SMELT BROOK AQUATIC ECOSYSTEM RESTORATION
Draft Feasibility Study

Appendix C: Engineering and Design

July, 2022

US Army Corps of Engineers®
New England District

SMELT BROOK AQUATIC ECOSYSTEM RESTORATION

DRAFT FEASIBILITY REPORT
APPENDIX C: ENGINEERING AND DESIGN
TABLE OF CONTENTS

This page intentionally left blank

1.0 INTRODUCTION

1.1 Study Area and Overview

Smelt Brook is located within the Monatiquot River-Frontal Quincy Bay watershed (Hydrologic Unit Code 010900010901) south of Boston, and forms a portion of the boundary between the towns of Braintree and Weymouth, Norfolk County, Massachusetts (Figure 1). The headwater of the Weymouth Fore River is formed by the confluence of the Monatiquot River and Smelt Brook in an area commonly referred to as Weymouth Landing, at the upstream limit of the existing Weymouth-Fore River Federal Navigation Project 6-foot upper channel segment.

As shown in **Figure 1**,

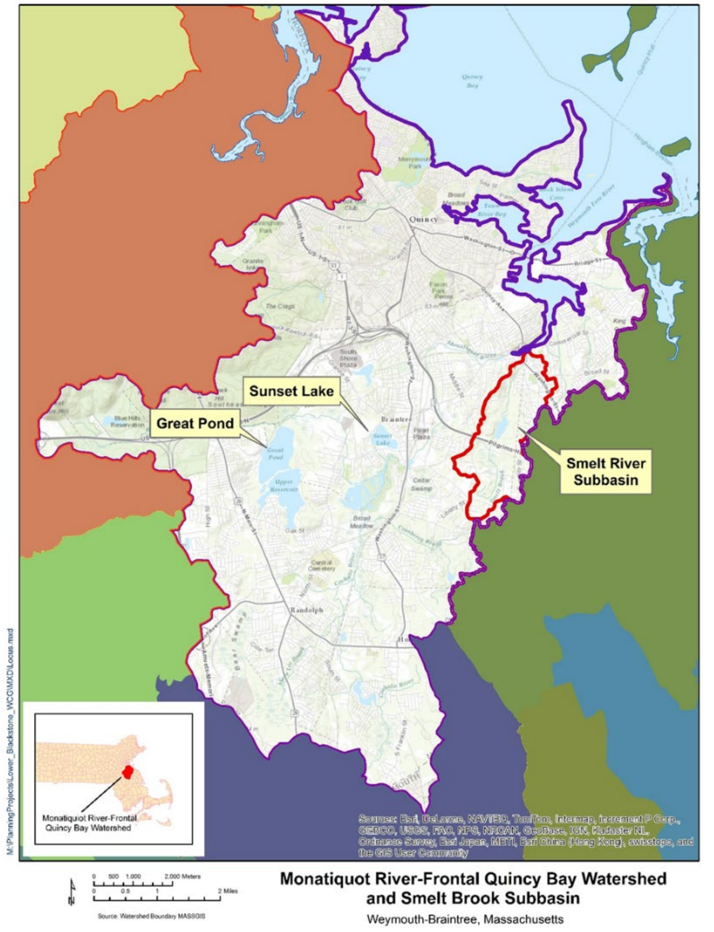


Figure 1: Plan View of Study Area

2.0 EXISTING CONDITIONS

2.1 Topographic and Subsurface Data

2.2 Public Records

2.3 CAD & GIS

3.0 DESIGN PROCESS

As part of the alternatives development and analysis, the project delivery team (PDT) considered various alternatives to correct the problem that human activities have altered over time. The goal is to improve the structure, function and dynamic processes of the Weymouth Fore River watershed to a point where significant degradation of aquatic habitat has resulted in reduced species diversity, increased the presence of non-native invasive species and extirpated diadromous fish.

3.1 No Action

3.2 Alternative One: Ladder on the Entire Stilling Basin.

There is adequate area in the existing stilling basin for 9 pools, each 6 inches higher than its downstream neighbor, with adequate volume for the pools. The analysis assumes 1-ft thick vertical walls.

Design was based on 2.4 square miles of basin contributing to the watershed. The area at the site of interest is 1.85 square miles according to USGS (StreamStats), and the design discharge for a 100-year design event at the upstream Pond Meadow Brook Dam was estimated at 320 cfs, but the flow along Brookside Road only 650 feet downstream of the CMP was stipulated in the O&M manual to be 600 cfs.

One drawback with this scheme is that the pools are smaller than 10 feet long by 5 feet wide, which is a recommended minimum spacing for a schooling species that prefers at least 10 feet between obstacles and requires frequent rest areas. If chosen for further development, then the geometrical changes outlined below might be considered instead.

3.2.1 Real Estate Requirements

3.2.2 Construction Plans

3.2.3 Structural

The concrete weir walls would be designed to provide rotational stability against flow exiting the conduit. Significant benefits to reducing concrete volume on this alternative is to use gabion baskets intermittently between the walls.

The concrete weirs selected for this and other alternatives were based on the criteria found in the Engineering Manuals:

- EM-1110-2-2100 - Stability Analysis of Concrete Structures
- EM-1110-2-2502 - Floodwalls and Other Hydraulic Retaining Walls
- EM-1110-2-2105 - Design of Hydraulic Steel Structures

3.3 Alternative Two: Ladder on One Side of the Stilling Basin (SELECTED)

Figure 2: Ladder on side of the Stilling Basin

An alternative layout with pools on one side only of the stilling basin could allow for excessive streamflows to bypass the system, leaving a more constant flow in the ladder pools. The floor of the current basin is opened up for fish that are not attracted to the fish ladder structure.

3.3.1 Real Estate Requirements

3.3.2 Construction Plans

3.3.3 Structural

The tentatively selected plan is Alt. #2 Ladder on One side of Stilling Basin. The other side of the stilling basin will be a plunge pool. The project will provide smelt an additional mile of reproductive habitat up to Pond Meadow Lake.

Concrete would be the most economical and durable material for the construction of the fish passage walls and slab. The Concrete walls will be supported by a 2.5 foot thick slab which is part of the existing stilling basin outlet. This original concrete construction is supported by rock which was most likely prepared for concrete installation. In an effort to keep material costs low, gabion basket can be placed between the walls and topped with a cover slab to allow fish transport. Surface preparation of the floor of the existing outlet should include power washing and repair of any spalling concrete. It is not anticipated there will be exposed reinforcing. An initial inspection of the outlet will be performed before and during the design phase of the project. The floor of the stilling basin will need to be drilled for the installation of vertical steel dowels that will extend into the bottom of the wall a minimum of 18”.

The concrete mix will be designed with air entrainment to handle the winter conditions endured in this area. This mix design will also perform well against water flow erosion wear on the concrete surfaces. A roughened broom finish slab will be the swimming surface for the smelt. The concrete quantity is approximately 25 c.y.

Dimensions of the walls shown on the plans will be reviewed and compared to the shop drawings submitted by the contractor. The contractor will be required to submit all shop drawings for all concrete structures. Access to the site will be challenging as care needs to be taken when operating equipment over existing conduits. The conduit needs protection by the use of mats and wood chips.

3.4 Alternative Three: Combination nature-like bypass with weirs at designated intervals

Extend a side-channel along the side of the steep “valley” so as to avoid the constraint of having the whole structure inside the stilling basin. This allows for longer pools, and smaller depths.

The objective is to funnel 15% of the spring flow through a side channel, so that it provides an attractive flow for any migrating fish. By adjusting the weir locations in the dividing walls between the separate pools, the total distance is increased to result in fish swimming in a channel with an effective 1% grade.

A key finding was that the design would lead to an excessively long ladder design. The design was therefore not pursued beyond a review with a biologist at USFWS. Approximately 9,500 square feet of riparian habitat would be displaced. Project alternative considered but not carried forward.

3.4.1 Real Estate Requirements

3.4.2 Construction Plans

3.4.3 Structural

The canals might need to be one long rectangular canal with sets of stoplog slots for weirs to be inserted with geometry designed to facilitate maintenance and later fine-tuning of the design. Designed like an aqueduct, the canal could be above or at or slightly below ground grade depending on location. Piers may be required in some places. The design should be for the canals filled with water. If the water should rise above this level then there would be an overflow to back into the stream.

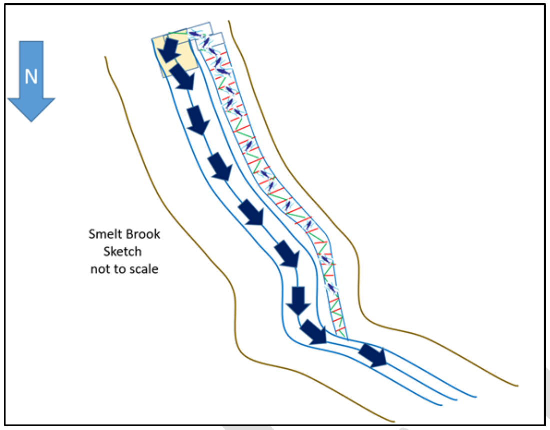


Figure 3: Alternative 3: Smelt Brook: alternative canal flow for fish passage

3.5 Alternative Four: Nature-like Bypass with "Switchback"

Allow for one narrow route approximately 5 feet wide, with a switchback distance of 175 feet. At a suitable location, there is a weir connection feeding the flow into a section that flows back towards the conduit for 180 feet. After this 180-ft detour, the flow is again reversed and the pool layout takes the flow downstream to join the stream channel. The total distance of 600 feet is extended by 2 lengths of 175 feet for a total extra length of 350 feet. The channelized flow reaches the stream channel after a diversion of 950 feet. Pool distances along this route are set to drop progressively by increments (decrements) of no more than 6 inches. Assuming that 4 inches is an acceptable minimum then the 9.5-foot total is achieved with a total of 9.5/0.333=28.5 (say 28) steps. The average gradient along this channel is 1%.

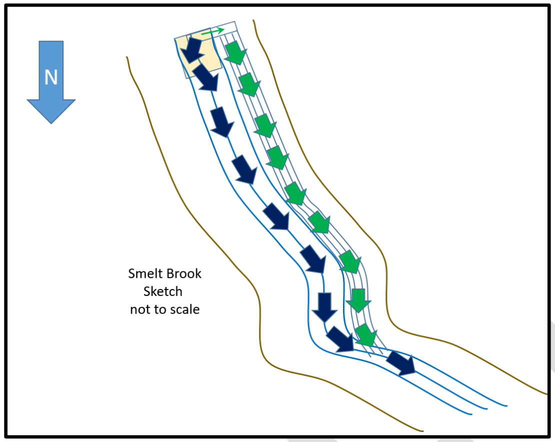


Figure 4: Alternative 4: Nature like Bypass with a "Switchback"

A key caveat was that the long switchback design, although theoretically possible, might prove to be too long and confusing for the smelt. The design was therefore not pursued beyond a review with a biologist at USFWS.

Approximately 9,500 square feet of riparian habitat would be displaced. Project alternative considered but not carried forward.

3.5.1 Real Estate Requirements

3.5.2 Construction Plans

3.5.3 Structural

None

3.6 Alternative Five: Engineered Weirs at Intervals Along the 600-ft length of the River Reach

A series of weirs across the entire stream section for several hundred feet. For an initial draft, the spacing has been set at 10 feet between the weirs. Weirs are designed with “notches” to allow for flow with at least three elevations. The intention is to ensure that, even at relatively low flows, the weirs will accommodate flow in adequate depths to promote the migration of smelt. Approximately 1,750 square feet of riparian habitat and 7,000 square feet of stream habitat would be displaced. Project alternative considered but not carried forward.

3.6.1 Real Estate Requirements

3.6.2 Construction Plans

3.6.3 Structural

Reinforced concrete weir wall construction similar to the selected option.

3.7 Alternative Six: Keyhole Slot at Base of Existing Culvert Exit

Figure 5: Alternative 6 View Shows the “Keyhole” Culvert exit

Dividing walls inside the culvert are assumed to be 0.5 foot wide. This may need to be refined during design of reinforcement. Upstream of each wall in the culvert is a pool 6 inches lower than the notch invert. The elevations shown assume a 1% grade for the current CMP.

The new walls inside the stilling basin would be sized (thickness) and reinforced in accordance with guidance from geotechnical and structural engineering. The notch-walls are assumed to be 1.0 ft thick. This may need to be refined during design of reinforcement.

As shown in the sketches, there is an extra area below the box invert that would need to be included in the total flows in order to pass an equivalent flow, but this extra area diminishes to zero at the upper extreme of the fish passage, and so should not be included in the overall capacity assumptions.

It is not clear that the need for the replacement culvert is obvious. Hydraulically, the capacity of the exposed channel would exceed the capacity of the closed-over channel. If the open “daylighted” section is extended upstream, then a new location should be chosen for the headwall shown in the figure, even if the current wall is retained.

The excavation option requires geotechnical consideration, and a review of whether the river would wander once the excavation occurred. There should also be a review of buried utility lines, prior to selection of this option over any other options.
Approximately 1,452 square feet of stream habitat (inside the stilling basin and CMP) would be displaced. Project alternative considered but not carried forward.

3.7.1 Real Estate Requirements

3.7.2 Construction Plans

3.7.3 Structural

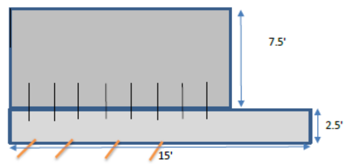
Reinforced concrete weir wall construction similar to the selected option.

4.0 DESIGN SUMMARY

4.1 Structural Concrete Calculations for Alternative 6

NEW ENGLAND DISTRICT U.S. ARMY CORPS OF ENGINEERS					
SUBJECT	Bearing Capacity of Stilling Basin Concrete and Rock Foundation at Smelt Brook, Weymouth, MA				
COMPUTATION	Bearing Capacity				
COMPUTED BY	DMS	CHECKED BY		DATE	27 Jul 2022

Determine the bearing capacity of the rock under the stilling basin. Analyze a 15' long x4' wide strip. Foundation is rock with bearing capacity 6k-8k psf.
The load on the stilling basin slab at Weir #1, The lengths of the weirs are 10'-0"
4'w x10'l x7.5'h=300. C.F.
300X150=45,000 LB. / 40S.F.= 1125 PSF.
The bearing load on the underlying rock slab would be 1125 psf additional load. The remaining slabs drop in elevation, so that weight is a reduced as the weirs progress downstream. The bearing capacity of the existing concrete at 2.5 feet thick distributes the weight evenly to the concrete.



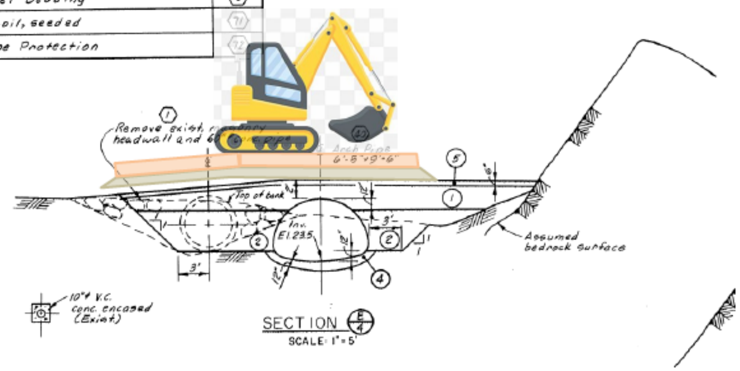
1.125 ksf < 20 ksf *OK*

- Presumptive (AASHTO 2006 Table 10.6.2.6-1 from NAVFAC DM-7)

TYPE OF BEARING MATERIAL	CONSISTENCY IN PLACE	BEARING RESISTANCE (KSF)	
		Ordinary Range	Recommended Value of Use
Massive crystalline igneous and metamorphic rock: granite, diorite, basalt, gneiss, thoroughly cemented conglomerate (sound condition allows minor cracks)	Very hard, sound rock	120 to 200	160
Foliated metamorphic rock: slate, schist (sound condition allows minor cracks)	Hard sound rock	60 to 80	70
Sedimentary rock: hard cemented shales, siltstone, sandstone, limestone without cavities	Hard sound rock	30 to 50	40
Weathered or broken bedrock of any kind, except highly argillaceous rock (shale)	Medium hard rock	16 to 24	20
Compaction shale or other highly argillaceous rock in sound condition	Medium hard rock	16 to 24	20
Well-graded mixture of fine- and coarse-grained soil: glacial till, hardpan, boulder clay (GW-GC, GC, SC)	Very dense	16 to 24	20
Gravel, gravel-sand mixture, boulder-gravel mixtures (GW, GP, SW, SP)	Very dense Medium dense to dense Loose	12 to 20 8 to 14 4 to 12	14 10 6
Coarse to medium sand, and with little gravel (SW, SP)	Very dense Medium dense to dense Loose	8 to 12 4 to 8 2 to 6	8 6 3
Fine to medium sand, silty or clayey medium to coarse sand (SW, SM, SC)	Very dense Medium dense to dense Loose	6 to 10 4 to 8 2 to 4	6 5 3
Fine sand, silty or clayey medium to fine sand (SP, SM, SC)	Very dense Medium dense to dense Loose	6 to 10 4 to 8 2 to 4	6 5 3
Homogeneous inorganic clay, sandy or silty clay (CL, CH)	Very stiff to hard Medium stiff to stiff Soft	6 to 12 2 to 6 1 to 2	8 4 1
Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand (ML, MH)	Very stiff to hard Medium stiff to stiff Soft	4 to 8 2 to 6 1 to 2	6 3 1

4.1 Geotechnical Calculations for Alternative 6

LEGEND - MATERIALS		
DESIG. NO.	DESCRIPTION	PAYMENT ITEM NO.
1	Dumped Random Fill	7
2	Compacted Random Fill	7
3	Compacted Pervious Fill	8
4	Gravel Bedding	12
5	Topsoil, seeded	
6	Stone Protection	



Narrative:

A fish passage will be installed in the Smelt Brook stilling basin. An excavator will be needed to move equipment, clear stones in the existing basin, and perform other work. The only accessible work and laydown location is on the south side of the stilling basin, which is only accessible from the north side of the culvert (Brookside Street). The excavator will need to cross the culvert, which will cause additional load on the 70 year old culvert. This calculation for planning purposes only provides the change in stress on top of the culvert.

Assumptions:

Komatsu PC-210 Excavator (midsize)

Operating Weight	=	53862	lbs
Track Length (Ground Contact)	=	144	in
Shoe Size (width)	=	26	in
Crawler Width	=	121	in
Ground Pressure (Brochure)	=	6.7	psi
Ground Pressure (Calculated)	=	7.19	psi

Change in Stress with Excavator Only

Using 2:1 Method

Z (depth)	=	24	in										
Δσ	=	Operating Weight	/	2	/(	Track Length	+	Z	)/(	Shoe Width	+	Z	)
Δσ	=	53862	/	2	/(	144	+	24	)/(	26	+	24	)
Δσ	=	3.21	psi										
Δσ	=	461.67	psf										

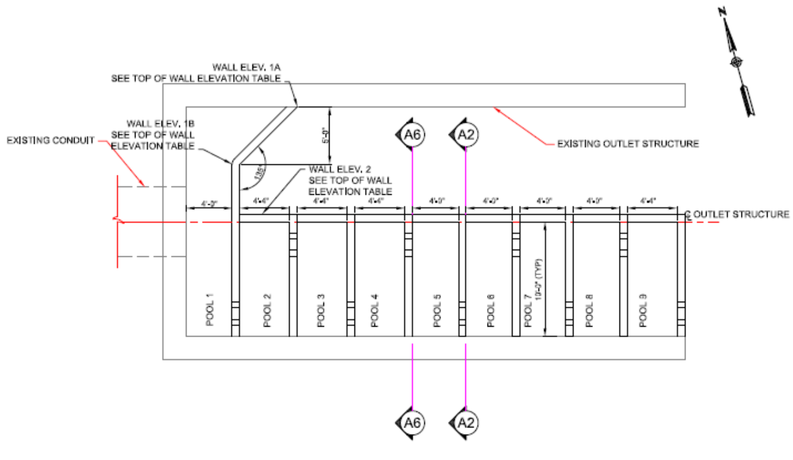
Change in Stress with 8 in Wood Chips and Crane Mats

Assume minimum width of surface pressure is width of crawler tracks.

Z (depth)	=	32	in									
σmat	=	27	psf =	0.19	psi							
σchips	=	13.58	psf =	0.09	psi							
Δσ	=	Operating Weight	/(	Track Length	+	Z	)/(	Crawler Width	+	Z	)+	σ cover
Δσ	=	53862	/(	144	+	32	)/(	121	+	32	)+	0.28
Δσ	=	2.28	psi									
Δσ	=	328.61	psf									

SECTION 5.0: DESIGN DRAWINGS

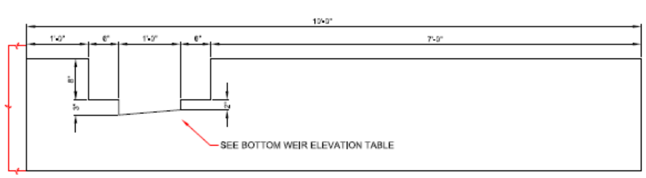
1. **ALTERNATIVE 2 - LADDER ON ONE SIDE OF STILLING BASIN**



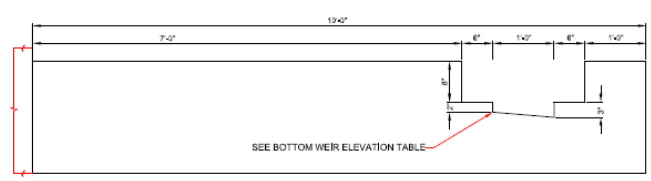
D1 PLAN VIEW - WEIR LAYOUT
SCALE: 1" = 4'

BOTTOM WEIR ELEVATION	
POOL	ELEV (FT)
1	22.50
2	22.00
3	21.50
4	21.00
5	20.50
6	20.00
7	19.50
8	19.00
9	18.50

TOP OF WALL ELEVATION	
POOL	WALL ELEV (FT)
1A	22.50
1B	23.50
2	23.50
3	23.00
4	22.50
5	22.00
6	21.50
7	21.00
8	20.50
9	20.00



A2 WEIR SECTION A
SCALE: 1" = 9"



A6 WEIR SECTION B
SCALE: 1" = 9"