative costs of the alternatives in terms of initial project, lifespan, and replacement costs, as applicable.

1.1 FISHERIES OVERVIEW

Many of the diadromous species designated within the target fish community for the Royal River have shown a marked decline in abundance throughout the Atlantic region (Figure 1). This decline is attributed in large part to loss of habitat, especially relating to dam installation (Limburg and Waldman 2009). The Royal River emulates a larger trend occurring within the region, where insufficient fish passage contributes to a decline in diadromous species upstream of the dams. Sampling efforts conducted by Maine Department of Marine Resources (MEDMR) between 1975 and 1989 documented anadromous river herring, sea-run brook trout, catadromous American eel, and one instance of American shad attempting to migrate past the dams (Stantec 2010). Multiple fish species that would have historically occupied the Royal River for varying parts of their life cycles have not been recently documented within the reach (Wippelhauser 2011). These species include Atlantic salmon (*Salmo salar*) which were found historically in the Royal River, but have since been extirpated from the system, likely influenced by the presence of migration barriers in the forms of dams and other factors.

Documented declines in alewives within this system suggests that upstream and downstream passage, habitat, and species dynamics may have been directly or indirectly impacted by the Bridge Street and East Elm Street dams. As further indication of this impact, American shad were restocked 10 miles above the head-of-tide on the Royal River between 1978 and 1981. Since the restocking of over 200 American shad, only one observation was recorded within the fish passes between 1975 and 1989 (Stantec 2010). These dams and their associated fishways are thought to impede upstream access to potential spawning and rearing habitat along the mainstem and its tributaries.

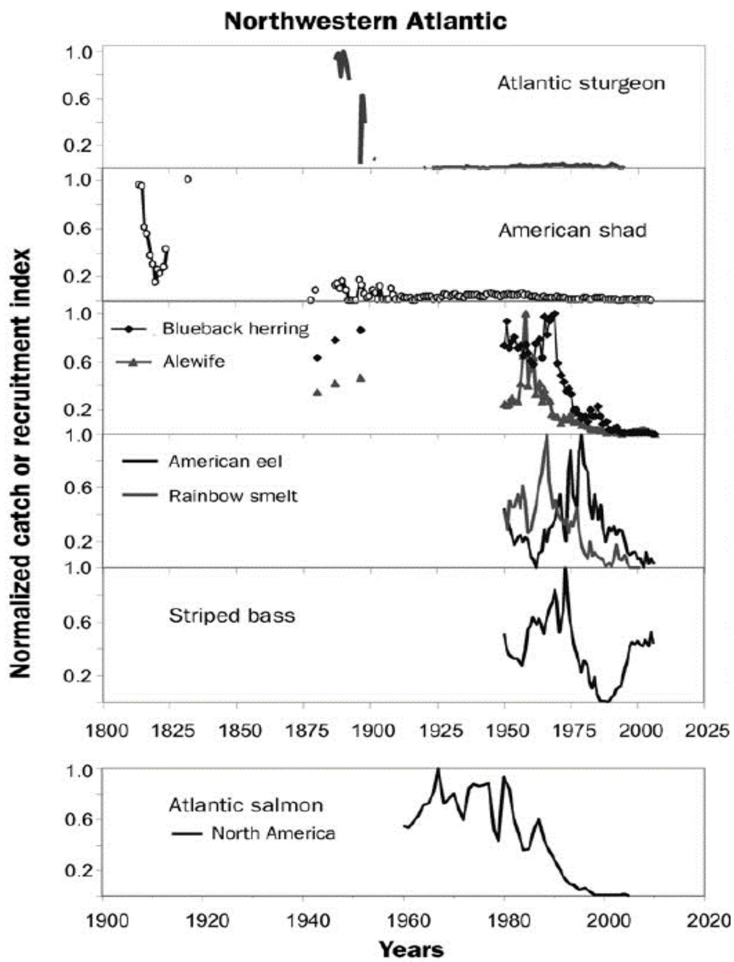

Figure 1: Normalized time series of abundance indices for five species of the target fish community. Data were derived from US summary statistics (Limburg and Waldman 2009).

1.2 SCOPE OF WORK

This report summarizes the results of two project phases, a detailed assessment of the current fish passage facilities at the two dams, and descriptions of alternatives and associated cost analyses. This report includes:

- *Field review* – Each facility was reviewed in the field, including general assessment of condition, configuration, orientation and observation of primary flow patterns at each site, and documentation of apparent deficiencies and operation/maintenance issues.
- *Qualitative Assessment* – The characteristics of each facility were compared against current prevailing design standards, resulting in qualitative descriptions of each facility including apparent trends in attraction flow, condition, and operation/maintenance issues.
- *Quantitative Assessment* – Utilizing existing hydrologic data, flow exceedance quantiles were developed to define the fish passage operational flow ranges integrated over the relevant bioperiods for the target fish community. Headwater rating curves were developed, and flow partitioning[1] was calculated between the fishways and their associated spillways. These analyses supported quantitative assessment of fishway hydraulics, and more detailed assessment of near-field and far-field attraction patterns.
- *Cost Analysis* – Up to four dam modification alternatives (no action, retrofit/rebuild, nature-like ramp/bypass, dam removal) were developed in concept for each facility with just enough detail to support the comparative cost analysis for each site. The intent for the cost analyses was to develop precision and accuracy that is greater than order of magnitude, but less formal than detailed design opinions of probable construction cost. The cost analysis includes design, permitting, construction, and estimated operation and maintenance costs for a thirty-year planning horizon, with appropriate inflation factors based on regional trends.

[1] At each dam, flow partitioning refers to the relative amounts of the total river flow that travel through the fishway, over the spillway, and through other pathways through the dam, such as gates, stop log weirs, and hydropower turbines. The proportion of flow available for attraction to the fishway entrance is an important factor on fish utilization. Table 2 summarizes attraction flow recommendations from USFWS (2016) and NOAA (2015).

2. Project Area

2.1 ROYAL RIVER WATERSHED

The Royal River drains an approximately 141 mi^2 watershed into Casco Bay (Figure 2). The headwaters of the mainstem of the Royal River initiate at Sabbathday Lake. The river continues downstream relatively unimpeded for approximately 39 miles through a watershed largely unaffected by human disturbance. The lower watershed transitions to a more densely populated and developed land use pattern before the river drains through Yarmouth Harbor into Casco Bay.

Approximately one mile upstream of the head of tide, the river increases in slope through the section known as the Yarmouth Cascades, and is adjacent to historical and current infrastructure within the river corridor. Historically, the Yarmouth Cascade section of the river was developed to provide power for paper and cotton manufacturing, lumber processing, tanneries, poultry processing plants and iron forging (Stantec 2010). In this segment of the river, two historical dams remain which are the subject of the current study. These include the East Elm Street Dam, a stone, gravity-type run-of-river structure, and the Bridge Street Dam, a masonry and reinforced concrete, gravity-type run-of-river structure (MSHV 2013).

Located between these two dam sites, the Middle Falls area of the Yarmouth Cascades was considered a possible constraint on upstream fish passage potential (Wippelhauser 2011). Removal of a small barrier in a side channel around the east side of Factory Island (which adjoins the Middle Falls) in 2012 may have partially or substantially mitigated this perceived passage limitation (Stantec 2013). It should be noted, however, that evaluation of passage potential at the Middle Falls is outside the scope of this study.

In the upper watershed, there are two notable known passage barriers in the Town of New Gloucester. The first is the Jordan Mill dam which is located approximately three river miles downstream of the Sabbathday Lake outlet (MSHV 2013). The second barrier in this vicinity is an outcrop of natural ledge that the river flows over, located approximately 100 yards downstream of the Jordan Mill dam (Craig 2017).

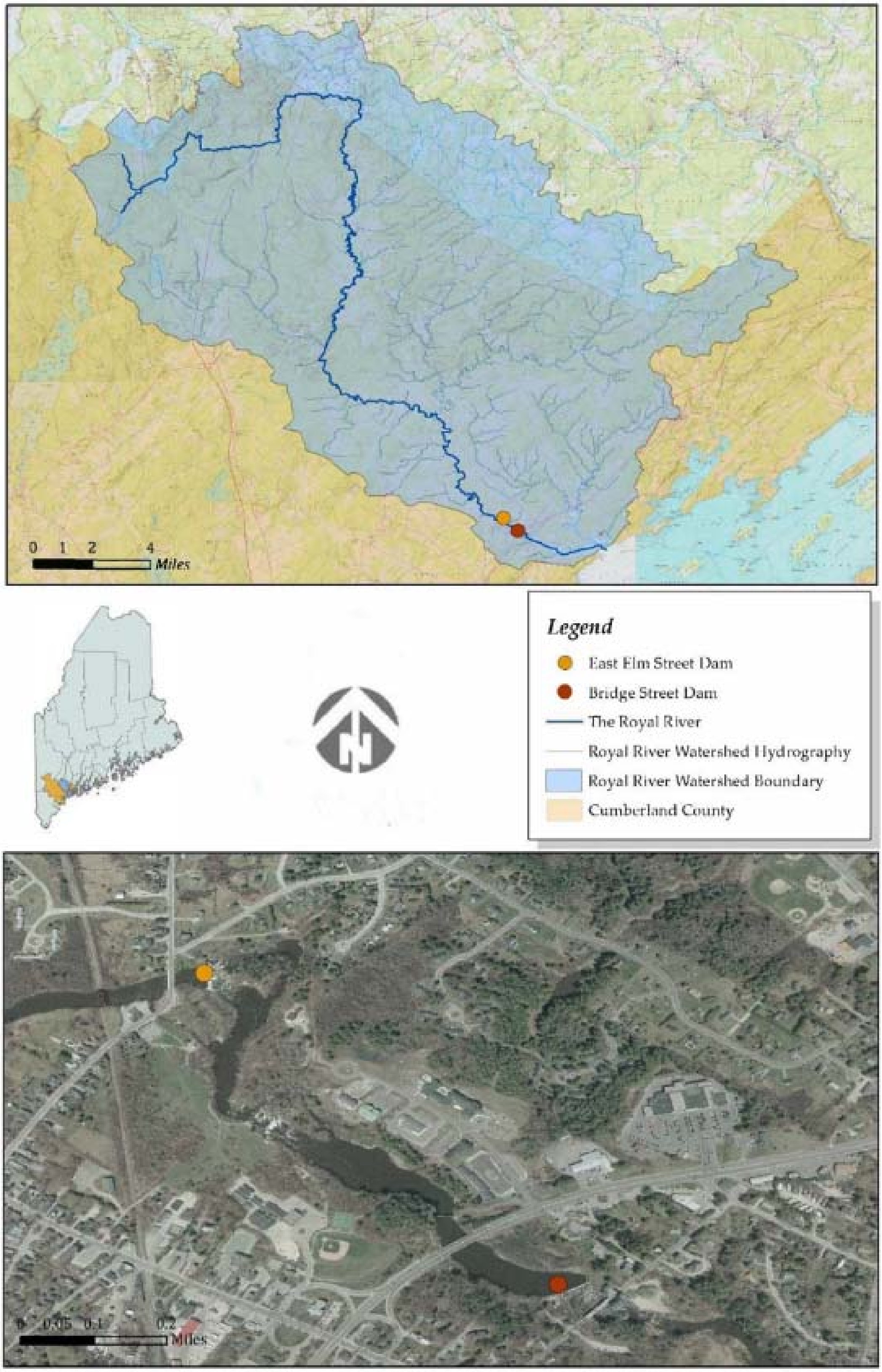

Figure 2: Royal River watershed boundaries, study reach and study sites. Data derived from Maine Office of Geographic Information Systems, Geo Spatial Data Gateway, and USGS HydroSHEDS.

2.2 PROJECT REACH DESCRIPTION

The section of the Royal River known as the “Yarmouth Cascades” incorporates the East Elm Street and Bridge Street Dams, the last two remaining dams on the mainstem (Figure 3). This section of river is characterized by steep drops or cascades over exposures of metamorphic bedrock. The composition of these metamorphic rocks (protoliths of basalt, mudstone and limestone) makes them highly resistant to erosional processes (Osberg 1985). The resulting longitudinal profile is characterized by cascades followed by deep and long pools. Upstream of the dams, impoundment zones are defined by increased water levels and sediment deposition, resulting from backwater associated with each obstruction. Dense vegetation lines the banks through the majority of the study reach, with short sections of man-made erosion control structures associated with current or historical dams.

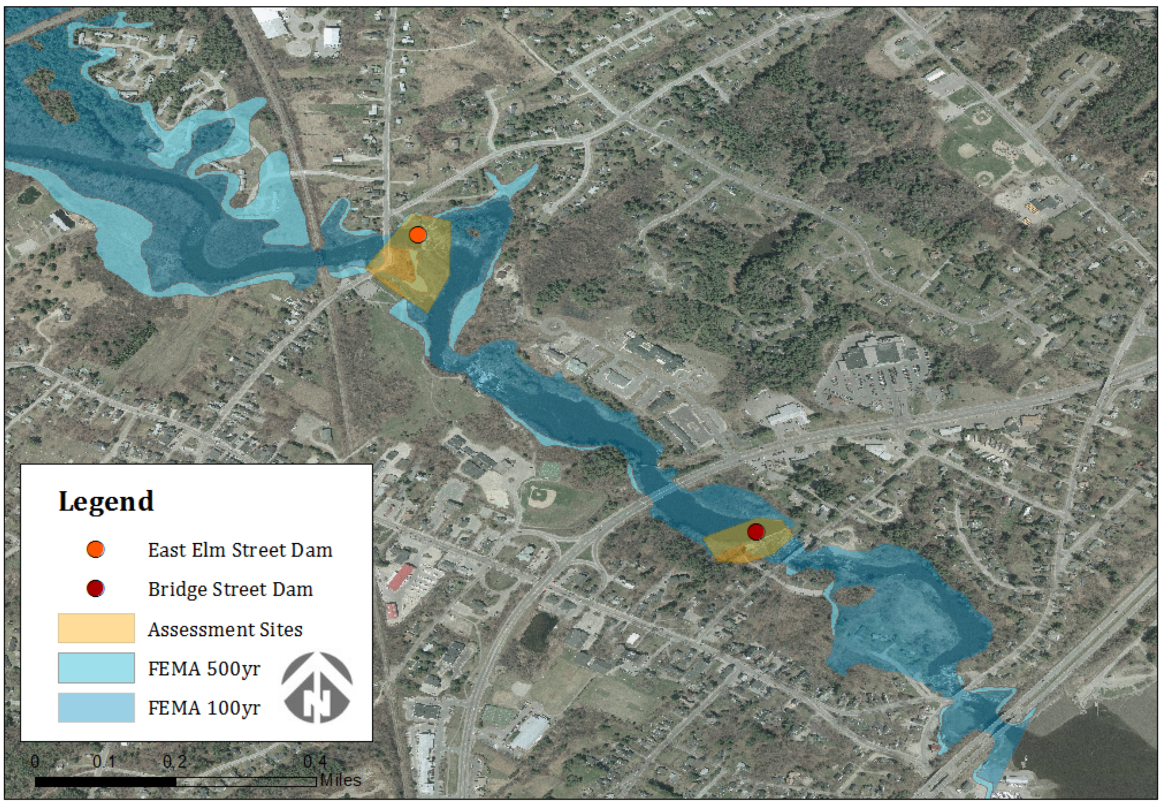

Figure 3: Overlays of assessment sites and FEMA flood risk delineations of the Yarmouth Cascades section of the Royal River. Downstream flow direction is from upper left to lower right.

2.2.1 Bridge Street Dam

The Bridge Street Dam is a masonry and reinforced concrete gravity-type run-of-river structure that spans the full width of the river at approximately 275 feet, with a 75-foot spillway at its center (Figure 4). It is constructed upon a metamorphic bedrock exposure known as the Second Falls, and lies 250 feet upstream from Bridge Street. Low-flow stop log weirs are built into the 10-foot tall structure on either side of the spillway. To provide upstream fish passage, a concrete Denil-type fishpass was built in 1974 at the southwest end of the spillway, discussed in more detail later in the report. At the time of the assessment, the majority of flow was running through the partially deployed stop log structure and the Denil fishway, with approximately 0.1 feet of flow over the spillway.

Figure 4: View looking upstream at Bridge Street Dam. Stop log weirs are indicated within the red squares and fishway entrance is indicated with a blue circle. Note surveyor for size. Flow direction is toward viewer.

The intake structures (trash rack, fish screen and water control) for the Sparhawk Mill hydroelectric facility are located at the far left[2] end of the dam. The intake supplies the penstock that delivers water to the generation facility located in the former mill facility immediately downstream of the Bridge Street bridge on the left bank of the river. The facility operates under an exemption from the Federal Energy Regulatory Commission (FERC; #08417). An assessment based on publicly-available information by Stantec (2010) reported prior documented plant capacity of up to 270 kW at flows of 240 cfs or greater. However, the prior documentation (Fay 2007) cited by Stantec highlighted several potential maintenance issues at the time of the earlier report. Additional inspections have been made

[2] Throughout the report, 'left' and 'right' indicate direction as if the viewer were looking downstream, in the direction of river flow. 'River left' and 'River right' are similar references.

by FERC every three years, with the last inspection in 2015 (FERC 2015). See Section 5.1 for additional detail on the most recent inspection results. It is unknown whether the maintenance issues were ever addressed, or whether the facility is currently in operation. When the facility is operational, it represents a potential source of revenue to the owner of the hydroelectric facility, as well as to the Town of Yarmouth who owns the dam, though the details of any associated financial instruments are unknown.

2.2.2 East Elm Street Dam

East Elm Street Dam consists of a 250-foot long stone masonry run-of-river gravity type structure approximately 12 feet in height (Figure 5). The full span of the dam functions as a spillway, allowing water to flow downstream onto a metamorphic bedrock exposure. A low-flow stop log weir is built into the structure at the right end of the spillway. To provide fish passage, a concrete Denil-type fishway was built in 1979 at the south end of the dam, discussed further in Section 3. At the time of field assessment, the stop logs were missing and the weir was partially blocked with large woody debris. The spillway was dry, with the majority of flow running through the partially blocked weir.

Figure 5: View looking upstream at East Elm Street Dam. Stop log weir is indicated within the red square and the fishway entrance is indicated with a blue circle. Flow direction is towards viewer.

3. Fishway Assessment

After reviewing the anticipated fish utilization of the Royal River and the associated hydrology, the fish passage facilities at each site are assessed in detail in the following section.

3.1 FISH UTILIZATION

The Royal River has been habitat to a variety of diadromous and resident fish. Many of the diadromous species are no longer present during rearing or spawning periods upstream of the Bridge Street Dam, the lowest of the two remaining dams. These diadromous species include alewife, American eel, American shad, blueback herring, sea-run brook trout, rainbow smelt, sea lamprey, and striped bass, which are the target species for the current study. Due to regional declines in Atlantic salmon populations and the exclusion of this river from the existing population range and essential habitat designation, they are not included as a realistic target species within this assessment.

The decline in native diadromous fish species on the Royal River is likely resultant from a lack of longitudinal connectivity following the installation of dams (Hall et al. 2011), and other factors. Previous sampling efforts conducted by MEDMR between 1975 and 1981 documented anadromous river herring (alewife), American shad, sea-run brook trout, and catadromous American eel attempting to migrate upstream past the dams through the Denil-type fishways (MEDMR 1981). Resident fish were also documented making use of the fishways. More recent MEDMR sampling efforts on the Royal River between 1983 and 1989 have indicated an estimate of the timing of attempts at upstream migration for diadromous fish (Table 1; Stantec 2010). Bioperiod estimates were subsequently derived from surveying efforts on neighboring river systems, and direct consultation with MEDMR, which indicate the anticipated upstream migration timing of these species, were sufficient passage to be provided (DMR 2009; Wippelhauser, 2016).

Table 1: Dates of capture on the Royal River between 1983 and 1989, and estimated bioperiods for upstream migration of target diadromous and resident fish species on the Royal River, using sampling efforts conducted on the Saco, Kennebec and Penobscot Rivers (Wippelhauser, 2016). Species marked with a "*" indicate those that were not documented using the fish passages on the Royal River in the 1983-1989 study (DMR 2009; Stantec 2010).

Species	Dates of Capture on Royal River (1983-1989)		Bioperiod
	Bridge Street Dam	East Elm Street Dam	**Upstream**
Alewife	May 1 - June 19	May 11 - July 3	**May 1-June 15**
American Eel	May 13 - June16	May 2 - July 3	**March 21-July 1**
American Shad	May 14	-	**May 21-July 15**
Blueback Herring*	-	-	**May 15-July 15**
Sea Run Brook Trout	May 23 - May 27	May 13 - June 11	**Sep1 -Dec 1**
Rainbow Smelt*	-	-	**March 15-May 15**
Sea Lamprey*	-	-	**May-June**
Striped Bass*	-	-	**June 1 – August 15**

3.2 FISH PASSAGE CRITERIA, STANDARDS AND ASSESSMENT METHODS

The following section describes the criteria, standards and assessment methods which governed the analysis.

Criteria and Standards

The Denil fishways at the two dam sites are of a standard design that is common at low head dams in northern New England. The standard Denil design was originally developed for passage of salmonids (early 1900s) but has since been deployed extensively to promote passage for a wide range of fishes (Haro et al. 1999). Primary recommended criteria for these types of fishways are provided the U.S. Fish and Wildlife Service (USFWS 2016), summarized in Table 2 and Table 3.

Specific criteria for Denil fishways that directly relate critical velocities to the swimming capabilities of target fish species are generally not available. This is due to the challenges of identifying a characteristic velocity in fishways of this hydraulically-complex design, characterized by high variability of velocity and turbulent structure of flow. Instead, aggregate design criteria (fishway width and slope, alignment characteristics, and other factors) based on empirical observations of passage success are typically preferred, such as those provided by USFWS (2016) for salmonids and American shad.

We did, however, review recent criteria published by Turek et al. (2016) for nature-like and pool and weir fishways, following past recommendations that these select criteria could also be provisionally-applied to a variety of structure types (Table 4) in the absence of directly applicable aggregate design criteria. It should be noted however that this comparison represents an imperfect surrogate for the applicable aggregate criteria, and this comparison should not be the sole basis for conclusion of whether the evaluated fishway provides adequate fish passage potential. Ideally, multiple lines of evidence or evaluation should be considered.

Table 2: General criteria for the design and operation of technical fishways (USFWS 2016).

General Technical Fishway Criteria	
Element	**Criteria**
Zone of Passage	Includes far- and near-field attraction, fishway and impoundment
Attraction Flow*	Minimum of 3% to 5% of powerhouse capacity during the migration period, or 50 cfs, whichever is greater*. Preference is that the entirety of the attraction flow be discharged through the fishway entrance.
Fish Passage Operational Flow	Low operational flow: 95% exceedance during migratory period High operational flow: 5% exceedance during migratory period
Flood capacity	Passage facility should not overtop at less than 50-year return period flood
Entrance Channel	Minimum depth: 2 feet Entrance velocity: 1.5 to 4 ft/s Entrance jet velocity: 4 to 6 ft/s for shad or herring
Exit Channel	Minimum depth: minimum of 2 body depths of target species Maximum velocity: 1.5 ft/s Maximum velocity of upstream river at exit: 4 ft/s
Trash Rack	Invert elevation: WSE at low operational discharge Top elevation: WSE at high operational discharge Configuration: sloped to enable cleaning Vertical bar spacing: 12 inch clear spacing Horizontal bars: not recommended Through velocity: 1.5 ft/s maximum
Downstream Passage	Receiving water should have pool that should have 25% of fall height or 4 feet, whichever is greater
Biological Capacity	Based on target population ranges, peak day and peak hour
Energy Dissipation Factor (EDF)	Shad: EDF<3.15 Salmon: EDF<4

*NOAA (2015) cite the USFWS criteria of 3% to 5% of turbine flow for Atlantic coast river basins, but also cite guidance established for Pacific salmon developed for the Pacific Northwest (NOAA 2008) that suggest attraction flow of 5% to 10% of the fish passage design high flow for rivers with mean annual flows exceeding 1000 cfs, and higher percentages (as much as feasibly possible) for smaller streams.

Table 3: General criteria for the design and operation of technical fishways, with emphasis on Denil fishways (USFWS 2016).

Denil Fishway Specific Criteria	
Element	**Criteria**
Depth	Minimum depth: 2 feet Maximum depth: 0.25 feet below cross braces
Slope	1:6 (16.7%) maximum for salmonids 1: 8 (12.5%) maximum for shad
Width	Minimum width for salmonids: 3 feet Minimum width for shad: 4 feet
Baffle height	Recommend 1′ taller than high passage design flow
Resting Pools	Provide for every 6 ft to 9 ft vertical rise Energy dissipation factor (salmon): 4 maximum Energy dissipation factor (shad): 3.15 maximum
Turning Pools	Limit to feasible minimum 90 degree or less turns preferred If > 90 degree turn required, weir in middle may be necessary to motivate fish to ascend

Table 4: Select design criteria adapted from Nature-like and Weir-type fish passage design guidance (Turek et al. 2016). Fish species represent target community identified for Royal River. TL refers to tail length, BD refers to body depth.

Species	Species Characteristics			Design Criteria	
	Minimum Size (cm)	**Maximum size (cm)**	**Maximum Body Depth (cm)**	**Maximum Weir Opening Water Velocity (ft/sec)**	**Minimum Flow Depth (ft)**
	TL_{min}	**TL_{max}**	**BD**	**V_{max}**	**3 x BD**
Alewife	22	38	8.9	6	0.88
American Eel (≤ 15 cm TL)	5	15	1	0.75	0.10
American Eel (> 15 cm TL)	15	125	7.9	1	0.78
American Shad	25	63	22.2	8.25	2.18
Blueback Herring	20	30	7.8	6	0.77
Sea Run Brook Trout	30	80	11.5	3.25	1.13
Rainbow Smelt	12	27	3.6	3.25	0.35
Sea Lamprey	60	86	6.2	6	0.61
Striped Bass	40	140	31.5	5.25	3.10

Methods

Field observation of the Denil fishways generally followed the protocol outlined by Towler et al. (2013), and utilized the field forms developed to accompany the protocol. Other observations were also made over the zone of passage at each site, including far-field and near-field attraction patterns. The field assessment was conducted on September 9, 2016.

The hydraulics of the Denil structures at the two sites were estimated based on equations from empirical studies (Odeh 2003; Katopodis et al. 1997; Katopodis 2002; Larinier 2002). The flow partitioning[3] analyses were accomplished by first calculating rating curves with a customized spreadsheet to estimate the flow through the various water conveying structures for increments of head pond elevation. Flow through the spillway and other standard structures such as stop log weirs was calculated using standard hydraulic equations for weir flow. Discharge through the Denil fishway was calculated using the equations from Odeh (2003). Flow through the Denil structures was capped when the capacity of the fishway was met. Lastly, flow through the Foundry channel at the East Elm Street dam was calculated with the Manning's equation, based on channel geometry and roughness characteristics that were measured and evaluated during the field assessment.

The flow partitioning through the fishway and other pathways at each site was then calculated as the proportion of their flow relative to the total river flow at the 95%, 75%, 50%, 25% and 5% exceedance quantiles of the fish passage operational range. Example calculations are included in Appendix C.

The flow field characteristics in the interior of the Denil fishways were calculated over the operational range of the fishways with custom spreadsheets developed for this purpose, which integrated equations obtained from Katopodis et al. (1997), Katopodis (1992), and Larinier (2002). This included calculation of the open flow area within the fishways that actually conveys water including effective width and depth, which led to subsequent calculation of average flow velocity in the central plane of the fishway (i.e., the open area of flow projected perpendicular to the sloping fishway floor). See also earlier discussion related to the direct comparison of calculated flow velocities within Denil fishways to the swimming capabilities of target fish. Lastly, the energy dissipation factor for the Denil fishway resting pools was calculated using the method of Towler et al. (2015), as reported in USFWS (2016).

[3] At each dam, flow partitioning refers to the relative amounts of the total river flow that travel through the fishway, over the spillway, and through other pathways through the dam, such as gates, stop log weirs, and hydropower turbines. The proportion of flow available for attraction to the fishway entrance is an important factor on fish utilization. Table 2 summarizes attraction flow recommendations from USFWS (2016) and NOAA (2015).

3.3 FISH PASSAGE HYDROLOGY

The hydrology of the Royal River watershed results in the highest river flows occurring between March and May (Table 5), a seasonal trend in flow that is consistent with many other rivers in the region. Hydrologic statistics and flow duration curves capturing the estimated upstream fish migration period for the target fish species were derived from gage data collected by the United States Geological Survey (USGS) at the Royal River gage (USGS 01060000; Table 6 and Figure 6). This gage was in operation between 10/01/1949 and 09/30/2004. Based on the upstream migration bioperiods for the target fish community (Table 1), and the concentration of higher operational flows within this time period, the longer April to June period was used for assessment purposes. Though fish species may be utilizing the upstream fish passage through October, this assessment addressed a time interval that captured higher operational flows to assess the upper limits of fish passage functionality.

At the time of the field assessment (September 9, 2016), based on comparisons to adjacent or nearby, currently-gaged watersheds, flow levels on the Royal River were likely at 30% of average flow levels for this 24-hr period. These comparisons and the incorporation of historical flow data acquired on the Royal River result in an approximate estimate of 37 cfs (30% daily average discharge of 126 cfs) on the day of field assessment.

Table 5: Average and median monthly flows on the Royal River. Values are derived from gage data acquired between 10/01/1949 and 09/30/2004 at the USGS 01060000 Royal River gage in Yarmouth, Maine.

Monthly Flows (cfs)												
Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	223	232	550	732	316	183	91	76	86	145	304	305
Median	162	183	496	734	292	142	70	56	54	85	246	257

Table 6: Flow duration exceedance percentiles during target migration periods derived from USGS gage 01060000 Royal River at Yarmouth, Maine.

Exceedance Percentile (%)	April 1 – June 30 (cfs)	May 1 – June 30 (cfs)
5	1340	720
25	470	275
50	235	154
75	119	94
95	60	54

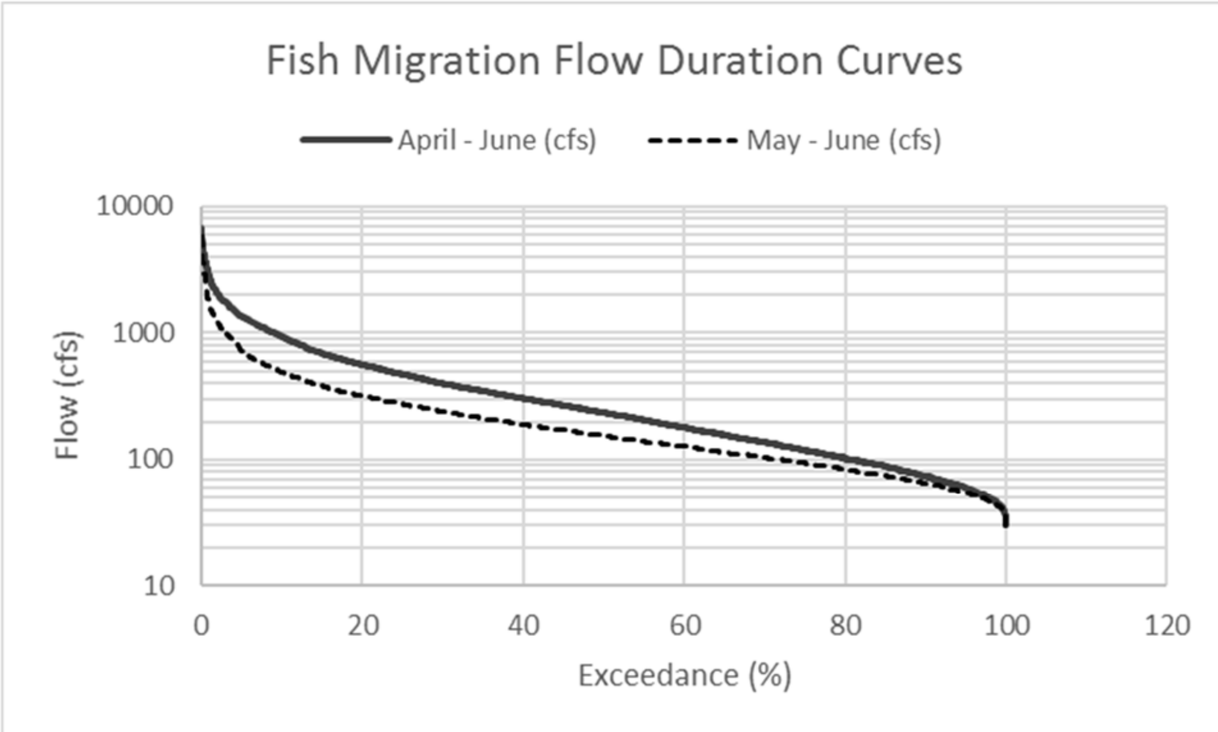

Figure 6: Flow-duration curves during target fish migration period.

3.4 BRIDGE STREET DAM FISHWAY

The fishway at Bridge Street Dam is a concrete Denil-type (i.e. baffled) structure built in 1974. At the date of inspection on September 9th, 2016, the fishway was watered and hydraulically operational. The completed inspection field form and selected photographs for this site are found in Appendix A.

3.4.1 Bridge Street - Physical Description and Qualitative Assessment

General Condition

The fishway is a 3-foot wide, 1:6 slope (16.7%) standard design that accommodates vertical rise of 12 feet via two Denil segments with 19 baffles each. A 13-foot long, 120 degree turning pool separates the two Denil segments. The fishway, entrance and exit channels are all in reasonable apparent working condition with the exception of minor debris in a few locations, and one blockage at baffle 10 of the lower segment, which creates a 6" vertical drop in the middle of the segment. There are no appurtenances to manage entrance conditions or the entrance jet, but depths in the entrance channel were adequate at the time of assessment. The working status of the head gate and its management (if any) to accommodate fluctuating impoundment levels is unknown. Any adjustment to the head gate must be accomplished manually. Repairs may lead to improved passage for a subset of the target fish community such as river herring as an interim measure.

Attraction

As upstream migrating fish approach the zone of passage, they first encounter the tailrace of the Sparhawk hydroelectric facility (Figure 7). During periods of operation, with maximum diversion capacity of approximately 250 cfs, this outflow could cause a competing signal for upstream passage as it equates to a substantial proportion of the total river flow over much of the fish passage operational range (Table 6 and Figure 6). However, the current operational status and future plans are unknown. At the time of the field assessment, the hydroelectric facility did not appear to be in active generation. If only modest generation were to occur, this competing attraction signal will be less of a concern.

Upstream of the tailrace, fish encounter the beginning of the ledge outcrop and the bridge. Based on the review of the available high resolution aerial photography and previous topographic survey results (Titcomb 2013), the predominant flow patterns downstream of the spillway over the ledge outcrop tend to orient to the river right margin, with several primary streams converging in the vicinity of the fishway entrance (Figure 8). During the highest flows, there is a secondary flow pathway on river left but based on review of the aerial photos, this appears to be a shallower, less substantial flow alignment. As fish migrate closer to the fishway entrance, however, they will encounter several competing signals during many flow conditions, with the exception of the lowest flows (Figure 7 and Figure 8). These patterns may present challenging far-field attraction conditions for upstream migrating fish over a notable portion of the fish passage operational range. This trend is exacerbated by the relatively modest discharge that is able to be passed through the fishway while still operating in the target flow condition for upstream passage (discussed in more detail below).

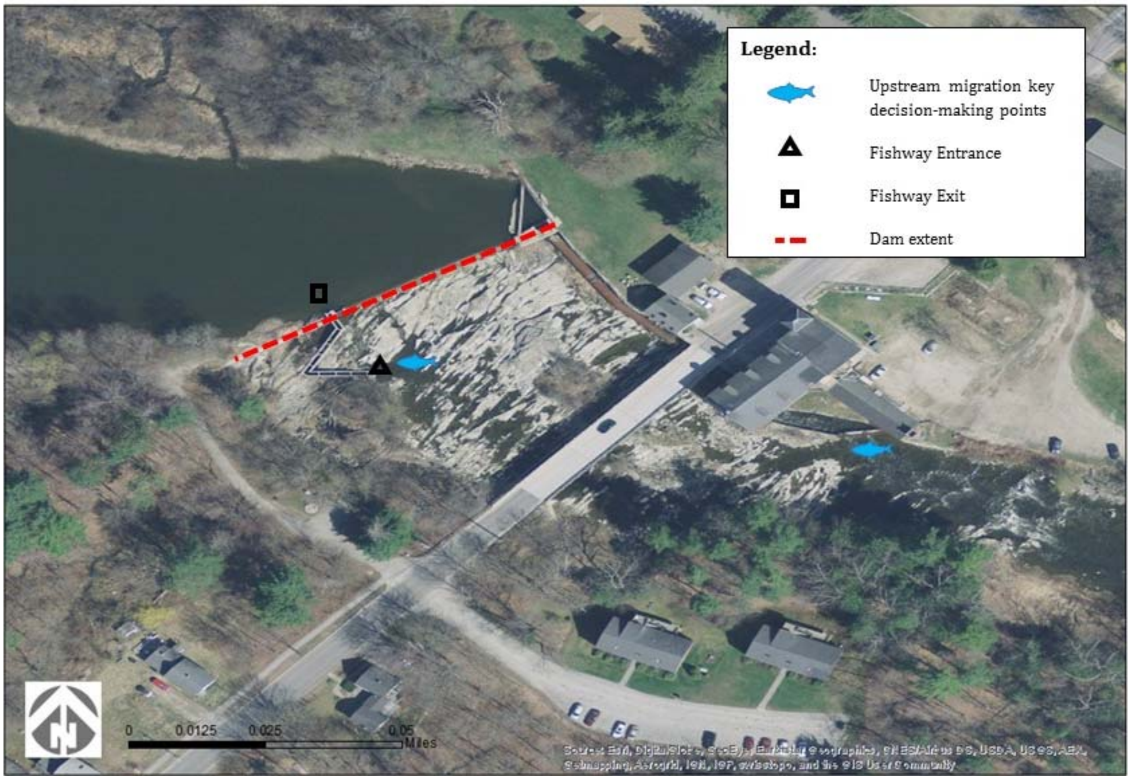

Figure 7: Site map of the Bridge Street site indicating key decision points for upstream migrating fish. Date of imagery is March 31, 2012. Flow direction is left to right.

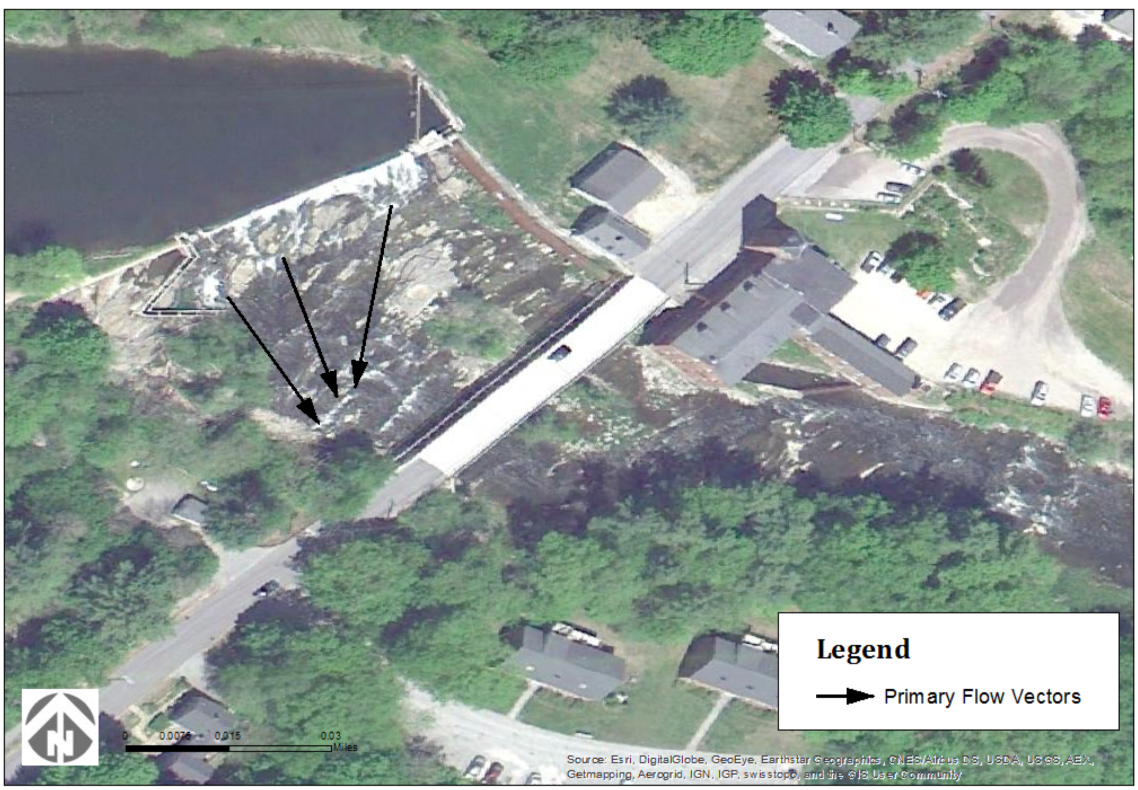

Figure 8: Site map of the Bridge Street site indicating primary flow vectors. Date of imagery is May 16, 2010. Flow direction is left to right.

Downstream Passage

There are no intentional or managed downstream passage facilities at the site. At the upper end of the fish passage operational range, fish may be able to pass over the spillway with relatively modest hydraulic drop. However, given the broad nature of the ledge outcrop and the dispersed nature of flow, there is a plausible risk of fish injury during outmigration during much of the passage flow range.

General Comparison to Prevailing Design Standards

While the fishway appears generally operational within its overall capacity, qualitative comparison to the prevailing design standards for technical fishways (Table 2 and Table 3) highlights several areas that suggest limitation for providing safe, timely and effective passage for the target fish community (Table 1).

Notably, the fishway is steeper and narrower than recommendations for passing American shad (Table 3), with a turning pool angle that is also more acute than recommended for the same species (Table 2). Haro and Santos (2012) suggest that while shad are able to swim swiftly, several factors reduce their success in utilizing smaller Denil fishways. They exhibit schooling behavior as juveniles and adults, and may be less willing to detach from the school to pass through the relatively narrow openings in the 3-foot wide Denil. They appear to prefer laminar and streaming flow as opposed to the highly turbulent and helical flow patterns in the Denil flow field, and exhibit reluctance to migrate past resting and turning pools. Provisions for downstream passage of all species, overall biological capacity, and upstream migration of juvenile American eels also do not meet current design standards for the target population.

3.4.2 Bridge Street – Quantitative Assessment

To explore the ability of the facility to provide safe, timely and effective passage in more detail, several quantitative analyses were completed, summarized below.

Denil Discharge and Flow Partitioning[4]

Based on the empirical equations of Odeh (2003), the capacity of the Denil fishway was assessed. The capacity calculation was constrained on the lower and upper ends by the USFWS (2016) criteria that minimum depth of 2 feet should be maintained in the Denil, while the high flow through the fishway should be below the bottom of structural braces that cross the top of the baffles. This results in a relatively narrow operational range for the Denil of approximately 8 to 25 cfs. It is physically possibly to pass more flow down the fishway, but at flows greater than 25 cfs the upper region of the flow field will impact the crossing braces inducing additional turbulence, intermittent pressure flow, and a possibly destabilized flow field. In order to constrain the maximum Denil discharge to 25 cfs, the head gate or other control structure would need to be set to limit the amount of flow that enters

[4] At each dam, flow partitioning refers to the relative amounts of the total river flow that travel through the fishway, over the spillway, and through other pathways through the dam, such as gates, stop log weirs, and hydropower turbines. The proportion of flow available for attraction to the fishway entrance is an important factor on fish utilization. Table 2 summarizes attraction flow recommendations from USFWS (2016) and NOAA (2015).

the fishway at the 50% and higher exceedance flows. This will cause pressure orifice flow at the fishway exit for the upper half of the fish passage flow range, which under certain flow conditions, may create a passage constraint at this location.

This discharge range was evaluated along with spillway flow patterns (and the possible discharge through the stop log weir adjacent to the fishway). This was done to assess the proportion of the total flow that could be passed through the fishway (or directly adjacent to it, in the case of the stop log weir) to create attraction to the fishway over the upstream migration operational range. If the flow is constrained to the Denil and the spillway, the percentage of flow through the Denil ranges from 33% (19.5 cfs) at the low operational flow to 2% (25 cfs) at the high operational flow (Table 7). Note that the USFWS recommendation for minimum percentage of attraction flow is 3 % to 5 % of powerhouse capacity, or 50 cfs, whichever is greater (USFWS 2016). Based on the analysis of Denil fishway hydraulics described above, it is not possible to meet the 50 cfs threshold with flow through the fishway providing the sole attraction flow. NOAA (2008) criteria developed for the Pacific salmon would suggest an even greater proportion of flow would be required.

If the stop log weir is operated to add attraction flow adjacent to the fishway, the percentage of total flow through the Denil ranges from 27% to 2%, but the combined flow through the Denil and the stop log weir ranges from 100% (60 cfs) to 12% (166 cfs) at the low and high operational flows, respectively (Table 8). Thus, in the latter case, while the actual flow through the Denil is modestly reduced, the amount of flow very close to the fishway entrance is substantially higher which should provide a near-field attraction benefit. Note that diversion to the hydroelectric facility was neglected in this analysis.

Table 7: Bridge St. dam flow partitioning between Denil fishway and dam spillway over the fish passage operational range, if flow is constrained to these two pathways. Table 2 summarizes attraction flow recommendations from USFWS (2016) and NOAA (2015).

Exceedance Percentile (%)	Fish Passage Flow (cfs)	Denil Flow (cfs)	Spillway Flow (cfs)	% of Flow Through Denil
5	1340	25	1315	**1.9%***
25	470	25	445	**5.3%****
50	235	25	210	**10.6%****
75	119	21	98	**17.6%****
95	60	19.5	40.5	**32.5%****

****Does not meet full USFWS recommendation for attraction.***

***** Meets USFWS 3% to 5% flow criteria, but does not meet 50 cfs threshold.***

Table 8: Bridge St. dam flow partitioning between Denil fishway, stop log weir, and dam spillway over the fish passage operational range. Table 2 summarizes attraction flow recommendations from USFWS (2016) and NOAA (2015).

Exceedance Percentile (%)	Fish Passage Flow (cfs)	Denil Flow (cfs)	Stop Log Weir Flow (cfs)	Spillway Flow (cfs)	% of Flow Through Denil	% of Flow Through Denil and Stop Log Weir Combined
5	1340	25	141	1174	**1.9%***	12.4%
25	470	25	102	343	**5.3%****	27.0%
50	235	22.5	88	124.5	**9.6%****	47.0%
75	119	19	78	22	**16.0%****	81.5%
95	60	16	44	0	**26.7%****	100.0%

****Does not meet full USFWS recommendation for attraction.***

** ***Meets USFWS 3% to 5% proportion of flow criteria, but does not meet 50 cfs threshold.***

Mean Fishway Velocity

For the target Denil fishway discharge range (8 to 25 cfs) determined above, the empirical relationships of Katopodis et al. (1997) were used to calculate the mean water column velocities of the central flow field plane (through the interior of the baffles). The estimated mean velocities range from 4.1 feet per second to 5.6 feet per second at fishway discharges ranging from 8 to 25 cfs, respectively, in the fully developed flow area of the fishway. When flow through the Denil is optimized for fishway operation and attraction, the estimated range in discharge is narrowed to 16 to 25 cfs, resulting in corresponding estimated range in velocities of 5.1 to 5.6 feet per second. As noted by Odeh (2003) and other researchers, at the upstream end of each Denil segment (downstream transition out of the exit channel or turning pools) there is typically a zone of flow acceleration that extends through the upstream-most one or two baffles. Velocities in this zone may exceed the estimated velocities by as much as 50%.

Table 9 compares the estimated velocities to common design velocities (Table 4) for each of the fish species in the target community. The comparison suggests that the common velocity thresholds may be exceeded for some or all of the operational flow range for several of the focal species. It should be noted, however, that hydraulic design criteria are typically set close to sustained swim speeds for the various fish species, but that in attempting to ascend Denil fishways, fish may accelerate to near burst speeds over the relatively short lengths that each Denil segment constitutes. Based on this, the passage potential for the range of species may not be as constraining as indicated in Table 9. It should also be noted that hydraulic design criteria are intentionally set at relatively conservative values to provide some factor of safety to account for aspects of the passage system which cannot truly be accurately predicted, as well as the fact that the populations targeted for restoration may be depressed. The goal in the restoration of the fish community is to pass all present individuals, not just the most-fit individuals.

Lastly, critical velocity thresholds such as those set by Turek et al. (2016) may not be strictly applicable to complex hydraulic structures such as Denil fishways, but are included here for comparison purposes since aggregate Denil fishway design criteria for all of the target fish species may not be available. After consultation with the USFWS (USFWS 2017), it is generally considered that a Denil fishway such as the one found at the Bridge Street dam, if properly-functioning and maintained, and with adequate attraction flow, should provide reasonable passage opportunity for river herring, trout and striped bass (who may not seek out the fishway, but may utilize the fishway in pursuit of other fish). Utilization of the Denil is less certain for shad (as described earlier in Section 3.4.1), eels, smelt and lamprey. It is anticipated that eels and lamprey may use a variety of means to ascend the site given the site characteristics and may not be solely reliant on the fishway.

Table 9: Comparison of estimated mean water column velocities in the central plane of the fully developed flow portions of the Bridge St. fishway, to recent (Turek et al. 2016) critical velocity design criteria over the fish passage operational range. 'X' indicates species and flow intervals where estimated mean velocities appear to exceed design criteria.

		Flow Quantile				
		95% (60 cfs)	75% (119 cfs)	50% (235 cfs)	25% (470 cfs)	5% (1340 cfs)
		Estimated Mean Velocity (ft/s)				
Species	**Maximum Weir Opening Water Velocity[1] (ft/s)**	5.1	5.3	5.6	5.6	5.6
Alewife	6					
American Eel (≤ 15 cm TL)	0.75	X	X	X	X	X
American Eel (> 15 cm TL)	1	X	X	X	X	X
American Shad	8.25					
Blueback Herring	6					
Sea Run Brook Trout	3.25	X	X	X	X	X
Rainbow Smelt	3.25	X	X	X	X	X
Sea Lamprey	6					
Striped Bass	5.25		X	X	X	X

[1] ***Velocity criteria from Turek et al. 2016***.

Energy Dissipation Factor

Lastly, the USFWS (2016) criteria for technical fishways require a resting pool to be provided for every 6 to 9 feet of vertical rise in a Denil system. At the Bridge St. site, there is no dedicated resting pool but the turning pool serves the function of a resting pool. While the 120-degree configuration of the turning pool does not meet the recommended 90 degree or less criteria, the energy dissipation function (EDF) was assessed. Using the recommended USFWS (2016) method, the range in EDF was estimated at 1.9 to 6.5 over the target Denil operational range of 8 to 25 cfs. However, based on the flow partitioning that attempts to maximize attraction to the fishway, likely Denil discharges are closer to the range of 16 to 25 cfs, which corresponds to EDF estimates of 4 to 6.5. This range is at or exceeds the recommended maximum EDF threshold for both shad and Atlantic salmon. The configuration and EDF pattern for the turning pool are most problematic for shad as they have been seen to have limitations in negotiating these features (Haro and Casto-Santos 2012).

3.4.3 Bridge Street - Assessment Summary

Based on the field evaluation and subsequent analyses, the following are the key results of the assessment of the Bridge St. dam fishway:

- *Qualitative Assessment of Denil Fishway:*
  - *General Condition*:
    - Presently operational but requires maintenance and continuous upkeep to successfully provide passage for target species at target populations, and thus regain full functionality. Repairs may lead to improved passage for a subset of the target fish community such as river herring as an interim measure. Does not match current design recommendations for American shad. Status of headgate operability is unknown.
  - *Far-Field Attraction*:
    - The outflow from the Sparhawk hydroelectric station may form a notable competing far field attraction signal when operating, though current and future operational plans are unknown.
  - *Near-Field Attraction*:
    - Attraction to the fishway entrance within the ledge outcrop appears fair to poor.
  - *Downstream Passage*:
    - No intentional facilities, moderate to high potential for injury during outmigration.
  - *General Comparison to prevailing design standards*:
    - Steeper, narrower, and angle of turning pool more acute than recommendations.
    - Shad Passage: several deficiencies– does not meet recommended minimum width or maximum slope, contains turning pools angled greater than 90 degrees.
    - Biological capacity was not evaluated, but unlikely to meet current standards for anticipated population size.
    - No provisions for juvenile eel passage.

- *Quantitative Assessment of Denil Fishway:*
  - *Flow Partitioning*:
    - Due to size limitations, narrow operational range requires control structure to limit flow into fishway for upper half of the fish passage flow range, which may result in a passage constraint at the control structure.
    - Upper operational flows likely result in insufficient attraction flows if the fishway is the only source of attraction flow.
    - Flow partitioned through the stop log structure modestly decreases flow directed through the fish passage, but could add substantial

supplemental attraction flow immediately adjacent to the fishway entrance.

- *Energy Dissipation Factor*:
    - At or exceeds recommendations in turning pools for target species at upper half of fish passage operational range
    - Most problematic for American shad.

3.5 EAST ELM STREET DAM FISHWAY

The fishway at East Elm Street Dam is similarly a concrete Denil structure, built in 1979. At the date of inspection on September 9th, 2016, the fishway was marginally watered, non-operational and in disrepair. The completed inspection field form and selected photographs for this site are found in Appendix B.

3.5.1 East Elm Street - Physical Description and Qualitative Assessment

General Condition

This fishway is also a 3-foot wide, 1:6 slope (16.7%) standard design that accommodates vertical rise of 11 feet via three Denil segments that accommodate 3 feet, 4 feet and 4 feet of vertical rise each. A 16-foot long, 90 degree turning pool separates segments 1 and 2, while a 180-degree turning pool separates segments 2 and 3. The fishway, entrance and exit channels are all non-functional. The entrance is blocked by large boulders and flow cascades transversely across the entrance channel from upstream. The trash rack is clogged with debris and the headgate is in disrepair. Nearly all of the baffles are missing in segments 1 and 3, with the baffles that remain in segment 2 also substantially damaged. The area around the fishway is generally overgrown.

There is a stop log weir adjacent to the spillway that is also non-functional with several pieces of large woody debris blocking the opening and preventing its operation, though the majority of flow was through this weir at the time of the assessment. In addition to the facilities at the dam, a bypass channel (referred to as the foundry channel) drains from the impoundment approximately 250 feet upstream of the fishway exit, upstream of the East Elm St. bridge, and re-enters the river approximately 475 feet downstream of the dam. Flow downstream of the spillway splits around Gooch Island, with the associated ledge outcrop close to or at the spillway elevation approximately 2/3 of the distance across the irregular crest from river right to left.

Although the fishway is currently in disrepair, the following discussion is oriented towards its intended operation as if it were repaired and functional.

Attraction

As upstream migrating fish approach the zone of passage, they first encounter the outlet of the foundry channel (Figure 9). Based on review of the aerial photography, the flow out of the foundry channel does not appear to create a substantial attraction cue (Figure 10), although the flow analysis reported in the next section suggests that the channel could convey a substantial proportion of the total flow particularly in the lower half of the fish passage flow range. The foundry channel does not appear to offer a passage pathway at present as the downstream confluence is over a relatively steep confluence fan with minimal depths of flow. In addition, there is a substantial vertical drop greater than 3 feet in height located in the upper 1/3 of the foundry channel where it flows over a former mill foundation or control structure.

Upstream of the foundry channel outlet, fish encounter the confluence of the primary channel and the secondary channel which drain around the right and left sides of Gooch Island, respectively. The outflow from the left (or back) side of Gooch Island also does not appear particularly prominent in the aerial photo record suggesting the primary attraction cue will be to the river right side of the island (Figure 9 and Figure 10).

Upstream migrating fish will then encounter the ledge outcrop approximately 150 feet downstream of the spillway and fishway entrance. Over the aerial photographic record, the predominant flow patterns downstream of the spillway over the ledge outcrop diverge into two primary streams (Figure 10). The first is located at river right extending downstream of the fishway entrance. It appears that ledge may have been removed along this alignment to facilitate use of the fishway. The second primary flow path is adjacent to Gooch Island. Based on the presence of the competing primary flow streams in addition to the dispersed and variable nature of flow over the ledge, far field attraction to the fishway is likely fair to poor over much of the fish passage flow range. Similar to the Bridge St. site, this trend is exacerbated by the relatively modest discharge that is able to be passed through the fishway while still operating in the target flow condition for upstream passage (discussed in more detail below).

Downstream Passage

There are no intentional or managed downstream passage facilities at the site. Similar to the Bridge St. site fish may be able to pass over the spillway with relatively modest hydraulic drop at the upper end of the fish passage operational range. However, given the broad nature of the ledge outcrop and the dispersed nature of flow, there is a plausible risk of fish injury during outmigration during much of the passage flow range.

General Comparison to Prevailing Design Standards

The fishway is presently non-operational. If it were restored to intended operational condition, the East Elm St. fishway shares similar trends as the Bridge St. fishway when qualitatively compared to the prevailing design standards for technical fishways (Table 2 and Table 3) as applied to the target native fish community (Table 1). Most notably, the fishway is steeper and narrower than recommendations for passing shad (Table 3), with one of the two turning pools having angle that is also more acute than recommended for the same species (Table 2). Provisions for downstream passage of all species, overall biological capacity, and upstream migration of juvenile eels also do not meet current design standards for the target community.

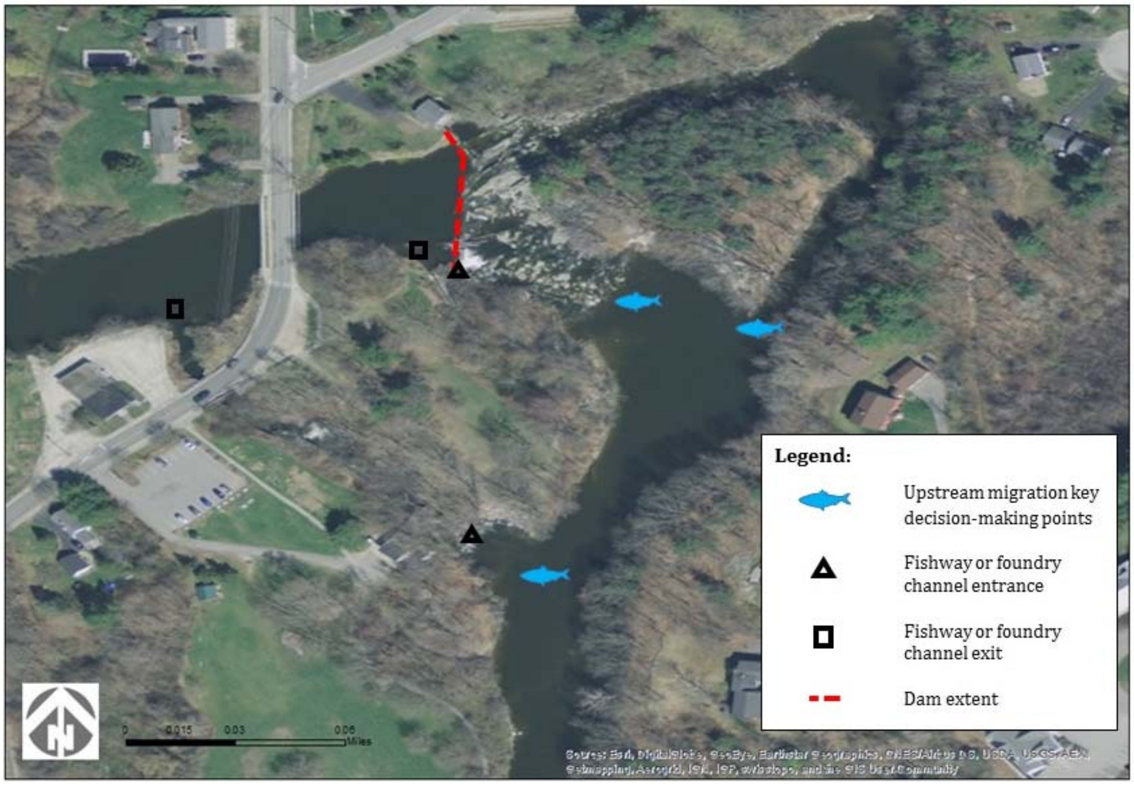

Figure 9: Site map of the East Elm Street site indicating key decision points for upstream migrating fish. Date of imagery is March 31, 2012. Flow direction is left to right at top of figure.

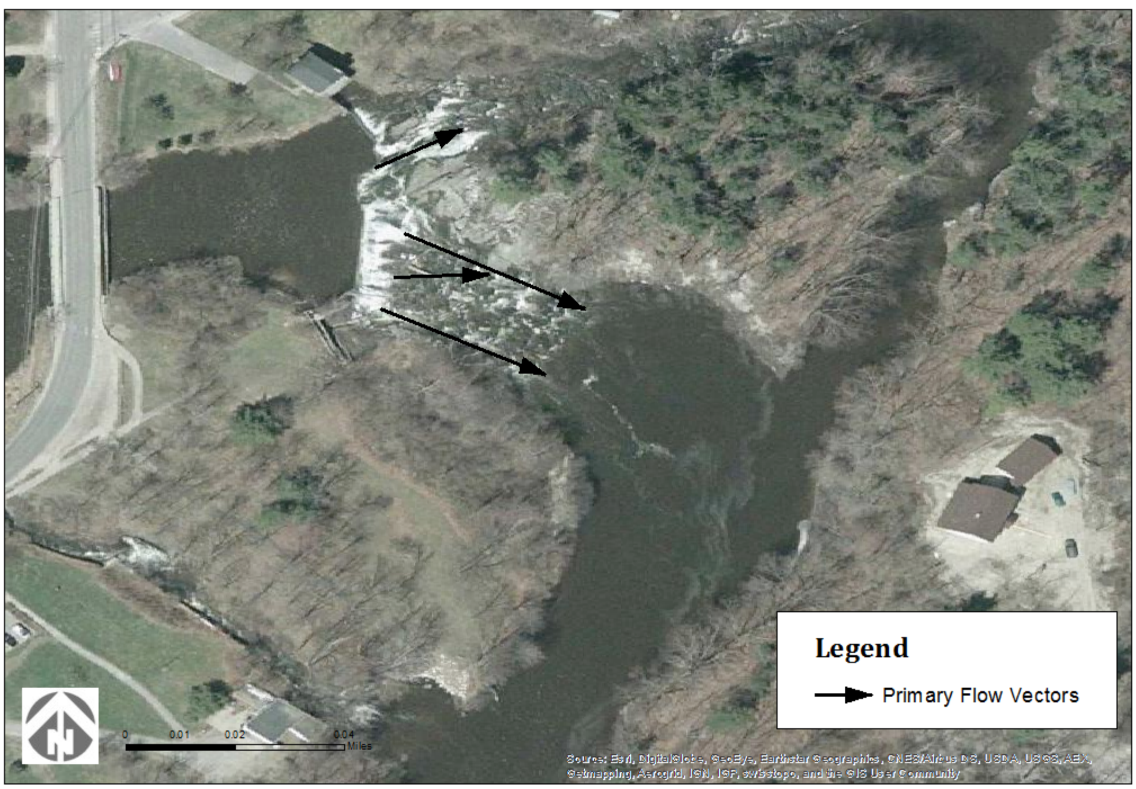

Figure 10: Site map of the East Elm Street site indicating primary flow vectors. Date of imagery is December 31, 2002. Flow direction aligns with flow vectors.

3.5.2 East Elm Street – Quantitative Assessment

To explore the ability of the facility to provide safe, timely and effective passage in more detail, similar quantitative analyses completed for the Bridge St. site were repeated for the East Elm St. fishway, summarized below.

Denil Discharge and Flow Partitioning[5]

The Denil capacity calculation based on the empirical equations of Odeh (2003), constrained on the lower and upper ends by the USFWS (2016) criteria, yields the same result as for the Bridge St. site given the nearly identical design. This results in a relatively narrow operational range for the Denil of approximately 8 to 25 cfs. Similar to the Bridge St. fishway, in order to constrain the maximum Denil discharge to 25 cfs, the head gate or other control structure would need to be set to limit the amount of flow that enters the fishway at the 50% and higher exceedance flows. This will cause pressure orifice flow at the fishway exit for the upper half of the fish passage flow range which under certain flow conditions may create a velocity barrier at this location.

The target operational discharge range was evaluated along with spillway and foundry channel flow patterns, as well as the possible discharge through the stop log weir adjacent to the fishway. This provides an assessment of the proportion of the total flow that could be passed through the fishway (or directly adjacent to it, in the case of the stop log weir) over the upstream migration operational range. If the flow is constrained to the Denil, the foundry channel, and the spillway, the percentage of flow through the Denil ranges from 13% (8 cfs) at the low operational flow to 2% (25 cfs) at the high operational flow (Table 10).

Note that the USFWS recommendation for minimum percentage of attraction flow is 3 % to 5 % of powerhouse capacity, or 50 cfs, whichever is greater (USFWS 2016). Since the East Elm Street dam is not a hydropower facility, these criteria are not strictly applicable in this case, yet also provide useful reference as surrogate criteria. Based on the analysis of Denil fishway hydraulics described above, it is not possible to meet the 50 cfs threshold with the current fishway configuration. NOAA (2008) criteria developed for the Pacific Northwest would suggest an even greater proportion of flow would be recommended.

If the stop log weir is operated to add attraction flow adjacent to the fishway, the percentage of flow through the Denil ranges from 13% to 2%, but the combined flow through the Denil and the stop log weir ranges from 40% (47 cfs) to 8% (100 cfs) depending on flow level (Table 11). Thus, in the latter case, the amount of flow very close to the fishway entrance is higher which should provide near-field attraction benefit.

---

[5] At each dam, flow partitioning refers to the relative amounts of the total river flow that travel through the fishway, over the spillway, and through other pathways through the dam, such as gates, stop log weirs, and hydropower turbines. The proportion of flow available for attraction to the fishway entrance is an important factor on fish utilization. Table 2 summarizes attraction flow recommendations from USFWS (2016) and NOAA (2015).

The other notable element of the flow partitioning analysis is the role of the foundry bypass in conveying water downstream of the dam site. The foundry channel has the potential to convey a majority of the flow up to the 50% exceedance passage flow and over 20% of the flow over the full fish passage range (Table 10 and Table 11). This may have the effect of providing a competing attraction cue relative to the flow passing the dam and bypass facilities. Given the confluence configuration and the vertical hydraulic drop in the upper 1/3 of the channel, it does not appear to be a viable or utilized passage in its current configuration.

Table 10: East Elm St. dam flow partitioning between Denil fishway, foundry channel, and dam spillway over the fish passage operational range if flow is constrained to these three pathways. Table 2 summarizes attraction flow recommendations from USFWS (2016) and NOAA (2015).

Exceedance Percentile (%)	Fish Passage Flow (cfs)	Denil Flow (cfs)	Foundry Flow (cfs)	Spillway Flow (cfs)	% of Flow Through Denil
5	1340	25	274	1041	**1.9%***
25	470	25	179	266	**5.3%****
50	235	20	143	72	**8.5%****
75	119	15	104	0	**12.6%****
95	60	8	52	0	**13.3%****

Does not meet full USFWS criteria for attraction.

** ***Meets USFWS 3% to 5% proportion of flow criteria, but does not meet 50 cfs threshold.***

Table 11: East Elm St. dam flow partitioning between Denil fishway, foundry channel, stop log weir, and dam spillway over the fish passage operational range. Table 2 summarizes attraction flow recommendations from USFWS (2016) and NOAA (2015).

Exceedance Percentile (%)	Fish Passage Flow (cfs)	Denil Flow (cfs)	Stop Log Weir Flow (cfs)	Foundry Flow (cfs)	Spillway Flow (cfs)	% of Flow Through Denil	% of Flow Through Denil and Stop Log Weir Combined
5	1340	25	75	268	972	**1.9%***	7.5%
25	470	24	57	173	216	**5.1%****	17.2%
50	235	19	50	136	30	**8.1%****	29.4%
75	119	11	36	72	0	**9.2%****	39.5%
95	60	8	0	52	0	**13.3%****	13.3%

Does not meet full USFWS recommendation for attraction.

** ***Meets USFWS 3% to 5% proportion of flow criteria, but does not meet 50 cfs threshold.***

Mean Fishway Velocity

Given the similarities of the East Elm Street Denil fishway to the Bridge Street site, the comparisons between estimated velocities and recommended design velocities are also similar to those described in Section 3.4.2. The same qualifications on strict interpretation of these results apply to the East Elm Street site as were discussed for the Bridge Street site.

Energy Dissipation Factor
Lastly, the USFWS (2016) criteria for technical fishways require a resting pool to be provided for every 6 to 9 feet of vertical rise in a Denil system. At the East Elm St. site, there is no dedicated resting pool but the turning pools serve the function of a resting pool. While the 180-degree configuration of the second turning pool does not meet the recommended 90 degree or less criteria, the energy dissipation function (EDF) was assessed. Using the recommended USFWS (2016) method, the range in EDF was estimated at 1.5 to 5.3 for the first turning pool and 2.0 to 7.0 for the second turning pool over the target Denil operational range of 8 to 25 cfs. Portions of these ranges are at or exceed the recommended maximum EDF threshold for both shad and Atlantic salmon. As stated previously, the configuration and EDF pattern for the turning pools are most problematic for shad as they have been seen to have limitations in negotiating these features (Haro and Castro-Santos 2012).

3.5.3 East Elm Street - Assessment Summary

Based on the field evaluation and subsequent analyses, the following are the key results of the assessment of the East Elm St. dam fishway:

- *Qualitative Assessment of Denil Fishway:*
    - *General condition*:
        - Presently non-functional and requires complete rehabilitation to regain operability and functionality, including replacement of all weirs, gates, trash racks and control structures.
        - The Entrance Channel is completely blocked with boulders and the adjacent river channel would require modification to provide suitable entrance conditions and minimize transverse water flow across the entrance.
        - The Stop log weir adjacent to the fishway is in disrepair and is blocked with debris. If used to supplement attraction flow, the weir is not presently able to be managed.
        - Configuration of river channel around entrance is very poor with water flowing transverse across the entrance channel. Would require reconfiguration.
    - *Far-Field Attraction*:
        - The outflow from the foundry bypass channel may form a notable competing far field attraction signal, but does not appears to possess high potential for providing passage itself in its current configuration.
    - *Near-Field Attraction*:
        - Attraction to the fishway entrance within the ledge outcrop appears fair to poor.
    - *Downstream Passage*:
        - No intentional facilities, moderate to high potential for injury during outmigration.

- *General comparison to prevailing design standards*:
  - Steeper, narrower, and angle of turning pool more acute than recommendations.
  - Shad passage: several deficiencies– does not meet recommended minimum width or maximum slope, contains turning pools angled greater than 90 degrees, EDF exceeds recommendations.
  - Biological capacity was not evaluated, but is unlikely to meet current standards for anticipated community and population size.
  - No provisions for juvenile eel passage.

- <u>*Quantitative Assessment of Denil Fishway*</u>*:*
  - *Flow partitioning:*
    - Due to size limitations, narrow operational range requires control structure to limit flow into fishway for upper half of the fish passage flow range, which may result in a passage constraint at the control structure.
    - Upper operational flows likely result in insufficient attraction flows if the fishway is the only source of attraction flow.
    - Flow partitioned through the stop log structure modestly decreases flow directed through the fish passage, but could add substantial supplemental attraction flow immediately adjacent to the fishway entrance.
  - *Energy Dissipation Factor*:
    - Exceeds recommendations in turning pools for upper half of fish passage operational range.
    - Most problematic for shad.

4. Fish Passage Alternatives

To support the cost analysis (Section 5), four dam modification conceptual alternatives (no action, retrofit/rebuild, nature-like ramp/bypass, dam removal) were identified for each facility. The intent was to develop the alternatives with just enough detail to support the comparative cost analysis for each site. For the three alternatives that enhance fish passage potential at each site, the approach endeavors to provide optimized long-term passage opportunity for the broadest range of the identified target species (see Section 3.1), subject to the constraints of the associated passage technology. We did not make any design decisions that would preclude passage by a species of perceived lesser value in favor of passage by a species of perceived higher value. Such evaluations between species, if required in later project stages in order to arrive as a consensus solution at each site, would be accomplished in direct consultation with project stakeholders. Additionally, for the technical fishway and nature-like fishway alternatives, it was assumed that the impoundment levels would need to be maintained at their current levels.

As the intent of the alternatives identification was to support relative cost comparison, detailed assessment of fish passage effectiveness is not included below. Design refinement and optimization, and detailed fish passage assessment would be required for any of the alternatives carried forward into subsequent planning phases. A brief description of each alternative and the potential corresponding constraints are included below.

4.1 BRIDGE STREET DAM

4.1.1 No Action

This alternative would make no enhancement to existing conditions. With time this alternative will result in a continued loss of upstream migration opportunity for the target fish communities, and the potential for ongoing depletion of these species in the Royal River. At present, the fishway provides inadequate passage potential for the target fish community, even when fully operational (Section 3.4). The no action alternative was assumed to include continued inspection, maintenance and potential repair of the dam. Maintenance of the fishway is presently minimal. Degradation of the dam and fishway with time will likely reduce the serviceability of the facilities. This option would not restore bidirectional fish passage, would not restore sediment, large wood and nutrient continuity, and would not improve impoundment water quality.

4.1.2 Fishway Retrofit/Rebuild

Since the existing fishway would provide inadequate passage potential for the target fish community even when fully operational (Section 3.4), this alternative involves replacement with new technical fish passage facilities targeted towards the broader fish community. This option would restore bidirectional fish passage to the extent practical, but would not restore sediment, large wood and nutrient continuity, and would not notably improve impoundment water quality.

The technical fishway alternative would require ongoing maintenance and repair of the dam and appurtenances in perpetuity, and operation and maintenance of the fishway itself. In particular, technical fishways are susceptible to shifts in head pond water levels, requiring keen attention to the water conveying facilities at the site, including a water control structure at the fishway exit to constrain flow when fishway flow capacity is exceeded.

Technical passage for American shad provides the most substantial upstream migration challenge, as they are known to become confused by acute bends, and require size and slope that are larger and flatter than the current fishway, respectively. A new Denil fishway meeting these requirements was assumed for this alternative as the least cost alternative for technical fish passage approaches. Vertical slot or Ice Harbor fishways would also be options to establish successful passage for American shad, but typically cost 200% to 400% more than Denil structures (NOAA and USFWS 2016).

The new Denil fishway would follow the design criteria established by the USFWS (2016). Specifications for the new fishway include 4-foot standard width, 1:8 slope, straight alignment, greater depth than the current structure, and increased resting pool length to meet EDF requirements. This alternative would also include installation of an eel ramp to facilitate passage by juvenile eels, selected dam and ledge modifications to facilitate safe downstream passage, and selected ledge modifications in the primary channel leading to the fishway entrance to facilitate upstream migration. The new fishway would be 45 feet longer than the existing fishway. One possible alignment for the new Denil fishway is shown in Figure 11.

In terms of qualitative fish passage potential, because the fishway entrance is substantially downstream of the dam, near-field attraction to the Denil may be challenged. Preliminary hydraulic calculations suggest that up to 4% of the high fish passage flow could be passed through new fishway as long as the water control structure at the fishway exit remains functional.

Figure 11: Possible Bridge Street dam site alignment and dimensions of new Denil fishway to meet USFWS criteria (Table 4).

4.1.3 Nature-like Fishway

This alternative would replace the existing Denil-type fish passageway with a nature-like bypass channel. This option would restore bidirectional fish passage, but may not fully restore sediment, large wood and nutrient continuity, may not notably improve impoundment water quality, and would require ongoing maintenance of the dam. Nature-like fishways are less susceptible to precise head pond water levels, but still require reliable head pond levels. In evaluating this alternative, it was assumed that the current general impoundment level would be maintained.

Nature-like bypass channels have been shown to be successful alternatives to fish ladders in a variety of habitats for a variety of target species (Aarestrup et al. 2003; Calles and Greenberg 2005; Katopodis et al. 2001). This type of fishway has been shown to be particularly successful for fish known for avoiding technical passage structures, such as American shad (Larinier 2002). Conversely, near-field attraction for bypass channels has been suggested to be a possible passage limitation when the bypass channel entrance is substantially downstream of the dam and when the proportion of flow through the bypass channel is limited (Bunt et al. 2012).

Alternative to the bypass channel concept, nature-like fishways are also constructed in the main channel itself via a rock ramp or similar approach with maximum slope of 5%, and preferably in the

2% to 3% range based on current design guidelines (Turek et al. 2016) and resource agency feedback. The benefit of nature-like construction in the main channel is that issues with near-field attraction to the fishway entrance are avoided. However, this was not considered a feasible approach at the Bridge street site because a rock ramp at 3 % that maintained the present impoundment level would extend over 200 feet downstream of Bridge Street (near or past the tailrace channel outlet), and require an extensive volume of rock fill. Even if constructed at 5%, the rock ramp concept would extend downstream of Bridge Street more than 100 feet. Based on this, construction of nature-like passage by means of rock ramp was considered impractical for this site and assessed to be infeasible within the parameters of the current study. Additional evaluation of alternative nature-like passage options, possibly paired with partial dam and impoundment modification scenarios, could be considered in future project phases to find alternative optimized nature-like passage options, but such evaluation was outside the scope of the present study.

Additional design development would be required to optimize the nature-like bypass approach. However, several potential alignments were identified (Figure 12), which range in average channel slope from ~2.5-7% (Table 12). Ideal nature-like average channel gradients fall in the 2% to 3% range or less, with a maximum of up to 5%. Flatter channel slopes will facilitate passage by the broadest range of target species. These potential alignments would accommodate 100% of low fish passage flows (95% exceedance quantile), 60% of median fish passage flows (50% exceedance quantile), and up to 20% of high fish passage flows (5% exceedance quantile). All alignment options would make use of natural channel features such as pools and riffles, step-pools, and resting boulders to dissipate energy and create a diversity of flow patterns that fish would utilize as they ascend the channel, similar to native flow patterns in a natural stream. The differences between the alternative alignments are generally simply related to their overall lengths. With a longer channel alignment, the associated slope will be flatter. With flatter slope, velocities and hydraulic forces are reduced, leading to a higher degree of fish passage performance. The diversity of velocity and depth within the nature-like fishway would result in sufficient opportunity to increase the success rate of upstream passage (Aaerestrup 2003; Calles and Greenberg 2005).

The potential Bridge Street Dam bypass channel would connect into the main channel upstream and downstream of the dam on river right. Several of the alternative alignments would require construction on the Town of Yarmouth parcel as well as an adjoining private parcel adjacent to the right dam abutment. Downstream constraints for the alignment of this alternative include sanitary sewer infrastructure 125 feet downstream of the dam on river right. Several of the alternative alignments shown in Figure 12 cross the existing footpath adjacent to the river, which would require reconfiguration of a short stretch of the path, and possible addition of a footbridge. For the purposes of the cost analysis, a 481-foot-long nature-like bypass channel was assumed, which represents the lowest slope option listed in Table 15. This is a conservative assumption, as this also results in the longest length of channel construction and hence the greatest estimated construction cost among the alternative alignments shown.

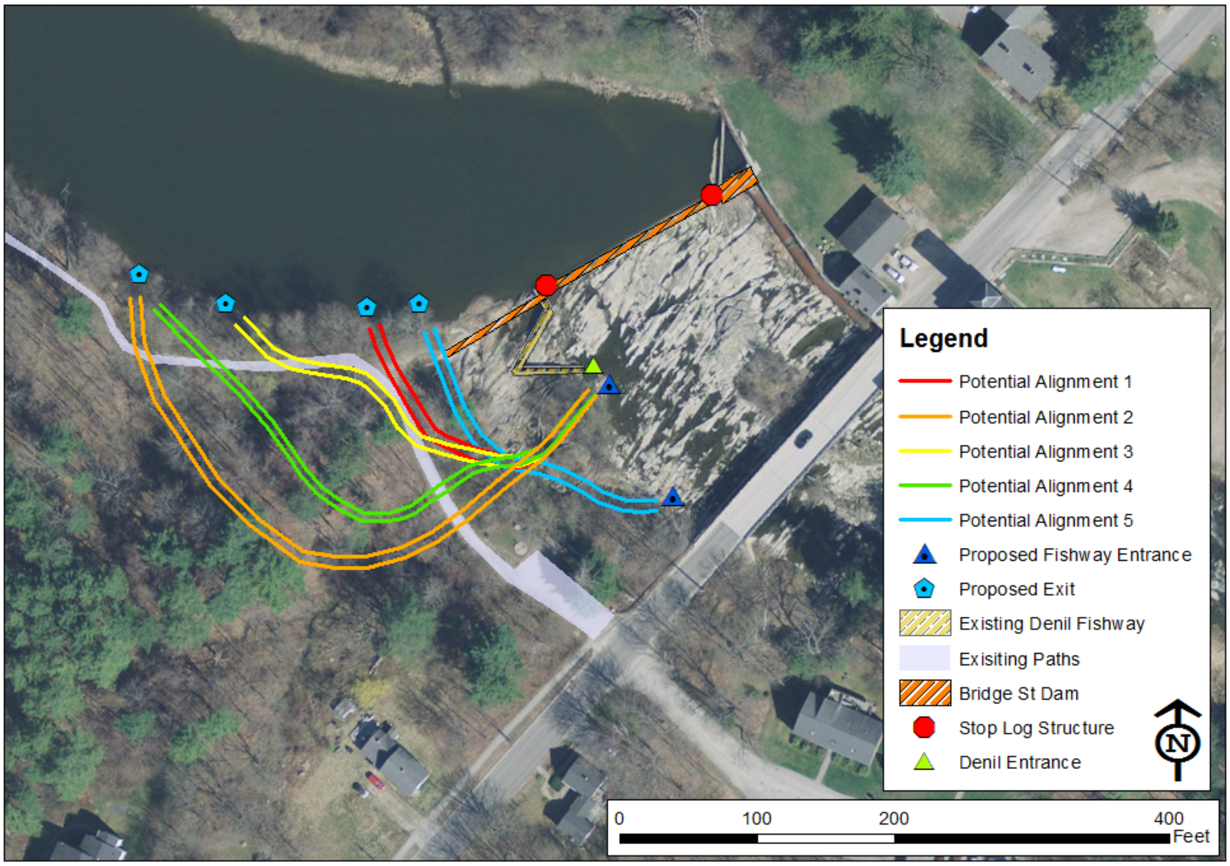

Figure 12: Potential alignment options for the nature-like fishway alternative at the Bridge Street dam Location. Potential nature-like fishway construction constraints are included, such as pump station and drainage outfall locations.

Table 12: Slopes and channel lengths associated with the potential nature-like fishway alignments shown in Figure 12.

Bridge Street Dam Nature-like Bypass Alignments			
Alignment #	**Color**	**Slope (ft/ft)**	**Length (ft)**
1	Red	0.058	223
2	Orange	0.027	481
3	Yellow	0.042	307
4	Green	0.035	409
5	Blue	0.071	225

4.1.4 Dam Removal

This alternative would remove the Bridge Street Dam in its entirety, along with the associated Denil fishway, and right abutment. It was assumed that a portion of the left abutment would be retained to provide stability for the retaining wall behind the private residence, and that the penstock and intake works for the Sparhawk hydropower facility would also be left in place.

Dam removal would result in restoration of bi-directional fish passage for target diadromous and resident fish species. Dam removal would also result in enhanced longitudinal continuity of nutrients, sediment and large wood, enhanced riparian and instream habitats, increased dissolved oxygen concentrations, and lower water temperatures (Bednarek 2001; Maclin and Sicchio 1999; Poff et al. 2002). Removal of the Bridge Street Dam would also eliminate liability and public safety concerns associated with the structure.

Conversely, the potential risk to downstream businesses such as the marinas in Yarmouth Harbor resulting from dam removal has been noted in ongoing public discussions. The primary risk would be related to downstream transport of impounded sediment, which was assessed to be negligible at this site in a prior study (Stantec 2010). To mitigate this risk, the cost analysis assumed that any potentially mobile impounded sediment found upstream of the Bridge Street dam would be excavated in conjunction with the dam removal alternative.

It is not clear whether modification of the pre-disturbance bedrock outcrop occurred during the historical development of the site, or whether such modifications changed the pre-disturbance fish passage potential at the site. It is plausible that modification of the natural bedrock did occur as such modifications were common at similar sites throughout New England to maximize the utility of the historical facilities. A detailed evaluation of natural ledge modifications could be accomplished through future field and historical evaluations.

Based on the current observable site condition, probable post-dam removal fish passage channels are indicated in Figure 13. These alignments were estimated based on comparisons of bedrock elevations, field observations, and aerial photograph analyses, and constitute the likely primary flow paths if the spillway were to be removed. Slopes and lengths of these channels are provided in Table 13. The average channel gradients along these alignments are relatively steep. It is anticipated that the diversity of flow patterns along the ledge outcrop would provide a variety of opportunities for passage by native fish, similar to that which occurs in numerous rivers in similar settings along the Maine Coast. However, it was also assumed that select enhancement of passage conditions through ledge modification may be required associated with dam removal. Optimization of the passage design associated with dam removal would need to be advanced in subsequent project phases.

See Section 5.1 for additional assumptions in the cost analysis related to mitigation of infrastructure impacts and sediment management.

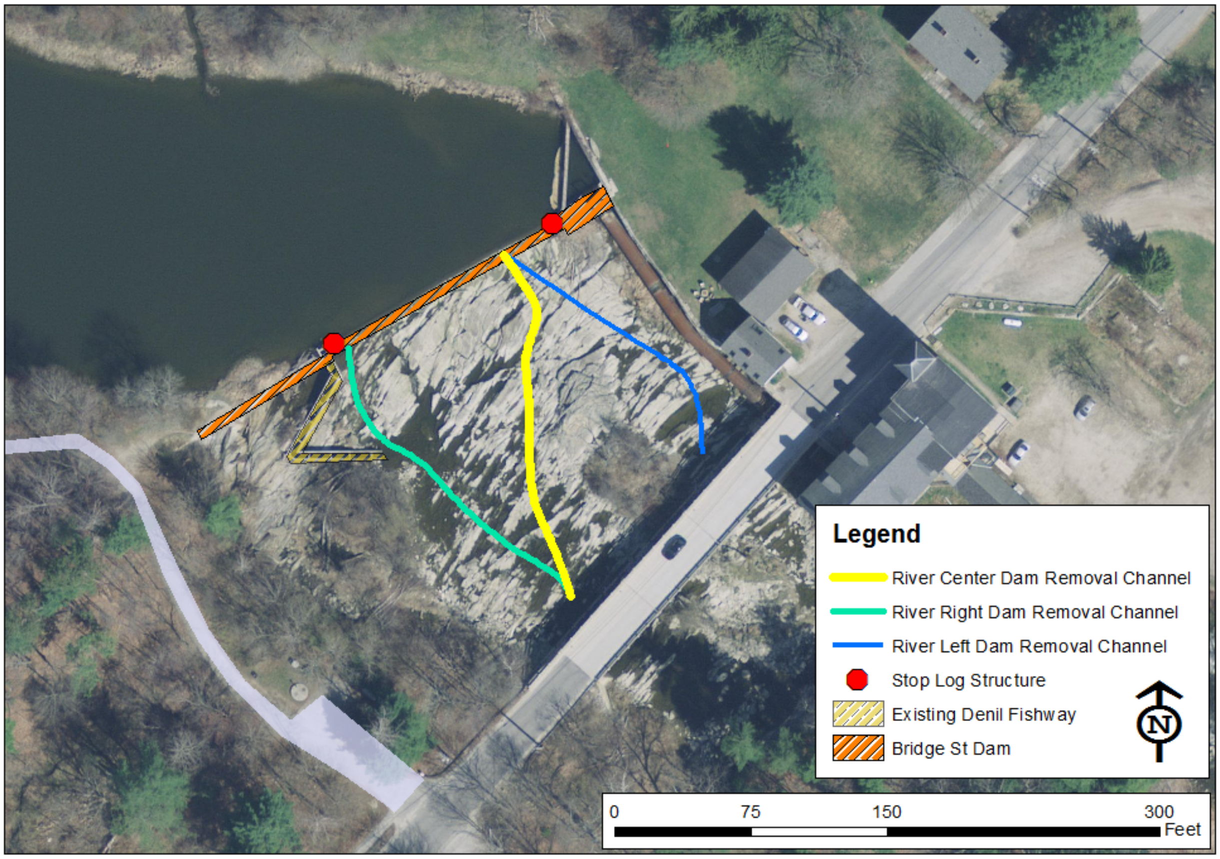

Figure 13: Probable post-dam-removal fish passage channels at the Bridge Street Dam site.

Table 13: Slopes and lengths of probable post-Bridge-Street-dam-removal fish passage channels shown in Figure 12.

Bridge Street Dam Removal Probable Passage Channels		
Location	**Slope (ft/ft)**	**Length (ft)**
River Right	0.057	207
River Center	0.048	215
River Left	0.058	209

4.2 EAST ELM STREET DAM

4.2.1 No Action

Similar to the case with the Bridge Street dam no action alternative, this alternative would make no enhancement to existing conditions. With time this alternative may result in a continued loss of upstream migration opportunity for the target fish communities, and the potential for ongoing depletion of these species in the Royal River. At present, the fishway is in disrepair and is not functional. The fishway would provide inadequate passage potential for the target fish community, even when fully operational (Section 3.5). The no action alternative was assumed to include continued inspection, maintenance and potential repair of the dam. Maintenance of the fishway is presently minimal. Degradation of the dam and fishway with time will likely reduce the serviceability of the facilities. This option would not restore bidirectional fish passage, would not restore sediment, large wood and nutrient continuity, and would not improve impoundment water quality.

4.2.2 Fishway Retrofit/Rebuild

Similar to the case for the Bridge Street dam technical fishway alternative, this alternative involves replacement with new technical fish passage facilities targeted towards the broader fish community since the existing fishway would provide inadequate passage potential for the target fish community even when fully operational (Section 3.5). This option would restore bidirectional fish passage to the extent practical, but would not restore sediment, large wood and nutrient continuity, and would not notably improve impoundment water quality.

The technical fishway alternative would require ongoing maintenance and repair of the dam and appurtenances in perpetuity, and operation and maintenance of the fishway itself. In particular, technical fishways are susceptible to shifts in head pond water levels, requiring keen attention to the water conveying facilities at the site, including a water control structure at the fishway exit to constrain flow when fishway flow capacity is exceeded.

As with the Bridge Street case, technical passage for American shad provides the most substantial upstream migration challenge, as they are known to become confused by acute bends, and require size and slope that are larger and flatter than the current fishway, respectively. A new Denil fishway meeting these requirements was assumed for this alternative as the least cost alternative for technical fish passage approaches.

The new Denil fishway would follow the design criteria established by the USFWS (2016). Specifications for the new fishway include 4-foot standard width, 1:8 slope, straight alignment, greater depth than the current structure, and increased resting pool length to meet EDF requirements. This alternative would also include installation of an eel ramp to facilitate passage by juvenile eels, selected dam and ledge modifications to facilitate safe downstream passage, and selected ledge modifications in the primary channel leading to the fishway entrance to facilitate upstream migration. The new fishway would be 70 feet longer than the existing fishway. One possible alignment for the new Denil fishway is shown in Figure 14.

In terms of qualitative fish passage potential, because the fishway entrance is substantially downstream of the dam, near-field attraction to the Denil may be challenged. Preliminary hydraulic calculations suggest that up to 4% of the high fish passage flow could be passed through new fishway as long as the water control structure at the fishway exit remains functional.

Figure 14: Location and dimensions of proposed retrofit of existing East Elm Street Denil fishway to meet USFWS criteria (Table 4).

4.2.3 Nature-like Fishway

Similar to the Bridge Street nature-like fishway alternative, this option would replace the East Elm Street dam site Denil fishway with a bypass channel. This option would restore bidirectional fish passage, but may not fully restore sediment, large wood and nutrient continuity, may not notably improve impoundment water quality, and would require ongoing maintenance of the dam. Nature-like fishways are less susceptible to precise head pond water levels, but still require reliable head pond levels. In evaluating this alternative, it was assumed that the current general impoundment level would be maintained.

The reader is referred to Section 4.1.3 for additional general discussion of nature-like passage approaches. Similar to the Bridge Street site, in-channel nature-like fish passage was not considered a feasible or practical approach at the East Elm Street site because of the extensive fill that would be required longitudinally and laterally to create suitable passage conditions. For example, a rock ramp set at 3% which maintained the current impoundment level would extend at least to the confluence of the side channel around Gooch's island. Based on this, construction of nature-like passage by means of rock ramp was considered impractical for this site and assessed to be infeasible within the parameters of the current study. Additional evaluation of alternative nature-like passage options, possibly paired with partial dam and impoundment modification scenarios, could be considered in future project phases to find alternative optimized nature-like passage options, but such evaluation was outside the scope of the present study.

As with the Bridge Street site, additional design development would be required to optimize the nature-like bypass approach. However, several potential alignments were identified (Figure 15), which range in average channel slope from ~2.5-3.7% (Table 14). The alternative alignment 5 takes advantage of an existing seam in the ledge outcrop near the left end of the spillway, and would require additional investigation of the potential for ledge outcrops upstream of the dam spillway to fully establish its feasibility. This alignment would route passage flows around the back side of Gooch's Island, which would likely provide adequate attraction signal at low passage flows, but may be more limited at high fish passage flows.

The remainder of the alternate alignments shown in Figure 15 would make use of the upstream inlet to the existing foundry channel. These alignments split from the foundry channel downstream of the historical spillway in the foundry channel, bending towards the main river channel across the park, with a fishway entrance at the terminus of the ledge outcrop in the existing main channel pool.

Ideal nature-like average channel gradients fall in the 2% to 3% range or less, with a maximum of up to 5%. Flatter channel slopes will facilitate passage by the broadest range of target species. These potential alignments would accommodate 100% of low fish passage flows (95% exceedance quantile), 60% of median fish passage flows (50% exceedance quantile), and up to 20% of high fish passage flows (5% exceedance quantile). All alignment options would make use of natural channel features such as pools and riffles, step-pools, and resting boulders to dissipate energy and create a diversity of flow patterns that fish would utilize as they ascend the channel, similar to native flow patterns in a natural stream. The differences between the alternative alignments are generally simply related to their overall lengths. With a longer channel alignment, the associated slope will be flatter. With flatter slope, velocities and hydraulic forces are reduced, leading to a higher degree of fish passage performance. The diversity of velocity and depth within the nature-like fishway would result in sufficient opportunity to increase the success rate of upstream passage (Aaerestrup 2003; Calles and Greenberg 2005).

Except for alignment 5, all of the alignments shown in Figure 15 would require construction on the adjacent parcel owned by the Town of Yarmouth. The same alignments cross the existing footpath between the foundry channel and the main river channel. This would require reconfiguration of a short stretch of the path, and possible addition of a footbridge. For the purposes of the cost analysis, a 512-foot-long new segment of channel was assumed. Added to the existing length of the foundry channel that would be utilized, this results in an assumed 652-foot-long nature-like bypass alignment, which represents the lowest slope option listed in Table 17. This is a conservative assumption, as this also results in the longest length of channel construction and hence the greatest estimated construction cost among the alternative alignments shown.

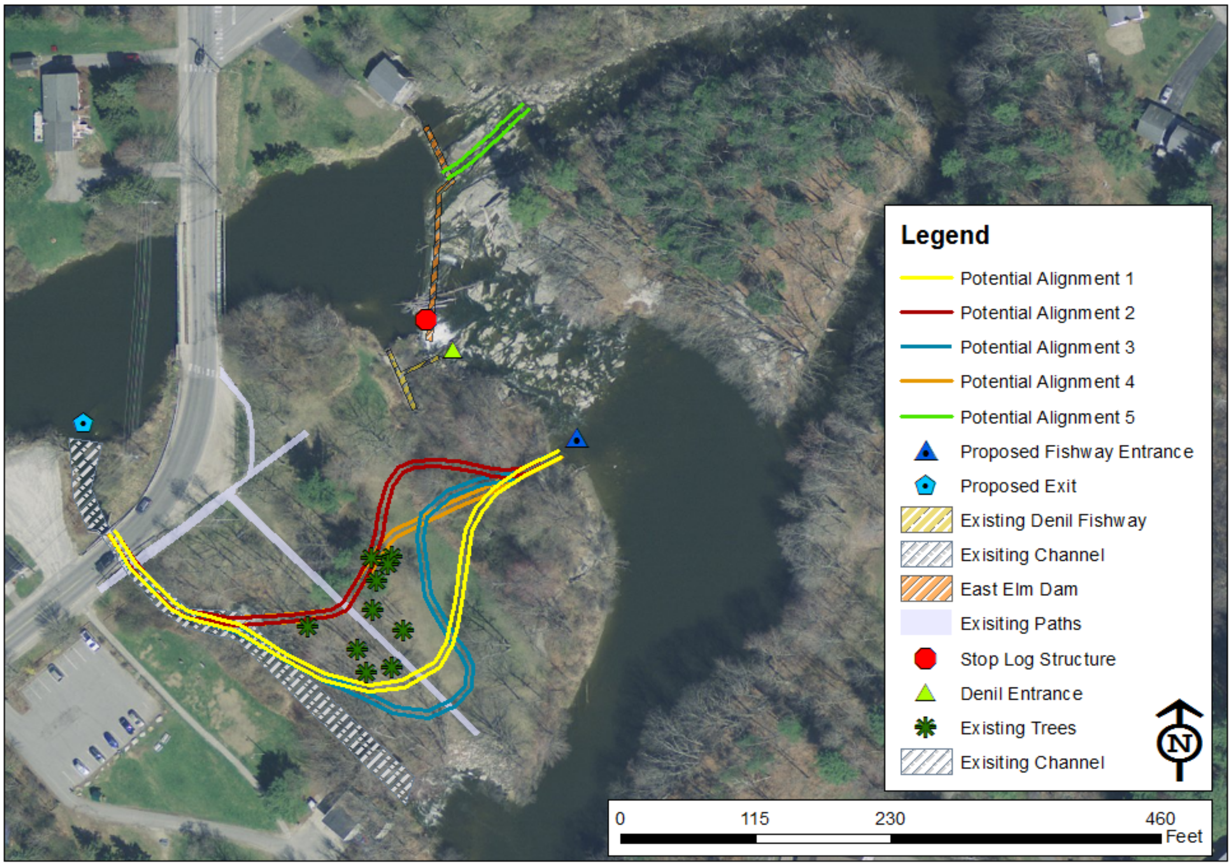

Figure 15: Potential alignment options for the nature-like fishway alternative at the East Elm Street dam site.

Table 14: Slopes and channel lengths associated with the potential nature-like fishway alignments at the East Elm Street dam site shown in Figure 14.

East Elm Street Dam Nature-like Bypass Alignments			
Alignment #	Color	Slope (ft/ft)	Length (ft)
1	Yellow	0.031	554
2	Red	0.034	504
3	Blue	0.026	652
4	Orange	0.037	468
5	Green	0.037	91

4.2.4 Dam Removal

This alternative would remove the East Elm Street Dam in its entirety, along with the associated Denil fishway, and right abutment. It was assumed that a portion of the left abutment would be retained to provide stability for the retaining wall behind the artist's studio.

Dam removal would result in restoration of bi-directional fish passage for target diadromous and resident fish species. Dam removal would also result in enhanced longitudinal continuity of nutrients, sediment and large wood, enhanced riparian and instream habitats, increased dissolved oxygen concentrations, and lower water temperatures (Bednarek 2001; Maclin and Sicchio 1999; Poff et al. 2002). Removal of the Bridge Street Dam would also eliminate liability and public safety concerns associated with the structure.

Conversely, as described earlier for the Bridge Street site, the potential risk to downstream businesses such as the marinas in Yarmouth Harbor resulting from dam removal has been noted in ongoing public discussions. The primary risk would be related to downstream transport of impounded sediment, which was assessed to be potentially notable at this site (110,000 cubic yards of potentially mobile sediment) in a prior study (Stantec 2013). To mitigate this risk, the cost analysis assumed that any potentially mobile impounded sediment found upstream of the East Elm Street dam would be excavated in conjunction with the dam removal alternative.

Similar to the Bridge Street site, it is not clear whether modification of the pre-disturbance bedrock outcrop occurred during the historical development of the site, or whether such modifications changed the pre-disturbance fish passage potential at the site. It is plausible that modification of the natural bedrock did occur as such modifications were common at similar sites throughout New England to maximize the utility of the historical facilities. A detailed evaluation of natural ledge modifications could be accomplished through future field and historical evaluations.

Based on the current observable site condition, probable post-dam removal fish passage channels are indicated in Figure 16. These alignments were estimated based on comparisons of bedrock elevations, field observations, and aerial photograph analyses, and constitute the likely primary flow paths if the spillway were to be removed. Slopes and lengths of these channels are provided in Table 15. As with the Bridge Street dam removal alternative, the average channel gradients along these alignments are relatively steep. It is anticipated that the diversity of flow patterns along the ledge outcrop would provide a variety of opportunities for passage by native fish, similar to that which occurs in numerous rivers in similar settings along the Maine Coast. However, it was also assumed that select enhancement of passage conditions through ledge modification may be required associated with dam removal. Optimization of the passage design associated with dam removal would need to be advanced in subsequent project phases.

See Section 5.1 for additional assumptions in the cost analysis related to mitigation of infrastructure impacts and sediment management. Sediment management associated with removal of East Elm Street dam in particular is a potentially major cost factor.

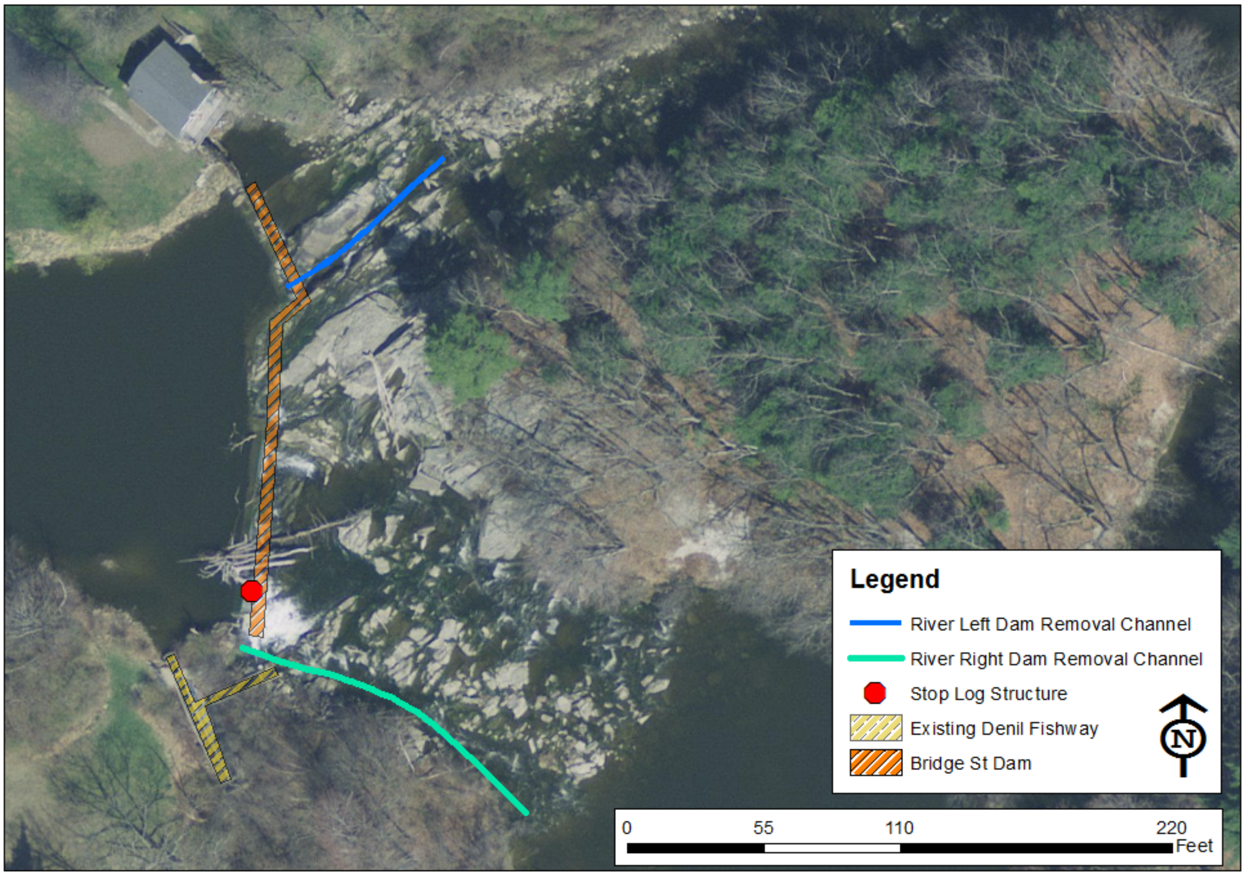

Figure 16: Probable post-dam-removal fish passage channels at the East Elm Street dam site.

Table 15: Slopes and lengths of probable post-East-Elm-Street-dam-removal fish passage channels shown in Figure 15.

Bridge Street Dam Removal Probable Passage Channels		
Location	**Slope (ft/ft)**	**Length (ft)**
River Right	0.054	92
River Left	0.04	91.5

4.3 SUMMARY OF FISH PASSAGE ALTERNATIVES

Detailed quantitative assessment of potential fish passage effectiveness and efficiency for each of the alternatives was outside the scope of the present study. In lieu of a detailed assessment, the efficacy of the alternative approaches at each site can be contrasted in qualitative terms. Of the four alternatives considered at each site, the no action alternative will be least effective in accomplishing the established goals. New technical fishways will enhance passage conditions for the target fish population, but attraction to the fishway entrances may be sub-ideal because the proportion of total flow during the upstream migration period would be less than the nature-like and dam removal options (Table 16). In addition, provisions to enhance utilization by species with behavioral nuances (such as shad) may dictate that the technical fishway entrances would be distant from the dam spillways themselves (See Sections 4.1.2 and 4.2.2 for additional detail).

The nature-like alternatives should provide flow field characteristics that are more intuitive to fish to utilize reducing behavioral limitations, and should substantially increase the proportion of flow through the passageway when compared to the technical fishway alternatives (Table 16). When combined with the ability to place the nature-like fishway entrances close to the bases of the spillways, attraction to the nature-like options should be substantially improved over the technical fishway options.

Lastly, the dam removal alternatives would eliminate the limitations related to attraction as the full river flow would be conveyed along the passage alignments, and also provide the most natural or native flow patterns for fish to utilize. The apparent passage pathways associated with dam removal suggest modestly steeper channel conditions than the most optimized nature-like bypass options. However, given the high degree of variability in flow field characteristics that would result from dam removal, it is assumed that passage potential associated with dam removal would be at least equivalent to the nature-like alternatives, while eliminating the potential concern over attraction to the fishway entrance. This would be particularly true to passage over the ledge outcrops were optimized in detailed design, potentially involving selected ledge modifications.

Table 16: Preliminary estimates of proportion of total flow routed through fish passage facilities associated with the alternative fish passage approaches.

Fish Passage Alternative	Proportion of Flow at Low Fish Passage Flow (95% exceedance)	Proportion of Flow at Median Fish Passage Flow (50% exceedance)	Proportion of Flow at High Fish Passage Flow (50% exceedance)
Technical Fishway	41%	13%	4%
Nature-like Fishway	100%	60%	20%
Dam Removal	100%	100%	100%

5. Cost Analysis

Opinions of probable cost were developed for each of the alternatives discussed in Section 4. These cost opinions are intended at the present juncture primarily to enable relative comparison between alternatives, with additional design development recommended to result in cost opinions that are suitable for advanced planning and for use in fundraising.

The goal for the cost analyses was to develop precision and accuracy that is greater than order of magnitude, but less formal than detailed design opinions of probable construction cost. According to the definitions developed by the American Association of Cost Engineering, the goal for the cost analysis fits in the range of Class 4 to Class 3 estimates. The cost analysis includes design, permitting, construction, estimated operation and maintenance costs for a thirty-year planning horizon, and eventual replacement costs if appropriate.

The cost opinions have been developed based on review of construction costs for similar items in past projects and applicable reference cost data. The actual implemented cost may vary from these estimates, based on market factors, detailed design development and possible optimization, and other factors.

5.1 ASSUMPTIONS

Several assumptions were required to facilitate preparation of the cost analysis, discussed below.

Dam Repair

Sustained operation of the technical fishway and nature-like fishway alternatives at each site rely on perseverance and continued operation of the dams at each site. The technical fishway alternatives will be incrementally more sensitive to changes in dam condition and reduced precision of operational capacity than the nature-like fishways. However, for the purposes of the current analysis, dam repair, maintenance and operational needs were considered uniform across fishway approaches.

HDR Engineering performed a visual inspection of both dams in September 2009 (HDR 2009). Both dams were found to be in 'good' condition, with potential to provide many years of additional service with minor repairs (Table 17). They qualify a rating of 'good' as follows:

> 'Good does not refer to the like-new condition but rather to the ability of the structure to perform its intended function with either no repairs or minor repairs. Any deterioration that does exist does not affect the structural integrity.'

FERC performs an inspection of the Bridge Street dam every three years under the terms of the license exemption for the Sparhawk hydroelectric facility, with the last inspection performed in June 2015. The full inspection report had not been obtained at the time of report preparation, but the primary repair recommendations were obtained from FERC correspondence (FERC 2015) subsequent to the inspection which preceded report preparation. The indicated repairs are generally consistent with recommendations made earlier by HDR, and are listed in Table 18.

Dam inspection was not a part of the present study. Because the last inspection of both dams occurred in 2009, it is recommended that the stakeholders commission a new inspection that also results in repair estimates for the recommended action items. Because the dam repairs present a notable portion of the estimated costs for two of the alternatives at each site (see Appendix D), a new study will facilitate refinement and precision of the cost analysis.

In the current cost analysis, it was assumed that the recommended repairs listed by HDR (2009) would be accomplished in association with the technical fishway and nature-like fishway alternatives. Although no fish passage improvements were included in the cost analysis for the no action alternatives, it was assumed that a proportion of the repairs identified by HDR would be accomplished under the no action alternatives.

Table 17: Repair recommendations of HDR based on visual inspection (2009).

Bridge Street Dam	
1.	Replace the 3/16-inch-thick concrete overlay on the downstream face of the right non-overflow section within the next 5 years. The de-bonded areas should be chipped out and repaired. This repair is for life extension only at this time.
2.	Replace the two lower stoplogs in the right sluice bay to reduce leakage and help maintain headpond storage.
3.	Replace the missing concrete overlay at the 10-foot-long void in the downstream face of the spillway at the right toe within the next 5 years (life-extension repair).
4.	Repair the deteriorated concrete areas on the intake section within the next 5 years (another life-extension repair)
5.	Initiate remediation measures for the sinkholes in the back lawn of the residence
6.	Remove the rock that is lodged between the penstock and the east wall
7.	Take measures to limit public access to the right non-overflow section
8.	Immediately start monitoring the condition of the east downstream channel wall annually for signs of horizontal movement. We recommend the Town obtain the services of a land surveyor for this task
East Elm Street Dam	
1.	The services of a qualified security and safety expert should be retained immediately to be sure that the public is properly protected from the hazards of the dam and the bypass. Standards, such as the NFPA 101 Life Safety Code, provide detailed information that must be applied with good judgment. We recommend that the Town install temporary barriers and signage immediately.
2.	Consider adding fencing around the full perimeter of the fish ladder to reduce the hazard potential for someone, especially a child, to fall into and become entrapped in the fish ladder.
3.	Remove the heavy vegetation around the right non-overflow section.
4.	Initiate measures to repair the deteriorated downstream face of the non-overflow section near the fish ladder. This area is marginally stable, and further deterioration could possibly affect the structural stability of the right non-overflow section. This is a case where a relatively minor repair in the near future could prevent the need for an expensive major repair.
5.	Repair two areas of the crest at and to the left of the bedrock island where the crest stones and/or concrete are displaced or missing. This is an optional maintenance item.
6.	Initiate measures to stabilize the old spillway in the bypass channel downstream of East Elm Street. The stabilization might be as simple as placing large stones downstream.
7.	At the bypass channel, consider initiating repairs for the void in the stone retaining wall downstream of the old spillway. Undermining of the embankment, especially during high flows, could cause a localized collapse of the wall.
8.	Recommend that some parts of the bypass channel be fenced to limit public access.
9.	Immediately start monitoring the condition of the east downstream channel wall annually for signs of horizontal movement. We recommend the Town obtain the services of a land surveyor for this task

Table 18: Repair recommendations of FERC based on their 2015 safety inspection as indicated in their letter (FERC 2015) which was issued subsequent to the inspection.

Bridge Street Dam	
1.	Per discussion with the project operator present at the site at the time of the inspection, some or all of the generating units at the project were inoperable. Provide a plan and schedule for the repairs and returning the generating units to service.
2.	Replace the missing concrete overlay at the 10-foot-long void in the downstream face of the spillway at the right toe, and the void remaining following the 2013/2014 repairs to this section should be filled.
3.	During the inspection, leakage was noted along the penstock and intake structure interface, and along the intake and retaining wall interface. The leakage should be documented and monitored for changes and findings should be included in the annual Dam Safety Surveillance and Monitoring Report.
4.	Leakage along the penstock joints should be repaired.
5.	A "Danger —Keep Off the Dam" sign should be posted at the right abutment non-overflow section since access to this area is not restricted, as noted in the October 2, 2012 FERC inspection follow-up letter. The public safety plan should be revised accordingly and submitted for review.
6.	A section of the intake trash rack is damaged and requires repairs.
7.	Vegetation present at the right abutment, fish ladder, penstock footings, and the stone wall should be removed and future growth should be limited, as noted in the October 2, 2012 FERC inspection follow-up letter.

Sediment management associated with dam removal

As noted in Section 4, the potential risk to downstream businesses such as the marinas in Yarmouth Harbor resulting to downstream transport of impounded sediment following dam removal has been noted in ongoing public discussions. Based on prior discussions with stakeholders, it was assumed that sediment identified as potentially mobile would be actively managed. Stantec (2013) estimated 110,000 cubic yards of potentially mobile sediment associated with removal of East Elm. This activity represents the dominant cost factor associated with the dam removal alternative. Stantec (2010) found negligible sediment in the Bridge Street impoundment, thus a nominal sediment management scope was included for the dam removal alternative at that site.

Mitigation of potential infrastructure impacts associated with dam removal

Potential infrastructure impacts associated with dam removal were initially discussed in the feasibility study (Stantec 2010). Follow-up analyses of selected impacts were completed as part of the Phase 2 study for the East Elm Street site (Stantec 2013). Mitigation was included in the cost analysis for those potential impacts identified in the Phase 1 study with greater than negligible risk of damage, unless their risks were specifically dismissed as a result of the Phase 2 study analyses. For the two dam removal alternatives, these mitigation measures represent notable cost factors. Subsequent planning phases should further evaluate these mitigation needs.

At the Bridge Street site, this included the Beth Condon footbridge, the Rte. 1 bridge, and the retaining wall behind the residence at the left abutment of the dam (the retaining wall was included in the repair work that was associated with the alternatives where the dam would be retained). At the East Elm Street site, this included the two railroad bridges, the water supply main, and the dry hydrant.

Nature-like Bypass Channel Length Assumptions

At each site, the longest of the potential nature-like bypass channel alignments that were identified were used as the basis of the respective cost analyses. These were intentionally conservative assumptions, as this also results in the longest length of channel construction and hence the greatest estimated construction cost among the alternative alignments shown for each site (See Sections 4.1.3 and 4.2.3 for additional detail). If selected, it is anticipated that subsequent design development would optimize the design of the nature-like passage options.

Capitalization of Lifespan and Replacement Costs

For those alternatives which retain the dams, annual operation and maintenance costs and periodic inspection and repair costs were included in the cost analysis. These lifespan costs were applied to both the dams and the fishways for the enhancement alternatives which retain the dam. Compared to the nature-like fishways, the technical fishways were assessed to have greater annual operation and maintenance costs, and greater periodic inspection and repair costs. For the no action alternatives, the lifespan costs were only applied to the dams themselves. Thus, the lifespan costs associated with the no action alternatives had the lowest recurring costs, followed by those associated with the nature-like fishway alternatives, with the technical fishway alternatives estimated to have the most intensive lifespan requirements. There were no lifespan costs associated with dam removal.

Lifespan costs were capitalized over a 30-year planning horizon, assuming a 3% rate of inflation. This rate of inflation was selected based on review of average rates of inflation over the last 30 year period (1986-2015). Over this period, inflation in the Consumer Price Index calculated by the U.S. Bureau of Labor Statistics was 2.67 for the nation and 2.89 for the northeast region. These rates were compared to inflation in the RS Means Heavy Construction Index (RS Means 2016) over the same period (3.15), to result in the selected value of 3.0.

Facility replacement costs were estimated as capitalized initial project costs for the alternatives that build new fish passage facilities, based on a 30-year planning horizon with an average rate of inflation of 3%.

Insurance and Taxes

These cost factors were disregarded in the cost analysis. Although important considerations, it is unclear what revenue the City of Yarmouth may realize over the planning horizon because the current and future operational plans for the Sparhawk facility are unclear and unknown. However, this potential loss of revenue associated with dam removal is unlikely significant to, and is within the resolution of the cost analysis. It is likely that liability insurance for the two sites are covered by broader liability coverage for Town lands and facilities. The incremental costs for coverage of the dams is also not likely significant to the cost analysis when used for the intended application.

Hydropower Operation Acquisition and Retirement
Similar to the above, this potential cost factor associated with removal of Bridge Street dam was disregarded in the analysis. The current and future operational plans for the Sparhawk facility are unclear and unknown. Once these are determined, a separate valuation should be completed to inform this element of the overall economics of the project.

Hydropower Operation Revenue Generation
When the Bridge Street hydroelectric facility is operational, it represents a potential source of revenue to the owner of the facility, as well as to the Town of Yarmouth who owns the dam, though the details of any associated financial instruments are unknown. As the facility does not presently appear to be generating electricity and future plans are unknown, the potential revenue generated by the facility was not included in the cost analysis.

5.2 COST ANALYSIS SUMMARY

The results of the cost analysis are summarized in Table 19. Aside from the no action alternative, dam removal had the lowest cost at the Bridge Street site in terms of both initial and total cost, followed by the nature-like fishway alternative. At the East Elm Street site, aside from the no action alternative, the nature-like fishway alternative had the lowest initial and total cost, followed by the technical fishway alternative. The primary factors that escalated the potential costs of dam removal at the East Elm Street site were the potential need for sediment management, and mitigation of potential impacts on bridges and other infrastructure.

Table 19: Summary of cost analysis, rounded to nearest $1,000.

Site	Alternative	Initial Cost* ($)	Lifespan Cost ($)	Replacement Cost ($)	Total Cost ($)
Bridge Street					
	No Action	107,000	394,000	0	501,000
	Technical Fishway	717,000	558,000	1,740,000	3,045,000
	Nature-like Fishway	619,000	441,000	1,459,000	2,520,000
	Dam Removal	540,000	0	0	540,000
East Elm Street					
	No Action	107,000	394,000	0	501,000
	Technical Fishway	784,000	558,000	1,848,000	3,221,000
	Nature-like Fishway	617,000	441,000	1,454,000	2,512,000
	Dam Removal	3,787,000	0	0	3,787,000

*Includes 30% design and construction contingency, and estimated project delivery costs.

6. Summary and Conclusions

This study included a detailed assessment of the fish passage potential at the Bridge Street and East Elm Street dams on the Royal River in the town of Yarmouth, Maine. The study also identified four alternative approaches to enhance fish passage at each dam, and summarized analyses to compare the relative costs of the identified alternatives at each site. The target native fish community identified for the study included alewife, American eel, American shad, blueback herring, sea-run brook trout, rainbow smelt, sea lamprey, and striped bass.

At the time of the assessment, the fishway at the Bridge Street dam was functioning hydraulically, but was found to have fair to poor ability to attract fish to the entrance of the fishway, with geometry and slope that are likely to discourage usage by American shad. The operational limits for the existing fishway are constrained by its size. The proportion of flow available for attraction was found to be partially within limits established by the U.S. Fish and Wildlife (USFWS 2016) for the lower 75 percent of the fish passage flows, but is below the established criteria for the upper 25 percent of the fish passage flows. Available guidance from NOAA suggests that the proportion of flow near the fishway is inadequate for attraction of upstream migrating fish to the fishway entrance. Resting areas within the fishway were found to be inadequate when compared to prevailing criteria (USFWS 2016). There are no provisions for upstream passage of juvenile eels, and there is notable potential for injury to downstream outmigrating fish. Overall, it can be concluded that the fishway at the Bridge Street dam is a likely constraint on the long-term restoration of bi-directional passage for the full target diadromous fish community.

At the time of the assessment, the fishway at the East Elm Street dam was not functioning and was in disrepair. If the fishway were restored to fully operational status, it would exhibit nearly identical trends to those summarized above for the Bridge Street fishway. Thus, it can also be concluded that the fishway at the East Elm Street dam is also a likely constraint on the long-term restoration of bi-directional passage for the full target diadromous fish community.

For the four alternatives (no action, retrofit/rebuild technical fishway, nature-like fishway, and dam removal) identified to enhance fish passage potential at each site, their relative costs were analyzed in terms of initial project costs, life span costs (operation, maintenance and repair) over a 30-year planning horizon, and eventual replacement costs. The lowest cost alternative in economic terms at each site was the no action alternative. However, based on the results summarized above, it can be concluded that this alternative would not achieve the stated goal of restoring bi-directional passage for the target native diadromous fish community.

Of the remaining alternatives that enhance fish passage at the Bridge Street site, the dam removal option had the lowest initial and total costs, followed by the nature-like fishway alternative. The technical fishway retrofit/rebuild alternative had the highest estimated initial and total costs at the Bridge Street site.

Of the remaining alternatives that enhance fish passage at the East Elm Street site, the nature-like fishway option had the lowest initial and total project costs, followed by the technical fishway retrofit/rebuild alternative. The dam removal alternative at the East Elm Street site had the highest estimated costs, primarily due to the potential need for proactive management of the potentially mobile sediment stored behind the dam, and the potential for mitigation associated with critical infrastructure resulting from dam removal.

7. References

Aarestrup, K., Lucas, M.C. and Hansen, J.A., 2003. Efficiency of a nature-like bypass channel for sea trout (Salmo trutta) ascending a small Danish stream studied by PIT telemetry. Ecology of freshwater fish, 12(3), pp.160-168.

Bednarek, A.T., 2001. Undamming rivers: a review of the ecological impacts of dam removal. Environmental management, 27(6), pp.803-814.

Bunt, C., Castro-Santos, T. and Haro, A. 2012. Performance of fish passage structures at upstream barriers to migration. River Research and Applications, 28: 457-478.

Calles, E.O. and Greenberg, L.A., 2005. Evaluation of nature-like fishways for re-establishing connectivity in fragmented salmonid populations in the river Emån. River research and applications, 21(9), pp.951-960.

Craig, M. 2017. Personal communication with Matt Craig, Casco Bay Estuary Partnership.

Department of Marine Resources and Department of Inland Fisheries and Wildlife, 2009. Operational Plan for the Restoration of Diadromous Fishes to the Penobscot River.

DeRoche, S. 1958. Royal River Drainage: Fish Management. Maine Department of Inland Fisheries and Game. Augusta, Maine.

Fay, 2007. A Power Production Study of the Sparhawk Mills Hydrogeneration Facility. Private report by Fay Engineering Services, Thorndike, Massachusetts August 2007.

FERC 2015. Letter to Mr. Allen Jagger. July 24.

Hall, C.J., Jordaan, A. and Frisk, M.G., 2011. The historic influence of dams on diadromous fish habitat with a focus on river herring and hydrologic longitudinal connectivity. Landscape Ecology, 26(1), pp.95-107.

Haro, A., Castro-Santos, T., Noreika, J. and Odeh, M., 2004. Swimming performance of upstream migrant fishes in open-channel flow: a new approach to predicting passage through velocity barriers. Canadian Journal of Fisheries and Aquatic Sciences, 61(9), pp.1590-1601.

Haro, A. and Castro-Santos, T. 2012. Passage of American Shad: Paradigms and Realities, Marine and Coastal Fisheries, 4:1, 252-261.

HDR 2009. Visual Inspection of Bridge Street Dam and East Elm Street Dam. Letter report prepared for Town of Yarmouth.

Katopodis, C., Kells, J.A. and Acharya, M., 2001. Nature-like and conventional fishways: Alternative concepts? Canadian Water Resources Journal, 26(2), pp.211-232.

Katopodis, C., Rajaratnam, N., Wu, S., and Tovell, D. 1997. Denil Fishways of Varying Geometry. Journal of Hydraulic Engineering. 123(7):624-631.

Katopodis, C. 2002. Introduction to Fishway Design. Canadian Department of Fisheries and Oceans. January.

Larinier, M., 2002. Biological factors to be taken into account in the design of fishways, the concept of obstructions to upstream migration. Bulletin Français de la Pêche et de la Pisciculture, Ch. 3. (364), pp.28-38.

Larinier, M., 2002. Baffle fishways. Bulletin Français de la Pêche et de la Pisciculture, Ch. 6. (364) pp.83-101.

Larinier, M. and Travade, F., 2002. The Design of fishways for shad. Bulletin Français de la Pêche et de la Pisciculture, Ch. 9. (364) pp.135-146.

Limburg, K.E. and Waldman, J.R., 2009. Dramatic declines in North Atlantic diadromous fishes. BioScience, 59(11), pp.955-965.

Maclin, E. and Sicchio, M., 1999. Dam removal success stories: restoring rivers through selective removal of dams that don't make sense. Washington, DC, Spec. Rep. by Friends of the Earth, American Rivers, and Trout Unlimited.

Maine Rivers, 2013. Summary of recreational changes associated with dam removal and river restoration. Royal River Restoration Project, Yarmouth, Maine.

Maine Stream Habitat Viewer (MSHV) 2013. Accessed at: https://webapps2.cgis-solutions.com/MaineStreamViewer/.

Turek, J., Haro, A., and Towler, B. 2016. Technical Memorandum. Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes.

NOAA 2015. Diadromous Fish Passage: A Primer on Technology, Planning and Design for the Atlantic and Gulf Coasts.

NOAA and USFWS 2016. Query of NOAA and USFWS technical staff regarding typical costs of alternate forms of technical fish passage structures.

Odeh, M. 2003. Discharge rating equation and hydraulic characteristics of standard Denil fishways. Journal of Hydraulic Engineering. 129(5):341-348.

Osberg, P. H., Hussey II, A. M., Boone, G. M., 1985. Bedrock Geologic Map of Maine, Maine Geological Survey.

Poff, N.L. and Hart, D.D., 2002. How Dams Vary and Why It Matters for the Emerging Science of Dam Removal. BioScience, 52(8), pp.659-668.

Ross, R.M., Backman, T.W. and Bennett, R.M., 1993. Evaluation of the anesthetic metomidate for the handling and transport of juvenile American shad. *The Progressive Fish-Culturist*, *55*(4), pp.236-243.

Royal River Study Committee 2008. Royal River Corridor Master Plan. Prepared by Terrance J. DeWan & Associates, Stantec Consulting, and the Greater Portland Council of Governments.

RS Means 2016. Site Work and Landscape Cost. Gordian Press.

Summary of Recreational Changes associated with Dam Removal and River Restoration, 2013.

Stantec Inc. Royal River Restoration Project: Phase II Analysis and Reporting.

Stantec 2010. Fisheries and aquatic habitat restoration feasibility study, Royal River Restoration Project, Yarmouth Maine. Prepared for Town of Yarmouth. November.

Titcomb Associates 2013. Royal River Topographic Survey.

Towler, B., Mulligan, K. and Haro, A. 2015. Derivation and application of the energy dissipation factor in the design of fishways. Ecological Engineering 83: 208-217.

Towler, Brett; Orvis, Curtis; Dow, Donald; and Haro, Alex, 2013. TR-2013-1 Fishway Inspection Guidelines. UMass Amherst Fish Passage Technical Reports. Paper 1. June.

USFWS 2016. Fish Passage Engineering Design Criteria. USFWS Region 5. January.

USFWS 2017. Personal communication with Brett Towler, Hydraulic Engineer.

Wippelhauser, G. 2011. Royal River Summary. Maine Department of Marine Resources.

8. Appendix A: Bridge Street Fishway Inspection Form and Photographs

FISHWAY INSPECTION CHECKLIST

Dam/Project Name: Bridge Street | Waterway: Royal River
Owner (Organization): Town of Yarmouth | Date/Time: 09/09/16
Inspector(s): Burke
Owner's Representative(s) On-site:
Comments:

STATUS

Reason for inspection: ☐ opening ☐ during season/run ☐ shutdown ☐ construction ☒ other Assessment

Fishway Status: ☐ de-watered/non-operational ☒ watered/operational ☐ watered or underwater/non-operational ☐ damaged/operational ☐ unknown damaged/non-operational

HYDROLOGY & ECOLOGY

1. Target species for fishway: See report for detail
2. U/S migration period: J F M A M J J A S O N D
3. U/S fish passage design flow: HIGH 1340 (cfs); LOW 60 (cfs)
4. D/S migration period: J F M A M J J A S O N D
5. Drainage & current river flow (if known): 141 (mi^2) 37 (estimated) (cfs)

Comments on Hydrology & Ecology:

HYDROPOWER OPERATIONS

6. Is the fishway and dam part of a hydroelectric project? ☒ YES ☐ NO
7. Is there a powerhouse at this location? ☒ YES ☐ NO
8. Powerhouse hydraulic capacity: 240 (cfs)
9. Project generating capacity: 0.270 (MW)
10. Number and type of hydroelectric turbines:

Francis:	Kaplan:	Bulb:	Other:

11. Are units sequenced on/off to enhance fish passage? ☐ YES ☒ NO

If YES, describe operations:

Comments on Hydropower Operations: Current hydropower operation unknown

Dam/Project Name: Bridge/Royal

UPSTREAM FISHWAY EXIT

12. Waterway upstream of the exit is clear of debris: ☐ YES ☒ NO
13. Headgate and/or headboards are in good condition ☒ YES *see comment* ☐ NO ☐ n/a
14. If operational, have headboards been removed or gates raised? ☐ YES ☐ NO ☐ n/a
15. Are adjustable weirs/baffles set to track HW? ☐ YES ☐ NO ☐ n/a
16. Trashrack is in place and clean? *In place but not clean, degrading* ☐ YES ☒ NO ☐ n/a
17. Trashbooms are in place? ☐ YES ☒ NO ☐ n/a
18. Is a staff gage installed in the fishway exit channel? ☐ YES ☒ NO
19. Is a staff gage installed in the headpond? ☐ YES ☒ NO
20. Differential head measured between exit and headpond: *0.9* (ft.)

Comments on Exit: Head gate not operated, functionality not known, 0.9' drop across trash/head gate *US impound depth 3.3'/temp 70 deg., exit channel depth 2.36'/measured velocity 1.2 fps*

LADDER (Not Applicable for Lifts or Locks)

21. Ladder type: ☐ Vertical Slot ☐ Ice Harbor ☐ Pool&Weir ☒ Denil ☐ Steeppass ☐ other:
22. Fishway is free of trash and large woody debris: ☐ YES ☒ NO
23. Was the fishway de-watered during inspection? ☐ YES ☒ NO ☐ n/a
24. Concrete walls/floors are free of cracks, erosion, leaks, spalling: ☒ YES ☐ NO ☐ n/a
    If NO, describe extent and location: *Minor; leaky downstream upper wall*
25. Pools are free of sand, rocks, and other material: ☐ YES ☐ NO ☐ n/a
    If NO, describe accumulations, locations and plan to remove: *None observed*
26. Baffles, baffles plates, and/or or weirs are installed properly, installed at the correct elevation, and were found in good condition: ☐ YES ☐ NO ☐ n/a
    If NO, describe problems and locations (e.g., number from entrance): *Exposed portions appear intact; though some play/vibration of individual*
27. Has the fishway been inspected for damage that created sharp edges, formed wooden splinters, or resulted in new obstacles (in the flow field) that could injure fish? ☐ YES ☒ NO ☐ n/a
    Comments:
28. Is the protective grating cover in place and structurally sound? ☐ YES ☒ NO ☐ n/a
29. Representative head measurement (over weir crest, through vertical slot): (ft.)
    If measured, describe location and method (e.g., pool number from entrance, with staff gage):

Comments on Ladder: *Neg. amts of veg hung up on 5 weirs*. *Both segments with 19 baffles, 1 turning pool*
vena contracta present upstream end both segments with depth of 1.9', measured point velocity 5.47 fps
developed flow portion depth 1.9' to 2', measured surface velocities 3.9 fps, at depth 1.8 fps
turning pool 2.3' deep, surface velocity 1.9 fps, 0.6 depth 0.4 fps
Baffle 10 in segment 1 with an obstruction creating 6" of head drop, streaming velocities of 5.5 fps

Dam/Project Name: *Bridge/Royal*	Page 3 of 5

FISHLIFT (Not applicable for Ladders)

30. Was the lift cycled (operated) during this inspection? ☐ YES ☐ NO
31. Holding pool is relatively free of debris: ☐ YES ☐ NO
32. Hopper raises smoothly without binding or vibrating: ☐ YES ☐ NO ☐ n/a
33. Mechanical crowder opens/closes/operates properly: ☐ YES ☐ NO ☐ n/a
34. Crowding proceeds in a manner consistent with design: ☐ YES ☐ NO
    If NO, describe problems and locations: ______________________
35. Hopper properly aligns with chute during exit channel transfer: ☐ YES ☐ NO ☐ n/a
36. Is the exit channel (between lift and exit) free of debris? ☐ YES ☐ NO ☐ n/a
37. Other mechanical components appear in good working order: ☐ YES ☐ NO
    If NO, describe problems and locations: ______________________
38. Lift appears free of sharp corners that could injure fish: ☐ YES ☐ NO
39. Lift cycles manually or automatically: ☐ Manual ☐ Automatically
40. Cycle time of lift (fishing to fishing): ______ (min.)
41. Hopper volume (if known): ______ (ft^3)

Comments on Lift: ______________________

UPSTREAM FISHWAY ENTRANCE

42. Is the approach to the entrance(s) free of debris and obstructions? ☒ YES ☐ NO
43. Are boards properly installed in the entrance? ☐ YES ☐ NO ☒ n/a
44. Are adjustable gates tracking TW? ☐ YES ☒ NO ☒ n/a
45. If operational, does the entrance jet appear appropriate? ☐ YES ☐ NO ☒ n/a
46. Is a staff gage installed in the fishway entrance channel? ☐ YES ☒ NO
47. Is a staff gage installed in the tailwater area? ☐ YES ☒ NO
48. Differential head measured between entrance and tailwater: *0* (ft.)

Comments on Entrance: *2' depth, surface velocity 1.7 fps, at depth 0.3 fps temperature at entrance 71 deg.*

AUXILIARY WATER SYSTEM

49. If the fishway is operational, is the AWS operating? ☐ YES ☐ NO ☐ n/a
50. AWS flow is driven by: ☐ Gravity ☐ Pump ☐ Other
51. The AWS intake screen is undamaged and free of debris: ☐ YES ☐ NO ☐ n/a
52. AWS appears free of debris or other blockages: ☐ YES ☐ NO
53. AWS flow (in cfs or % of turbine discharge) ______
54. Has this flow been verified? ☐ YES ☐ NO ☐ n/a
    If YES, by whom and/or how? ______________________

Comments on AWS: ______________________

Dam/Project Name: *Bridge/Royal*	

DOWNSTREAM PASSAGE FACILITIES

55. Are there facilities specifically design for d/s passage on site? ☐ YES ☒ NO
56. If so, are d/s facilities open and operational? ☐ YES ☐ NO ☐ n/a
57. Identify all possible SAFE routes for d/s passage at this site:
   ☐ d/s bypass ☐ spillway ☐ floodgate ☐ logsluice ☐ surface collect.
   If other routes, describe: *All DS passage routes appear to land on ledge with exception of via fishway*
58. Flow field in impoundment appears conducive to d/s passage: ☐ YES ☐ NO ☐ n/a
   If NO, describe problems and locations: ______
59. If appropriate, are overlays in place on trash racks? ☐ YES ☐ NO ☐ n/a
60. Are screens (or overlays on trashracks) relatively free of debris? ☐ YES ☐ NO ☐ n/a
61. Is there any evidence of fish impingement on racks or screens? ☐ YES ☐ NO
   If YES, describe problems and locations: ______
62. Is the d/s bypass intake adequately lit and free of debris? ☐ YES ☐ NO ☐ n/a
63. Is the d/s conveyance free of debris and obstructions? ☐ YES ☐ NO ☐ n/a
64. Are sharp corners evident in the bypass which could injure fish? ☐ YES ☐ NO ☐ n/a
65. Approximate depth of flow over bypass crest: ______ (ft.)
66. Does d/s bypass discharge into sufficiently deep pool/water? ☐ YES ☐ NO ☐ n/a
67. Approximate plunge height from d/s bypass crest to receiving pool/water: ______ (ft.)
68. Is there evidence of significant predation at receiving pool/water? ☐ YES ☐ NO
   If YES, describe: ______
69. D/S Bypass flow (in cfs or % of turbine discharge) ______ (cfs/%)

Comments on D/S Passage: *No DS passage facilities, all pathways land on ledge with exception of fishway*

COUNTING & TRAPPING

70. Is the facility equipped for trapping & sorting? ☐ YES ☐ NO
71. Systems for transfer from tank to truck appear in order? ☐ YES ☐ NO ☐ n/a
72. Do mech. components (e.g., winches, gates) appear serviceable? ☐ YES ☐ NO ☐ n/a
73. Were gates/winches tested during inspection? ☐ YES ☐ NO
   Note any concerns: ______

XX

74. Is there a counting house/room at the site? ☐ YES ☐ NO
75. Is the counting window clean and properly lit? ☐ YES ☐ NO ☐ n/a
76. Is CCTV and camera system operating properly? ☐ YES ☐ NO ☐ n/a
77. If counts are automated (e.g. resistance), is it functioning? ☐ YES ☐ NO ☐ n/a

Comments on Counting & Trapping: ______

Dam/Project Name: *Bridge/Royal*	Page 5 of 5

EEL PASS

78. Is there an eel pass on site? ☐ YES ☒ NO ☐ n/a

79. If YES, what is the type of eel pass:
   ☐ volitional ramp (TW to HW) ☐ permanent ramp & trap/lift ☐ temporary ramp & bucket

80. Describe the eel pass substrate media type:
   ☐ stud (peg) ☐ bristle ☐ geotextile mat ☐ other: ____________

81. Is the eel pass currently operating (i.e., wetted and installed)? ☐ YES ☐ NO ☐ n/a
   Identify the water source (i.e., gravity, pump): ____________

82. Is the media clean of debris and watered throughout? ☐ YES ☐ NO ☐ n/a
   Describe depth of flow and adequacy of attraction: ____________

   Comments on Eel Pass: ____________

OBSERVATIONS ON THE PRESENCE AND/OR MOVEMENT OF FISH DURING INSPECTION:

None

GENERAL COMMENTS:

See report for additional comments on attraction

RECOMMENDATIONS:

Version 6/3/2013. Fishway Inspection Guidelines, TR-2013-01. For updates or suggested revisions, contact brett_towler@fws.gov

Figure 17: Selection of photos of Bridge Street Dam Fishway. (A) View is downstream at fishway entrance on river right. (B) View at a sample baffle section showing turbulent streaming flow. Flow is from right to left. (C) View is upstream towards first baffle section, with second baffle section extending towards the right. (D) Exit of fishway into impoundment showing trash and debris blockage.

9. Appendix B: East Elm Street Fishway Inspection Form and Photographs

FISHWAY INSPECTION CHECKLIST

Dam/Project Name: East Elm Street Waterway: Royal River
Owner (Organization): Town of Yarmouth Date/Time: 09/09/16
Inspector(s): Burke
Owner's Representative(s) On-site: NA
Comments:

STATUS

Reason for inspection: ☐ opening ☐ during season/run ☐ shutdown ☐ construction
☒ other Assessment

Fishway Status: ☐ de-watered/non-operational ☐ watered/operational
☒ watered or underwater/non-operational ☐ damaged/operational
☐ unknown damaged/non-operational

HYDROLOGY & ECOLOGY

1. Target species for fishway: See report for detail
2. U/S migration period: J F M A M J J A S O N D
3. U/S fish passage design flow: HIGH 1340 (cfs) LOW 60 (cfs)
4. D/S migration period: J F M A M J J A S O N D
5. Drainage & current river flow (if known): 141 (mi^2) 37 (cfs)

Comments on Hydrology & Ecology:

HYDROPOWER OPERATIONS

6. Is the fishway and dam part of a hydroelectric project? ☐ YES ☒ NO
7. Is there a powerhouse at this location? ☐ YES ☒ NO
8. Powerhouse hydraulic capacity: (cfs)
9. Project generating capacity: (MW)
10. Number and type of hydroelectric turbines:

Francis:	Kaplan:	Bulb:	Other:

11. Are units sequenced on/off to enhance fish passage? ☐ YES ☐ NO
If YES, describe operations:

Comments on Hydropower Operations:

Dam/Project Name: East Elm/Royal	Page 2 of 5

UPSTREAM FISHWAY EXIT

12. Waterway upstream of the exit is clear of debris:	☐ YES	☒ NO	
13. Headgate and/or headboards are in good condition	☐ YES	☒ NO	☐ n/a
14. If operational, have headboards been removed or gates raised?	☒ YES	☐ NO	☐ n/a
15. Are adjustable weirs/baffles set to track HW?	☐ YES	☒ NO	☐ n/a
16. Trashrack is in place and clean?	☐ YES	☒ NO	☐ n/a
17. Trashbooms are in place?	☐ YES	☒ NO	☐ n/a
18. Is a staff gage installed in the fishway exit channel?	☐ YES	☒ NO	
19. Is a staff gage installed in the headpond?	☐ YES	☒ NO	

20. Differential head measured between exit and headpond: 2.5 (ft.)

Comments on Exit: trashrack blocked, 0.75 ft of drop, 1.8' of drop across stop logs just DS of trash rack 1.6' depth in impoundment, lots of aquatic veg, temp 71 deg, depth 0.04 feet in exit channel

LADDER (Not Applicable for Lifts or Locks)

21. Ladder type: ☐ Vertical Slot ☐ Ice Harbor ☐ Pool&Weir ☒ Denil ☐ Steeppass ☐ other: ____

22. Fishway is free of trash and large woody debris:	☐ YES	☒ NO	
23. Was the fishway de-watered during inspection?	☐ YES	☒ NO	☐ n/a
24. Concrete walls/floors are free of cracks, erosion, leaks, spalling:	☐ YES	☒ NO	☐ n/a

If NO, describe extent and location: Concrete pitted in locations but appears sound

25. Pools are free of sand, rocks, and other material:	☐ YES	☒ NO	☐ n/a

If NO, describe accumulations, locations and plan to remove: ____

26. Baffles, baffles plates, and/or or weirs are installed properly, installed at the correct elevation, and were found in good condition: ☐ YES ☒ NO ☐ n/a

If NO, describe problems and locations (e.g., number from entrance): segment 1 blocked by broken baffles and debris, segment 2 missing 2 baffles and others leaking, swirling flow, segment 3 missing all baffles

27. Has the fishway been inspected for damage that created sharp edges, formed wooden splinters, or resulted in new obstacles (in the flow field) that could injure fish? ☐ YES ☐ NO ☐ n/a

Comments: lots of obstructions

28. Is the protective grating cover in place and structurally sound? ☐ YES ☒ NO ☐ n/a

29. Representative head measurement (over weir crest, through vertical slot): ____ (ft.)

If measured, describe location and method (e.g., pool number from entrance, with staff gage):

Comments on Ladder: very poor, non functional condition, all baffles require replacement
resting pool 1 90 deg, Resting pool 2 180 degrees, fishway overgrown
3 segments, segment 1 depth 0.25', segment 2 depth 1 ft, plunging flow down in V, segment 3 depth 0.15 ft
turning pool 1 0.4 ft depth, 2.23 fps, turning pool 2depth 0.9, velocity 1.2

Dam/Project Name: East Elm/Royal

FISHLIFT (Not applicable for Ladders)

30. Was the lift cycled (operated) during this inspection?	☐ YES	☐ NO	
31. Holding pool is relatively free of debris:	☐ YES	☐ NO	
32. Hopper raises smoothly without binding or vibrating:	☐ YES	☐ NO	☐ n/a
33. Mechanical crowder opens/closes/operates properly:	☐ YES	☐ NO	☐ n/a
34. Crowding proceeds in a manner consistent with design:	☐ YES	☐ NO	

If NO, describe problems and locations: ______

35. Hopper properly aligns with chute during exit channel transfer:	☐ YES	☐ NO	☐ n/a
36. Is the exit channel (between lift and exit) free of debris?	☐ YES	☐ NO	☐ n/a
37. Other mechanical components appear in good working order:	☐ YES	☐ NO	

If NO, describe problems and locations: ______

38. Lift appears free of sharp corners that could injure fish:	☐ YES	☐ NO	
39. Lift cycles manually or automatically:	☐ Manual	☐ Automatically	

40. Cycle time of lift (fishing to fishing): ______ (min.)

41. Hopper volume (if known): ______ (ft^3)

Comments on Lift: ______

UPSTREAM FISHWAY ENTRANCE

42. Is the approach to the entrance(s) free of debris and obstructions?	☐ YES	☒ NO	
43. Are boards properly installed in the entrance?	☐ YES	☒ NO	☐ n/a
44. Are adjustable gates tracking TW?	☐ YES	☒ NO	☒ n/a
45. If operational, does the entrance jet appear appropriate?	☐ YES	☒ NO	☐ n/a
46. Is a staff gage installed in the fishway entrance channel?	☐ YES	☒ NO	
47. Is a staff gage installed in the tailwater area?	☐ YES	☒ NO	

48. Differential head measured between entrance and tailwater: ______ (ft.)

Comments on Entrance: All very poor entrance conditions
entrance blocked by ledge and large boulders, flow from upstream transverse across entrance
backwater to baffle 1 location, entrance 0.75' drops to ledge no depth, 2nd drop to 2.3' deeper pool
cut into ledge, 2.7 fps, temp at entrance 70 deg., multiple flow chutes converge at this point.

AUXILIARY WATER SYSTEM

49. If the fishway is operational, is the AWS operating?	☐ YES	☐ NO	☐ n/a
50. AWS flow is driven by:	☐ Gravity	☐ Pump	☐ Other
51. The AWS intake screen is undamaged and free of debris:	☐ YES	☐ NO	☐ n/a
52. AWS appears free of debris or other blockages:	☐ YES	☐ NO	

53. AWS flow (in cfs or % of turbine discharge) ______

54. Has this flow been verified?	☐ YES	☐ NO	☐ n/a

If YES, by whom and/or how? ______

Comments on AWS: ______

Dam/Project Name: East Elm/Royal

DOWNSTREAM PASSAGE FACILITIES

55. Are there facilities specifically design for d/s passage on site? ☐ YES ☒ NO
56. If so, are d/s facilities open and operational? ☐ YES ☐ NO ☐ n/a
57. Identify all possible SAFE routes for d/s passage at this site:
    ☐ d/s bypass ☐ spillway ☐ floodgate ☐ logsluice ☐ surface collect.
    If other routes, describe: None, all pathways directly onto ledge except fishway, also not functional
58. Flow field in impoundment appears conducive to d/s passage: ☐ YES ☐ NO ☐ n/a
    If NO, describe problems and locations: ____________________
59. If appropriate, are overlays in place on trash racks? ☐ YES ☐ NO ☐ n/a
60. Are screens (or overlays on trashracks) relatively free of debris? ☐ YES ☐ NO ☐ n/a
61. Is there any evidence of fish impingement on racks or screens? ☐ YES ☐ NO
    If YES, describe problems and locations: ____________________
62. Is the d/s bypass intake adequately lit and free of debris? ☐ YES ☐ NO ☐ n/a
63. Is the d/s conveyance free of debris and obstructions? ☐ YES ☐ NO ☐ n/a
64. Are sharp corners evident in the bypass which could injure fish? ☐ YES ☐ NO ☐ n/a
65. Approximate depth of flow over bypass crest: ______ (ft.)
66. Does d/s bypass discharge into sufficiently deep pool/water? ☐ YES ☐ NO ☐ n/a
67. Approximate plunge height from d/s bypass crest to receiving pool/water: ______ (ft.)
68. Is there evidence of significant predation at receiving pool/water? ☐ YES ☐ NO
    If YES, describe: ____________________
69. D/S Bypass flow (in cfs or % of turbine discharge) ______ (cfs/%)

Comments on D/S Passage: ____________________

COUNTING & TRAPPING

70. Is the facility equipped for trapping & sorting? ☐ YES ☐ NO
71. Systems for transfer from tank to truck appear in order? ☐ YES ☐ NO ☐ n/a
72. Do mech. components (e.g., winches, gates) appear serviceable? ☐ YES ☐ NO ☐ n/a
73. Were gates/winches tested during inspection? ☐ YES ☐ NO
    Note any concerns: XX
74. Is there a counting house/room at the site? ☐ YES ☐ NO
75. Is the counting window clean and properly lit? ☐ YES ☐ NO ☐ n/a
76. Is CCTV and camera system operating properly? ☐ YES ☐ NO ☐ n/a
77. If counts are automated (e.g. resistance), is it functioning? ☐ YES ☐ NO ☐ n/a

Comments on Counting & Trapping: ____________________

Dam/Project Name: East Elm/Royal

EEL PASS

78. Is there an eel pass on site? ☐ YES ☒ NO ☐ n/a

79. If YES, what is the type of eel pass:
☐ volitional ramp (TW to HW) ☐ permanent ramp & trap/lift ☐ temporary ramp & bucket

80. Describe the eel pass substrate media type:
☐ stud (peg) ☐ bristle ☐ geotextile mat ☐ other: ____________

81. Is the eel pass currently operating (i.e., wetted and installed)? ☐ YES ☐ NO ☐ n/a
Identify the water source (i.e., gravity, pump): ____________

82. Is the media clean of debris and watered throughout? ☐ YES ☐ NO ☐ n/a
Describe depth of flow and adequacy of attraction: ____________

Comments on Eel Pass: ____________

OBSERVATIONS ON THE PRESENCE AND/OR MOVEMENT OF FISH DURING INSPECTION:

NONE

GENERAL COMMENTS:

Very poor condition, very difficult entrance location and condition. See report

RECOMMENDATIONS:

Version 6/3/2013. Fishway Inspection Guidelines, TR-2013-01. For updates or suggested revisions, contact brett_towler@fws.gov

Figure 18: Selection of photos of East Elm Street Dam Fishway. (A) View is upstream at fishway exit into impoundment; (B) view of trashrack blocked by debris; (C) view is downstream at second baffle section blocked by broken baffles and debris; (D) entrance to fishway blocked by large wood and rubble.

10. Appendix C: Flow Partitioning Calculations

10.1 BRIDGE STREET DAM ANALYSES

Bridge Street Dam Flow Partitioning Analysis

Date:	10/14/16	
By:	Burke	The below calculations are summarized in Tables 8, 9, 12 and 13.

Analysis Description

The goal of this analysis is to determine the total discharge capacity of the Bridge St Dam up to the elevation of the top of the denil fishway.
The dam has an uncontrolled spillway, two sluice gates, hydropower station, and denil fishway.
This run up to top of abutments (no abutment overflow), free overflow, hydropower station assumed not operating, acts as left abutment.
Right abutment top elevation of 38.6 assumed top elevation for simulation

Assumptions

1 - The spillway acts as a broad crested weir.
2 - Discharge through any gate is calculated as weir flow until 2/3 of the head on the gate invert is larger than the gate's opening. Flow will pass through critical depth as it passes the gates, and therefore orifice flow does not begin until the water surface is at an elevation higher than the top of the gate openings.
3- The effects of tailwater submergence are neglected, as tailwater submergence in the fish passage range does not occur due to downstream channel slope.

References

Odeh, M. 2003. Discharge rating equation and hydraulic characteristics of standard Denil fishways. Journal of Hydraulic Engineering. 129(5):341-348.
Titcomb Associates, 2013. Topographic Survey, Yarmouth, ME.
USFWS 2016. Fish Passage Engineering Design Criteria. USFWS Region 5. January.

Dam Physical Parameters

Spillway (Broad Crested Weir Calculation)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Spillway Length, L_T (ft) =	145
Concrete Crest El. (ft) =	36
Number of Contractions, N =	2
Contraction Loss Coefficients, K =	0.1
Approximate Height of Dam (along spillway), P (ft) =	6.7

Right Stop Log Weir (Broad Crested Weir Calculation)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Length, L (ft) =	6
Concrete Crest El. (ft) =	33
Number of Contractions, N =	2
Contraction Loss Coefficients, K =	0.1
Approximate Height of Dam (along powerhouse section), P (ft) =	3.7

Flood Gates (Not Used)	
Acceleration due to Gravity, g (ft/s^2) =	
Gate Width, L_T (ft) =	
Top of Gate El. (ft) =	
Gate Invert El. (ft) =	
Orifice Flow Discharge Coefficient, C =	
Number of Side Contractions, N =	
Contraction Loss Coefficients, K =	
Approximate Height of Dam (from gate invert), P (ft) =	

Denil entrance (Orifice Equation)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Gate Width, L_T (ft) =	3.00
Top of Gate El. (ft) =	34.00
Gate Invert El. (ft) =	33.00
Orifice Flow Discharge Coefficient, C =	0.60
Number of Side Contractions, N =	2.00
Contraction Loss Coefficients, K =	0.04
Approximate Height of Dam (from gate invert), P (ft) =	3.70

Right Spillway Abutment (assumed no overflow, not used)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Spillway Length, L_T (ft) =	20
Concrete Crest El. (ft) =	151.2
Number of Contractions, N =	1
Contraction Loss Coefficients, K =	0.1

Denil Discharge (Odeh 2003)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Fishway Width, W (ft) =	3
Exit Channel Invert El. (ft) =	32.95
Fishway Slope, S =	0.167
Discharge Coefficient, Cd =	1.033
Clear Width, b (ft) =	1.74
height of V-notch invert, c (ft) =	0.75

Equations	
Weir Discharge Equation:	$Q = C_d*L_e*H^{3/2}$
Effective Length:	$L_e = L_T - K*N*H$
Weir Discharge Coefficient:	$C_d = (2/3)*\sqrt{(2g)}*(0.611+0.08*(H/P)$
Orifice Discharge Equation:	$Q = C*A*\sqrt{(2gH)}$

Downstream Ground Elevation		
Elevation extracted from Titcomb Survey (Ref)		
DS ground El. =	29.3	feet

Water Surface Elevation (ft)	Spillway Head, H (ft)	Spillway Discharge, Q (cfs)	Denil Discharge, Q (cfs)	Stop Log Weir Discharge, Q (cfs)	Denil + 1 Stop Log Weir Discharge, Q (cfs)	Denil + Spillway Discharge (cfs)	Denil + Spillway + 1 Stop Log Discharge (cfs)
33.70	0	0	0.11	6	9.1	0.1	9.1
33.90	0	0	0.54	8	13.6	0.5	14
34.15	0	0	1.42	12	20.1	1.4	20
34.40	0	0	2.65	16	27.6	2.6	28
34.65	0	0	4.19	19	35.8	4.2	36
34.90	0	0	6.02	20	44.7	6.0	45
35.15	0	0	8.12	21	54.3	8.1	54
35.40	0	0	10.50	22	64.5	10	64
35.65	0	0	13.12	24	75.2	13	75
35.90	0	0	16.00	25	86.4	16	86
36.13	0.13	22	18.86	26	97.1	41	119
36.15	0.15	27	19.12	26	98.1	46	125
36.20	0.2	42	19.77	26	100.5	62	143
36.30	0.3	78	21.10	26	105.3	99	183
36.35	0.35	98	21.78	26	107.7	120	206
36.40	0.4	120	22.47	27	110.2	142	230
36.45	0.45	143	23.16	27	112.7	166	255
36.50	0.5	167	23.87	27	115.1	191	283
36.55	0.55	193	24.59	27	117.6	218	311
36.60	0.6	220	25.31	27	120.2	246	341
36.65	0.65	249	26.04	28	122.7	275	372
36.70	0.7	278	26.79	28	125.2	305	404
36.75	0.75	309	27.54	28	127.8	336	437
36.80	0.8	341	28.30	28	130.4	369	471
36.85	0.85	373	29.07	28	133.0	402	506
36.90	0.9	407	29.85	29	135.6	437	543
37.15	1.15	591	33.87	29	148.8	625	740
37.40	1.4	797	38.11	30	162.4	835	959
37.65	1.65	1,024	42.57	31	176.3	1,067	1,201
37.70	1.7	1,072	43.48	31	179.1	1,116	1,251
37.75	1.75	1,121	44.40	31	181.9	1,165	1,303
37.80	1.8	1,170	45.34	32	184.7	1,215	1,355
37.85	1.85	1,220	46.28	32	187.6	1,267	1,408
37.90	1.9	1,271	47.23	32	190.4	1,318	1,462
38.15	2.15	1,537	52.09	33	204.9	1,589	1,742
38.40	2.4	1,820	57.17	34	219.5	1,878	2,040
38.65	2.65	2,121	62.44	34	234.4	2,184	2,356

Water Surface Elevation (ft)	Weir Gate 1 Discharge, Q (cfs)	Weir Gate 2 Discharge, Q (cfs)	Spillway H_s/H_c	Spillway C_s/C_d	Spillway C_d	Spillway Cs	Stop Log Weir Gate Head, H (ft)	Stop Log Weir Gate C_d
33.70	9.0	9.0	0.00	0.99	0	0	1	3
33.90	13	13	0.00	0.99	0	0	1	3
34.15	19	19	0.00	0.99	0	0	1	3
34.40	25	25	0.00	0.99	0	0	1	3
34.65	32	32	0.00	0.99	0	0	2	3
34.90	39	39	0.00	0.99	0	0	2	3
35.15	46	46	0.00	0.99	0	0	2	3
35.40	54	54	0.00	0.99	0	0	2	3
35.65	62	62	0.00	0.99	0	0	3	3
35.90	70	70	0.00	0.99	0	0	3	3
36.13	78	78	0.00	0.99	3	3	3	3
36.15	79	79	0.00	0.99	3	3	3	3
36.20	81	81	0.00	0.99	3	3	3	3
36.30	84	84	0.00	0.99	3	3	3	3
36.35	86	86	0.00	0.99	3	3	3	3
36.40	88	88	0.00	0.99	3	3	3	3
36.45	89	89	0.00	0.99	3	3	3	3
36.50	91	91	0.00	0.99	3	3	4	3
36.55	93	93	0.00	0.99	3	3	4	3
36.60	95	95	0.00	0.99	3	3	4	3
36.65	97	97	0.00	0.99	3	3	4	3
36.70	98	98	0.00	0.99	3	3	4	3
36.75	100	100	0.00	0.99	3	3	4	3
36.80	102	102	0.00	0.99	3	3	4	3
36.85	104	104	0.00	0.99	3	3	4	3
36.90	106	106	0.00	0.99	3	3	4	3
37.15	115	115	0.00	0.99	3	3	4	3
37.40	124	124	0.00	0.99	3	3	4	3
37.65	134	134	0.00	0.99	3	3	5	3
37.70	136	136	0.00	0.99	3	3	5	3
37.75	137	137	0.00	0.99	3	3	5	3
37.80	139	139	0.00	0.99	3	3	5	3
37.85	141	141	0.00	0.99	3	3	5	3
37.90	143	143	0.00	0.99	3	3	5	3
38.15	153	153	0.00	0.99	3	3	5	3
38.40	162	162	0.00	0.99	3	3	5	3
38.65	172	172	0.00	0.99	3	3	6	3

Water Surface Elevation (ft)	Stop Log Weir Gate Discharge, Q (cfs)	Approximate Tailwater Elevation (ft)	Denil Exit Channel H	Denil headwater h_u	Sluice Gate Head, H (ft)	Sluice Gate H_s/H_c	Sluice Gate C_s/C_d	Sluice Gate C_d	Sluice Gate C_s
33.70	9	29.30	0.75	0.14	0.7	0.00	1.00	3.35	3.35
33.90	13	29.30	0.95	0.34	0.9	0.00	1.00	3.37	3.37
34.15	19	29.30	1.20	0.59	1.2	0.00	1.00	3.40	3.40
34.40	25	29.30	1.45	0.84	1.4	0.00	1.00	3.43	3.43
34.65	32	29.30	1.70	1.09	1.7	0.00	1.00	0.60	0.60
34.90	39	29.30	1.95	1.34	1.9	0.00	1.00	0.60	0.60
35.15	46	29.30	2.20	1.59	2.2	0.00	1.00	0.60	0.60
35.40	54	29.30	2.45	1.84	2.4	0.00	1.00	0.60	0.60
35.65	62	29.30	2.70	2.09	2.7	0.00	1.00	0.60	0.60
35.90	70	29.30	2.95	2.34	2.9	0.00	1.00	0.60	0.60
36.13	78	29.30	3.18	2.57	3.1	0.00	1.00	0.60	0.60
36.15	79	29.30	3.20	2.59	3.2	0.00	1.00	0.60	0.60
36.20	81	29.30	3.25	2.64	3.2	0.00	1.00	0.60	0.60
36.30	84	29.30	3.35	2.74	3.3	0.00	1.00	0.60	0.60
36.35	86	29.30	3.40	2.79	3.4	0.00	1.00	0.60	0.60
36.40	88	29.30	3.45	2.84	3.4	0.00	1.00	0.60	0.60
36.45	89	29.30	3.50	2.89	3.5	0.00	1.00	0.60	0.60
36.50	91	29.30	3.55	2.94	3.5	0.00	1.00	0.60	0.60
36.55	93	29.30	3.60	2.99	3.6	0.00	1.00	0.60	0.60
36.60	95	29.30	3.65	3.04	3.6	0.00	1.00	0.60	0.60
36.65	97	29.30	3.70	3.09	3.7	0.00	1.00	0.60	0.60
36.70	98	29.30	3.75	3.14	3.7	0.00	1.00	0.60	0.60
36.75	100	29.30	3.80	3.19	3.8	0.00	1.00	0.60	0.60
36.80	102	29.30	3.85	3.24	3.8	0.00	1.00	0.60	0.60
36.85	104	29.30	3.90	3.29	3.8	0.00	1.00	0.60	0.60
36.90	106	29.30	3.95	3.34	3.9	0.00	1.00	0.60	0.60
37.15	115	29.30	4.20	3.59	4.2	0.00	1.00	0.60	0.60
37.40	124	29.30	4.45	3.84	4.4	0.00	1.00	0.60	0.60
37.65	134	29.30	4.70	4.09	4.7	0.00	1.00	0.60	0.60
37.70	136	29.30	4.75	4.14	4.7	0.00	1.00	0.60	0.60
37.75	137	29.30	4.80	4.19	4.8	0.00	1.00	0.60	0.60
37.80	139	29.30	4.85	4.24	4.8	0.00	1.00	0.60	0.60
37.85	141	29.30	4.90	4.29	4.8	0.00	1.00	0.60	0.60
37.90	143	29.30	4.95	4.34	4.9	0.00	1.00	0.60	0.60
38.15	153	29.30	5.20	4.59	5.2	0.00	1.00	0.60	0.60
38.40	162	29.30	5.45	4.84	5.4	0.00	1.00	0.60	0.60
38.65	172	29.30	5.70	5.09	5.7	0.00	1.00	0.60	0.60

10.2EAST ELM STREET DAM ANALYSES

East Elm Street Dam Flow Partitioning Analysis	
Date:	10/14/16
By:	Burke

Analysis Description

The goal of this analysis is to determine the total discharge capacity of the East Elm St Dam up to the elevation of the top of the denil fishway.
The dam has an uncontrolled spillway, two sluice gates, hydropower station, and denil fishway.
This runs up to top of abutments (no abutment overflow), free overflow, hydropower station assumed not operating, acts as left abutment.
Right abutment top elevation of 38.6 assumed top elevation for simulation

Assumptions

1 - The spillway acts as a broad crested weirs.
2 - Discharge through any gate is calculated as weir flow until 2/3 of the head on the gate invert is larger than the gate's opening. Flow will pass through critical depth as it passes the gates, and therefore orifice flow does not begin until the water surface is at an elevation higher than the top of the gate openings.
3- The effects of tailwater submergence are neglected, as tailwater submergence in the fish passage range does not occur due to downstream channel slope.

References

Odeh, M. 2003. Discharge rating equation and hydraulic characteristics of standard Denil fishways. Journal of Hydraulic Engineering. 129(5):341-348.
Titcomb Associates, 2013. Topographic Survey, Yarmouth, ME.
USFWS 2016. Fish Passage Engineering Design Criteria. USFWS Region 5. January.

Dam Physical Parameters

Spillway (Broad Crested Weir Calculation)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Spillway Length, L_T (ft) =	185
Concrete Crest El. (ft) =	70
Number of Contractions, N =	2
Contraction Loss Coefficients, K =	0.1
Approximate Height of Dam (along spillway), P (ft) =	40.7

Right Stop Log Weir (Broad Crested Weir Calculation)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Length, L (ft) =	4
Concrete Crest El. (ft) =	67
Number of Contractions, N =	2
Contraction Loss Coefficients, K =	0.1
mate Height of Dam (along powerhouse section), P (ft) =	2

Bypass - Foundry Channel (Mannings Equation)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Width (ft) =	10.00
Low chord El. (ft) =	77.10
Invert El. (ft) =	68.10
Est. Slope (ft/ft) =	0.03
Manning n =	0.05

Denil entrance (Orifice equation)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Gate Width, L_T (ft) =	3.00
Top of Gate El. (ft) =	72.70
Gate Invert El. (ft) =	67.00
Orifice Flow Discharge Coefficient, C =	0.60
Number of Side Contractions, N =	2.00
Contraction Loss Coefficients, K =	0.04
Approximate Height of Dam (from gate invert), P (ft) =	2.00

Right Spillway Abutment (assumed no overflow, not used)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Spillway Length, L_T (ft) =	20
Concrete Crest El. (ft) =	151.2
Number of Contractions, N =	1
Contraction Loss Coefficients, K =	0.1

Denil Discharge (Odeh 2003)	
Acceleration due to Gravity, g (ft/s^2) =	32.2
Fishway Width, W (ft) =	3
Exit Channel Invert El. (ft) =	67
Fishway Slope, S =	0.167
Discharge Coefficient, Cd =	1.033
Clear Width, b (ft) =	1.74
height of V-notch invert, c (ft) =	0.75

Equations	
Weir Discharge Equation:	$Q = C_d*L_e*H^{3/2}$
Effective Length:	$L_e = L_T - K*N*H$
Weir Discharge Coefficient:	$C_d = (2/3)*\sqrt{(2g)}*(0.611+0.08*(H/P)$
Orifice Discharge Equation:	$Q = C*A*\sqrt{(2gH)}$

Downstream Ground Elevation		
Elevation extracted from Titcomb Survey (Ref)		
DS ground Elev =	65	feet

Headpond Water Surface Elevation (ft)	Spillway Head (depth over spillway), H (ft)	Spillway Discharge, Q (cfs)	Denil Discharge, Q (cfs)	Stop Log Weir Discharge, Q (cfs)	Bypass Discharge, Q (cfs)	Spillway+Denil +Bypass (cfs)	Spiilway+Denil +Bypass+Stop Log	Denil + 1 Stop Log Weir Discharge, Q (cfs)	Denil + Spillway Discharge (cfs)	Denil + Spillway + 1 Stop Log Discharge (cfs)
67.70	0	0	0.05	6	0.0	0.0		6.0	0.0	6.0
67.90	0	0	0.41	9	0.0	0.4		9.0	0.4	9
68.15	0	0	1.22	13	0.3	1.6		13.4	1.2	13
68.40	0	0	2.38	17	6.7	9.1		18.6	2.4	19
68.65	0	0	3.86	22	17.8	21.6		24.3	3.9	24
68.90	0	0	5.63	27	32.2	37.9		30.6	5.6	31
69.15	0	0	7.68	33	49.3	57.0		37.3	7.7	37
69.20	0	0	8.12	34	53.0	61.1	67.1	38.7	8	39
69.25	0	0	8.58	36	56.8	65.3	73.9	40.1	9	40
69.30	0	0	9.04	37	60.6	69.6	81.9	41.5	9	42
69.35	0	0	9.52	38	64.5	74.0	90.2	43.0	10	43
69.40	0	0	10.00	39	68.5	78.5	99.0	44.4	10	44
69.45	0	0	10.50	41	72.6	83.1	108.0	45.9	10	46
69.50	0	0	11.00	42	76.7	87.7	117.3	47.4	11	47
69.55	0	0	11.52	43	80.9	92.4	123.0	48.9	12	49
69.60	0	0	12.04	45	85.2	97.2	128.7	50.4	12	50
69.65	0	0	12.58	46	89.5	102.1	134.6	51.9	13	52
69.70	0	0	13.12	48	93.9	107.0	140.5	53.5	13	53
69.75	0	0	13.68	49	98.3	112.0	146.4	55.1	14	55
69.80	0	0	14.25	50	102.8	117.1	152.5	56.6	14	57
69.85	0	0	14.82	52	107.4	122.2	158.6	58.2	15	58
69.90	0	0	15.40	53	112.0	127.4	164.8	59.8	15	60
69.95	0	0	16.00	55	116.7	132.7	171.0	61.4	16	61
70.00	0	0	16.60	56	121.4	138.0	177.3	63.1	17	63
70.05	0.05	7	17.22	58	126.1	150.0	190.4	64.7	24	71
70.10	0.1	19	17.84	59	130.9	167.7	209.1	66.4	37	85
70.15	0.15	35	18.47	61	135.8	189.1	231.4	68.0	53	103
70.20	0.2	54	19.12	62	140.7	213.4	256.8	69.7	73	123
70.25	0.25	75	19.77	64	145.6	240.3	284.7	71.4	95	146
70.30	0.3	98	20.43	65	150.6	269.5	314.9	73.1	119	172
70.35	0.35	124	21.10	67	155.7	300.8	347.3	74.8	145	199
70.40	0.4	152	21.78	68	160.7	334.1	381.6	76.5	173	228
70.45	0.45	181	22.47	70	165.8	369.2	417.7	78.2	203	259
70.50	0.5	212	23.16	72	171.0	406.0	455.6	80.0	235	292
70.52	0.5175	223	23.41	72	172.8	419.3	469.9	80.6	247	304
70.58	0.58	265	24.30	74	179.3	468.4	520.0	82.8	289	348
70.63	0.63	300	25.02	76	184.5	509.3	562.0	84.6	325	384
70.68	0.68	336	25.75	77	189.8	551.0	604.7	86.4	362	423
70.73	0.73	374	26.49	79	195.1	594.1	648.9	88.1	400	462
70.78	0.78	413	27.24	81	200.5	638.6	694.4	89.9	440	503
70.83	0.83	454	28.00	83	205.9	684.4	741.2	91.7	482	545
70.88	0.88	495	28.76	84	211.3	731.4	788.6	93.6	524	589
70.93	0.93	538	29.54	86	216.7	779.7	838.2	95.4	568	633
70.98	0.98	582	30.32	88	222.2	829.2	888.8	97.2	612	679
71.03	1.03	627	31.11	89	227.7	879.9	940.5	99.1	658	726
71.08	1.08	673	31.91	91	233.2	931.7	993.4	100.9	705	774
71.13	1.13	721	32.72	93	238.8	984.7	1,047.4	102.8	754	824
71.18	1.18	769	33.54	95	244.4	1,038.7	1,102.5	104.7	803	874
71.23	1.23	819	34.37	97	250.0	1,093.8	1,158.6	106.5	853	925
71.28	1.28	869	35.21	98	255.6	1,150.0	1,215.9	108.4	905	978
71.33	1.33	921	36.05	100	261.3	1,207.2	1,274.1	110.3	957	1,031
71.39	1.386	980	37.01	102	267.7	1,272.5	1,340.4	112.4	1,017	1,092
71.44	1.436	1,033	37.87	104	273.4	1,331.8	1,400.8	114.4	1,071	1,148
71.44	1.443	1,041	37.99	105	274.2	1,340.2	1,410.2	114.6	1,079	1,156
71.49	1.493	1,096	38.86	106	280.0	1,400.6	1,471.7	116.5	1,135	1,212
71.54	1.543	1,151	39.74	108	285.8	1,462.0	1,534.2	118.5	1,191	1,270
71.59	1.593	1,208	40.63	110	291.6	1,524.4	1,597.6	120.4	1,248	1,328
71.64	1.643	1,265	41.53	112	297.4	1,587.6	1,661.9	122.3	1,307	1,388
71.69	1.693	1,324	42.44	114	303.2	1,651.8	1,727.2	124.3	1,366	1,448
71.74	1.743	1,383	43.35	116	309.1	1,716.9	1,793.4	126.2	1,426	1,509
71.79	1.793	1,443	44.27	118	315.0	1,782.8	1,859.5	128.2	1,487	1,571
71.84	1.843	1,504	45.21	120	320.9	1,849.7	1,927.4	130.2	1,549	1,634
71.89	1.893	1,566	46.15	122	326.8	1,917.4	1,996.1	132.2	1,612	1,698

Headpond Water Surface Elevation (ft)	Weir Gate 1 Discharge, Q (cfs)	Weir Gate 2 Discharge, Q (cfs)	Bypass Head, H (ft)	Bypass Radius, R (ft)	Spillway H_s/H_c	Spillway C_s/C_d	Spillway C_d	Spillway Cs	Stop Log Weir Gate Head, H (ft)
67.70	5.9	5.9	0	0.00	0.00	0.99	0	0	1
67.90	9	9	0	0.00	0.00	0.99	0	0	1
68.15	12	12	0.05	0.05	0.00	0.99	0	0	1
68.40	16	16	0.3	0.28	0.00	0.99	0	0	1
68.65	20	20	0.55	0.50	0.00	0.99	0	0	2
68.90	25	25	0.8	0.69	0.00	0.99	0	0	2
69.15	30	30	1.05	0.87	0.00	0.99	0	0	2
69.20	31	31	1.1	0.90	0.00	0.99	0	0	2
69.25	32	32	1.15	0.93	0.00	0.99	0	0	2
69.30	32	32	1.2	0.97	0.00	0.99	0	0	2
69.35	33	33	1.25	1.00	0.00	0.99	0	0	2
69.40	34	34	1.3	1.03	0.00	0.99	0	0	2
69.45	35	35	1.35	1.06	0.00	0.99	0	0	2
69.50	36	36	1.4	1.09	0.00	0.99	0	0	2
69.55	37	37	1.45	1.12	0.00	0.99	0	0	3
69.60	38	38	1.5	1.15	0.00	0.99	0	0	3
69.65	39	39	1.55	1.18	0.00	0.99	0	0	3
69.70	40	40	1.6	1.21	0.00	0.99	0	0	3
69.75	41	41	1.65	1.24	0.00	0.99	0	0	3
69.80	42	42	1.7	1.27	0.00	0.99	0	0	3
69.85	43	43	1.75	1.30	0.00	0.99	0	0	3
69.90	44	44	1.8	1.32	0.00	0.99	0	0	3
69.95	45	45	1.85	1.35	0.00	0.99	0	0	3
70.00	46	46	1.9	1.38	0.00	0.99	0	0	3
70.05	47	47	1.95	1.40	0.00	0.99	3	3	3
70.10	49	49	2	1.43	0.00	0.99	3	3	3
70.15	50	50	2.05	1.45	0.00	0.99	3	3	3
70.20	51	51	2.1	1.48	0.00	0.99	3	3	3
70.25	52	52	2.15	1.50	0.00	0.99	3	3	3
70.30	53	53	2.2	1.53	0.00	0.99	3	3	3
70.35	54	54	2.25	1.55	0.00	0.99	3	3	3
70.40	55	55	2.3	1.58	0.00	0.99	3	3	3
70.45	56	56	2.35	1.60	0.00	0.99	3	3	3
70.50	57	57	2.4	1.62	0.00	0.99	3	3	3
70.52	57	57	2.4175	1.63	0.00	0.99	3	3	4
70.58	59	59	2.48	1.66	0.00	0.99	3	3	4
70.63	60	60	2.53	1.68	0.00	0.99	3	3	4
70.68	61	61	2.58	1.70	0.00	0.99	3	3	4
70.73	62	62	2.63	1.72	0.00	0.99	3	3	4
70.78	63	63	2.68	1.74	0.00	0.99	3	3	4
70.83	64	64	2.73	1.77	0.00	0.99	3	3	4
70.88	65	65	2.78	1.79	0.00	0.99	3	3	4
70.93	66	66	2.83	1.81	0.00	0.99	3	3	4
70.98	67	67	2.88	1.83	0.00	0.99	3	3	4
71.03	68	68	2.93	1.85	0.00	0.99	3	3	4
71.08	69	69	2.98	1.87	0.00	0.99	3	3	4
71.13	70	70	3.03	1.89	0.00	0.99	3	3	4
71.18	71	71	3.08	1.91	0.00	0.99	3	3	4
71.23	72	72	3.13	1.92	0.00	0.99	3	3	4
71.28	73	73	3.18	1.94	0.00	0.99	3	3	4
71.33	74	74	3.23	1.96	0.00	0.99	3	3	4
71.39	75	75	3.286	1.98	0.00	0.99	3	3	4
71.44	76	76	3.336	2.00	0.00	0.99	3	3	4
71.44	77	77	3.343	2.00	0.00	0.99	3	3	4
71.49	78	78	3.393	2.02	0.00	0.99	3	3	4
71.54	79	79	3.443	2.04	0.00	0.99	3	3	5
71.59	80	80	3.493	2.06	0.00	0.99	3	3	5
71.64	81	81	3.543	2.07	0.00	0.99	3	3	5
71.69	82	82	3.593	2.09	0.00	0.99	3	3	5
71.74	83	83	3.643	2.11	0.00	0.99	3	3	5
71.79	84	84	3.693	2.12	0.00	0.99	3	3	5
71.84	85	85	3.743	2.14	0.00	0.99	3	3	5
71.89	86	86	3.793	2.16	0.00	0.99	3	3	5

Headpond Water Surface Elevation (ft)	Stop Log Weir Gate C_d	Stop Log Weir Gate Discharge, Q (cfs)	Approximate Tailwater Elevation (ft)	Denil Exit Channel H	Denil headwater h_u	Sluice Gate Head, H (ft)	Sluice Gate H_s/H_c	Sluice Gate C_s/C_d	Sluice Gate C_d	Sluice Gate C_s
67.70	3	6	65.00	0.70	0.09	0.7	0.00	1.00	3.42	3.42
67.90	3	9	65.00	0.90	0.29	0.9	0.00	1.00	3.46	3.46
68.15	3	12	65.00	1.15	0.54	1.2	0.00	1.00	3.51	3.51
68.40	3	16	65.00	1.40	0.79	1.4	0.00	1.00	3.57	3.57
68.65	3	20	65.00	1.65	1.04	1.7	0.00	1.00	3.62	3.62
68.90	3	25	65.00	1.90	1.29	1.9	0.00	1.00	3.68	3.68
69.15	3	30	65.00	2.15	1.54	2.2	0.00	1.00	3.73	3.73
69.20	3	31	65.00	2.20	1.59	2.2	0.00	1.00	3.74	3.74
69.25	3	32	65.00	2.25	1.64	2.3	0.00	1.00	3.75	3.75
69.30	3	32	65.00	2.30	1.69	2.3	0.00	1.00	3.76	3.76
69.35	3	33	65.00	2.35	1.74	2.3	0.00	1.00	3.77	3.77
69.40	3	34	65.00	2.40	1.79	2.4	0.00	1.00	3.78	3.78
69.45	3	35	65.00	2.45	1.84	2.4	0.00	1.00	3.79	3.79
69.50	3	36	65.00	2.50	1.89	2.5	0.00	1.00	3.80	3.80
69.55	3	37	65.00	2.55	1.94	2.5	0.00	1.00	3.81	3.81
69.60	3	38	65.00	2.60	1.99	2.6	0.00	1.00	3.83	3.83
69.65	3	39	65.00	2.65	2.04	2.6	0.00	1.00	3.84	3.84
69.70	3	40	65.00	2.70	2.09	2.7	0.00	1.00	3.85	3.85
69.75	3	41	65.00	2.75	2.14	2.7	0.00	1.00	3.86	3.86
69.80	3	42	65.00	2.80	2.19	2.8	0.00	1.00	3.87	3.87
69.85	3	43	65.00	2.85	2.24	2.8	0.00	1.00	3.88	3.88
69.90	3	44	65.00	2.90	2.29	2.9	0.00	1.00	3.89	3.89
69.95	3	45	65.00	2.95	2.34	2.9	0.00	1.00	3.90	3.90
70.00	3	46	65.00	3.00	2.39	3.0	0.00	1.00	3.91	3.91
70.05	3	47	65.00	3.05	2.44	3.0	0.00	1.00	3.92	3.92
70.10	3	49	65.00	3.10	2.49	3.1	0.00	1.00	3.93	3.93
70.15	3	50	65.00	3.15	2.54	3.1	0.00	1.00	3.94	3.94
70.20	3	51	65.00	3.20	2.59	3.2	0.00	1.00	3.95	3.95
70.25	3	52	65.00	3.25	2.64	3.2	0.00	1.00	3.96	3.96
70.30	3	53	65.00	3.30	2.69	3.3	0.00	1.00	3.98	3.98
70.35	3	54	65.00	3.35	2.74	3.3	0.00	1.00	3.99	3.99
70.40	3	55	65.00	3.40	2.79	3.4	0.00	1.00	4.00	4.00
70.45	3	56	65.00	3.45	2.84	3.4	0.00	1.00	4.01	4.01
70.50	3	57	65.00	3.50	2.89	3.5	0.00	1.00	4.02	4.02
70.52	3	57	65.00	3.52	2.90	3.5	0.00	1.00	4.02	4.02
70.58	3	59	65.00	3.58	2.97	3.6	0.00	1.00	4.03	4.03
70.63	3	60	65.00	3.63	3.02	3.6	0.00	1.00	4.05	4.05
70.68	3	61	65.00	3.68	3.07	3.7	0.00	1.00	4.06	4.06
70.73	3	62	65.00	3.73	3.12	3.7	0.00	1.00	4.07	4.07
70.78	3	63	65.00	3.78	3.17	3.8	0.00	1.00	4.08	4.08
70.83	3	64	65.00	3.83	3.22	3.8	0.00	1.00	4.09	4.09
70.88	3	65	65.00	3.88	3.27	3.9	0.00	1.00	4.10	4.10
70.93	3	66	65.00	3.93	3.32	3.9	0.00	1.00	4.11	4.11
70.98	3	67	65.00	3.98	3.37	4.0	0.00	1.00	4.12	4.12
71.03	3	68	65.00	4.03	3.42	4.0	0.00	1.00	4.13	4.13
71.08	3	69	65.00	4.08	3.47	4.1	0.00	1.00	4.14	4.14
71.13	3	70	65.00	4.13	3.52	4.1	0.00	1.00	4.15	4.15
71.18	3	71	65.00	4.18	3.57	4.2	0.00	1.00	4.16	4.16
71.23	3	72	65.00	4.23	3.62	4.2	0.00	1.00	4.17	4.17
71.28	3	73	65.00	4.28	3.67	4.3	0.00	1.00	4.18	4.18
71.33	3	74	65.00	4.33	3.72	4.3	0.00	1.00	4.20	4.20
71.39	3	75	65.00	4.39	3.77	4.4	0.00	1.00	4.21	4.21
71.44	3	76	65.00	4.44	3.82	4.4	0.00	1.00	4.22	4.22
71.44	3	77	65.00	4.44	3.83	4.4	0.00	1.00	4.22	4.22
71.49	3	78	65.00	4.49	3.88	4.5	0.00	1.00	4.23	4.23
71.54	3	79	65.00	4.54	3.93	4.5	0.00	1.00	4.24	4.24
71.59	3	80	65.00	4.59	3.98	4.6	0.00	1.00	4.25	4.25
71.64	3	81	65.00	4.64	4.03	4.6	0.00	1.00	4.26	4.26
71.69	3	82	65.00	4.69	4.08	4.7	0.00	1.00	4.27	4.27
71.74	3	83	65.00	4.74	4.13	4.7	0.00	1.00	4.28	4.28
71.79	3	84	65.00	4.79	4.18	4.8	0.00	1.00	4.29	4.29
71.84	3	85	65.00	4.84	4.23	4.8	0.00	1.00	4.31	4.31
71.89	3	86	65.00	4.89	4.28	4.9	0.00	1.00	4.32	4.32

11. Appendix D: Detailed Cost Analysis Tables

11.1BRIDGE STREET DAM DETAILED COST ANALYSES

Table D-1. Detailed Cost Analysis for ***Bridge Street Dam, No Action Alternative*** .

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 4,500.00	$ 4,500	7.5% of other items; includes clearing and grubbing; traffic control as
2	Erosion, Pollution & Water Control	1	LS	$ 10,000	$ 10,000	misc control activities
Site Work						
3	Dam Repair	1	LS	$ 50,000	$ 50,000	Placeholder - most recent inspection report not available to date.
			Construction Subtotal		$ 64,500	
			Contingency (30%)		$ 19,350	
			Project Contruction Total		**$ 83,850**	
Initial Project Delivery Costs						
Item					**Total Cost**	**Notes**
Project Management (3% of Construction Subtotal)					$1,935	
Permitting (7.5% of Construction Subtotal)					$4,838	
Engineering Design (15% of Construction Subtotal)					$9,675	
Construction Contract Administration (5% of Construction Subtotal)					$3,225	
Construction Observation (5% of Construction Subtotal)					$3,225	
Initial Project Delivery Costs Total					**$22,898**	
Total Initial Project Costs					**$106,748**	

Lifespan Costs - 30-year planning horizon					
Item	**Event Cost**	**Intervals**	**Interest**	**Total Cost**	**Notes**
Operation and Maintenance	$5,000	30	3%	$237,877	Estimated $5000/annum (2016 dollars) for 30 years, 3% inflation
Repair and Rehabilitation	$15,000	6	3%	$155,825	Assumed $15,000 (2016 dollars) renovation/repairs every 5 years, 3% inflation
Total Lifespan Costs				**$393,702**	

Replacement Costs - Year 2047		
Item	**Total Cost**	**Notes**
Facility Replacement	NA	Replacement unlikely

Table D-2. Detailed Cost Analysis for ***Bridge Street Dam Technical Fishway Retrofit, Rebuild Alternative***.

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 28,950.00	$ 28,950	7.5% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 20,000	$ 20,000	misc control activities
Site Work						
3	Dam Repair	1	LS	$ 60,000	$ 60,000	Placeholder - most recent inspection report not available to date.
4	Remove Existing Denil Fishway	1	LS	$ 16,000	$ 16,000	Reinforced concrete = 80 CY estimated
5	Excavation	1	LS	$ 5,000	$ 5,000	Misc for installation of new fishway
6	Subgrade preparation	1	LS	$ 5,000	$ 5,000	Misc for installation of new fishway
7	Denil Fishway Concrete	110	CY	$ 1,200	$ 132,000	4' wide 1:8 standard design, 6 ft deep, 165 feet long including resting pool, entrance and exit channel
8	Sub-ladder retaining wall	40	CY	$ 1,200	$ 48,000	estimated, needs advanced design alignment to optimize
9	Gates and appurtenances	1	LS	$ 20,000	$ 20,000	estimated, needs advanced design alignment to optimize
10	Fencing, signage and appurtenances	1	LS	$ 10,000	$ 10,000	estimated, needs advanced design alignment to optimize
11	Eel passage	1	LS	$ 30,000	$ 30,000	estimated, needs advanced design alignment to optimize
12	Downstream Passage Enhancement	1	LS	$ 20,000	$ 20,000	300 SF pool, 5 ft ledge excavation plus new headgate and uniform acceleration weir
13	Ledge Shaping	1	LS	$ 10,000	$ 10,000	select ledge shaping along primary passage alignment, 50 CY
Site Landscape & Restoration						
14	Revegetation	1	LS	$ 10,000	$ 10,000	Placeholder
			Construction Subtotal		$ 414,950	
			Contingency (30%)		$ 124,485	
			Project Contruction Total		**$ 539,435**	
Initial Project Delivery Costs						
Item					**Total Cost**	**Notes**
Project Management (3% of Construction Subtotal)					$12,449	
Permitting (7.5% of Construction Subtotal)					$31,121	
Engineering Design (15% of Construction Subtotal)					$62,243	
Construction Contract Administration (5% of Construction Subtotal)					$20,748	
Construction Observation (5% of Construction Subtotal)					$20,748	
Effectiveness Monitoring (Estimated)					$30,000	
Initial Project Delivery Costs Total					**$177,307**	
Total Initial Project Costs					**$716,742**	

Lifespan Costs - 30-year planning horizon					
Item	**Event Cost**	**Intervals**	**Interest**	**Total Cost**	**Notes**
Annual Operation and Maintenance	$8,000	30	3%	$380,603	Dam and Fishway, estimated $8000/annum (2016 dollars) for 30 years, 3% inflation
Periodic Inspection, Repair and Rehabilitation (every 5 years)	$20,000	6	3%	$207,766	Dam and Fishway, Assumed $20,000 (2016 dollars) inspection/renovation/repairs every 5 years, 3% inflation
Total Lifespan Costs				**$588,370**	

Replacement Costs - Year 2047		
Item	**Total Cost**	**Notes**
Fish Passage Facility Replacement	$1,739,722	2016 new project cost escalated to 2047

Table D-3. Detailed Cost Analysis for *Bridge Street Dam, Naturelike Fishway (Bypass) Alternative*.

No.	Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Initial Project Costs						
Construction Cost Items						
Direct Costs						
1	Mobilization	1	LS	$ 24,837.75	$ 24,838	7.5% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 15,000	$ 15,000	misc control activities
Site Work						
3	Dam Repair	1	LS	$ 60,000	$ 60,000	Placeholder - most recent inspection report not available to date.
4	Excavation	2,500	CY	$ 15	$ 37,500	481 LF new channel x 4 FT average depth - 12 FT bottom width, 2:1 sideslopes, plus extra for off-channel area
5	Streambed Construction	1,100	CY	$ 100	$ 110,000	481 LF new channel x 3 FT depth - bed and lower banks - includes subgrade excavation
6	Channel Bank Construction	481	LF	$ 70	$ 33,670	1 fabric excapsulated lift on each bank of new channel construction, includes subgrade excavation
7	Ledge Shaping	1	LS	$ 10,000	$ 10,000	select ledge shaping along primary passage alignment, 50 CY
8	Decommision and Fill Denil fishway	1	LS	$ 5,000	$ 5,000	close off flow, backfill with excavation spoils
Site Landscape & Restoration						
9	Footpath realignment & Footbridge	1	LS	$ 40,000	$ 40,000	Placeholder
10	Revegetation	1	LS	$ 20,000	$ 20,000	Placeholder
				Construction Subtotal	$ 356,008	
				Contingency (30%)	$ 106,802	
				Project Contruction Total	**$ 462,810**	
Initial Project Delivery Costs						
Item					**Total Cost**	**Notes**
Project Management (3% of Construction Subtotal)					$10,680	
Permitting (7.5% of Construction Subtotal)					$26,701	
Engineering Design (15% of Construction Subtotal)					$53,401	
Construction Contract Administration (5% of Construction Subtotal)					$17,800	
Construction Observation (5% of Construction Subtotal)					$17,800	
Effectiveness Monitoring (Estimated)					$30,000	
Initial Project Delivery Costs Total					**$156,383**	
Total Initial Project Costs					**$619,193**	

Item	Event Cost	Intervals	Interest	Total Cost	Notes
Lifespan Costs - 30-year planning horizon					
Annual Operation and Maintenance	$6,000	30	3%	$285,452	Dam and Fishway, estimated $6000/annum (2016 dollars) for 30 years, 3% inflation
Periodic Inspection, Repair and Rehabilitation (every 5 years)	$15,000	6	3%	$155,825	Dam and Fishway, Assumed $15,000 (2016 dollars) inspection/renovation/repairs every 5 years, 3% inflation
Total Lifespan Costs				**$441,277**	

Item	Total Cost	Notes
Replacement Costs - Year 2047		
Facility Replacement	$1,459,168	2016 new project cost escalated to 2047

Table D-4. Detailed Cost Analysis for *__Bridge Street Dam, Dam Removal Alternative__*.

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 21,075.00	$ 21,075	7.5% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 40,000	$ 40,000	misc control activities
Site Work						
3	Spillway Demolition & Disposal	1	LS	$ 25,000	$ 25,000	remove spillway - 7 ft average structural height x 145 ft x 10 ft (est) = 200 CY, masonry capped with concrete overlay
4	Remove Right Non-Overflow Section	1	LS	$ 10,000	$ 10,000	non-overflow section - 102 ft x 7 ft average structural height x 3.5 ft thick = 100 CY, masonry capped with concrete overlay
5	Remove Denil Fishway	1	LS	$ 16,000	$ 16,000	Reinforced concrete = 80 CY estimated
6	Enhance Fish Passage Channels	1	LS	$ 20,000	$ 20,000	select ledge shaping along primary passage alignments, 100 CY
7	Impounded Sediment Management	2,000	CY	$ 15	$ 30,000	Minimal impounded sediment (Stantec 2010)
8	Bridge Scour Countereasures	1	LS	$ 100,000	$ 100,000	Beth Condon footbridge and Rte 1 footbridge identified as potentially vulnerable (Stantec 2010). Requires additional scour analysis to conclude necessity and extent.
9	Stabilize Masonry wall behind residence	1	LS	$ 20,000	$ 20,000	
Site Landscape & Restoration						
10	Revegetation	1	LS	$ 20,000	$ 20,000	Placeholder
			Construction Subtotal		$ 302,075	
			Contingency (30%)		$ 90,623	
			Project Contruction Total		**$ 392,698**	
Initial Project Delivery Costs						
Item					**Total Cost**	**Notes**
Hydroelectric Project Acquisition and/or Retirement					*	Not estimated. Present status unknown, requires valuation
Project Management (3% of Construction Subtotal)					$9,062	
Permitting (7.5% of Construction Subtotal)					$22,656	
Engineering Design (15% of Construction Subtotal)					$45,311	
Construction Contract Administration (5% of Construction Subtotal)					$15,104	
Construction Observation (5% of Construction Subtotal)					$15,104	
Effectiveness Monitoring (Estimated)					$40,000	
Initial Project Delivery Costs Total					**$147,237**	
Total Initial Project Costs					**$539,934**	
Lifespan Costs - 30-year planning horizon						
Item		**Event Cost**	**Intervals**	**Interest**	**Total Cost**	**Notes**
Operation and Maintenance		-	-	-	NA	Maintenance burden ceases with dam removal
Repair and Rehabilitation		-	-	-	NA	Repair burden ceases with dam removal
Replacement Costs - Year 2047						
Item					**Total Cost**	**Notes**
Facility Replacement					NA	Facility Removed through dam removal

11.2EAST ELM STREET DAM DETAILED COST ANALYSES

Table D-5. Detailed Cost Analysis for ***East Elm Street Dam, No Action Alternative*** .

No.	Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 4,500.00	$ 4,500	7.5% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 10,000	$ 10,000	misc control activities
Site Work						
3	Dam Repair	1	LS	$ 50,000	$ 50,000	Placeholder - most recent inspection report not available to date.
				Construction Subtotal	$ 64,500	
				Contingency (30%)	$ 19,350	
				Project Contruction Total	**$ 83,850**	

Initial Project Delivery Costs	Total Cost	Notes
Item	**Total Cost**	**Notes**
Project Management (3% of Construction Subtotal)	$1,935	
Permitting (7.5% of Construction Subtotal)	$4,838	
Engineering Design (15% of Construction Subtotal)	$9,675	
Construction Contract Administration (5% of Construction Subtotal)	$3,225	
Construction Observation (5% of Construction Subtotal)	$3,225	
Initial Project Delivery Costs Total	**$22,898**	
Total Initial Project Costs	**$106,748**	

Lifespan Costs - 30-year planning horizon					
Item	**Event Cost**	**Intervals**	**Interest**	**Total Cost**	**Notes**
Operation and Maintenance	$5,000	30	3%	$237,877	Estimated $5000/annum (2016 dollars) for 30 years, 3% inflation
Repair and Rehabilitation	$15,000	6	3%	$155,825	Assumed $15,000 (2016 dollars) renovation/repairs every 5 years, 3% inflation
Total Lifespan Costs				**$393,702**	

Replacement Costs - Year 2047		
Item	**Total Cost**	**Notes**
Facility Replacement	NA	Replacement unlikely

Table D-6. Detailed Cost Analysis for *East Elm Street Dam Technical Fishway Retrofit, Rebuild Alternative*.

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 31,800.00	$ 31,800	7.5% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 25,000	$ 25,000	misc control activities
Site Work						
3	Dam Repair	1	LS	$ 60,000	$ 60,000	Placeholder - not inspected since 2009
4	Remove Denil Fishway	1	LS	$ 18,000	$ 18,000	Reinforced concrete = 90 CY estimated
5	Excavation	1	LS	$ 5,000	$ 5,000	Misc for installation of new fishway
6	Subgrade preparation	1	LS	$ 10,000	$ 10,000	Misc for installation of new fishway
7	Denil Fishway Concrete	130	CY	$ 1,200	$ 156,000	4' wide 1:8 standard design, 6 ft deep, 195 feet long including resting pool, entrance and exit channel
8	Sub-ladder retaining wall	50	CY	$ 1,200	$ 60,000	estimated, needs advanced design alignment to optimize
9	Gates and appurtenances	1	LS	$ 20,000	$ 20,000	estimated, needs advanced design alignment to optimize
10	Eel passage	1	LS	$ 30,000	$ 30,000	estimated, needs advanced design alignment to optimize
11	Fencing, signage and appurtenances	1	LS	$ 10,000	$ 10,000	estimated, needs advanced design alignment to optimize
12	Downstream Passage Enhancement	1	LS	$ 20,000	$ 20,000	300 SF pool, 5 ft ledge excavation plus new headgate and uniform acceleration weir
Site Landscape & Restoration						
13	Revegetation	1	LS	$ 10,000	$ 10,000	Placeholder
				Construction Subtotal	$ 455,800	
				Contingency (30%)	$ 136,740	
				Project Contruction Total	**$ 592,540**	
Initial Project Delivery Costs						
Item					**Total Cost**	**Notes**
Project Management (3% of Construction Subtotal)					$13,674	
Permitting (7.5% of Construction Subtotal)					$34,185	
Engineering Design (15% of Construction Subtotal)					$68,370	
Construction Contract Administration (5% of Construction Subtotal)					$22,790	
Construction Observation (5% of Construction Subtotal)					$22,790	
Effectiveness Monitoring (Estimated)					$30,000	
Initial Project Delivery Costs Total					**$191,809**	
Total Initial Project Costs					**$784,349**	

Lifespan Costs - 30-year planning horizon					
Item	**Event Cost**	**Intervals**	**Interest**	**Total Cost**	**Notes**
Annual Operation and Maintenance	$8,000	30	3%	$380,603	Dam and Fishway, estimated $8000/annum (2016 dollars) for 30 years, 3% inflation
Periodic Inspection, Repair and Rehabilitation (every 5 years)	$20,000	6	3%	$207,766	Dam and Fishway, Assumed $15,000 (2016 dollars) renovation/repairs every 5 years, 3% inflation
Total Lifespan Costs				**$588,370**	

Replacement Costs - Year 2047		
Item	**Total Cost**	**Notes**
Fish Passage Facility Replacement	$1,848,370	2016 new project cost escalated to 2047

Table D-7. Detailed Cost Analysis for *East Elm Street Dam, Naturelike Fishway (Bypass) Alternative*.

No.	Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Initial Project Costs						
Construction Cost Items						
Direct Costs						
1	Mobilization	1	LS	$ 24,738.00	$ 24,738	7.5% of other items; includes clearing and grubbing; traffic control and access development as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 15,000	$ 15,000	misc control activities
Site Work						
3	Dam Repair	1	LS	$ 60,000	$ 60,000	Placeholder - not inspected since 2009
4	Excavation	1,600	CY	$ 15	$ 24,000	512 LF new channel x 4 FT average depth - 12 FT bottom width, 2:1 sideslopes
5	Streambed Construction	1,200	CY	$ 100	$ 120,000	512 LF new channel x 3 FT depth - bed and lower banks - includes subgrade excavation
6	Channel Bank Construction	512	LF	$ 70	$ 35,840	1 fabric excapsulated lift on each bank of new channel construction, includes subgrade excavation
7	Ledge Shaping	1	LS	$ 10,000	$ 10,000	select ledge shaping along primary passage alignment, 50 CY
8	Decommission and Fill Denil fishway	1	LS	$ 5,000	$ 5,000	close off flow, backfill with excavation spoils
Site Landscape & Restoration						
9	Footpath realignment & footbridge	1	LS	$ 40,000	$ 40,000	Placeholder
10	Revegetation	1	LS	$ 20,000	$ 20,000	Placeholder
			Construction Subtotal		$ 354,578	
			Contingency (30%)		$ 106,373	
			Project Contruction Total		**$ 460,951**	

Item	Total Cost	Notes
Initial Project Delivery Costs		
Project Management (3% of Construction Subtotal)	$10,637	
Permitting (7.5% of Construction Subtotal)	$26,593	
Engineering Design (15% of Construction Subtotal)	$53,187	
Construction Contract Administration (5% of Construction Subtotal)	$17,729	
Construction Observation (5% of Construction Subtotal)	$17,729	
Effectiveness Monitoring (Estimated)	$30,000	
Initial Project Delivery Costs Total	**$155,875**	
Total Initial Project Costs	**$616,827**	

Item	Event Cost	Intervals	Interest	Total Cost	Notes
Lifespan Costs - 30-year planning horizon					
Annual Operation and Maintenance	$6,000	30	3%	$285,452	Dam and Fishway, estimated $6000/annum (2016 dollars) for 30 years, 3% inflation
Periodic Inspection, Repair and Rehabilitation (every 5 years)	$15,000	6	3%	$155,825	Dam and Fishway, Assumed $15,000 (2016 dollars) inspection/renovation/repairs every 5 years, 3% inflation
Total Lifespan Costs				**$441,277**	

Item	Total Cost	Notes
Replacement Costs - Year 2047		
Facility Replacement	$1,453,592	2016 new project cost escalated to 2047

Table D-8. Detailed Cost Analysis for *East Elm Street Dam, Dam Removal Alternative*.

Initial Project Costs						
Construction Cost Items						
No.	**Item**	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**	**Notes**
Direct Costs						
1	Mobilization	1	LS	$ 157,950	$ 157,950	7.5% of other items; includes clearing and grubbing; traffic control as necessary
2	Erosion, Pollution & Water Control	1	LS	$ 40,000	$ 40,000	misc control activities
Site Work						
3	Spillway Demolition & Disposal	1	LS	$ 25,000	$ 25,000	remove spillway - 5 ft average height x 180 ft x 5 ft (est) = 200 CY
4	Remove Right Non-Overflow Section	1	LS	$ 3,000	$ 3,000	non-overflow section -20 ft x 7 ft average structural height x 3.5 ft thick = 15 CY, reinforced concrete
5	Remove Denil Fishway	1	LS	$ 18,000	$ 18,000	Reinforced concrete = 90 CY estimated
6	Enhance Fish Passage Channels	1	LS	$ 20,000	$ 20,000	select ledge shaping along primary passage alignments, 100 CY
7	Impounded Sediment Management	110,000	CY	$ 15	$ 1,650,000	volume of potentially mobile sediment (Stantec 2013), assumed to not require special disposal
8	Bridge Scour Countereasures	1	LS	$ 200,000	$ 200,000	Placeholder. 2 RR bridges identified as potentially vulnerable (Stantec 2013). Requires additional study to conclude necessity and extent.
9	Water Supply Pipeline Stabilization	1	LS	$ 50,000	$ 50,000	Placeholder. Additional scour analysis required
10	Dry Hydrant Modification	1	LS	$ 50,000	$ 50,000	Placeholder. Additional evaluation required
Site Landscape & Restoration						
11	Revegetation	1	LS	$ 50,000	$ 50,000	Placeholder
			Construction Subtotal		$ 2,263,950	
			Contingency (30%)		$ 679,185	
			Project Contruction Total		**$ 2,943,135**	
Initial Project Delivery Costs						
Item					**Total Cost**	**Notes**
Project Management (3% of Construction Subtotal)					$67,919	
Permitting (7.5% of Construction Subtotal)					$169,796	
Engineering Design (15% of Construction Subtotal)					$339,593	
Construction Contract Administration (5% of Construction Subtotal)					$113,198	
Construction Observation (5% of Construction Subtotal)					$113,198	
Effectiveness Monitoring (Estimated)					$40,000	
Initial Project Delivery Costs Total					**$843,702**	
Total Initial Project Costs					**$3,786,837**	

Lifespan Costs - 30-year planning horizon					
Item	**Event Cost**	**Intervals**	**Interest**	**Total Cost**	**Notes**
Operation and Maintenance	-	-	-	NA	Maintenance burden ceases with dam removal
Repair and Rehabilitation	-	-	-	NA	Repair burden ceases with dam removal

Replacement Costs - Year 2047		
Item	**Total Cost**	**Notes**
Facility Replacement	NA	Facility Removed through dam removal