-- Fyfeshire Pond Dam --
PHASE II
INVESTIGATIONS REPORT

Dam Name:	Fyfeshire Pond Dam
State Dam ID#:	3-14-34-2
NID#:	MA01512
Owner:	Town of Bolton Conservation Commission
Owner Type:	Municipal
Town:	Bolton
Consultant:	Fuss & O'Neill
Date of Completion:	October 30, 2009

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Disciplines to Deliver

FYFESHIRE POND DAM PHASE II INVESTIGATIONS
Town of Bolton Conservation Commission

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1.0 DESCRIPTION OF PROJECT

1.1 Introduction

Fuss & O'Neill, Inc. has been retained to perform a Phase II Inspection and Investigation of the dam at Fyfeshire Pond in Bolton, Massachusetts (*Figure 1*).

The Owner received a Certificate of Non-Compliance and Dam Safety Order, dated March 13, 2009 for the structure, requiring:

- Lowering of the impoundment level to the fixed spillway crest elevation.
- The preparation of this Phase II Inspection and Investigation with submission to the Office of Dam Safety by October 1, 2009.
- Inspection of the structure every 90 days until the dam is removed or brought into compliance, with reports submitted to Office of Dam Safety.
- Bring dam into compliance with Office of Dam Safety requirements by October 1, 2010.

1.2 Purpose of this Report

The purpose of this investigation is to assess the current condition of the dam, the options available for its repair or removal, the costs for those options, the approach to bringing it into compliance, and the permitting that is likely to be necessary. The findings will be used by the Bolton Advisory Committee and Conservation Commission to assess the available options and determine the future of the structure and pond.

Additionally, the purpose of this report is to assess consequences to downstream property and inhabitants that could be affected should the dam fail. DCR needs to understand not only the options that the Town of Bolton is interested in, but what other options may exist for eliminating the potential hazard posed by this dam, such as the complete or partial removal of this dam. This report is intended to aid the Town and DCR in determining a reasonable course of action for this dam given the potential outcomes that may develop.

1.3 Dam Data

Dam Name:	Fyfeshire Pond Dam
AKA Name:	Fish Pond Dam
Nat. ID Number:	MA01512
State ID Number:	3-14-34-2
Town	Bolton
Dam Owner/Caretaker:	Town of Bolton Conservation Commission Town Hall, 663 Main Street Bolton, MA 01740 Contact: Carol Gumbart
Hazard Potential:	Significant
Size Classification:	Small
Location of Dam (town):	Bolton
Coordinate location (lat, long):	42.41530, -71.64902
Street Address/Nearest Intersection:	516 Wattaquadock Hill Road

Purpose of the Dam:	Current: Recreation and Conservation Historical: Early industrial hydropower
Constructed:	ca. 1878
Length*:	80 feet
Structural Height*:	9 feet
Hydraulic Height*:	4.5 feet
Type of Dam:	Earth embankment with dry stone masonry walls
Low-Level Outlet:	Hand-operated small diameter outlet (reported)

** Determined as part of this study, superseding values previously reported*

1.4 Description of Dam

Fyfeshire Pond Dam consists of earth fill with downstream dry masonry walls. The spillway consists of concrete masonry walls and reportedly has a weir constructed of concrete. A concrete weir, referred to as a 'sill,' is cast within the spillway and maintains the impoundment water surface elevation. A small diameter low level outlet is reportedly present within the spillway or the weir, but has not been operated in recent years. The embankment is vegetated with grass and shrubs. A steel footbridge spans the spillway, resting on the spillway training walls, and reinforcing the walls to maintain their stability. The overall length of the dam is approximately 80 feet. The spillway weir is approximately 27.5 feet long.

1.5 Summary of Deficiencies

Recent visual inspections of Fyfeshire Pond Dam include a Phase I inspection performed by AMEC Earth & Environmental, Inc., July 17, 2008, a follow-up inspection performed by AMEC in May of 2009, and a follow-up inspection performed by Fuss & O'Neill on July 16, 2009. A cursory Jurisdictional and Ownership Inspection was performed by Tighe & Bond, Inc. on July 18, 2007. Previous inspections were performed in 1975 and 1979.

During the Phase I inspection, the dam was found to be in unsafe condition. Following that inspection, the accumulated debris was removed from the spillway channel, such that the imminent threat to the dam was removed. Otherwise; the condition of the dam remains poor; no other significant changes appeared to have occurred during follow-up inspections. The primary deficiencies identified during these inspections include:

As reported by AMEC (2008):

- Failing spillway – "The right spillway training wall includes a horizontal crack extending from upstream to downstream. The left wall of the spillway has a large horizontal crack, which appears to penetrate completely through the thickness of the wall and extends from upstream to downstream. The left wall of the spillway appears to be bulged or folded such that the horizontal crack projects toward the center of the spillway many inches and the portion above and below the crack is leaning significantly (estimated 10 degrees) away from the center of the spillway"

- Bulging embankment – "The downstream face of the dam is a vertical dry-stacked stone wall on both sides of the spillway. The left side of the wall is straight and has no noticeable batter. There is a large tree at the base of the wall… The right side of the downstream face… is bulged and leaning significantly along its length."
- Growth of large trees – "At the corner of the right abutment, a tree has fallen over, removing the root ball and exposing a spherical volume within the pond embankment…trees are present on the right side [upstream] face… there is one large tree at the base of the [left downstream masonry] wall."
- Poor soil cover on crest – "Evidence of significant erosion is found on the left side of the dam at the point where the spillway wall and the earth dam structure meet. The area was recently repaired with small 2-foot tall, cast-in-place concrete walls, retaining the soil within the walking path."
- Debris in spillway channel – "The spillway is currently partially choked above the sill with branches, mud, and sticks."
- Lack of documentation

As supplemented by Fuss & O'Neill:

- Poor vegetative cover – Poor vegetative cover with exposure of erodible soils is present along the crest left and right of the spillway where a walking path has developed.

Please refer to the *Poor and Unsafe Condition Dam Follow-up Inspection Form* as completed for the required 90-day inspections (Appendix A) and the Phase I Inspection/Evaluation Report (AMEC, 2008) for a more detailed description of inspection findings and the condition of the dam.

2.0 EXISTING SITE RESOURCES

2.1 Hydrology

Fyfeshire Pond is approximately 9.1 acres in surface area and is located in the headwaters of North Brook, a tributary of the Assabet River in the SuAsCo watershed, which discharges to the Merrimac River at Lowell. The pond is relatively shallow, with emergent vegetation growing in much of its northern portions. The dam is located in a narrow cove of the pond that is also shallow, although a deeper pool is located upstream of the dam. The shallow depth of the impoundment may be the result of significant sediment accumulation; the pond bottom elevation at the dam is several feet higher than natural ground on the downstream side.

Fyfeshire Pond is fed primarily by an unnamed perennial stream from the east. The perennial stream flows into a smaller impoundment located approximately 200 feet upstream before discharging to Fyfeshire Pond. Fyfeshire Pond is also fed by several smaller intermittent streams around its perimeter as well as overland flow and shallow groundwater discharge. The watershed, shown in *Figure 2*, is approximately 1.11 square miles in total, the majority of which is pasture, but also includes significant areas of residential development.

Fyfeshire Pond is located along North Brook. Downstream from Fyfeshire Pond is Collins Road in the Town of Berlin, a subdivision road crossing with a small culvert. Although the culvert appears to have been installed in the last 10 to 20 years, the roadway is shown on flood mapping dating from 1980. Collins Road is the only means of access to the residences in the subdivision. Between Fyfeshire Pond and the road crossing is a wetland of approximately 5.2 acres in surface area.

Fyfeshire Pond is surrounded by 100-year flood zones as mapped on the applicable Federal Emergency Management Agency (FEMA) Flood Rate Insurance Map (FIRM). Collins Road, shown on the adjacent FIRM panel in Berlin, is also mapped within the 100-year flood zone, which appears to significantly overtop the road (*Figure 3*).

2.2 Soils

Soil mapping from Natural Resource Conservation Service (NRCS) suggests that the area surrounding Fyfeshire Pond contains a mixture of till-derived and glacial outwash-derived soils. The pond itself is formed in outwash-derived sands and gravels, and the upland areas adjacent to the pond are primarily Merrimac soils. The outwash soils are generally confined to the north, west, and south of the pond with predominantly till derived soils (i.e., Charlton, Hollis, Paxton and Woodbridge series) to the east. Hydric soils are largely confined to the lower elevations and are coincident with existing streams and the pond. NRCS soil mapping shows these soils to primarily consist of the Scarboro and Swansea series.

Based on field observations, the hydric soils observed upstream and downstream of the Fyfeshire Dam are primarily consistent with the Scarboro series. These soils were classified as Histic Humaquepts.

NRCS mapping was also reviewed to determine the runoff and infiltration characteristics of the soil in the Fyfeshire Pond watershed (*Figure 4*). Each hydrologic soil group is represented within the watershed. Soil types B and C, which are moderately well drained and moderately poorly drained, respectively, are dominant, with smaller areas of well drained (Type A) soil surrounding the pond and poorly drained soil (Type D) immediately surrounding the stream channel upstream of the pond.

2.3 Vegetation

The upland areas consist of hardwood transition forest. Common species observed include red oak (*Quercus rubra*), beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), sugar maple (*Acer saccharum*), striped maple (*Acer pensylvanicum*), maple-leaved viburnum (*Viburnum acerfolium*), with hazel (*Hamamelis virginiana*), clubmoss (*Lycopodium sp.*), hay-scented fern (*Dennstaedtia punctilobula*), and Canada mayflower (*Maianthemum canadense*).

Wetland areas consisted of alluvial red maple swamps. Common species observed include red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), arrow-wood (*Viburnum recognitum*), skunk cabbage (*Symplocarpus foetidus*), cinnamon fern (*Osmunda cinnemoma*), false hellebore (*Veratrum viride*), sedges (*Carex spp.*), jack-in-the-pulpit (*Arisaema triphyllum*), and horsetail (*Equisetum sp.*)

2.4 Resource Areas

Two resource areas – Bordering Vegetated Wetlands (BVW) and Banks – were specifically delineated in the field on July 1, 2009. Below is a brief description of the resource areas that were delineated. *Figure C0.1* presents a survey plan of existing conditions at the site including delineated Bank and BVW. Since the discharge stream from the dam forms a perennial stream as defined by the Rivers Protection Act, the Riverfront area is associated with it.

2.4.1 Bordering Vegetated Wetlands

BVW within approximately 200 feet upstream and downstream of the Fyfeshire Dam were delineated in accordance with the methods described in "Delineating Boarding Vegetated Wetlands" (MADEP, 1995) and the criteria articulated in 310 CMR 10.55. Sufficient vegetative cover was available to delineate BVW on site using the 50% wetland vegetation criterion alone. Hydric soils and hydrologic conditions were also inspected in the field to support the delineations. Areas containing over 50% domination by wetland indicator plants as well as hydric soils and other indicators of wetland hydrology were included within the delineated BVW.

Bordering Vegetated Wetlands (BVW) within the study area were found in association with Fyfeshire pond as well as in certain pockets along the stream flowing from the dam to the south and west. BVW is located directly downstream of the dam, possibly caused by elevated groundwater levels that may by driven by pond levels. BVW were delineated in the field and numbered with the prefix "BVW." Four BVW areas were delineated: BVWA100-113, BVWB200-204, BVWD400-416, and BVWE522.

2.4.2 Bank

Banks were delineated in accordance with 310 CMR 10.54(2)(a). Specifically, the upper limits of Bank, or mean annual flood level (MAFL), were delineated based on observations of topographic and vegetative changes. Bank is found all around the Fyfeshire Pond and the outlet stream as a broad line between the average annual high water elevation and the annual low water elevation. The upper limits of Bank were delineated in the field and numbered with the prefix "BK." Two continuous banks were delineated in the field: BKA100-121 and BKC300-318.

2.4.3 Riverfront

At the location where the discharge stream from Fyfeshire Pond passes the spillway weir, the stream adopts riverine characteristics, and since the stream is shown as a solid blue line on 1:24,000 scale USGS mapping, it is considered perennial under the Rivers Protection Act. As such, the statutory resource of Riverfront is associated with the stream beginning at this location. No distinction at the site could be made between MAFL and the Mean Annual High Water Line (MAHW) associated with the discharge stream at the location where the resource first becomes riverine, so the inner limit of Riverfront was defined as the upper limit of Bank. Riverfront extends 200 feet perpendicularly outward from the location where the river begins.

2.5 Habitat

Fyfeshire Pond and the surrounding upland are mapped as both Priority Habitat under the jurisdiction of the Massachusetts Endangered Species Act (MESA) and Estimated Habitat under the Wetlands Protection Act (WPA). An Information Request was submitted to the Natural Heritage and Endangered Species Program (NHESP) to determine what species have been documented in the project area and to request a preliminary assessment of the potential impact of the proposed project on state listed species.

NHESP reports that Blanding's Turtle (Emydoidea blandingii) has been found in the vicinity of the site. The NHESP information sheet on this turtle includes the following description:

> *a mid-sized turtle ranging between 16 and 22 cm (6-9 in.) in shell length. Its high-domed carapace (top shell) is dark and covered with pale yellow flecking. The lower shell (plastron) is yellow with large black blotches on the outer posterior corner of each scute (scale). The plastron is hinged, allowing movement; however, the shell does not close tightly. In older individuals, the entire plastron may be black. The most distinguishing feature is its long, yellow throat and chin, which makes it recognizable at a distance. Males have slightly concave plastrons, females have flat plastrons. The tails of males are thicker and their cloacal opening (the common orifice of the digestive, reproductive and urinary systems) is located beyond the edge of the carapace. Hatchlings have a brown carapace and brown to black plastron, and range between 3.4 and 3.7 cm (1.3-1.5 in.) in length* (NHESP 2007).

Blanding's turtles use both upland and wetland habitat, and overwinter in wetlands during their inactive season. One of the dam caretakers stated during a site visit that the turtles have been observed passing between Fyfeshire Pond and wetland areas downstream via a natural low area west of and adjacent to the dam that may serve as an auxiliary spillway for the impoundment.

In addition to NHESP comments, the Massachusetts Department of Fish and Wildlife Division of Fisheries ('Fisheries") also contributed comments. Fisheries stated that the receiving stream from the dam, North Brook, is a coldwater fisheries resource, which is rare within the SuAsCo watershed.

Fourteen species of fish have been found during surveys, including American eel (*Anguilla rostrata*), blacknose dace (*Rhinichthys atratulus*), bluegill (*Lepomis macrochirus*), native brook trout (*Salvelinus fontinalis*), brown bullhead (*Ameiurus nebulosus*), reproducing brown trout (*Salmo trutta*), chain pickerel (*Esox niger*), fallfish (*Semotilus corporalis*), golden shiner (*Notemigonus crysoleucas*), largemouth bass (*Micropterus salmoides*), pumpkinseed (*Lepomis gibbosus*), redfin pickerel (*Esox americaitus*), white sucker (*Catastomus commersoni*) and yellow bullhead (*Ameiurus natalis*). Fisheries also stated that the brook is annually stocked with brook trout, brown trout, rainbow trout (*Oncorhynchus mykiss*) and tiger trout (*Salmo trutta x Salvelinus fontinalis*).

Native, eastern brook trout is a high priority for conservation for several groups active in Massachusetts, including the Eastern Brook Trout Joint Venture and the Association of Fish and Wildlife Agencies. Since the resource is unique, Fisheries stated in the response letter that they are in favor of either removing the dam in its entirety or creating a breach of adequate size such that it no longer impounds water. NHESP also added a comment that removal of the dam or creating a breach in the dam such that it no longer impounds water are compatible with Blanding's Turtle, subject to slow drawdown of the impoundment only during seasons when the turtles are active (May 15 through October 1).

2.5.1 Historical Resources

The site where Fyfeshire Pond Dam is located, know as Fyfeshire, is a historical resource of local significance, and the location is listed with the Massachusetts Historical Commission. The conservation area, approximately 31 acres in size, is listed in its entirety, with several resources identified. Of particular interest is the small pond upstream of Fyfeshire Pond which is thought to be the location of a button factory that operated during the late 19th century, and was perhaps earlier operated as a comb factory. The age and use of Fyfeshire Pond Dam is not clear based on the historical record, other than its inclusion on the property. A letter to the Massachusetts Historical Commission requesting information was prepared and submitted. At this time, no response to the letter has been received.

3.0 HYDROLOGIC AND HYDRAULIC (H&H) ASSESSMENTS

3.1 Spillway Design Flood Capacity Assessment

The significant hazard class and small size of Fyfeshire Pond Dam, an existing dam, dictate that the spillway must safely pass the 100-year storm (the Spillway Design Flood, or SDF) per 302 CMR 10.00. Since no documentation regarding the dam's spillway capacity appears to exist, a hydraulic assessment was completed as part of this project. Adequate freeboard is generally preferred between the peak water surface elevation and the top of the dam such that waves do not cause overtopping. For a small impoundment such as Fyfeshire Pond, adequate freeboard is generally considered to be one foot.

From the National Weather Bureau Technical Paper 40 (TP-40) (Hershfield 1961), the 100-year precipitation event consists of approximately 6.6 inches of precipitation in 24 hours. This rainfall quantity was routed through the pond as described in *Section 3.3* to assess the capacity of the dam's spillway.

Results suggest that the spillway capacity is inadequate; the dam is predicted to overtop slightly, by less than 0.1 inch during a 100-year storm. Any wave action occurring under these conditions could cause the dam to overtop more severely. This is a minor depth of overtopping, and small variations in the design of the structure could be effective in allowing the dam to safely pass the SDF. By raising the top of the dam (dam crest) slightly, to elevation 372.0 feet from the current low point of approximately 370.7 feet, the SDF may pass through the spillway with 1.3 feet of freeboard, which is sufficient for design purposes. As such, raising the dam crest was included in each alternative presented in *Section 4.0* other than the Dam Removal alternative.

Additionally, beaver activity is known to be an issue at this location. Beaver have partially blocked the spillway with debris in the past, causing the water surface elevation to rise, and constant maintenance is required by Town personnel to keep the normal pool impoundment level from rising. Repair alternatives, therefore, should also consider methods to prevent blockage by beaver.

It is important to note that, during the 25-year storm and larger storms, a low area located west of the dam in natural ground begins to flow as an emergency spillway. This area was included in the hydraulic analyses as such. Since the flow path is a long distance over natural ground, significant or damaging erosion of this area during overflow is not anticipated. The Dam Safety regulations do allow emergency or auxiliary spillways that, for a significant hazard, small size dam, begin to pass flow for storms with 25-year recurrence intervals and less frequent.

3.2 Hazard Class Assessment

Prior to a jurisdictional inspection performed on behalf of the Office of Dam Safety on July 18, 2007 (Tighe & Bond 2007), Fyfeshire Pond Dam was considered not to be within Office of Dam Safety jurisdiction. However, the jurisdictional inspector found the dam to be of significant hazard potential based on potential damage to Collins Road in Berlin and low-lying homes along Lancaster Road.

As a first step in confirming the significant hazard potential of the structure, a hydrologic and hydraulic assessment of the Collins Road culvert and crossing was performed as part of the project. Elements describing the Collins Road crossing, a broad wetland upstream of the crossing, and the drainage area to the culvert design point were included in the hydrologic model. The model was then run for a number of design storms to determine the culvert capacity.

Results indicate that the culvert is likely to be undersized. The culvert is a 30-inch reinforced concrete pipe with approximately one foot of freeboard available above the inlet crown of the culvert. Results suggest that the culvert cannot pass a 5-year storm without the roadway overtopping slightly. As such, during the SDF, Collins Road is likely to overtop by approximately 0.7 feet without a dam breach. A concurrent breach of the dam could exacerbate flooding and damage that may already be occurring. As such, a 'significant' hazard classification for the structure is appropriate. Although this analysis is somewhat conservative, additional or more detailed hydraulic analysis, such as using the computer program HEC RAS, is not expected to yield a significantly different result.

3.3 Model Description

The hydrologic and hydraulic model used for this report, presented in *Appendix B*, was prepared using the Army Corps of Engineers Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) Version 3.3. HEC-HMS incorporates the TR-55 rainfall/runoff routing method, which was used for this project. The model was developed for predicting peak water surface elevation impounded by Fyfeshire Pond Dam resulting from 2, 5, 10, 25, 50 and 100-year storm events. The rainfall/runoff hydrograph developed for each storm event was routed through stream reaches, sub-basins, Fyfeshire Pond Dam, the small attenuation dam upstream of Fyfeshire Pond, and the culvert conveying stormwater under Collins Road. Elevations of the existing spillway, dam crest, and other features are variable, conservative value were selected for analysis. These include:

- Spillway elevation - 366.61 feet
- Top of the dam - 370.70 feet (lowest elevation surveyed)
- Low area serving as emergency spillway - 369.44 feet.

A detailed list of model parameters for Fyfeshire Pond Dam, the upstream attenuation pond, and Collins Road culvert are presented in *Appendix B*.

The hydrologic and hydraulic properties of the watershed and streams were determined from available topographic, land use, soils, hydrography, recent land survey data, and typical literature values. A composite curve number for each of five sub-basins were determined from land use and hydrologic soils group and range from 50.3 to 67.9. Storm hyetographs are based on the Soil Conservation Service Type III storm events, with storm depths determined from TP-40. *Appendix B* presents the model elements and hydraulic and hydrologic parameters used in the HEC-HMS model.

3.4 Model Validation

Although no flow data is known to exist for the project area, the Berlin, Massachusetts Flood Insurance Rate Map (FIRM) presents a peak 100-year flood elevation of 366 feet immediately upstream of Collins Road. Although this elevation was likely determined with different modeling methods than the model prepared for this project, the HEC HMS model predicts a peak 100-year water surface elevation at Collins Road of 366.15 feet, which is within rounding error of the FIRM value. This result validates the accuracy of the model developed for this project.

4.0 GEOTECHNICAL ASSESSMENT

4.1 General

The dam was assessed for seepage and structural stability for the purpose of determining whether structural improvements to the dam are necessary and, if so, what remedial measures should be taken. To accomplish this objective, a soil boring program was undertaken to provide the data necessary to perform the required analyses.

Two borings were performed on the dam crest on October 5 and 15, 2009. Boring B-1 was performed by GeoSearch Drilling of Fitchburg, Massachusetts, and logged by a Fuss & O'Neill engineer. Boring B-2 was performed by Fuss & O'Neill using a hand auger. The locations are indicated on the Figure 1, labeled borings B-1 and B-2.

4.2 Subsurface Explorations

The borings were completed at the site along the crest of the dam in the locations indicated on the attached plan. Boring B-1 was performed the vicinity of the spillway, approximately 20 feet right of the spillway. The other boring, B-2, was performed approximately 10 feet left of the spillway. Boring B-1 was advanced with hollow stem augers to a depth of 50 feet below the dam crest surface. Standard Penetration Testing (ASTM D 1586) and split spoon sampling was performed continuously in the upper 8 feet and at 5-foot intervals thereafter to a depth of 32 feet. The boring was then advanced directly to 50 feet without sampling due to the onset of darkness. Soil samples were classified in accordance with the Unified Soil Classification System (USCS). The hand auger, B-2, was performed using a bucket auger and was advanced to a depth of 18 inches below the crest surface, where the hand auger encountered refusal in cobbles and gravel.

An observation well was installed in boring B-1 at a depth of 20 feet below the dam crest surface to obtain a stabilized groundwater elevation in the dam embankment. The well consisted of 15 feet of 2-inch PVC screen backfilled with sand. PVC riser was installed and covered with a protective casing set in concrete.

4.3 Subsurface Conditions

The soil profile encountered through the dam and underlying foundation soil consisted of approximately 6 feet of embankment fill underlain by a similar natural soil deposit to a depth of approximately 19 feet below the dam crest. Both the embankment fill and the underlying layer to a depth of 19 feet consisted of gravel, rounded stones and cobbles intermixed with smaller quantities of sand and silt. Beneath the gravel and cobbles, sand was encountered from 19 to 32 feet. The boring was advanced to a depth of 50 feet without sampling, where it was terminated. Boring B-2 was terminated when encountering the very dense gravel and cobble layer at approximately 1.5 feet. Although the hand auger was unable to advance below 1.5 feet, it did confirm the presence of the same gravel and cobble fill encountered on the right side of the spillway. The similarity of the fill and the underlying material to a depth of 19 feet is consistent with the method of dam construction 100 years ago, where fill material was generally excavated from the surrounding area. Below the coarse gravel and cobbles sand was encountered to a depth of 32 feet.

Densities of the dam embankment fill and similar underlying natural gravel and cobbles were variable, ranging from loose to very dense; however, these densities are suspect due the chances of directly encountering and breaking stones versus slipping through them. No soil was brought to the surface by the augers during drilling, although stones were observed on the augers near the surface, which would then slip back down the borehole. This is not atypical for this type of soil. There are likely voids in the stone where soil was being lost from the augers. The underlying natural sand below 19 feet ranged from very loose to medium dense.

Groundwater was encountered in the piezometer at a depth 7.4 feet below ground surface during drilling. Ten days later the stabilized depth below ground surface was measured to be 7.5 feet Boring logs are included in Appendix D.

4.4 Stability Analysis

Embankment stability analysis was performed using Galena Version 4.0 software and Bishop's Simplified methodology with circular failure surfaces. The resulting slope stability analysis indicated there is a factor of safety against failure of 0.79 at the highest point of the wall under full pond conditions. Under normal pond elevation conditions (water at the spillway crest), the factor of safety was found to be 1.00. The critical failure surfaces for all scenarios occurred through the near-vertical downstream wall. This dam has no capability of sudden drawdown so no stability analysis was performed for this condition.

The vertical dry-laid field stone wall comprising the down stream face of the dam is over hanging in the area left of the spillway. Not enough information is available on the wall to accurately assess the stability of the wall for sliding and overturning, but the age and condition of the wall provide information that leads to some conclusions concerning wall stability. There appears to have been no sliding of the wall, which would be evidenced by sinkholes at the surface behind the wall or linear unevenness at the base, but there is evidence that the downstream wall is bulging and some stones have fallen out of the wall, especially on the right side of the spillway. This is not unexpected, considering the dam is more than 100 years old. The concrete spillway training walls were reconstructed 20 or 30 years ago with unreinforced concrete. The soil pressures from the abutting earthen embankment are buckling the unreinforced walls, and the steel footbridge may be providing support to the concrete spillway walls.

The subgrade soil is suitably coarse and dense to support a reconstructed dam and spillway, if the dam is to be reconstructed, without any special soil improvement considerations.

4.5 Seepage Analysis

Seepage analysis was performed using soil information obtained from drilling and field observations. We chose the highest point of the dam to analyze. In addition to being the highest point of the dam, this area coincides with minor seepage at the base of the right downstream wall. The analysis indicates there are no excessive gradients or vertical gradients at the toe of the wall within the embankment at normal pond level. There is no confining layer within 50 vertical feet of the top of the embankment that could cause excessive seepage pressure or vertical gradients. Based on the water level in the pond and the piezometric surface measured in the piezometer, the phreatic surface formed is an approximately constant slope through the embankment. At higher elevations in the pond, the phreatic surface indicates the water elevation would intersect the toe of the embankment, which was confirmed by our observations of minor seepage at the toe of the right downstream embankment when the water level was higher, before the beaver debris was removed from the spillway. When analyzed for full pond conditions, where the water level is at the top of the dam, the results indicated a slight upward gradient at the downstream embankment toe. It appears the observed minor seepage is likely a result of voids forming within the embankment itself and not seepage pressure due to confined flow conditions.

4.6 Conclusions

Stability of the dam is inadequate in its present condition, but this dam has been in existence for many years. Over time, the wall has bulged and lost a few face stones, and some minor seepage has occurred. However, if the dam is to be retained and repaired, the spillway must be replaced. This construction will require removal of most of the dam embankment. Therefore, the dam will be effectively rebuilt and the issue of the current instability is not a factor. The alternative is to remove the spillway and dam, which also eliminates the instability issue.

5.0 EVALUATION OF REPAIR ALTERNATIVES

Alternatives selected for the repair of Fyfeshire Pond Dam were selected to address the existing structural deficiencies, ensure that the dam can safely pass the SDF, and otherwise bring the dam into compliance with Office of Dam Safety design regulations and dam safety design practice. The alternatives selected are intended to represent a range of costs, level of historical considerations, and resource area impacts. Two alternatives consider reconstruction of the downstream masonry walls of the dam, while two consider buttressing the downstream side with an earthen embankment. The alternatives do not consider repair of the existing spillway. The unreinforced concrete of the spillway would be unfeasibly difficult to repair, making repair an inviable option.

Dam removal is also considered as an option, as its advantages and disadvantages are important to consider. A discussion of the selected alternatives is presented in the following sections.

The alternatives are designated using a two-digit identifier. The first digit refers to the method of supporting the downstream side of the dam, and the second digit relates to whether a cast-in-place or precast spillway would be used.

Cost estimates included in this section are of budgetary accuracy based on the information available for the writing of this report. Budgetary accuracy cost estimates are generally accurate within a range of -15% to +30%. The cost estimates include estimated monitoring, inspection, and maintenance costs, which for repair alternatives were included for a 50 year design life of the project, and for removal alternatives were included for a two year establishment period.

5.1 Alternative 1.1 – Cast-in-place Spillway with Inlet and Reconstructed Stone Walls

This alternative, shown in *Figure C1.1*, was selected to be consistent with the historical appearance and methods of construction used for the original dam, while providing additional water level control with a new low-level outlet and upstream intake. The spillway would be oriented in a similar manner to the existing dam, and the dry stone masonry wall would be constructed using materials and construction similar to those originally used while meeting current acceptable dam safety construction practices. This alternative includes:

- Reconstruction of the downstream dry stone masonry walls of the dam to similar heights and widths of the existing walls
- Replacement of the existing spillway with a cast-in-place reinforced concrete spillway.
- Installation of a low level outlet to provide control over the impoundment water surface elevation.
    - Since the structure is cast-in-place, the low-level outlet could be constructed adjacent to the spillway weir with a tailrace that joins the weir discharge within the spillway structure. Combining the discharge within the structure would avoid the need for widening the downstream channel and possible wetland disturbance

  - To prevent blockage by beaver, an inlet pipe with trash rack would be installed at a low point in the impoundment upstream, leading into a weir board chamber within the spillway. The weir boards would be used to maintain water surface elevation.
- Removal of trees, shrubs, and other unsuitable woody vegetation from the embankment.
- Establishment of maintainable herbaceous groundcover vegetation to facilitate maintenance and inspection.
- Restoration of armor along the upstream face
- Regrading the crest to a uniform elevation of 372.0 ft to ensure that the dam can safely pass the SDF with adequate freeboard.
- Constructing a new pedestrian footbridge across the spillway.

Casting the spillway in-place allows for formation of a larger, more complex structure. This alternative uses this advantage by including an outlet structure within the spillway that would be more difficult to form using precast methods.

5.1.1 Hydrology and Dam Safety Considerations

This alternative is anticipated to result in slightly increased discharges from the dam during storms under normal circumstances. The existing spillway is 11 feet in width. The width of the weir boards in the outlet structure would effectively add additional spillway width since it would be constantly receiving flow. Under base flow conditions, when pond inflows are relatively constant and the water surface elevation of the pond is not rising or falling, the additional capacity would not affect downstream discharges.

However, during a storm event when inflows increase rapidly, the additional capacity provided by the weir boards would allow the dam to pass more flow, decreasing the attenuation in the pond and increasing downstream flows. The purpose of the dam is not for flood control, and the increase in flows would likely be minor. However, since the Collins Road culvert is likely to be undersized, increases in downstream discharges could impact the road.

If this alternative is selected, additional work should be performed to optimize the capacity of the outlet structure and the primary spillway. For example, if the outlet pipe extending into the impoundment were to drain freely into the weir board chamber, then a decrease in width of the primary spillway could be considered to match existing capacity. However, if a gate closure is provided for the outlet pipe, there is the potential that the gate would be closed during an SDF event, limiting discharge capacity and potentially threatening the dam due to overtopping.

Including a low-level outlet operated by a gate is beneficial from a dam safety perspective, as it would allow the owner to draw down the impoundment if an emergency situation were to arise. Using the gate, the inlet could be closed, allowing personnel to enter the weir board chamber and remove the weir boards more easily to draw down the impoundment.

Additionally, a low-level outlet with pond elevation maintained by weir boards is beneficial for other reasons. Even if the primary spillway were blocked, the inlet pipe could still flow freely. The primary spillway would need to be cleared to ensure capacity for passing storm flows, but this arrangement would provide an additional level of safety against overtopping of the dam as a result of beaver activity.

The embankment repairs proposed as part of this alternative are important dam safety considerations, since they provide protection against future breaching of the dam. Regrading the crest to a uniform elevation will ensure that the dam can safely pass the SDF. Repairing the downstream masonry wall and the spillway will ensure that these components are stable, preventing dam failure that could result from continued decay of these components.

5.1.2 Habitat and Listed Species Considerations

Although disturbance of the site will occur during construction, following completion of the project aquatic, wetland, and upland habitat will remain similar to existing conditions. The pond area and volume will remain approximately the same, North Brook will not be altered, and wetlands downstream of the dam will not be altered provided that any construction-period disturbance that occurs is mitigated properly. This alternative is not anticipated to improve wildlife habitat, including coldwater fisheries habitat that may be improved as part of removal alternatives.

However, the orientation of the inlet pipe provides a measure of defense against beaver activity. Since the inlet pipe extends out into the impoundment, construction of a beaver dam anywhere downstream of the inlet would not cause the impoundment level to rise, since the inlet pipe would be constructed through the beaver dam. Results of beaver activity would still need to be removed to ensure that the primary spillway could still pass the SDF.

5.1.3 Historical Considerations

This alternative is intended to maintain a condition similar to historical conditions such that the appearance and impression of the dam and surrounding area are maintained. The dam will appear to be constructed using historical methods, including the downstream stone masonry wall and concrete spillway. The spillway and embankment would be reconstructed with a similar orientation and location. Necessary differences would include reinforcement in the spillway concrete, which would not be noticeable to the public, the differing orientation of the low-level outlet, and replacement of trees and shrubs on the embankment with grass, which is a required dam safety feature.

5.1.4 Permitting Considerations

This alternative is likely to include a low to moderate permitting effort, and resource area disturbance is likely to be limited to the construction period. It is anticipated that the hydrostatic pressure from the pond will need to be relieved during construction to facilitate earthwork and concrete work, which can be accomplished through a combination of impoundment drawdown and construction of a temporary dam (cofferdam) upstream of Fyfeshire Dam, with water piped around the construction area either by gravity or with a bypass pump.

Since the pond provides fish, wildlife, and bird habitat, and since Blanding's Turtle is present within the impoundment, it would likely be preferable for the pond surface elevation to be maintained throughout construction. If the pond were to be drained to allow work to occur, drawdown should be performed during the Blanding's Turtle active season (May 15 through October 1), and should be performed in accordance with the *2004 Eutrophication and Aquatic Plan Management in Massachusetts Final Generic Environmental Impact Report* (GEIR).

To allow installation of the inlet pipe to the weir board chamber, as well as to excavate parts of the embankment below the upper limit of Bank, excavation of sediment would be required. Excavation of sediment in excess of 100 cubic yards requires application for a 401 Water Quality Certification from Massachusetts DEP, and to obtain certification, sediment quality analysis must be performed. Additionally, projects proposing between 100 and 1,000 cubic yards of dredging are automatically covered under Section 404 of the Clean Water Act, but projects including greater than 1,000 cubic yards of dredging must apply for coverage under the Army Corps of Engineers Programmatic General Permit.

A significant advantage of this project is that, since the downstream masonry wall will be reconstructed, the footprint of the dam is anticipated to remain the same. BVW has been delineated immediately downstream of the dam, and buttressing the dam would result in filling of the BVW, requiring mitigation elsewhere. This alternative may require temporary wetlands disturbance during construction for equipment to access the downstream masonry walls for reconstruction, but the disturbance can then be mitigated in place following completion of the project. Restoration of disturbed wetlands in place where no fill was added, no material was removed, and the hydrogeology of the site remains the same is more straightforward, with a greater likelihood of success, than replication of wetlands in an upland area.

Since this alternative includes additional hydraulic capacities, impacts of this alternative on Collins Road should be considered in more detail once final design is proposed to ensure that the roadway is not adversely impacted. Although the Collins Road culvert is likely to be undersized as it is, damage to the stream crossing following increasing the capacity of Fyfeshire Pond Dam could subject the Town to liability. It may be necessary to apply for a Letter of Map Revision (LOMR) with the Federal Emergency Management Agency (FEMA) and the Towns of Bolton and Berlin for increasing flood flows in a mapped floodplain.

5.1.5 Maintenance and Monitoring Considerations

Maintenance and monitoring of the reconstructed dam under this alternative will be similar to maintenance and monitoring of the existing dam. The caretaker will monitor the spillway to keep it clear of debris. Vegetation on the embankment will be cut and maintained to prevent erosion and the establishment of unsuitable vegetation. The dam will need to be inspected by a professional engineer at the interval specified by the Dam Safety regulations (currently every 5 years). The primary spillway would need to be kept clear of debris, as would the trash rack at the inlet to the low-level outlet. In addition, since an outlet valve may be provided as part of this alternative, the valve should be exercised and greased periodically.

If BVW disturbance occurs, in accordance with the Massachusetts Inland Wetland Replication Guidelines, the mitigation area will need to be monitored by a professional wetland scientist for at least two years following construction to ensure establishment of at least 75% wetland vegetation.

5.1.6 Cost Considerations

This alternative is estimated to cost $471,000. The budgetary estimate range of accuracy associated with this cost is $400,000 to $612, 000 (-15% to +30%). It is the most expensive alternative, but provides the best operational control and would be most resistant to beaver activity.

5.1.7 Funding Opportunities

Not many funding opportunities are available for repair of an existing dam. There may be ways that American Recovery and Reinvestment Act (ARRA) funding could be obtained and leveraged for the proposed project, but specific programs are not clear since the dam does not provide significant flood control and the project would not be expected to improve species habitat. Additionally, ARRA funding may no longer be available once this feasibility study is approved, the preferred alternative selected, and final design plans completed. Most likely, the Town of Bolton would be required to pay for the project.

5.2 Alternative 1.2 – Precast Spillway with Weir Boards and Reconstructed Stone Walls

This alternative, shown in *Figure C1.2*, was selected to be consistent with the historical appearance of the original dam, while providing cost savings through replacing the existing spillway with a precast spillway. The spillway would be oriented in a similar manner to the existing dam, and the dry stone masonry wall would be constructed using materials and construction similar to those originally used while meeting current acceptable dam safety construction practices. Details regarding this alternative include:

- Reconstruction of the downstream dry stone masonry walls of the dam to similar heights and widths of the existing walls
- Replacement of the existing spillway with a precast reinforced concrete spillway.
- Installation of a spillway weir and weir boards within the precast section to provide control over the impoundment water surface elevation.
- Removal of trees, shrubs, and other unsuitable woody vegetation from the embankment.
- Establishment of maintainable herbaceous groundcover vegetation to facilitate maintenance and inspection.
- Restoration of armor along the upstream face
- Regrading the dam crest to a uniform elevation of 372.0 ft to ensure that the dam can safely pass the SDF.
- Constructing a new pedestrian footbridge across the spillway.

Precasting the spillway would likely preclude inclusion of a separate water control structure as proposed in *Alternative 1.1*, so it would be difficult to provide a submerged low-level inlet to avoid blockage by beaver. However, the potential cost savings justifies consideration of this alternative.

5.2.1 Hydrologic and Dam Safety Considerations

This alternative is anticipated to result in identical discharges to the existing structure under all circumstances, since the proposed spillway would be equal in width and invert elevation to the existing structure. As such, the proposed modifications would not impact Collins Road.

The weir boards that could be included within the spillway weir could be used to function as a low-level outlet when removed, similar to the dam immediately upstream of Fyfeshire Pond. To draw down the impoundment, the boards could be removed one at a time. In an emergency situation, such as high flows, weir boards can be difficult to remove. As such, the top weir board would be set at an elevation to ensure that the dam could still pass the SDF with it in place. For storms larger than the SDF, the weir boards could be removed or broken by heavy machinery to increase dam capacity.

Similar to *Alternative 1.1*, the embankment repairs proposed as part of this alternative are the important dam safety considerations, since they provide protection against potential dam failure. Regrading the crest to a uniform elevation will ensure that the dam can safely pass the SDF. Repairing the downstream masonry wall and the spillway will ensure that these components are stable, preventing dam failure that could result from continued decay of these components.

5.2.2 Habitat and Listed Species Considerations

Anticipated habitat and species impacts as part of this alternative are anticipated to be similar to *Alternative 1.1*. Although disturbance of the site will occur during construction, following completion of the project, aquatic, wetland, and upland habitat will remain similar to existing conditions. The pond area and volume will remain approximately the same, North Brook will not be altered, and wetlands downstream of the dam will not be altered provided that any construction-period disturbance that occurs is mitigated properly. A small area of wetlands may be filled, so a wetland mitigation area of 110 square feet has been set aside as part of this alternative, although there is a possibility that the fill could be avoided with careful final design. This alternative is not anticipated to improve wildlife habitat, including coldwater fisheries habitat that may be improved as part of removal alternatives.

5.2.3 Historical Considerations

This alternative is intended to maintain a condition similar to historical conditions such that the appearance and impression of the dam and surrounding area are maintained. The dam will appear to be constructed using historical methods, including the downstream stone masonry wall and concrete spillway. The spillway and embankment would be reconstructed with a similar orientation and location. That the spillway would be precast would not be noticeable to the public compared to casting the spillway in place as proposed in *Alternative 1.1*. Since this alternative would not include an outlet structure, the appearance of this alternative is more consistent with existing conditions.

Necessary differences would include reinforcement in the spillway concrete, which would not be noticeable to the public and replacement of trees and shrubs on the embankment with grass, which is a required dam safety feature. Since there are fewer differences between the existing structure and the structure proposed under this alternative than other alternatives, this alternative may be preferable from a historical resources perspective.

5.2.4 Permitting Considerations

Alternative 1.2 is likely to include a low to moderate permitting effort, with the majority of resource area disturbance limited to the construction period. Permitting considerations are expected to be similar to *Alternative 1.1*, with the exception of flow impacts to Collins Road. Since the spillway elevation and width proposed under this alternative are the same to existing conditions, flood flows at Collins Road will not change.

Otherwise, it is anticipated that the hydrostatic pressure from the pond will need to be relieved during construction to facilitate earthwork and concrete work, which can be accomplished through a combination of impoundment drawdown and construction of a temporary dam upstream of Fyfeshire Dam, with water piped around the construction area either by gravity or with a bypass pump.

Since the pond provides fish, wildlife, and bird habitat, and since Blanding's Turtle is present within the impoundment, it would likely be preferable for the pond surface elevation to be maintained throughout construction. If the pond were to be drained to allow work to occur, drawdown should be performed during the Blanding's Turtle active season (May 15 through October 1), and should be performed in accordance with the *2004 Eutrophication and Aquatic Plan Management in Massachusetts Final Generic Environmental Impact Report* (GEIR).

To excavate parts of the embankment below the upper limit of Bank, excavation of sediment would be required. Excavation of sediment in excess of 100 cubic yards requires application for a 401 Water Quality Certification from Massachusetts DEP, and to obtain certification, sediment quality analysis must be performed. Additionally, projects proposing between 100 and 1,000 cubic yards of dredging are automatically covered under Section 404 of the Clean Water Act, but projects including greater than 1,000 cubic yards of dredging must apply for coverage under the Army Corps of Engineers Programmatic General Permit.

A significant advantage of this project is that, since the downstream masonry wall will be reconstructed, the footprint of the dam is anticipated to remain the same. BVW has been delineated immediately downstream of the dam, and buttressing the dam would result in filling of the BVW, requiring mitigation elsewhere. This alternative may require temporary wetlands disturbance during construction for equipment to access the downstream masonry walls for reconstruction, but the disturbance can then be mitigated in place following completion of the project. Restoration of disturbed wetlands in place where no fill was added, no material was removed, and the hydrogeology of the site remains the same is more straightforward than restoration elsewhere, with a greater likelihood of success.

However, since the proposed spillway structure would be precast, less flexibility exists in its construction. Since the existing spillway is angled slightly, it may be necessary for the eastern corner of the spillway to project into the impoundment slightly, resulting in a small area of wetland fill. As such, a mitigation area has been set aside as part of this alternative in case it is necessary. Careful final design may preclude the need for this mitigation area.

5.2.5 Maintenance and Monitoring Considerations

Maintenance and monitoring of the reconstructed dam under this alternative will be similar to maintenance and monitoring of the existing dam. The caretaker will monitor the spillway to keep it clear of debris. Vegetation on the embankment will be cut and maintained to prevent erosion and the establishment of unsuitable vegetation. The dam will need to be inspected by a professional engineer at the interval specified by the Dam Safety regulations (currently every 5 years). The primary spillway would need to be kept clear of debris. No gate is included, reducing required maintenance somewhat by eliminating the need to grease and exercise the operator.

If BVW disturbance occurs, in accordance with the Massachusetts Inland Wetland Replication Guidelines, the mitigation area will need to be monitored by a professional wetland scientist for at least two years following construction to ensure establishment of at least 75% wetland vegetation.

5.2.6 Cost Considerations

This alternative is estimated to cost $455,000. The budgetary estimate range of accuracy associated with this cost is $387,000 to $592,000 (-15% to +30%). It is the least expensive alternative involving repair and is most consistent with the current appearance and operation of the dam. However, the structure would remain susceptible to beaver blockage.

5.2.7 Funding Opportunities

As described in *Alternative 1.1*, few funding opportunities are available for repair of an existing dam. There may be ways that American Recovery and Reinvestment Act (ARRA) funding could be obtained and leveraged for the proposed project, but specific programs are not clear since the dam does not provide significant flood control and the project would not be expected to improve species habitat. Additionally, ARRA funding may no longer be available once this feasibility study is approved, the preferred alternative selected, and final design plans completed. Most likely, the Town of Bolton would be required to pay for the project.

5.3 Alternative 2.1 – Cast-in-place Spillway with Buttressing Downstream Face

This alternative, shown in *Figure C2.1*, was selected to save costs compared to reconstructing the downstream masonry walls, since reconstruction of those walls requires handwork and is likely to be costly. The spillway would still need to be replaced, and under this alternative the replacement spillway would be cast-in-place concrete. The downstream walls of the structure would be buttressed with dumped stone, which would lie at a stable slope of approximately 2H:1V.

Since the proposed improvements to the dam will result in a structure that is much wider at the base than the existing structure, the spillway will need to be extended beyond the proposed toe of the fill slope. This alternative would not be consistent with the historical appearance of the site, but it would maintain the resource values of the impoundment and the overall impression of the conservation property. Details regarding this alternative include:

- Buttressing the downstream masonry walls of the dam with dumped stone placed at a 2H:1V slope.
- Replacement of the existing spillway with a cast-in-place reinforced concrete spillway.
- Installation of a low level outlet to provide drawdown capacity, but without the weir board control structure included in Alternative 1.1.
- Removal of trees, shrubs, and other unsuitable woody vegetation from the embankment.
- Establishment of maintainable herbaceous groundcover vegetation to facilitate maintenance and inspection.
- Restoration of armor along the upstream face
- Regrading the dam crest to a uniform elevation of 372.0 ft to ensure that the dam can safely pass the SDF.
- Constructing a new pedestrian footbridge across the spillway.

Since the spillway proposed under this alternative must be longer than in Alternatives 1.1. and 1.2, the quantity of concrete work required is much greater, so the adjacent water level control structure considered in Alternative 1.1 is not included, and instead an inlet pipe extending into the impoundment and terminating at the spillway weir with a gate on the downstream side is substituted.

5.3.1 Hydrology and Dam Safety Considerations

This alternative is anticipated to result in discharges identical to the existing structure under all circumstances, since the proposed spillway would be equal in width and invert elevation to the existing structure. As such, the proposed modifications would not impact Collins Road.

This alternative provides a compromise between *Alternative 1.1*, which is designed to maintain the pond elevation at normal pool even if the spillway were to become blocked by beaver activity, and Alternatives 1.2 and 2.2, which do not provide protection against blockage by beaver. This alternative would include an inlet pipe extending into the impoundment, but would not include a weir board rack downstream from the discharge point of the pipe. As such, under typical operation of Alternative 2.1, the gate would be closed and the spillway would maintain the water surface elevation of the impoundment. If the spillway were to become blocked, the gate could be manually opened to reduce the water level until the blockage could be removed. Additionally, the gate could be used for impoundment drawdown during emergencies or for management of invasive aquatic species if they become a concern.

Similar to the other alternatives presented, the embankment repairs proposed as part of this alternative are important dam safety considerations, since they provide protection against future dam failure. Regrading the crest to a uniform elevation will ensure that the dam can safely pass the SDF. Buttressing the downstream masonry wall will restore the stability of the dam, and reconstruction of the spillway will ensure that these components are stable, preventing dam failure that could result from continued decay of these components.

5.3.2 Habitat and Listed Species Considerations

Disturbance of the site will occur during construction, and following construction some mitigation of lost resources will be required. Aquatic and upland habitat will remain similar to existing conditions, but wetland fill will be required on the downstream side of the dam to support the stone buttress slopes. This alternative is not anticipated to improve wildlife habitat, including coldwater fisheries habitat that would be improved as part of removal alternatives.

However, the inlet pipe provides a measure of defense against beaver activity. Since the inlet pipe extends out into the impoundment, if the spillway becomes blocked by beaver activity, the caretaker could open the inlet gate to restore the water surface elevation of the pond until the material could be removed.

5.3.3 Historical Considerations

This alternative would not be consistent with the historical construction methods or orientation of the dam. Following construction, the dam would appear to be a new structure that was constructed with modern methods. However, the condition of the pond would remain similar to current conditions and would remain the dominant feature of the surrounding conservation area.

5.3.4 Permitting Considerations

This alternative is likely to require a moderate permitting effort, with temporary resource area disturbance during construction and permanent disturbance requiring mitigation elsewhere.

There are many similarities in permitting considerations between this alternative and *Alternative 1.1*. It is anticipated that the hydrostatic pressure from the pond will need to be relieved during construction to facilitate earthwork and concrete work, which can be accomplished through a combination of impoundment drawdown and construction of a temporary dam upstream of Fyfeshire Dam, with water piped around the construction area either by gravity or with a bypass pump.

Since the pond provides fish, wildlife, and bird habitat, and since Blanding's Turtle is present within the impoundment, it would likely be preferable for the pond surface elevation to be maintained throughout construction. If the pond were to be drained to allow work to occur, drawdown should be performed during the Blanding's Turtle active season (May 15 through October 1), and should be performed in accordance with the *2004 Eutrophication and Aquatic Plan Management in Massachusetts Final Generic Environmental Impact Report* (GEIR).

To allow installation of the inlet pipe as well as to excavate parts of the embankment below the upper limit of Bank, excavation of sediment would be required. Excavation of sediment in excess of 100 cubic yards requires application for a 401 Water Quality Certification from Massachusetts DEP, and to obtain certification, sediment quality analysis must be performed. Additionally, projects proposing between 100 and 1,000 cubic yards of dredging are automatically covered under Section 404 of the Clean Water Act, but projects including greater than 1,000 cubic yards of dredging must apply for coverage under the Army Corps of Engineers Programmatic General Permit.

Differences in permitting considerations between this alternative and *Alternative 1.1* are related to buttressing the downstream masonry wall of the dam with stone rather than reconstructing it. Buttressing the wall in this manner will result in a significant widening of the dam on the downstream side, requiring filling of BVW on both the left and right sides of the discharge stream. This wetland filling will require construction of up to 450 square feet of wetlands loss that cannot be mitigated in place.

A potential mitigation area is located downstream of the dam on the west side of the discharge stream, where a peninsula of upland projects eastward into BVW. Groundwater is likely to be relatively high in this area, such that, through regrading and appropriate soil amendment, wetland species could be established in this area. However, the risk of failure exists in constructing wetland mitigation areas, such that unknown future impacts and costs may be incurred if the mitigation area fails to meet applicable performance criteria.

5.3.5 Maintenance and Monitoring Considerations

Maintenance and monitoring of the reconstructed dam under this alternative will be similar to maintenance and monitoring of the existing dam. The caretaker will monitor the spillway to keep it clear of debris. Vegetation on the embankment will be cut and maintained to prevent erosion and the establishment of unsuitable vegetation. If the dam is buttressed with dumped stone on the downstream side, it may not be necessary to maintain grass cover if the stone resists erosion. If finer soils are used for the buttressed slopes, groundcover vegetation will be necessary, which will require periodic mowing.

The dam will need to be inspected by a professional engineer at the interval specified by the Dam Safety regulations (currently every 5 years). The primary spillway would need to be kept clear of debris, as would the trash rack at the inlet to the low-level outlet. In addition, since an outlet valve would be provided as part of this alternative, the valve should be exercised and greased periodically.

Since BVW disturbance is likely, in accordance with the Massachusetts Inland Wetland Replication Guidelines, the mitigation area will need to be monitored by a professional wetland scientist for at least two years following construction to ensure establishment of at least 75% wetland vegetation. If this performance criterion is not met, additional work will be required, such as regrading, replanting, or improving soil conditions, to ensure success.

5.3.6 Cost Considerations

This alternative is estimated to cost $462,000. The budgetary estimate range of accuracy associated with this cost is $393,000 to $601,000 (-15% to +30%). It is within the range of costs of other alternatives and provides a means of manually thwarting beaver blockage, although the appearance of the structure would not be consistent with its historical appearance.

5.3.7 Funding Opportunities

Limited funding opportunities exist for repair of an existing dam. There may be ways that American Recovery and Reinvestment Act (ARRA) funding could be obtained and leveraged for the proposed project, but specific programs are not clear since the dam does not provide significant flood control and the project would not be expected to improve species habitat. Additionally, ARRA funding may no longer be available once this feasibility study is approved, the preferred alternative selected, and final design plans completed. Most likely, the Town of Bolton would be required to pay for the project.

5.4 Alternative 2.2 – Precast Spillway with Buttressing the Downstream Face

This alternative, shown in *Figure C2.2*, was selected to be the least costly alternative, through pre-casting the replacement spillway, buttressing the downstream face of the dam with fill material rather than rebuilding the downstream masonry walls, and providing weir boards for a low-level outlet rather than an intake pipe and valve. This alternative is similar to *Alternative 2.1* in most ways, with the exception of the spillway casting method and the inlet pipe.

5.4.1 Hydrology and Dam Safety Considerations

This alternative is anticipated to result in discharges identical to the existing structure under all circumstances, since the proposed spillway would be equal in width and invert elevation to the existing structure. As such, the proposed modifications would not impact Collins Road.

This alternative would be similar in operation to *Alternative 1.2*, since weir boards would be provided for pond drawdown in place of a more advanced low level outlet arrangement. Under normal conditions, weir boards would be installed to the elevation of the existing spillway weir. To draw down the impoundment, the boards could be removed one at a time. In an emergency situation, such as high flows, weir boards can be difficult to remove, so they cannot be dependably removed in some emergency situations where additional capacity is required, such as a storm larger than the SDF, or back to back storms. As such, the top weir board would be set at an elevation to ensure that the dam could still pass the SDF with it in place. For storms larger than the SDF, the weir boards could be removed or broken by heavy machinery to increase dam capacity.

Similar to the other alternatives presented, the embankment repairs proposed as part of this alternative are important dam safety considerations, since they provide protection against future dam failure. Regrading the crest to a uniform elevation will ensure that the dam can safely pass the SDF. Buttressing the downstream masonry wall will restore the stability of the dam, and reconstruction of the spillway will ensure that these components are stable, preventing dam failure that could result from continued decay of these components.

5.4.2 Habitat and Listed Species Considerations

Disturbance of the site will occur during construction, and following construction some mitigation of lost resources will be required. Aquatic and upland habitat will remain similar to existing conditions, but wetland fill will be required on the downstream side of the dam to support the stone buttress slopes. This alternative is not anticipated to improve wildlife habitat, including coldwater fisheries habitat that would be improved as part of removal alternatives. Additionally, this alternative also does not provide a means to reduce the impact of beaver activity. Debris would need to be removed manually as it accumulates.

5.4.3 Historical Considerations

As in *Alternative 2.1*, this alternative would not be consistent with the historical construction methods or orientation of the dam. Following construction, the dam would appear to be a new structure that was constructed with modern methods. However, the condition of the pond would remain similar to current conditions and would remain the dominant feature of the surrounding conservation area.

5.4.4 Permitting Considerations

Permitting considerations anticipated under this alternative are equal to permitting considerations in *Alternative 2.1*, except for dredging for installation of the low level inlet pipe. The permitting effort is likely to be moderate, with temporary resource area disturbance during construction and permanent disturbance requiring mitigation elsewhere.

It is anticipated that the hydrostatic pressure from the pond will need to be relieved during construction to facilitate earthwork and concrete work, which can be accomplished through a combination of impoundment drawdown and construction of a temporary dam upstream of Fyfeshire Dam, with water piped around the construction area either by gravity or with a bypass pump.

Since the pond provides fish, wildlife, and bird habitat, and since Blanding's Turtle is present within the impoundment, it would likely be preferable for the pond surface elevation to be maintained throughout construction. If the pond were to be drained to allow work to occur, drawdown should be performed during the Blanding's Turtle active season (May 15 through October 1), and should be performed in accordance with the *2004 Eutrophication and Aquatic Plan Management in Massachusetts Final Generic Environmental Impact Report* (GEIR).

Parts of the embankment below the upper limit of Bank would be considered 'dredged material' if removed under 314 CMR 9.00, and since excavation of this material for installation of the spillway structure could trip permitting thresholds. Excavation of dredged material in excess of 100 cubic yards requires application for a 401 Water Quality Certification from Massachusetts DEP, and to obtain certification, sediment quality analysis must be performed. Additionally, projects proposing between 100 and 1,000 cubic yards of dredging are automatically covered under Section 404 of the Clean Water Act, but projects including greater than 1,000 cubic yards of dredging must apply for coverage under the Army Corps of Engineers Programmatic General Permit.

Differences in permitting considerations between this alternative and *Alternatives 1.1* and *1.2* are related to buttressing the downstream masonry wall of the dam with stone rather than reconstructing it. Buttressing the wall in this manner will result in a significant widening of the dam on the downstream side, requiring filling of BVW on both the left and right sides of the discharge stream. This wetland filling will require construction of up to 450 square feet of wetlands loss that cannot be mitigated in place.

A potential mitigation area is located downstream of the dam on the west side of the discharge stream, where a peninsula of upland projects eastward into BVW. Groundwater is likely to be relatively high in this area, such that, through regrading and appropriate soil amendment, wetland species could be established in this area. However, the risk of failure exists in constructing wetland mitigation areas, such that unknown future impacts and costs may be incurred if the mitigation area fails to meet applicable performance criteria.

5.4.5 Maintenance and Monitoring Considerations

Maintenance and monitoring of the reconstructed dam under this alternative will be similar to maintenance and monitoring of the existing dam. The caretaker will monitor the spillway to keep it clear of debris. Vegetation on the embankment will be cut and maintained to prevent erosion and the establishment of unsuitable vegetation. If the dam is buttressed with dumped stone on the downstream side, it may not be necessary to maintain grass cover if the stone resists erosion. If finer soils are used for the buttressed slopes, groundcover vegetation will be necessary, which will require periodic mowing.

The dam will need to be inspected by a professional engineer at the interval specified by the Dam Safety regulations (currently every 5 years). The primary spillway would need to be kept clear of debris to maintain capacity.

Since BVW disturbance is likely, in accordance with the Massachusetts Inland Wetland Replication Guidelines, the mitigation area will need to be monitored by a professional wetland scientist for at least two years following construction to ensure establishment of at least 75% wetland vegetation. If this performance criterion is not met, additional work will be required, such as regrading, replanting, or improving soil conditions, to ensure success.

5.4.6 Cost Considerations

This alternative is estimated to cost $463,000. The budgetary estimate range of accuracy associated with this cost is $394,000 to $602,000 (-15% to +30%). It is within the range of costs provided by the other repair alternatives and is not significantly different in cost that *Alternative 2.1*. This alternative provides no advantages over other alternatives, since the structure would remain susceptible to beaver blockage, and the precast method of construction has no cost advantage over cast-in-place construction with a spillway of the size required. Additionally, this alternative does not maintain the historical appearance of the structure.

5.4.7 Funding Opportunities

Limited funding opportunities exist for repair of an existing dam. There may be ways that American Recovery and Reinvestment Act (ARRA) funding could be obtained and leveraged for the proposed project, but specific programs are not clear since the dam does not provide significant flood control and the project would not be expected to improve species habitat. Additionally, ARRA funding may no longer be available once this feasibility study is approved, the preferred alternative selected, and final design plans completed. Most likely, the Town of Bolton would be required to pay for the project.

5.5 Alternative 3.0 – Partial Removal

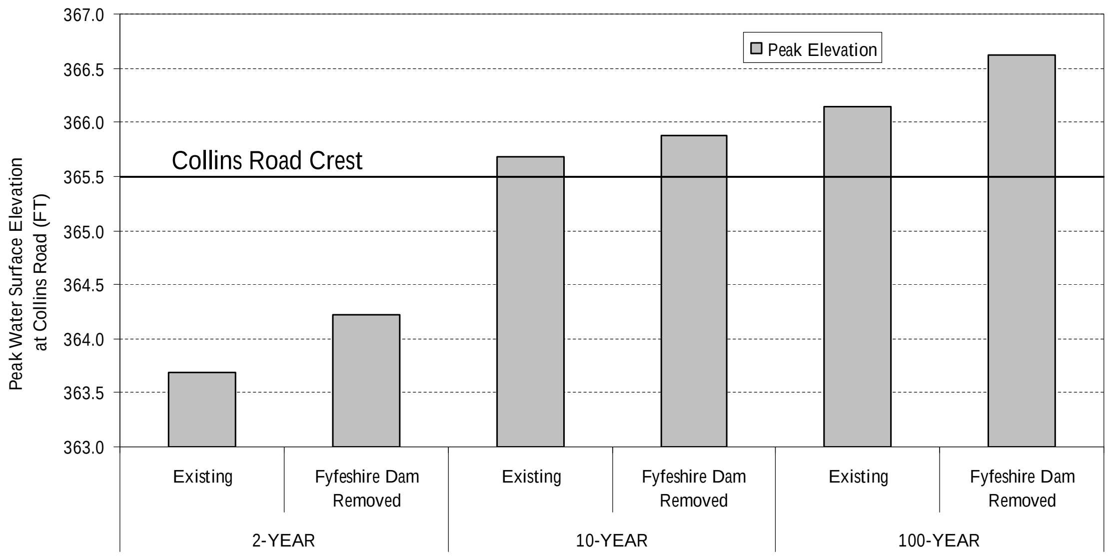
This alternative includes partial removal of Fyfeshire Pond Dam through excavation of a breach in the dam such that the dam no longer impounds water. The breach would be constructed to keep the majority of impounded sediment in place, while providing fish passage and enhancing downstream fish habitat. This alternative includes the following elements:

- Demolish and remove the existing spillway and appurtenances.
- Excavate a section of the embankment surrounding the spillway to meet the existing stream on the downstream side.
- Carve a moderately-sloping stream channel through the sediment beginning at the dam toe and continuing northward.
- Line the channel below the anticipated bankfull width with rounded cobbles and stones bedded in gravel to provide quality substrate and stabilize sediment.
- Deposit log and stone barbs at intervals of approximately 0.25 to 0.5 feet elevation gain to form pools and riffles along the restoration reach and random boulder clusters throughout the restored channel.
- Install an upstream stone and log weir to receive and train the stream through the former impoundment to the upstream end of the restoration reach.
- Allow a stream channel to form naturally on the former pond bottom upstream of the restoration reach.
- Seed and plant sediment surrounding the restoration reach with a mix of native wetland and upland plant species.

These elements were selected since a large quantity of sediment may be present in the former impoundment bottom. The restoration reach would provide a 'ramp' for the stream and aquatic organisms. The ramp would be installed on top of sediment that would otherwise be eroded by the flowing water of a stream, and has accumulated solely because the dam slowed the flow of water, causing the sediment to settle. Although the restoration reach proposed as part of this alternative is intended to appear natural, it is an engineered structure that is working against the tendency of the restored stream to erode the fine materials. Careful execution is critical to its success.

5.5.1 Hydrologic and Dam Safety Considerations

This alternative removes the hazard posed by Fyfeshire Pond Dam on downstream areas, and would eliminate the structure from Office of Dam Safety jurisdiction. The loss of impoundment storage would result in increased peak flows downstream. For example, the HEC HMS model predicts that peak 100-year flows at Collins Road would more than double, from 335 cubic feet per second (cfs) to 693 cfs. The figure below presents predicted peak storm elevations at Collins Road with and without the dam in-place. It is important to note that, in general, the increases in peak flow resulting from dam removal can be acceptable to stream ecology since they often approximate natural conditions; it is the artificial structures in the stream system that are more likely to be adversely impacted from dam removal projects.



Impacts of Dam Removal on Collins Road

The peak flow increases would result in increased water surface elevation in the wetland upstream of Collins Road, increasing the depth of overtopping of Collins Road by approximately 0.5 feet.

However, the increase in overtopping during more typical drainage design events, such as the 10-year storm, is less severe. Currently, the roadway is predicted to overtop by approximately 0.18 ft (approximately 2 inches) during a 10-year event, whereas with the dam removed, the roadway will be overtopped by approximately 0.38 ft (approximately 4.5 inches). An important corollary to increased depth of overtopping during events of a specified size is that there will also be an increased frequency of overtopping of the roadway with the dam removed, as the roadway will be overtopped by storms of smaller sizes.

As such, if the dam is to be removed, the Town of Bolton should coordinate with the Town of Berlin to agree on measures to be taken regarding Collins Road. The culvert should be considered for replacement under any circumstance; since it is undersized, residents dependent on the road may be stranded during storms of relatively small size (a roadway culvert should be designed for at least a 25-year storm). Additionally, since the culvert is small, it is likely to be a barrier to passage of fish and aquatic wildlife. A replacement crossing would need to meet current stream crossing standards, which are currently the *Massachusetts River and Stream Crossing Standards* (RSCP 2006). These standards include:

- Use a bridge or open-bottom culvert.
- Embed abutments in natural substrate.

- Provide a span of at least 1.2 times the bankfull width.
- Provide a natural bottom within the structure.
- Design the crossing and streambed to provide similar water depths and velocities similar to natural conditions for a variety of flows.
- Provide a crossing large enough so that the ratio of cross sectional area (in square meters) divided by the length (in meters) is greater than 0.25.

If removal is the selected alternative, Bolton should consider approaching the Town of Berlin to be a partner in the project and apply for funding for replacement of the Collins Road crossing concurrently.

If Bolton removes Fyfeshire Pond Dam without addressing issues at Collins Road, Bolton could potentially have increased liability associated with storm damage to the road. Conversely, if a repair alternative is selected solely to avoid exacerbating flooding at Collins Road, Bolton taxpayers would be providing flood control for Berlin residents. Neither of these situations is ideal, so it will be important that Bolton consider these issues when deciding on the selected alternative.

5.5.2 Habitat and Listed Species Considerations

Alternatives that include removal, including *Alternatives 3.0* and *4.0*, will provide the most habitat and species benefit in the long term. Permanent impacts are likely to include loss of BVW associated with Fyfeshire Pond, and will include loss of Land Under Water (LUW) when the pond is permanently drawn-down. However, LUW is a relatively common habitat type in the SuAsCo watershed and in Massachusetts at large, whereas Mass Fisheries has found that coldwater fishery habitat is rare.

As such, replacement of an artificial, larger, and more common warm water habitat with a locally rare cold water habitat is a resource area improvement. It is also important to note that the project will result in colder water downstream of the dam since water will no longer be warmed in Fyfeshire Pond, improving coldwater habitat beyond the project limits.

However, it is notable that *Alternative 3.0* includes construction of an engineered restoration channel that will end a short distance into the former impoundment. Stream substrate upstream of the inlet to this channel will likely be characterized by a relatively fine particle size unless it is amended, which is not generally ideal for cold water fish species.

NHESP has indicated on a preliminary basis that removal of the dam can be consistent with avoiding a 'take' of Blanding's Turtle which have been reported near the impoundment. NHESP involvement should begin early in the removal design process to ensure that Blanding's Turtle populations can be maintained.

It is also notable that, to ensure a successful project where fish passage is restored, it may also be necessary to improve the road crossing at Collins Road as mentioned in *Section 5.5.1*.

5.5.3 Historical Considerations

Excavation of a breach in Fyfeshire Pond Dam is not consistent with the historical nature of the pond or property. Massachusetts Historical Commission may require mitigation for loss of the resource. However, the dam upstream of Fyfeshire Pond which would remain in-place is thought to be the structure with the most historical value, so the majority of the property's historical interest would remain. Mitigation for loss of a historically-listed structure may require photographic and written documentation of the structure and its components.

5.5.4 Permitting Considerations

The permitting effort associated with removal of Fyfeshire Pond Dam is likely to be high since the project is likely to result in relatively large areas of wetlands disturbance, wetlands loss, habitat transformation, and flood impacts.

Execution of a dam breaching alternative would require drawdown of the impoundment before work began, and could potentially involve bypassing flows around the work area during construction. Since the pond provides fish, wildlife, and bird habitat, and since Blanding's Turtle is present within the impoundment, drawdown should be performed consistent with these habitat requirements and be limited to the Blanding's Turtle active season (May 15 through October 1), and should be performed in accordance with the *2004 Eutrophication and Aquatic Plan Management in Massachusetts Final Generic Environmental Impact Report* (GEIR).

Soils and sediment below the upper limit of Bank is considered dredged material if removed, and since excavation of this material is required for breaching the dam and constructing the restoration channel, this alternative is likely to trip dredging permitting thresholds. Excavation of sediment in excess of 100 cubic yards requires application for a 401 Water Quality Certification from Massachusetts DEP, and to obtain certification, sediment quality analysis must be performed. Additionally, projects proposing between 100 and 1,000 cubic yards of dredging are automatically covered under Section 404 of the Clean Water Act, but projects including greater than 1,000 cubic yards of dredging must apply for coverage under the Army Corps of Engineers Programmatic General Permit.

Since the project may include loss of certain types of wetland in significant quantities (potentially approaching nine acres based on the impoundment surface area), however, it may be necessary to obtain an individual permit from the Army Corps of Engineers for the proposed project. Typically, an individual permit is required for wetland impacts of greater than 1 acre.

Additionally, this alternative differs from *Alternatives 1.1* through *2.2* in that environmental policy act review is likely to be required. Dam removal projects typically require Massachusetts Environmental Policy Act (MEPA) review since the quantity of wetland impacts, although they include a net benefit, are typically relatively large. The MEPA regulations include several thresholds requiring either an Environmental Notification Form (ENR) or an Environmental Impact Report (EIR) that could be triggered by this project.

In at least one recent instance, MEPA has waived a required EIR in favor of an expanded ENF for dam removal and resource area improvement projects.

This alternative also differs from *Alternatives 1.2* through *2.2* in that the project will result in significant hydraulic changes to a dam located within a flood zone. As such, it will be necessary to coordinate the project with FEMA, model the proposed changes with hydraulic modeling software, and request a Letter of Map Revision (LOMR) from FEMA to present the changes in flood elevations.

Additionally, since the proposed dam breach would include an engineered restoration channel to allow much of the sediment to remain in-place, this alternative may not be as acceptable to the regulating community as complete removal with removal of much of the sediment. Although the restoration channel would be designed to mimic coldwater fish species native habitat, the habitat may not continue beyond the upstream end of the channel since the stream substrate would be fine grained material. Additionally, there is potential for the condition of the restoration channel to degrade in the future if not properly designed or constructed, decreasing the habitat quality and potentially releasing sediment.

5.5.5 Maintenance and Monitoring Considerations

Since the proposed project will require local and state wetland permitting, the implemented wetland restoration areas will require monitoring for at least two years following construction to ensure establishment of at least 75% native wetland species. Other monitoring may be required depending on whether grants are received for construction that includes monitoring requirements.

The Town of Bolton should also consider conducting monitoring on their own on a long-term basis, since the Conservation Commission will have expended significant staff and volunteer effort in planning and executing the project and a successful project benefits the resources that are subject to their jurisdiction.

However, once the dam is breached, the status of the dam can be changed to 'non-jurisdictional' in the Office of Dam Safety database, and no future dam safety inspections will be required unless an unforeseen change in regulation occurs.

5.5.6 Cost Considerations

This alternative is estimated to cost $324,000. The budgetary estimate range of accuracy associated with this cost is $275,000 to $421,000 (-15% to +30%). It is the least expensive alternative overall, and is likely to improve downstream coldwater fisheries water quality, but may be difficult to design and construct properly, and may provide only limited fish passage.

5.5.7 Funding Opportunities

Since this alternative would include improvement of a rare variety of resource area, a number of potential grant program opportunities may exist for investigation, design, permitting, and construction. Some are not offered each year, and deadline dates, quantity of funding, and other attributes vary annually. Additionally, some of the grant programs include local match requirements, which would require the Town of Bolton to fund the project in part, but the cost of the project to the Town may still be substantially reduced. It is also likely that replacement of the Collins Road culvert could be included as part of a more comprehensive restoration project and could also qualify for funding. *Table 2* presents a summary of grant application programs for which the project may qualify.

5.5.8 Additional Investigation Required

This alternative will require additional investigation to allow for proper design. These investigations will include:

- Impoundment depth and sediment depth measurements in the area upstream of the dam to determine the depth of sediment and the volume of sediment removal required.
- Physical analysis of sediment to determine its engineering characteristics such as grain size distribution, permeability, and organic material content to facilitate understanding of its behavior if left in place.
- Chemical analysis of sediment as required by the 401 Water Quality Certification regulations, to determine whether the material is clean or if it contains concentrations of contaminants that would limit its reuse or disposal.
- Examination of reference reaches along the stream corridor to aid restoration reach design.
- Identification of sediment reuse options.
- Coordination with the Town of Berlin regarding the Collins Road culvert, and preparation of a replacement design that conforms to the Massachusetts Stream Crossing Standards.
- Perform a Wildlife Habitat Evaluation for resource areas to be impacted as required by 310 CMR 10.60.

5.6 Alternative 4.0 – Complete Removal

This alternative includes complete removal of Fyfeshire Pond Dam through excavation of the dam embankment and removal of sediment to the hard natural bottom of the impoundment along the likely historical stream channels through the impoundment. Stream reaches upstream and downstream of the dam would be inspected and measured for substrate type, bank characteristics, floodplain, slope, and dimensions. The restored reaches would be constructed to mimic reference reaches. The area surrounding the stream would be planted with native wetland and facultative plant species, and a riparian buffer would be planted surrounding the stream. This alternative includes the following elements:

- Demolish and remove the existing spillway and appurtenances.
- Excavate the dam embankment.
- Excavate sediment along stream reaches from the outlet of the dam to the locations of the former tributary mouths within the stream channel and to form viable overbank floodplain area.
- Place anchored woody debris, boulder clusters, and rounded cobbles along the proposed stream channel below the anticipated bankfull width to match references reaches.

- Allow a stream channel to form naturally on the former pond bottom upstream of the restoration reach.
- Seed and plant sediment surrounding the restoration reach with a mix of native wetland and upland plant species, focusing wetland plants in a fringe surrounding the stream, surrounded by an upland riparian corridor of native species that will grow to provide shade for the restoration reach.

This alternative is likely to provide more habitat that is favorable to coldwater fish species than *Alternative 3.0* since the restoration reach will more closely mimic natural conditions, as if the dam had not existed. However, the improved performance comes at what is likely to be a significant cost; the quantity of sediment that would require removal and reuse or disposal may be far greater than would be required by *Alternative 3.0*.

5.6.1 Hydrologic and Dam Safety Considerations

The hydrologic and dam safety considerations that relate to *Alternative 4.0* are, for the most part, identical to *Alternative 3.0*, so refer to *Section 5.5.1* for a detailed discussion. Generally, the restored channel provided in Alternative 4.0 is likely to have a similar capacity to that in *Alternative 3.0*, and will result in similar increases in downstream flows and water levels at Collins Road. It is important to note that, in general, the increases in peak flow resulting from dam removal can be acceptable to stream ecology since they are anticipated to approximate natural conditions; it is the artificial structures in the stream system that are more likely to be adversely impacted from dam removal projects.

5.6.2 Habitat and Listed Species Considerations

Alternatives that include removal, including *Alternatives 3.0* and *4.0*, will provide the most habitat and species benefit in the long term. Permanent impacts are likely to include loss of BVW associated with Fyfeshire Pond, and will include loss of Land Under Water (LUW) when the pond is permanently drawn-down. However, LUW is a relatively common habitat type in the SuAsCo watershed and in Massachusetts at large, whereas Mass Fisheries has found that coldwater fishery habitat is relatively rare.

As such, replacement of an artificial, larger, and more common warm water habitat with a locally rare cold water habitat is a resource area improvement. It is also important to note that the project may result in colder water downstream of the dam since water will no longer be warmed in Fyfeshire Pond, improving coldwater habitat beyond the project limits.

From a habitat perspective, *Alternative 4.0* includes a restoration channel that will be intended to approximately natural conditions as nearly as possible, providing an improved opportunity for population by locally native species than the engineered restoration channel that is included in *Alternative 3.0*.

NHESP has indicated on a preliminary basis that removal of the dam can be consistent with avoiding a 'take' of Blanding's Turtle which have been reported near the impoundment. NHESP involvement should begin early in the removal design process to ensure that Blanding's Turtle populations can be maintained.

It is also notable that, to ensure a successful project where fish passage is restored, it may also be necessary to improve the road crossing at Collins Road as mentioned in *Section 5.5.1*.

5.6.3 Historical Considerations

As in *Alternative 3.0*, excavation of a breach in Fyfeshire Pond Dam is not consistent with the historical nature of the pond or property. Massachusetts Historical Commission may require mitigation for loss of the resource. However, the dam upstream of Fyfeshire Pond which would remain in-place is thought to be the structure with the most historical value, so the majority of the property's historical interest would remain. Mitigation for loss of a historically-listed structure may require photographic and written documentation of the structure and its components.

5.6.4 Permitting Considerations

As with *Alternative 3.0*, the permitting effort associated with removal of Fyfeshire Pond Dam is likely to be high since the project is likely to result in relatively large areas of wetlands disturbance, wetlands loss, habitat transformation, and flood impacts. However, *Alternative 4.0* would be a resource area improvement project that is likely to provide more cold water fisheries habitat than other alternatives, which should increase the likelihood of successful and straightforward permitting.

Execution of a dam breaching alternative would require drawdown of the impoundment before work began, and could potentially involve bypassing flows around the work area during construction. Since the pond provides fish, wildlife, and bird habitat, and since Blanding's Turtle is present within the impoundment, drawdown should be performed consistent with these habitat requirements and be limited to the Blanding's Turtle active season (May 15 through October 1), and should be performed in accordance with the *2004 Eutrophication and Aquatic Plan Management in Massachusetts Final Generic Environmental Impact Report* (GEIR).

Soils and sediment below the upper limit of Bank is considered dredged material if removed, and since excavation of this material is required for breaching the dam and constructing the restoration channel, this alternative is likely to trip dredging permitting thresholds. Excavation of sediment in excess of 100 cubic yards requires application for a 401 Water Quality Certification from Massachusetts DEP, and to obtain certification, sediment quality analysis must be performed.

Additionally, projects proposing between 100 and 1,000 cubic yards of dredging are automatically covered under Section 404 of the Clean Water Act, but projects involving between 1,000 and 25,000 cubic yards of dredging must apply for coverage under the Army Corps of Engineers Programmatic General Permit, and projects requiring more than 25,000 cubic yards of dredging will require an Individual Permit. The proposed quantity of dredging as part of this alternative is approximately 500 cubic yards, although disturbance of a greater quantity of sediment for access is likely.

Since the project may include loss of certain types of wetland in significant quantities (potentially approaching nine acres based on the impoundment surface area), however, it may be necessary to obtain an individual permit from the Army Corps of Engineers for the proposed project regardless of the dredging quantity. Typically, an individual permit is required for wetland impacts of greater than 1 acre.

Additionally, this alternative differs from *Alternatives 1.1* through *2.2* in that environmental policy act review is likely to be required. Dam removal projects typically require Massachusetts Environmental Policy Act (MEPA) review since the quantity of wetland impacts, although they include a net benefit, are typically relatively large. The MEPA regulations include several thresholds requiring either an Environmental Notification Form (ENR) or an Environmental Impact Report (EIR) that could be tripped by this project. In at least one recent instance, MEPA has waived a required EIR in favor of an expanded ENF for dam removal and resource area improvement projects.

This alternative also differs from *Alternatives 1.2* through *2.2* in that the project will result in significant hydraulic changes to a dam located within a flood zone. As such, it will be necessary to coordinate the project with FEMA, model the proposed changes with hydraulic modeling software, and request a Letter of Map Revision (LOMR) from FEMA to present the changes in flood elevations.

5.6.5 Cost Considerations

This alternative is estimated to cost $443,000. The budgetary estimate range of accuracy associated with this cost is $377,000 to $576,000 (-15% to +30%). It is more expensive than the partial removal alternative, yet is still less expensive than each of the repair alternatives examined. It is more likely to result in successful fish passage than *Alternative 3.0*, although each will result in similar improvements to downstream habitat through improved temperature and flow regimes.

5.6.6 Maintenance and Monitoring Considerations

Since the proposed project will require local and state wetland permitting, the implemented wetland restoration areas will require monitoring for at least two years following construction to ensure establishment of at least 75 percent native wetland species. Other monitoring may be required depending on whether grants are received for construction that includes monitoring requirements.

The Town of Bolton should also consider conducting monitoring on their own on a long-term basis, since the Conservation Commission will have expended significant staff and volunteer effort in planning and executing the project and a successful project benefits the resources that are subject to their jurisdiction.

However, once the dam is breached, the status of the dam can be changed to 'non-jurisdictional' in the Office of Dam Safety database, and no future dam safety inspections will be required unless an unforeseen change in regulation occurs.

5.6.7 Funding Opportunities

Since this alternative would include improvement of a rare variety of resource area, a number of potential grants may be obtained for investigation, design, permitting, and construction. Some are not offered each year, and deadline dates, quantity of funding, and other attributes vary annually. Additionally, some of the grant programs include local match requirements, which would require the Town of Bolton to fund the project in part, but the cost of the project to the Town may still be greatly reduced. It is also likely that replacement of the Collins Road culvert could be included as part of a more comprehensive restoration project and could also qualify for funding. *Table 2* presents a summary of grant application programs for which the project may qualify.

5.6.8 Additional Investigation Required

This alternative will require additional investigation to allow for proper design. These investigations will include:

- Impoundment depth and sediment depth measurements throughout the impoundment upstream of the dam to determine the depth of sediment, the anticipated restoration channel locations and orientations, and the volume of dredging required.
- Physical analysis of sediment to determine its engineering characteristics such as grain size distribution, permeability, and organic material content to facilitate understanding of its behavior if left in place.
- Chemical analysis of sediment as required by the 401 Water Quality Certification regulations, to determine whether the material is clean or if it contains concentrations of contaminants that would limit its reuse or disposal.
- Examination of reference reaches along the stream corridor to aid restoration reach design.
- Identification of sediment reuse options.
- Coordination with the Town of Berlin regarding the Collins Road culvert, and preparation of a replacement design that conforms to the Massachusetts Stream Crossing Standards.
- Perform a Wildlife Habitat Evaluation for resource areas to be impacted as required by 310 CMR 10.60.

6.0 CONSTRUCTION METHODS

This section presents general guidelines for materials and methods of major components of the project that may occur under any of the alternatives described in this report. These items may not be applicable to every concept; for example, a description of methods for both rebuilding the downstream masonry walls and buttressing the dam on the downstream side are described, even though none of the alternatives include both actions.

6.1 Downstream Masonry Wall Reconstruction

The downstream masonry wall would be reconstructed by a mason, who would most likely disassemble the wall, regrade and recompact the foundation, cut away a small portion of the dam embankment behind it, and rebuild it completely. The space between the replaced stones and the embankment soils would be filled with freely draining sand to ensure that and groundwater pressure is relieved. The reconstructed wall would remain unmortared to allow for free drainage.

A graded filter drain would be necessary to prevent the sand and embankment materials from migrating through the wall. These drains consist of layers of uniformly-graded soils that gradually increase in grain size to prevent embankment soils from being carried by groundwater through voids between stones in the larger adjacent layer. Alternatively, a properly-selected filter fabric could be used for this purpose.

6.2 Embankment Buttressing

Rather than being reconstructed, the downstream masonry wall would be buttressed with dumped stone to resist the forces of frost heaving, water, and erosion that may have caused the existing damage to the wall, and prevent the wall from toppling under applied loading conditions. It is important to note that the proposed spillway structure would serve as a retaining wall for the fill material along the spillway channel. As such, the spillway would need to be installed first, and the buttress fill added later.

To install the buttress, the topsoil would be stripped from the estimated footprint of the buttress fill and stockpiled (since wetlands are present, this soil could be used for the wetland mitigation area that will be required since it already contains wetland plant roots and seeds).

The area would then be filled with a well-graded fill material that includes larger gravel and cobble-sized particles, such as a crusher-run stone, to a level approximately 1 foot below finished grade. Riprap slope protection with an average stone diameter of four to five inches, with little fine material, would be installed on top. The riprap slope protection will provide adequate resistance to erosion without grass cover. Additionally, if undesired vegetation growth begins, it could be easily hand pulled or cut with a string trimmer.

6.3 Spillway Demolition and Replacement Earthwork

The quantity of excavation required to construct the new spillway is a significant concern. Excavation side slopes must be sloped back at 2H:1V at steepest (3H:1V preferred) to ensure proper compaction of new soils against existing soils. Since Fyfeshire Pond Dam is not a very long structure, the quantity of excavation required to install the new spillway would involve removal and replacement of the majority of the dam during construction.

6.4 Concrete Spillway

Alternatives assessed include both cast-in-place and precast concrete spillways. Installation of both requires demolition of the existing spillway and removal of debris, excavating the embankment to accept the new spillway (see *Section 6.3*), and preparation of a base for the new spillway. Both methods require installation of cast-in-place concrete cutoff walls below and on both sides of the spillway to prevent seepage along the bottom of the spillway concrete. Forms for the bottom cut-off wall would be placed and the concrete poured.

Following formation of the cut-off wall, the alternatives begin to differ. A precast spillway would be constructed off-site, most likely in sections, and then hauled to the site. The sections would then be set in place by crane on the prepared base. The precast section corresponding to the location of the cut-off walls would have steel reinforcing projecting from it that would connect the precast section to the cut-off walls. After each of the spillway sections is placed, the seams would be filled with non-shrink grout. The side cut-off walls would then be formed and poured. The spillway structure would then be backfilled in lifts and the soil compacted to finish grade.

The cast-in-place spillways would be formed in place to the required dimensions and poured on site. The bottom and side cut-off walls would be poured at approximately the same time. Any expansion joints would then be filled following removal of the forms. Backfill would then be placed around the completed structure in the same manner as for the precast structure.

For the alternatives that include a gate as part of a low-level outlet, a thimble provided by the gate manufacturer should be cast into the concrete to accept the inlet pipe and to allow for mounting of the gate. Using a thimble results in a more secure gate installation than mounting the gate directly onto a concrete surface. A thimble could be included in a precast or cast-in-place structure.

6.5 Inlet Pipe

Extending an inlet pipe into the impoundment would be relatively straightforward. The pipe would connect to the valve thimble at the outlet structure, and then be installed in sections into the impoundment to the desired length. Sediment would be excavated to the desired installation depth, and then replaced after the pipe is positioned. The pipe would be anchored by concrete blocks at intervals determined during final design, which would keep the pipe aligned laterally and would also prevent the pipe from floating if one or both ends were to become blocked while it was entrained with air. The pipe material would be ductile iron, and it would be lined with cement to resist internal corrosion. A trash rack would be constructed for the end using a flange attached to the end of the pipe with threaded rod bolted to it and projecting out beyond the pipe's end. A blank flange would be bolted to the threaded rod on the opposite end.

6.6 Tree Removal

Removing trees from a dam embankment must be undertaken carefully to ensure proper strength following completion, and would ideally be performed with the impoundment drawn down since excavating the embankment reduces its factor of safety against instability. Trees should be removed by cutting, followed by grinding of the stumps and removal by excavation of any roots greater in diameter than ½ inch. Any unsuitable material should then be removed from the resulting void, including organic soil, and replaced with suitable, impervious fill that is compacted in place.

6.7 Wetland Mitigation

Implementation of wetland mitigation components of the project are highly dependent on site specific attributes, details of which are not yet known. On general, wetland mitigation should be performed in conformance with the *Massachusetts Inland Wetland Replication Guidelines*. In general, the proposed replication area must have a groundwater elevation, annual inundation period, and soil characteristics sufficient to support the target species community. Post-construction monitoring and follow-up is necessary to ensure that native wetland species establish and not invasive species or upland species.

6.8 Sediment Management

Each of the proposed alternatives are likely to require some level of dredged material management, with relatively small quantities of dredged material management likely under *Alternatives 1.1* through *2.2*, and significant quantities of sediment management required under *Alternatives 3.0* and *4.0*. Management of dredged material management in Massachusetts in quantities greater than 100 cubic yards is subject to the 401 Water Quality Certification regulations of 314 CMR 9.00, which defines 'dredged material' as:

> Sediment and associated materials that are moved from below the mean high tide line for coastal waters and below the high water mark for inland waters during dredging activities.

To manage dredged material properly, it must be sampled for a suite of physical and chemical parameters presented in the regulations and managed using one of several options. The appropriate options are prescribed in part by the sediment quality. No sediment quality data is known to exist for the materials that would be managed as part of the proposed project, but for the purposes of this analysis, it is assumed that the material is free of harmful levels of contaminants since the watershed does not have a recent industrial history.

As such, assuming they are free of harmful levels of contaminants, several options may available for reuse or disposal of sediments. These include:

- Natural Redistribution
- Shoreline Placement
- Upland Material Reuse at a Known Location
- Use as Daily Cover in a Landfill
- Disposal in a Non-beneficial Manner

In instances where off-site reuse or disposal of the material is proposed, dewatering will be necessary to ensure that no free liquids are present during truck transport. 314 CMR 9.07(4) now allows an intermediate facility to be established for the transfer and dewatering of dredged sediments within certain siting restrictions. When one or more specific applications are selected when the project is in the final design stage, a more detailed reuse analysis should be completed to further evaluate the appropriateness of the proposed option.

6.8.1 Re-vegetation and Natural Redistribution

This sediment management option is only applicable if dam removal is the selected alternative. It includes allowing a stream channel to form naturally within sediment in the area of the former impoundment following dam removal, and vegetating and otherwise stabilizing the surrounding sediment such that it remains in place.

This option includes some significant advantages, since project designers would not have to anticipate the fluvial geomorphology of the restoration stream channel through the impoundment as part of the design process. Instead, the stream would choose its own course, sinuosity, and width, which is likely, in the end, to result in the most healthy stream system in a state of equilibrium based on its flow regime, slope, and sediment characteristics. The restoration channel would evolve during the course of storms, down-cutting first, then widening during large storms, then accumulating sediment and reaching a state of dynamic equilibrium.

However, although the end result of this process may be the most consistent with a healthy stream in equilibrium, care must be taken to ensure that significant impacts to surrounding stream ecology do not occur. As part of this option, sediment quality sampling would be required as part of permitting to ensure that sediment discharged downstream will not result in human health impacts or adversely affect the quality of downstream benthic substrate.

The quantity and rate of sediment released is also an important consideration, since suspended sediment can contribute to turbidity and aggradation, potentially resulting in impacts to coldwater fisheries habitat, which is inconsistent with the habitat improvement intent of the removal option.

Appropriate design could be used to reduce these potential impacts, such as removing the dam embankment in increments, releasing a portion of the contained sediment, and allowing time to pass between each increment to allow conditions to stabilize. An arrangement such as this would need to be coordinated with permitting agencies to determine if this strategy is permissible and to determine the upper limit of sediment load that downstream reaches could tolerate. Additionally, it is not clear whether a 401 Water Quality Certification could be obtained for a project involving the release of sediment.

As the dam was breached in increments, the portion of the pond bottom exposed during each increment could be seeded and planted as well, to avoid encroachment of invasive species and extend project costs over longer periods.

The restoration of natural flow regimes to rivers can have significant environmental and aesthetic benefits. However, the removal of any dam comes with some risk, including the suspension and re-deposition of sediment.

6.8.2 Shoreline Placement

As allowed by 314 CMR 9.07(9)a, dredged material can be permanently placed near its location of origin within the buffer zone to the resource area or within a 100-year floodplain, whichever is a greater distance from the resource, assuming that the proposed placement meets the requirements of 310 CMR 9.00 (Waterways) and 310 CMR 10.00 (the Wetland Protection Act regulations) and adequate compensatory storage is provided.

It is assumed that placement of sediment within the area of the former impoundment near the proposed stream channel would qualify for this option, however this would need to be confirmed since the bottom of the former impoundment currently qualifies as a resource area under the Wetland Protection Act. Although mapped floodplain is present, the extents of the floodplain are likely to vary following completion of the project, such that placement of material within the currently delineated 100-year floodplain could actually be beyond the floodplain extents following completion of the project.

Placement of the sediment would need to occur in a manner that would not negatively affect Blanding's Turtle habitat.

6.8.3 Upland Material Reuse at a Known Location

As allowed by 314 CMR 9.07(9)b, the material dredged could be reused at upland locations if concentrations of oil and hazardous material in the dredged material are below appropriate thresholds, and that certain other performance standards are met. A 401 Water Quality Certification application for dredging would need to identify the reuse location for this option to be available.

6.8.4 Use as Daily Cover in a Landfill

If the sediment parameter levels are lower than the levels specified in the Mass DEP policy COMM-97-001 (Reuse and Disposal of Contaminated Soil at Massachusetts Landfills), the soil could be transported to a nearby landfill and used for daily cover. Generally, a tipping fee would still apply, such that this management option is better applied to somewhat contaminated sediments that exceed upland reuse chemical levels but attain the COMM-97-001 policy thresholds and thus have reduced options for reuse. As such, it is a less desirable and less cost effective option for this project.

6.8.5 Disposal in a Non-beneficial Manner

314 CMR 9.07(1)e states that dredged material shall not be disposed if a feasible alternative exists that involves reuse, recycling, or contaminant destruction and/or detoxification. Since many reuse options exist due to the relatively uncontaminated nature of the soil, disposal is unlikely to be permitted.

7.0 ANTICIPATED PERMITS REQUIRED FOR CONSTRUCTION

The permits presented in this section are anticipated to be necessary for implementation of one or more of the alternatives discussed as part of this project. An important overall consideration of obtaining permits for this project is that the owner of the project site is itself a permitting authority that would be required to issue a permit.

When considering the best alternative for future action regarding the dam, the principal difference in permitting effort will be between the removal options and the repair options. While all the alternatives will involve the same permitting agencies, the removal alternatives will require more scrutiny and thus are likely to require more time in permit preparation and in review by the various agency, despite the fact that most every agency would rather see the dam removed than repaired. Thus, in the attached cost estimates, removal alternatives would likely fall in the upper portions of the permitting cost ranges. Regarding permitting as related to meeting time tables for completing the selected alternative, the removal alternatives will likely require more time for permit review by the various agencies. However, time used for review of permit applications by the agencies should not be considered a major decision parameter affecting the Town's decision for which alternative is best for the Town, since the Town has no control over permit review time.

7.1 Local Permits

Order of Conditions to be issued by the Town of Bolton Conservation Commission
This permit is required for work within wetlands and the wetland buffer downstream of the Dam, the riverfront area of the downstream channel, and within Fyfeshire Pond and its wetland buffer. In addition, the Town has Wetland Bylaws that will need to be addressed as part of the local wetland permitting process. The Wetlands Protection Act has no provisional processes for an applicant to also be the approving authority as the situation is somewhat unusual. To avoid a conflict of interest, be it perceived or real, this situation should be avoided, and an alternative entity within the Town of Bolton, such as the Board of Selectmen, should serve as the applicant for all of the permitting programs.

7.2 State Permits

7.2.1 MGL Chapter 253 - Dam Safety Permit issued by Massachusetts DCR

This permit is required for the construction, repair, material alterations, breach, or removal of a dam, and would be required for this project.

7.2.2 Clean Water Act Section 401 Water Quality Certification

This permit is required for projects that involve more than 100 cubic yards of dredging and management and disposal of dredged materials, for disturbance of more than 5,000 square feet of BVW or LUW, and for state review of an activity that requires a permit from the Army Corps of Engineers related to wetlands and waterways. Other thresholds exist which may require a permit application when exceeded. A detailed discussion of sediment management options and requirements are presented in *Section 6.8*. The proposed removal options will likely require application for a 401 Water Quality Certification as both the dredging and disturbance thresholds are likely to be tripped, and the repair options are likely to trip the dredging threshold only.

7.2.3 Massachusetts Environmental Policy Act Environmental Notification Form

This review process must be undertaken for projects that involve alternation of more than 5,000 square feet of bordering or isolated vegetated wetlands, which is likely to occur if dam removal is the selected alternative. The MEPA regulations state that a mandatory Environmental Impact Report (EIR) would be required if construction would increase the impoundment capacity by 20% or more or cause any decrease in the impoundment capacity. However, MEPA has recently allowed proponents of dam removal projects to file an expanded ENF in place of an EIR in some cases. Prior to submission of an ENF, an advisory opinion should be obtained from MEPA to agree upon what additional materials, if any, could be submitted as part of the ENF to constitute and expanded ENF, or if input from the Public would be required to determine the additional contents of the expanded ENF.

7.3 Federal Permits

7.3.1 Clean Water Act Section 404

Compliance with this permitting program administered by the Army Corps of Engineers is required for excavation and dredging in wetlands and waterways. The category of permit will depend on quantity of disturbance. Several of the alternatives proposed as part of this project might qualify for Category 1 of coverage under the Programmatic General Permit (PGP), which is non-reporting, whereas the removal alternatives may require an individual permit. This permitting program is closely associated with the 401 Water Quality Certification program.

7.3.2 FEMA Letter of Map Revision

Proponents of projects that would result in changes to mapped floodplain elevations are required to apply to revise the FIRM and FIS to reflect changed conditions. The majority of the proposed repair alternatives would not significantly vary flows discharging to the downstream floodplain since the replacement spillway capacity would be the same as the existing spillway capacity under most alternatives. However, *Alternative 1.1* would increase capacity slightly by adding weir boards, and the removal alternatives are predicted to increase discharges downstream. As such, a FEMA Letter of Map Revision would be required for these alternatives to revise the affected FIRM and FIS.

8.0 RECOMMENDATIONS

8.1 Preferred Alternatives

Based on the assessments presented and discussed in this report, Fuss & O'Neill's opinion of the preferred alternative for repairing Fyfeshire Pond Dam is presented as *Alternative 1.1*. Although this alternative is the most expensive, it is only marginally more expensive than the other alternatives, but provides the best level of control and will maintain the normal pool water surface elevation even when the spillway is blocked by debris or beaver activity (although the debris would still need to be removed to maintain spillway capacity).

If the dam is to be removed, we believe *Alternative 4.0* is should be selected, since complete removal and restoration of a stream channel through the former impoundment provides the best ecological restoration potential, and as such is more likely to qualify for grant funding for design and construction.

9.0 REFERENCES

9.1 Documents and Reports

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9.2 Regulations

MA Department of Conservation and Recreation Dam Safety Regulations, 302 CMR 10.00.

TABLES

FYFESHIRE POND DAM
PHASE II INVESTIGATION

Table 1. Alternative Screening Evaluation

Alt.	Description	Advantages	Disadvantages	Est. Cost	Summary
1.1	Repair dam embankment and rebuild masonry wall. Construct cast-in-place spillway with low-level outlet structure and stop log level control	• Consistent with historical appearance and orientation • Improved operational control • Reduces impact of beaver blockage	• Relatively high cost • Does not address coldwater fisheries habitat improvement • Dam remains jurisdictional. Continued inspection, maintenance, and liability cost	$495,000	Best repair option Operation – best Cost – highest Habitat – no change Historical – consistent Jurisdictional Status-Unchanged
1.2	Repair dam embankment and rebuild masonry wall. Install precast spillway with weir boards for level control.	• Consistent with historical appearance and orientation • Similar operational control to existing structure • Cost savings through precast construction	• Similar susceptibility for spillway blockage by debris and beaver activity • Does not address coldwater fisheries habitat improvement • Dam remains jurisdictional. Continued inspection, maintenance, and liability cost • Difficult connection of precast components to cast-in-place cut-off walls	$479,000	Moderate repair option Operation – poor Cost – low Habitat – no change Historical – consistent Jurisdictional Status-Unchanged
2.1	Repair dam embankment and buttress downstream face with wall. Construct cast-in-place spillway with low-level outlet structure and stop log level control. Extend inlet pipe into impoundment without weir board level control to save cost	• Buttressing more cost effective than masonry wall reconstruction • Cast-in-place spillway allows more flexibility with design than a precast structure • Outlet pipe extending into impoundment would allow manual control of water level if debris blockage of the spillway occurred	• Increased quantity of concrete work required to extend spillway beyond toe of buttress slope, increasing cost • Inconsistent with historical appearance of structure • Would require manual gate operation to respond to spillway blockage • Does not address coldwater fisheries habitat improvement • Dam remains jurisdictional. Continued inspection, maintenance, and liability cost • Increased wetlands impacts	$486,000	Moderate repair option Operation – fair Cost – moderate Habitat – no change Historical – inconsistent Jurisdictional Status-Unchanged

Alt.	Description	Advantages	Disadvantages	Est. Cost	Summary
2.2	Repair dam embankment and buttress downstream face with wall. Construct precast spillway with weir boards for level control.	• Buttressing more cost effective than masonry wall reconstruction • Similar operational control to existing structure • Cost savings through precast construction	• Similar susceptibility for spillway blockage by debris and beaver activity • Inconsistent with historical appearance of structure • Does not address coldwater fisheries habitat improvement • Dam remains jurisdictional. Continued inspection, maintenance, and liability cost • Difficult connection of precast components to cast-in-place cut-off walls • Increased wetlands impacts	$487,000	Poor repair option Operation – poor Cost – moderate Habitat – no change Historical – inconsistent Jurisdictional Status- Unchanged
3.0	Partially remove the dam, creating an engineered stream channel on top of pond sediment to minimize sediment excavation	• Partial habitat improvement through likely reduction in downstream water temperatures • Reduced sediment management cost • Reduction in future liability through breaching the dam • Dam no longer jurisdictional. Elimination of future maintenance and inspection costs following stabilization of stream restoration features	• Restoration stream channel above organic sediments may be difficult to stabilize • Difficult to ensure passage of some fish species through restoration stream channel due to slopes and weirs • Reduction in water dependent recreational opportunity through loss of pond. • Loss of habitat for warm water fish species	$324,000	Fair removal option Operation – none Cost – low Habitat – moderate improvement Historical – inconsistent Jurisdictional Status- Not jurisdictional
4.0	Completely remove the dam and remove sediment along stream restoration reach to the pond's hard bottom.	• Habitat improvement through reduction in downstream water temperatures • Best fish passage potential through dam site • Reduction in future liability through breaching the dam • Dam is no longer jurisdictional. Elimination of future maintenance and inspection costs following stabilization of stream restoration features	• Higher sediment management cost potential • Reduction in water dependent recreational opportunity through loss of pond. • Loss of habitat for warm water fish species	$443,000	Best removal option Operation – none Cost – low Habitat – moderate improvement Historical – inconsistent Jurisdictional Status- Not jurisdictional

*Budgetary costs are shown which are assumed to be accurate to within -15% to + 30%.

Table 2. Potential Removal Funding Sources - 2009

Grant Opportunity	Open/Close Date	Eligibility	Matching	Amount	Details
Eastern Brook Trout Joint Venture	Close 10/2/09	Yes	Required 1:1 from other sources, including Federal	$10,000-50,000	Need sponsoring USFWS office; for native brook trout habitat enhancement
NOAA Atlantic Salmon Conservation Grants	Close 11/09	Currently Unknown	Not required, but encouraged as is leveraging. Other Federal money cannot be used as match.	$50,000-250,000	For projects that lead to long-term ecological habitat improvements for Atlantic Salmon – Merrimack River
Gulf of Maine Council on the Environment Restoration Grants	Letter of Intent 2/09 Close 5/1/09	Currently Unknown	Non-federal 1:1 match	$25,000-75,000	Funds habitat restoration projects located within the United States portion of the Gulf of Maine watershed. During open announcements, applications should be directed to the Gulf of Maine Council.
American Rivers-NOAA Community Based Restoration Grants	Close 12/3/2008	Currently Unknown	Not required, but encouraged.	$25,000-$50,000	Diadromous fish habitat must benefit Funds feasibility analysis, engineering design, and construction – NOT ANNOUNCED FOR 2009
Riverways Priority Projects	Close 9/22/09	Yes	No.	$10,000-$30,000	Release date is variable each year
USFWS Partners Grant	Open 5/09 Close 10/1/09	Yes	No	Max $25,000	
FishAmerica Conservation Grants	Open Year Round; 9-12 month review	Yes	No	Typical amount is $7,500.	Will fund dam removal-related projects. – NOT CURRENTLY ACCEPTING APPLICATIONS.
Massachusetts Environmental Trust	Letter of Intent: 10/31/09	Yes	No	$10,000-$50,000	Must have a community outreach/involvement component.
Trout Unlimited Embrace-a-Stream	Typical- Open Sept 2009 Close Dec 2009	Yes	Yes 1:1	~$5,000	Need to contact local Chapter

Although the majority of the grant applications close dates have passed, these grants may be available in 2010 and future years.

FIGURES

FYFESHIRE POND DAM
PHASE II INVESTIGATION

APPENDIX A

VISUAL INSPECTION UPDATE

APPENDIX B

H&H MODEL REPORTS

APPENDIX C

STABILITY MODEL DATA

APPENDIX D

SOIL BORING LOGS

APPENDIX E

OPINION OF CONSTRUCTION COST WORKSHEETS