Draft Feasibility Report
Dam Feasibility and Impact Analysis

Macallen Dam, Newmarket, NH

Volume 1 of 2: Main Report

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Acronyms

ACHP	Advisory Council of Historic Preservation
APE	Area of Potential Effect
AUR	Activity Use Restriction
cfs	cubic feet per second
CLF	Conservation Law Foundation
CWA	Clean Water Act
DBC	Durham Boat Company
DO	dissolved oxygen
EAP	Emergency Action Plan
FERC	Federal Energy Regulatory Commission
FIS	Flood Insurance Study
GPS	global positioning system
GSE	Gomez and Sullivan Engineers, P.C.
IDF	Inflow Design Flood
KW	kilowatt
KWH	kilowatt-hour
LFA	Lead Federal Agency
LiDAR	Light Detection and Ranging
LOD	Letter of Deficiency
NAVD88	North American Vertical Datum of 1988
NBI	National Bridge Inventory
NCA	National Coastal Assessment
NHDES	New Hampshire Department of Environmental Services
NHDHR	New Hampshire Division of Historic Resources
NHDOT	New Hampshire Department of Transportation
NHFGD	New Hampshire Fish and Game Department
NHNHB	New Hampshire Natural Heritage Bureau

Acronyms (continued)

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRHP	National Register of Historic Places
OMR	Operation, Maintenance and Response Form
PAD	Pre-Application Document
PAH	Polynuclear aromatic hydrocarbon
PAL	Public Archeology Laboratory, Inc.
PCB	polychlorinated biphenyls
RAE	Restore America's Estuaries
RPR	Request for Project Review
RTE	rare, threatened and endangered
RTK-GPS	Real Time Kinematic-Global Positioning System
SHPO	State Historic Preservation Officer
SVOC	semi-volatile organic compound
THPO	Tribal Historic Preservation Officer
TOC	total organic carbon
Town	Town of Newmarket
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	volatile organic compound
WSE	water surface elevation

Executive Summary

ES-1 Background

Aerial View of Macallen Dam

The Town of Newmarket (Town) owns and operates the Macallen Dam, the head of tide dam on the Lamprey River in downtown Newmarket, NH. The 27-foot high stone-block dam includes a 70-foot long spillway and three gates on the left[1] side of the dam that permit partial lowering of the impoundment above the dam. The current dam was constructed in 1887; however, a dam is shown at this approximate location on historical maps of Newmarket as early as 1832. Between the Macallen Dam and the upstream Veteran's Bridge (Main Street) are remnants of a timber crib legacy dam that remains inundated when the impoundment is full, but are exposed when the gates are opened.

The Macallen Dam creates an impoundment extending approximately 2.5 miles up the Lamprey River and approximately 0.75 miles up the Piscassic River – a major tributary to the Lamprey River. The impoundment extends into Durham, NH and creates several backwater/bay areas (see Figure ES-1 at the end of this Executive Summary). The impounded reach of the Piscassic River extends from its confluence with the Lamprey River to the upstream bedrock falls marking the upstream extent of the Macallen Dam impoundment on the Piscassic River. The lower portion of impoundment – on the Lamprey River from the dam to the confluence of the Piscassic River and along the impounded Piscassic River – is lined with condominiums or apartments overlooking portions of the impoundment. A boat launch is located on the Piscassic River impounded reach.

In May 2008 and May 2010, the Town received a Letter of Deficiency (LOD) from the New Hampshire Department of Environmental Services (NHDES) Dam Bureau indicating that the dam has various dam safety-related deficiencies that must be addressed. The most problematic deficiency is the dam has insufficient hydraulic capacity to safely pass the 100-year flood flow with one foot of freeboard as required by NHDES Dam Bureau regulations. In accordance with the NHDES Dam Bureau regulations for this dam's hazard classification, a dam failure could potentially result in the loss of human life below the dam. As such, changes are needed to increase the dam's spillway capacity to bring it into compliance.

From 2008 through 2013, the Town contracted with Wright-Pierce to conduct various studies on the dam. The latest Wright-Pierce report, dated February 2013, included an alternatives analysis to increase

[1] The left or right side of the river assumes one is looking in a downstream direction.

the dam's spillway capacity to meet dam safety requirements. Alternatives evaluated included: a) lowering the spillway crest elevation; b) lengthening the spillway; c) raising the abutments; and d) combinations of the above. For those alternatives deemed feasible by Wright-Pierce, conceptual level cost estimates were developed ranging from $1.1 to $4.6 million[2] to increase the spillway hydraulic capacity and another $315,500 to address other improvements to the existing dam and retaining walls.

Triggered by recent flood events in May 2006, April 2007 and March 2010 and the recent LOD, a May 2011 citizen-petitioned warrant article requested the Town to raise and appropriate monies to study the removal of Macallen Dam, which was voted upon and passed by Newmarket residents. The Town applied for various grants to offset the costs associated with conducting a dam removal feasibility study. In the fall of 2011, the Town was awarded a $40,000 grant from the Restore America's Estuaries Fund (RAE), a partnership of the National Oceanic and Atmospheric Administration (NOAA) and Conservation Law Foundation (CLF) to evaluate the feasibility of removing the Macallen dam and the upstream legacy dam. The grant monies, along with the Town's appropriation ($41,700), were used to fund this dam removal feasibility study. The cost of this feasibility study was $81,700.

ES-2 Study Purpose

The original scope of the dam[3] removal feasibility study (termed "dam-out" below) included numerous elements that are commonly evaluated in a comprehensive study such as evaluating the impacts of dam removal on infrastructure, flooding, sediment, recreation, environmental resources, cultural resources, and aesthetics. However, due to funding limitations, the study scope was curtailed accordingly. Sediment testing and management is a major element that was not conducted as part of this study and can greatly influence dam removal costs. Recognizing that a comprehensive dam removal feasibility study was not conducted, a budgetary estimate to remove the dam and legacy dam was developed; however, it includes several assumptions relative to sediment management as noted in Section ES-9. In addition, the Town requested a budgetary estimate to complete those feasibility-related tasks dropped from the comprehensive assessment such that the Town had both additional feasibility costs and a budgetary dam removal cost.

Gomez and Sullivan Engineers (GSE) were originally contracted by the Town to conduct a dam removal feasibility study. However, as the study progressed we were requested by the Town and Project Partners[4] to identify other potential alternatives, other than dam removal, to pass the 100-year flood with one foot of freeboard based on our review of past studies and the information gained/learned as the study progressed. Thus, although beyond our current scope of services, we listed other alternatives, but excluded costs as described in Section ES-8.

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[2] Wright-Pierce notes in their report the following relative to the cost: "*the costing presented here is conceptual in nature and is based on data collected from across the nation. Alternatives do not include costs to address the required fish ladder improvements.*" The Wright-Pierce estimates are based on other studies conducted throughout the country.

[3] For this project, dam removal consists of removing a) the dam's spillway, b) the right abutment wall (including the fish ladder), c) the left abutment gate structure, and d) the upstream timber crib legacy dam.

[4] Project Partners include those entities participating in this feasibility study, whether financially or through technical assistance. They include: the Macallen Dam Study Committee, Town, NHDES, New Hampshire Fish and Game Department (NHFGD), NOAA, and CLF.

ES-3 Hydraulic Model Findings

One of key elements of the feasibility study was developing a hydraulic model of the Lamprey River from just below the Macallen Dam to the upstream extents of the impoundment on the Lamprey and Piscassic Rivers. The purpose for developing the model was to predict the changes in depth, velocity and channel width along the impounded reach under dam-in and dam-out conditions. The hydraulic model was used to determine if removing Macallen Dam: a) reduces the area of inundation under the 100-year flood and hence provide flood reduction benefits; b) reduces the river width and depth under an average annual flow; c) creates a barrier to fish passage; and d) requires infrastructure improvements to protect against scour. The model was also updated to include a flow split, whereby under extremely high flows, some water from the Lamprey River is conveyed to the Oyster River. The hydraulic model showed the following:

- Under dam-out conditions and under the 100-year flood, there are marginal flood benefits realized from removing the dam as shown in the inundation map in Figure ES-2. The greatest reduction in the flood depths occurs between the dam and Veterans Bridge and decreases above the Veterans Bridge. Based on the bathymetric mapping and hydraulic modeling there is a hydraulic control at Veterans Bridge due to the narrowing of the channel width as well as an elevated channel bed beneath the bridge.

- Under dam-out conditions and under the average annual flow, the impounded reach width would be reduced, with the most drastic changes occurring in the backwatered bays and in the Piscassic impounded reach as shown in Figure ES-3. The current boat launch on the Piscassic River would be rendered unusable. The river depth would be reduced on the order of 5 to 9 feet above the Veterans Bridge as shown in Figure ES-4.

- Under dam-out conditions, there are two areas between the Macallen Dam and Veterans Bridge where water velocities exceed 10 feet per second (fps) under a flow of 472 cfs (represents the flow in the spring when migratory fish such as river herring are moving into freshwater to spawn), which creates a velocity barrier to most migratory fish passage. In addition, the reach between the Veterans Bridge and the Macallen Dam is very steep. While the presence of the legacy dam prevents a full understanding of the riverbed slope, it is possible that these steeper areas may create vertical barriers to fish passage unless mitigating actions are taken. In addition it is unclear if the falls beneath the dam could also act as a physical barrier to fish passage.

- In October 2013, the impoundment was purposely drawn down by opening the gates such that more of the impoundment and underwater infrastructure could be observed. Removing the dam could potentially create a fish passage barrier beneath the railroad bridge due to logs extending along the channel bed (see inset, next page). In addition, further analysis is needed to determine if structural

measures are needed to the railroad bridge should the dam be removed.

- There is an important finding from the hydraulic modeling relative to the flow split. Under dam-in conditions and under the 100-year flood, 4,260 cfs is currently predicted to be conveyed to the Oyster River leaving 10,260 cfs inflowing to the Macallen Dam. Any alternative involving removing the dam or lowering the spillway crest (and hence lowering the overall water surface profile along the impounded reach) will result in less water being conveyed to the Oyster River and more water inflowing to the Macallen Dam. Removing the Macallen Dam will result in the Lamprey River passing a higher proportion of the 100-year flow (~11,525 cfs) than the current 10,260 cfs.

ES-4 Sediment

The NHDES has established protocols for assessing sediment associated with dam removal project; these protocols are currently being revised. On this project, limited sediment assessment was conducted.

Relative to sediment quality, a due diligence assessment was conducted to inform what, if any, sediment testing should be conducted as part of a feasibility assessment. The due diligence involved reviewing existing data sources to determine the potential for having contaminated sediment in the impoundment. If the project were to proceed further, it is recommended that sediment sampling and laboratory analysis be conducted above, within and below the impounded reaches.

Relative to sediment quantity, sediment thickness measurements were collected along 11 transects[5] throughout the impoundment. The transect locations were selected based on where new channel bed hydraulic controls would emerge if the dam was removed. These locations represent those areas most likely to scour and erode (mobilization of sediment). The findings showed that between the dam and Veterans Bridge there was little to no sediment present. Greater sediment thickness was measured at transects upstream of the Veterans Bridge. The most sediment was measured in the Piscassic River impounded reach. Based on the sediment probing, the sediment composition consisted primarily of fine grain material such as sand, with some silty material in deeper portions of the impoundment. Based on kayaking the impounded reach during the October 2013 drawdown, it is expected that dam removal would result in mobilizing instream sediments. In addition, significant sloughing of the river banks was observed during the drawdown.

To estimate the sediment volume that would become mobilized if the dam was removed, additional data is needed including: a) additional sediment thickness transects, b) sediment samples for grain size analysis, and c) transect information below the Macallen Dam. Using the sediment thickness data and grain size analysis, a sediment transport model would be developed to predict the mobile sediment volume above the dam and depositional areas below the dam if it were removed. The sediment transport model is part of the existing hydraulic model developed for the project. Once the quality[6] of sediment and mobile sediment volume are determined, it informs the sediment management

[5] Five (5) transects were located above the Piscassic/Lamprey River confluence, one (1) was located in the Piscassic River below the Railroad Crossing, and the remaining five (5) transects were located between the dam and Piscassic/Lamprey River confluence.

[6] Quality refers to whether the sediment poses an ecological or human health risk.

alternatives which could range from allowing the sediment to naturally mobilize upon dam removal to dredging of the impounded sediment.

In sum, if the project proceeds additional coordination would be required with NHDES, and other state and federal agencies relative to sediment testing, analysis and management.

ES-5 Fisheries

The Macallen Dam is equipped with a denil-style fish ladder that is owned and operated by the NH Fish and Game Department (NHFGD), and began operation in 1972. The NHFGD annually monitors diadromous[7] and resident fish passing through the fish ladder. The most prominent fish species enumerated are river herring migrating upstream through the ladder to reach freshwater spawning habitat above the dam from April through June. The NHFGD estimates that approximately 1,400,000 river herring have passed through the fish ladder since 1972. The NHFGD has also documented several other species passing the fish ladder, including Atlantic salmon, sea lamprey, American shad, American eel, various trout, sunfish and perch species, among others, which are native to the project area.

ES-6 Infrastructure

Veteran's Bridge and Buildings

Hoyle, Tanner and Associates (HTA) conducted a visual observation of the infrastructure between Veterans Bridge and the Macallen Dam during the October 2013 drawdown including Veterans Bridge, retaining walls located downstream of the bridge and two buildings (Selectwood Building and Durham Book Exchange Building) located near the dam. No assessment of the railroad bridges passing over the Piscassic and Lamprey impounded reach was conducted. HTA conducted only visual observations; no structural calculations or testing was completed. HTA findings and those of the New Hampshire Department of Transportation (NHDOT) are summarized below.

- The NHDOT Bureau of Bridge Design provided the most recent Veterans Bridge inspection report from 2011. NHDOT indicated that they did not have any information on the bridge's substructure (i.e., the stone block abutments/foundation). They indicated that no formal scour calculations had been completed on the bridge, but that screening-level assessments indicated that the bridge was at low risk for scour. NHDOT's 2011 underwater inspection indicated that the river bed around the bridge consists of bedrock with cobbles. Based on our probing of the substrate, the Veterans Bridge appears to be founded on bedrock or large boulders.

- Overall the southwest retaining wall and transverse wall adjacent to the dam on the right side of the river between the bridge and dam are in satisfactory condition. Although there is minor local bulging of the stones, the walls remain stable. The stone in front of the walls appears stationary and provides some protection from scour.

- The condition of the Durham Book Exchange building foundation (right side of river, immediately below dam) is good as no concerns related to scour were observed. The condition

[7] Diadromous fish spend a portion of their life cycle within both freshwater and saltwater.

of the Selectwood Building (left side of river, just upstream of the dam) foundation is poor and appears to be settling and unstable. Scour protection should be investigated for this building.

Well Survey

There is some concern that if Macallen Dam is removed, the lower in-river water levels may also impact Durham residents along the impoundment that rely on well water[8]. To investigate this issue, all 50 Durham property owners abutting the impoundment were contacted via mail and asked to provide information on their well (type, depth, etc.). Fourteen (14) owners responded (28% return rate), with 12 having bedrock wells and two (2) uncertain. There were approximately six (6) wells having water levels within 20-30 feet (in the vertical plane) of the impoundment water level. While all of the wells are drilled to much deeper depths than the static water level (at least 100 feet below the static depth in most cases), there is a remote possibility that long-term changes in the level of the Lamprey River could impact some static well levels. It is unclear whether these changes in static well levels may ultimately impact the ability of any individual well to continue to yield an acceptable water flow.

Fire Use

Per the Town, the impoundment is not used as a water supply source to fill pumper trucks.

ES-7 Cultural Resources

The potential removal of the Macallen Dam must take into account historic resources including archaeological and architectural resources. Section 106 of the National Historic Preservation Act (NHPA) of 1966 requires federal agencies take into account the effects of their undertakings (in this case dam removal) on known or potential historic properties and afford the Advisory Council of Historic Preservation (ACHP) a reasonable opportunity to comment. Compliance with Section 106 of the NHPA is required of most dam removal projects that require a federal permit (such as USACOE permit for activities involving the placement of fill in waters of the United States) or if the project receives federal funding or assistance. It is likely that a federal permit will likely be required even if dam modification is pursued instead of dam removal, meaning the town may need to address the Section 106 process even if dam removal is not pursued.

All federal agencies (e.g. United States Fish and Wildlife Service, United States Environmental Protection Agency, National Resource Conservation Services, National Oceanic and Atmospheric Administration) are responsible for addressing Section 106 of the NHPA. To make the process more efficient, typically a lead federal agency (LFA) is identified. NOAA is serving as the LFA for the dam removal feasibility phase of the Town's assessment of the Macallen dam.

Public Archaeological Laboratory (PAL) conducted the following aspects of the cultural resource study:

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[8] Newmarket is serviced by public water and sewer.

- A Pedestrian Survey and Recommended Delineation of the Area of Potential Effect (APE)[9]
- Completion of the New Hampshire Division of Historic Resources (NHDHR) Request for Project Review Form (RPR).

To begin review and consultation with the NHDHR, the Town must submit a RPR form to the NHDHR. The form requires background information on the Project specific to architectural and archaeological resources. PAL conducted a site file review at the NHDHR and summarized their findings in the RFR form that will be sent to NHDHR in June 2014. PAL noted the following in their review:

- Macallen Dam is not included in the NHDHR architectural inventory files. The dam is located within, but not listed as a contributing resource to the Newmarket Commercial and Industrial Historic District (the Historic District), which was listed in the National Register of Historic Places (NRHP) in 1980.

- Twenty-four (24) archaeological sites are recorded within a five-kilometer (km) radius of the proposed study area: nine pre-contact sites, six post-contact sites, and nine sites with pre- and post-contact components. None of the recorded archaeological sites are located within the study area.

PAL recommended the following next steps, should the dam removal feasibility study advance further:

- Intensive survey and National Register evaluation (i.e. Individual Inventory Form) of the Macallen Dam is recommended to assess the significance and contributing status of the structure within the established Historic District.

- A Phase 1A Archaeological Survey is recommended to establish a final recommended archaeological APE for the dam removal feasibility study. The survey should include comprehensive pre- and post-contact histories of the study area, including any ethnographic or historical references to migratory fish being present upstream before a dam was located at the "First Falls;" detailed archaeological sensitivity statements; and recommendations for additional Phase 1B Archaeological Survey, as required.

ES-8 Other Alternatives

As noted above, at the Town and Project Partner's request, other potential alternatives to dam removal were identified. No engineering analysis was conducted to determine if any of the alternatives are feasible, and no cost estimates were developed. Also, it is important to remember that any impacts to the Lamprey-Oyster flow diversion should be considered as part of any alternative being considered as (such as lowering the spillway crest). Other alternatives considered included:

a) removing the dam's gates[10] and extending the spillway length;

[9] The area of potential effect is defined as the area in which eligible properties may be affected by the undertaking, including direct effects (such as destruction of the property) and indirect effects (such as visual, audible, and atmospheric changes which affect the character and setting of the property).

b) removing the dam's gates, extending the spillway length, and raising the right abutment;

c) removing the dam's gates, extending the spillway length, raising the right abutment and lowering the spillway crest by three feet but installing flashboards[11] that would fail under high flows; and

d) conducting a stability analysis to determine if the dam is safe against sliding, overturning, or erosion by overtopping under the 100-year flood flow.

Initial hydraulic calculations indicate that alternatives (a), (b), and (c) still do not pass enough flow to meet the one foot of freeboard requirement, although other iterations (such as higher flashboards) around option (c) may be worth investigating further. Additionally, the Town may want to consider options to assess the Durham Book Exchange building on river right's influence on dam stability, or even the possibility of constructing a new dam closer to the Veterans Bridge where the river is wider and may allow for a larger spillway/overflow section. Note that this latter option is considered a very remote alternative.

ES-9 Budgetary Estimates

A conceptual dam removal plan was developed to assist in developing a budgetary estimate (called an Opinion of Probable Construction Costs or OPCC) for dam removal. It should be noted that the OPCC estimate for dam removal represents a starting point relative to removal costs (costs will only increase). Additional feasibility related steps are also needed to further inform the OPCC; the additional feasibility related steps and costs are described in Table 10.2-1 in the main report. A few key assumptions were made relative to the dam removal OPCC estimate including:

- The OPCC estimate assumes sediments do not pose an ecological/human risk and thus would be permitted to mobilize and transport downstream following dam removal. In contrast, if the sediments do pose an ecological/human risk and require dredging, the costs could escalate rapidly due to accessing, dredging, hauling, and disposing of the contaminated material.

- The OPCC estimate assumes the railroad bridge crossing the Piscassic River would not require any further restoration work such as scour protection, structural stabilization or restoration work to permit fish passage. HTA did not conduct a structural investigation or scour analysis of this bridge. Note that per discussions with the NHDES if it was determined that the railroad bridge would require scour protection or stabilization measures, the Town would not bear these costs.

- The OPCC estimate assumes no fish passage issues. However, as noted above there appears to be a velocity barrier to fish passage beneath Veterans Bridge, as well as a vertical barrier to fish

[10] NHDES Dam Safety typically requires a low-level outlet to permit dewatering of the impoundment.

[11] Note that if this alternative is considered, the flashboards are intended to fail under a high flow event and cannot be replaced until flows recede. If flashboard failure were to occur it would render the existing fish ladder inoperable.

passage, if the dam was removed. Additional mitigation alternatives would require investigation to enable fish to move through this reach.

- The OPCC estimate assumes dam removal would not impact the sewer line traversing the Piscassic River in the impounded reach. No assessment of this sewer line has been conducted and thus it is unknown if any measures are needed to protect the line.

The OPCC estimate for removing the Macallen Dam and legacy dam is $743,000, which includes the costs associated with engineering and administration, permitting, bidding phase, and construction management as well as a 25% contingency for unknowns.

As noted above, not all of the elements typically included in a feasibility study were conducted as part of this study. However, the Town requested a budget estimate to address other elements that were not addressed in this feasibility study. Note that it is not possible to firmly estimate all feasibility-related costs as earlier findings will dictate the scope/cost of future steps. This is particularly relevant to sediment above the dam. For now, we have provided a description and budgetary estimates for tasks where the scope of work can be reasonably defined. In those instances where the scope/budget is not as clear, we have described the potential additional work, but have not included a cost estimate due to the many unknowns. Readers should refer to Table 10.2-1 in the main report for individual task line item estimates, and those tasks for which no budget could be estimated at this time.

Table ES-1 summarizes the total costs relative to:

- Cost expended on this feasibility study
- Cost associated with additional feasibility-related study tasks (see Table 10.2-1 in main report for details)
- Budgetary cost associated with removing the dam

Table ES-1: Summary of Budgetary Costs Associated with Feasibility Study and Dam Removal Alternative

Items	Budgetary Cost
Partial Feasibility Study	$81,700[1] (2014 dollars)
Completion to Full Feasibility Study	$171,000[2] (2014 dollars)
OPCC for Dam Removal	$743,000[2] (2014 dollars)
TOTAL	**$995,700 (2014 dollars)**

[1]Includes $40,000 from a grant.
[2]Grants could be pursued to lower the cost to the Town.
NOTE: The budgetary estimate for dam removal should be considered a starting point as the cost will likely increase as more is learned on the project.

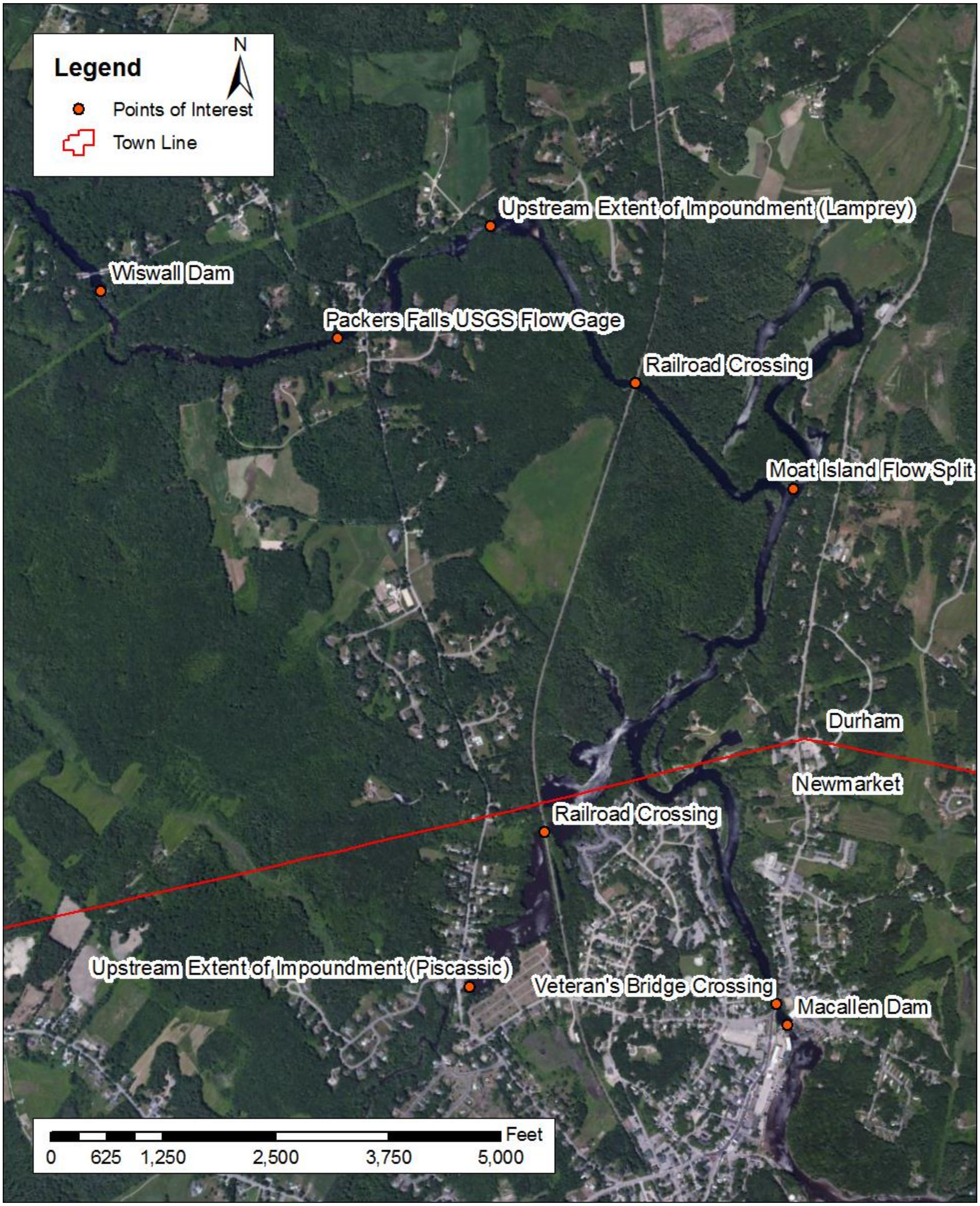

Figure ES-1: Dam and Impoundment Overview

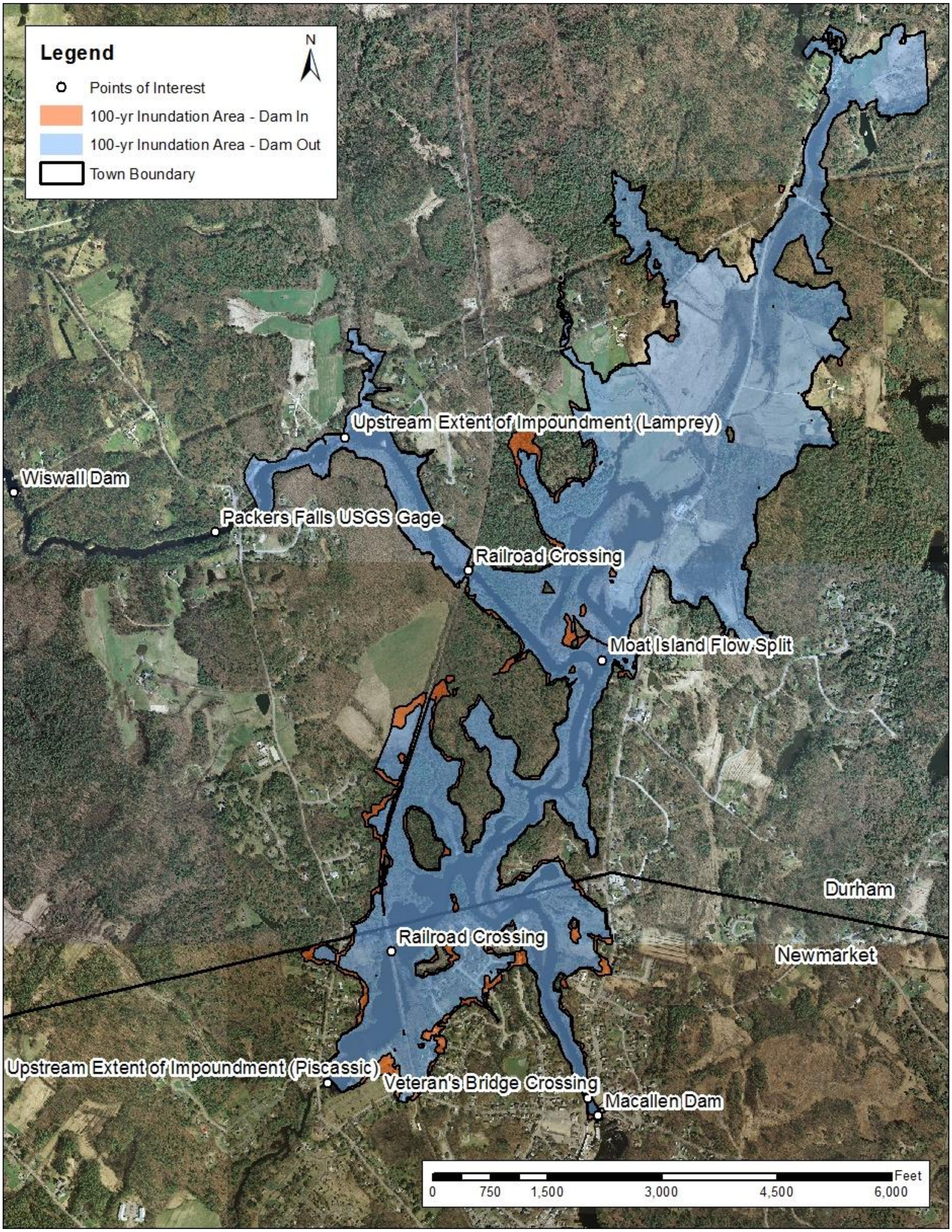

Figure ES-2: Inundation Map for the 100-year flow for Dam-in and Dam-Out conditions.

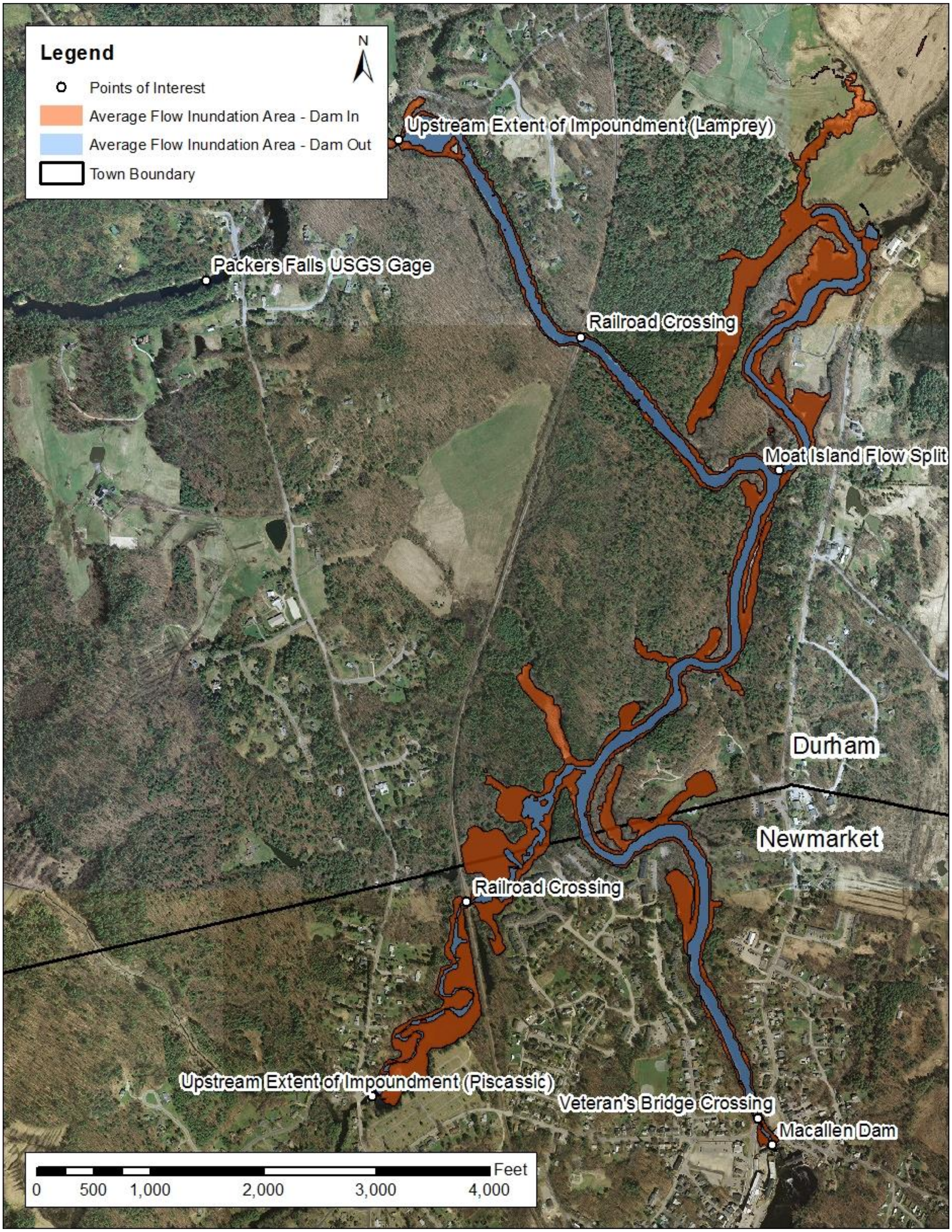

Figure ES-3: Inundation Map for the Average Annual Flow for Dam-In and Dam-Out conditions

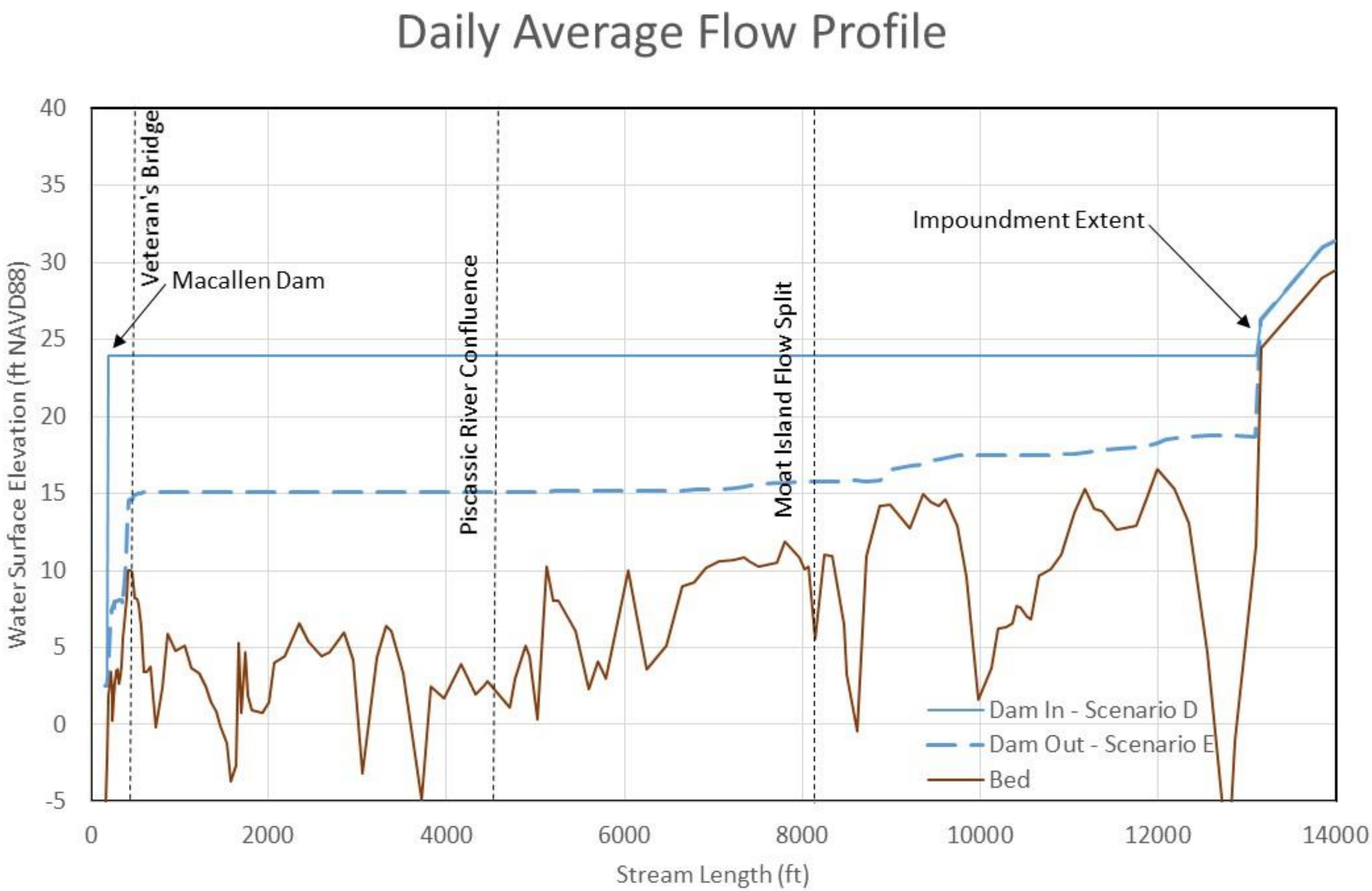

Figure ES-4: Longitudinal WSE profile for the Average Annual Flow for Dam-In and Dam-Out conditions.

1.0 Introduction

1.1 Background

Aerial View of Macallen Dam

The Town of Newmarket (Town) owns and operates the Macallen Dam; the head of tide dam on the Lamprey River. After the Lamprey River passes over the Macallen Dam, it empties into Great Bay, which receives water from the Squamscott, Lamprey, and Winnicut Rivers. Figure 1.1-1 is a map of the Lamprey River watershed showing the towns in the basin and key points of interest. The Macallen Dam consists of an approximate 27-foot high stone-block dam located in downtown Newmarket, NH. The current dam was constructed in 1887, as indicated by the engraved stone on the front of the dam[12]. It consists of three main sections including the right[13] abutment, the 70-foot-long spillway section, and the left abutment/gate section. Just upstream of the Macallen Dam are remnants of a timber crib legacy dam[14] that remains inundated.

In May 2008 and May 2010, the Town received a Letter of Deficiency (LOD) from the New Hampshire Department of Environmental Services (NHDES) Dam Bureau indicating the dam had various deficiencies that needed to be addressed. Although several deficiencies were identified, the most problematic deficiency is that the dam has insufficient spillway capacity and cannot safely pass the 100-year flood flow with one foot of freeboard. NHDES is concerned that a dam failure could potentially result in the loss of human life below the dam. As such, changes are needed to increase the dam's spillway capacity to bring it into compliance.

From 2008 through 2013, the Town contracted with Wright-Pierce to conduct various investigations including a re-evaluation of the 100-year flood flow and a dam failure analysis. Wright-Pierce's latest evaluation, completed in February 2013, included an alternatives analysis to increase the dam's spillway capacity to meet dam safety requirements. Alternatives evaluated included a) lowering the spillway crest elevation; b) lengthening the spillway; c) raising the abutments; and d) combinations of the above. Some alternatives were deemed infeasible by Wright-Pierce. For those alternatives deemed feasible by Wright-Pierce, they developed conceptual level cost estimates ranging from $1.1 to $4.6 million to

[12] Gomez and Sullivan Engineers (GSE) received information during the October 2013 drawdown that there is at least one other date-engraved stone located under the normal water line on the right abutment with a different year. The date is unknown.
[13] When referring to the left or right side of the river, it assumes one is looking in a downstream direction.
[14] The dam removal alternative described herein includes removal of the legacy dam.

increase the spillway capacity and another $315,500[15] to address other improvements to the existing dam and retaining walls.

A streamflow monitoring gage, operated by the United States Geological Survey (USGS), is located on the Lamprey River near Packers Falls Road just upstream of the impoundment created by the Macallen Dam. The gage records the Lamprey River's stage and streamflow, and has been active since 1935. In reviewing the instantaneous annual peak flows at this gage, the first and second highest peak flows on record occurred on May 16, 2006 (8,970 cubic feet per second, cfs) and April 18, 2007 (8,450 cfs). In addition, the fifth highest instantaneous peak flow occurred on March 16, 2010 (6,760 cfs). These three recent floods (May 2006, April 2007, and March 2010) suggest that long-term historic flow records may not fully represent the frequency and magnitude of flooding along the Lamprey River in future years[16]. Triggered in part by these recent flooding events, a May 2011 citizen-petitioned warrant article[17] requesting the Town to raise monies to evaluate removing Macallen Dam and to apply for federal and state grants to subsidize the cost of a dam removal feasibility study was voted upon by Newmarket residents. The warrant article passed and efforts were made to secure grants to help subsidize the overall feasibility study costs.

In 2010, the town applied for various grants to conduct a dam removal feasibility study. In the fall of 2011, the town was awarded a $40,000 grant from Restore America's Estuaries (RAE), a partnership of the National Oceanic Atmospheric Administration (NOAA) and the Conservation Law Foundation (CLF), to evaluate the feasibility of removing the Macallen Dam. The grant monies along with the Town's contribution ($41,700) were used to fund this dam removal feasibility study. The cost of this feasibility study is $81,700.

1.2 Scope and Purpose of Feasibility Study

It is important to understand the objectives of this feasibility study. The original scope of the dam removal feasibility study included numerous elements commonly evaluated in a full feasibility study. Due to funding limitations, however, the study budget and scope was curtailed accordingly. Thus, this document should not be considered a full feasibility study, as there are several outstanding issues and concerns associated with the potential removal of the Macallen Dam that have not been fully evaluated.

This study is one of many steps that will be necessary for the Town to determine how to address the outstanding LOD. As such, some of the key issues have been addressed in this report, while other issues will require further investigation if the Town opts to proceed further with the dam removal alternative.

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[15] $315,500 was the phase 2 work that was necessary. All phase 1 work was included in the spillway capacity conceptual cost estimates.

[16] For more information about climate change and land use impacts on flood flows in the Lamprey River, please refer to following website: http://100yearfloods.org/.

[17] Article 9 asked "*Shall the town raise and appropriate the sum of $85,000 through this special article for the purpose of evaluating the removal of the McCallen Dam [sic], as a precedent to any proposed capital investment toward its repair, in order, but not limited, to mitigate flooding in Newmarket from the Lamprey River; and further to authorize the Town Council to apply for, obtain and accept federal, state or other grants that may be available to subsidize costs associated with this feasibility study?*".

Table 1.2-1 contains a brief summary of what is included in this assessment, and what is recommended for future study if the Town decides to further advance the feasibility study. Later in this report we expand on the recommended additional feasibility-related tasks. For the Town's information, we have provided budgetary-level cost estimates to conduct these tasks. Finally, a budgetary estimate for removing the dam was developed, while recognizing that a full feasibility study has not been completed. In lieu of having a complete feasibility study to develop detailed cost estimates from, several simplifying assumptions had to be made. Therefore, the dam removal budgetary estimate should be considered a starting point of potential costs, as it is likely that costs will increase as more is learned.

Table 1.2-1: Issues Addressed in this Study and Issues Requiring Further Assessment Relative to Macallen Dam Removal

Issue	Issues Addressed in this Dam Removal Feasibility Study	Issues Requiring Further Assessment as part of a Full Dam Removal Feasibility Study
Survey	• Existing Conditions Plan was developed for laying out conceptual level dam removal options.	• Deed and title search of properties in the vicinity of the dam relative to access rights is needed. • Deed and title search is needed in any locations requiring access to the river (sediment removal, structural improvements to infrastructure). • Potential survey of the railroad bridge crossing the Piscassic River may be needed to determine if dam removal would require structural stabilization measures.
Infrastructure Impacts	• Cursory assessment of potential impacts to wells in Durham; Newmarket is on town sewer/water. • There is one sewer line traversing the Piscassic River below the first dam on the Piscassic River. • Cursory evaluation of the Newmarket's water supply intake on Piscassic River. • Per the fire department, the Town does not use water from the impounded reaches to fight fires or fill pumper trucks. • Preliminary structural assessment of infrastructure including Veterans Bridge, retaining walls, and buildings in proximity of the dam.	• Conduct structural and scour assessment at the railroad bridges spanning the impounded reach. Veterans Bridge was already assessed. • Determine what, if any, structural measures are needed to secure buildings or retaining walls adjacent to the dam. • Determine if structural measures are needed to secure other bridges potentially impacted by dam removal. • Determine if any underground utilities (water/sewer lines/water supply withdrawals) traversing the impounded reaches could be impacted by dam removal. • Conduct riverine ice survey.
Flooding	• A hydraulic model of Lamprey and Piscassic River was developed to determine the reduction in 100-year floodplain if the dam was removed.	• The hydraulic model is used as a tool in the design phase should dam removal be pursued. The same model is also used to assess sediment transport and to conduct scour analysis of infrastructure.
Sediment	• Conducted due diligence relative to potential sediment contamination. • Sediment thickness mapping at 11 transects.	• Develop sediment sampling plan. • Collect sediment samples. • Conduct laboratory (chemical) analysis of sediment cores. • Conduct ecological/human risk assessment of sediments using laboratory findings. • Pending chemical results may require additional sediment sampling for further chemical testing or potentially toxicity testing. • Conduct sediment transport analysis to predict mobile sediment volume. • Pending mobile sediment volume and contaminant levels, develop sediment management plan (and access plan should the sediment require dredging).

Issue	Issues Addressed in this Dam Removal Feasibility Study	Issues Requiring Further Assessment as part of a Full Dam Removal Feasibility Study
Environmental Resources	• Identified existing water quality issues. • Summarized reported rare, threatened and endangered species in the towns of Newmarket and Durham.	• Conduct wetlands delineation and assessment. • Conduct wildlife assessment. • Conduct aquatic (fish, macroinvertebrate, mussel, etc.), resource assessment. • Assess rare, threatened and endangered species in impounded reaches and just below the dam.
Recreation Resources	• Conducted cursory review (field observations) based on site visits in the summer on weekday and weekends.	• Assess dam removal impacts on angling, on-water kayaking, boating, access, Piscassic River boat ramps, existing docks, etc.
Aesthetic Resources	• A photo rendering was developed to illustrate what the dam area could look like absent the dam. • Numerous photographs were taken during the October 2013 drawdown to provide a sense of the visual impact if the dam was removed.	• Evaluation of viewscape and auditory changes if dam is removed.
Historic	• Developed Request for Project Review Form and preliminarily identified the Area of Potential Effect.	• Archeological surveys including, at a minimum, Phase 1A, and pending the Phase 1A findings, Phase 1B and Phase II to determine if a site is eligible for the National Register of Historic Places (NRHP). • Historic structures including a Phase I historic/architectural/engineering survey to determine the dam's eligibility for the NRHP. • If the lead federal agency finds the dam is eligible for the NRHP and the dam is removed, a Memorandum of Agreement identifying mitigation would be developed.
Property Value and Tax Implications	• Not Assessed.	• Assessment of property values and tax implications for those property owners abutting the impoundment.
Dam Removal Opinion of Probable Construction Costs	• Dam removal budgetary estimate was developed as part of this study. It includes several assumptions and thus should be considered a starting point relative to cost.	• Dam removal budgetary estimate would be refined after completion of the above additional feasibility tasks. Budgetary estimate should be considered a starting point of potential costs; removal costs likely to rise if any assumptions (e.g., sediment poses no ecological/human risk) are not correct.

Recognizing that this is not a complete feasibility study, this initial assessment provides preliminary data for the Town to determine whether the additional feasibility steps should be advanced or not. After a full feasibility assessment is complete, the Town can make an informed decision on what alternative (dam repair/modification or dam removal) to pursue in order to meet NHDES Dam safety requirements.

Regardless of whether the dam removal feasibility alternative is advanced, the Town must address the NHDES Dam Bureau's LOD to bring the dam into safety compliance, as the status quo alternative is not a viable alternative. Gomez and Sullivan Engineers (GSE) were contracted by the Town to conduct this feasibility assessment and to evaluate only the dam removal alternative; our scope did not include evaluating other alternatives. As noted above, Wright-Pierce conducted a few studies on the Macallen Dam for the Town including a dam break analysis, estimation of the 100-year flood and an evaluation of alternatives to modify the dam so it can pass the 100-year flood with one foot of freeboard. As the study progressed we were requested by the Town, Dam Committee (listed below), and other Project Partners (listed below) to identify other potential alternatives, other than dam removal, based on our review of past studies (primarily the Wright-Pierce reports) and the information gained/learned as part of this project. Thus, although beyond our current scope of services, we have identified other alternatives the Town may wish to pursue, but have excluded costs.

It is also important to understand that no decision relative to removing or modifying the dam has been made; the Town is only seeking information and facts at this juncture to make an informed decision relative to next steps. The Town is currently in the preliminary stages of evaluating the feasibility of potentially removing the dam. If the Town were to advance the feasibility study and in the end were to select dam removal as the preferred alternative, our experience suggests the full process could take years to advance from the study phase to the actual removal phase. Finally, if the Town were to opt for dam removal, a bid document would be prepared such that competitive bids for removing the dam would be obtained from contractors.

1.3 Project Partners

Project Partners include those entities participating in this feasibility study, whether financially or through technical assistance. The study was managed by the Newmarket Town Planner and was overseen by the Macallen Dam Study Committee, comprised of the Town Planner, the Town Public Works Director, a member of the Newmarket Conservation Commission, a member of the Lamprey River Advisory Committee and three at-large Newmarket citizens. Besides the above, other Project Partners included the NHDES, New Hampshire Fish and Game Department (NHFGD), NOAA, and CLF.

This study was conducted by GSE, with support from Hoyle Tanner Associates (HTA, for structural assessment) and Public Archaeological Laboratory (PAL, for cultural assessment).

1.4 Report Format and Survey Datum

Report Format

This report consists of two volumes. Volume 1 of 2 (this document) contains text and smaller tables. Volume 2 of 2 contains all of the figures, larger tables and appendices.

Survey Datum

As described later, a survey of the dams and other infrastructure was conducted as part of this study. The vertical control of the survey is based on the North American Vertical Datum (NAVD) of 1988 (NAVD88). All elevations reported herein are based on NAVD88, unless otherwise noted. The horizontal control of the survey is based on NH State Plane Coordinates.

2.0 Project Setting, Dam Features and Operation

2.1 Setting

The Macallen Dam is located on the Lamprey River in downtown Newmarket, NH. Figure 2.1-1 is an aerial map of the impoundment; Figure 2.1-2 is a close-up aerial view of the dam. Based on existing mapping and survey conducted as part of this study, an existing conditions plan of the dam and project area was developed as shown in Figure 2.1-3. The dam is readily visible from the Veterans Bridge (Route 108) located immediately upstream of the dam, from the walkway spanning the Lamprey River below the dam, and from various locations on each side of the river. There is considerable infrastructure development around the dam including buildings and parking lots (see Figures 2.1-2 and 2.1-3) making access for a potential dam removal challenging. The dam creates an impoundment extending approximately 2.5 miles up the Lamprey River and approximately 0.75 miles up the Piscassic River – a major tributary to the Lamprey River. The impoundment extends into Durham, NH and creates several backwater/bay areas, including an impounded area nearly circling what is referred to as Moat Island. The dam's presence creates a backwater extending up the Piscassic River from its confluence with the Lamprey River to the bedrock falls marking the upstream extent of the Macallen Dam impoundment.

There are several condominium or apartment complexes and residential houses flanking the impoundment in the lower portion of the Macallen Dam's impoundment. Based on GSE's field observations from a boat on the impoundment, some housing structures are located on a bluff and not likely flooded; while other structures are located closer to the river and have less topographic relief making them susceptible to flooding. The river supports recreational activity as evidenced by several docks and a boat ramp at the end of Piscassic Street. No detailed recreation study was conducted, but based on GSE's three on-the-water site visits to the impoundment (summer weekend, summer weekday and fall weekday) there were several kayakers, canoeists and small motorized boats observed on the impoundment. The impoundment also provides recreational uses in the form of fishing (open water and ice fishing), cross-country skiing, ice skating, snowmobiling, swimming, paddleboarding, bird watching and snorkeling.

2.2 Dam Geometry and Operation

Dam Geometry

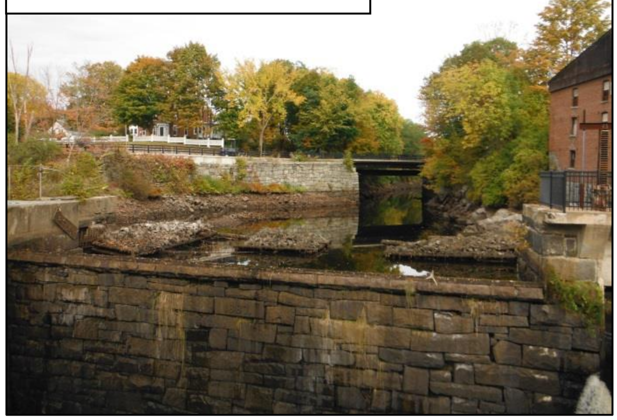
The Macallen Dam is an approximately 27-foot high stone-block dam. The current dam structure was constructed in 1887, as indicated by the engraved stone on the front of the dam. The dam was constructed on or near what some history books have referred to as "*the First Falls*." Based on cursory research, historic documents suggest there have been dams located at or near this location perhaps as far back as the late 1600's.

Looking across Macallen Dam

The dam consists of the following three main sections: the right abutment (Figure 2.2-1), the spillway section (Figure 2.2-2), and the left abutment/crest gate section (Figure 2.2-3). The right abutment is a stone-block and concrete wall, which is structurally attached to the fish ladder. The right abutment has a crest elevation of 28.47 feet. Immediately below the right abutment is a brick building currently housing a commercial business (the Durham Book Exchange). The retaining wall on the right abutment appears to connect to the Durham Book Exchange building's foundation as well as to a portion of the fish ladder (see above inset photograph, taken during the October 2013 drawdown). The spillway is constructed of stone-block, with a crest elevation of 22.35 feet[18]. It is unknown if the stone block structure contains any mortar or internal pins. Based on visual observations, the downstream face of the dam does not appear to have mortar between the stone blocks.

There is a small metal lip along the center of the spillway (crest elevation 22.42 feet) that further controls water levels. The lip appears to be a relic from when the spillway was equipped with flashboards[19]. The left abutment/gate section is a stone-block and concrete section with three 7-foot-wide by 7-foot-high manually-operated crest gates. The gates are adjusted on-site using an electric-powered motor. A backup generator is available for use if the normal power supply is unavailable. The gates have a crest elevation of 16.15 feet and a top elevation of 23.15 feet. While the gates are 7 feet high, the NHDES Dam Bureau's September 17, 2010 inspection report stated that the gates cannot fully open and listed 5.5 feet above the crest as the maximum opening height (elevation 21.65 feet). The gates have since had extenders installed so that they can open the full 7 foot height (Personal Communication, Newmarket Public Works Director, March 2014), with a maximum opening height of 23.15 ft. With a gate crest elevation of 16.15 feet and a spillway crest elevation of 22.42 feet (at the metal lip), the water level behind the dam can be lowered up to approximately 6.3 feet. The left abutment, located above the gates, has a crest elevation of 30.20 feet.

Legacy Dam in background



Remnants of a timber crib legacy dam are located between the Macallen Dam and Veterans Bridge. Historically, it was not uncommon to construct a new dam below an older dam as the older structure served to control flow during construction of the new dam. The inset shows parts of the timber crib dam when the impoundment was lowered in October 2013 as part of this study.

[18] A previous survey by Wright-Pierce indicated that the dam's crest elevation was approximately 22.18 feet, a difference of 0.17 feet. This difference may be explained by a combination of both surveys' measurement accuracy.

[19] Flashboards are commonly constructed of wood and are affixed to the spillway crest to raise the water level behind the dam typically to increase hydroelectric generation.

Dam Operation

The Macallen Dam is operated as a run-of-river facility, where inflow equals outflow on a near continuous basis. This means that water levels behind the dam are typically maintained at the spillway crest elevation or higher as inflow increases. The gates are typically in a closed position and all flow is passed over the spillway or through the fish ladder, when operating. If, for example, inflow to the dam was 30 cfs and the fish ladder was not operating, then the discharge over the spillway would be approximately 30 cfs; no water is “stored” behind the dam. If inflow exceeds the discharge capacity of the spillway and gates, then water starts backing up behind the dam—as experienced in the May 2006, April 2007, and March 2010 floods, among others.

The Macallen Dam has two means of passing water: the overflow spillway and the crest gates. During normal hydrologic conditions, flow passes exclusively over the spillway (or a small amount through the fish ladder during certain times of the year). During high flow or flood events, the crest gates are typically opened to allow more flow to pass with the goal of not overtopping[20] the dam. During some recent extreme flood events (May 2006, April 2007, March 2010), the dam abutments were overtopped even with the gates open (Figure 2.2-4), and sandbagging was needed as described later.

In our experience with dam removal projects, the public is not always aware of how a dam operates or its intended function. The Macallen Dam was originally constructed to harness the vertical drop in water to power the mills below the dam. However, like many dams of this vintage, the mills are gone and it no longer produces power (although the dam creates an impoundment used for recreational purposes). The dam was not constructed to provide flood storage capacity, such as a US Army Corps of Engineer Dam and reservoir. As such, the dam provides no flood control benefits; instead it artificially raises the river’s water surface elevation (WSE).

[20] Overtopping means if the water level rises above the dam’s abutment elevation.

3.0 Regulatory Oversight, Letter of Deficiency and Past Studies

3.1 Regulatory Oversight

The NHDES Dam Bureau is responsible for dam oversight in New Hampshire. NHDES classifies dams as Class AA, Class A, Class B, or Class C. The hazard classification is based on a dam's size (height), volume of impounded water and the potential loss of life, structures, and property if dam failure were to occur. The Macallen Dam is classified as a Class C structure (i.e., high hazard dam). A high hazard classification means that loss of life is likely to occur if the dam were to fail. Specifically, the NHDES regulations (Env-Wr 101.09) state that:

"Class C Structure means a dam that has a high hazard potential because it is in a location and of a size that failure or misoperation of the dam would result in probable loss of human life as a result of:

- *(a) Water levels and velocities causing the structural failure of a foundation of a habitable residential structure or a commercial or industrial structure which is occupied under normal conditions;*
- *(b) Water levels rising above the first floor elevation of a habitable residential structure or a commercial or industrial structure which is occupied under normal conditions when the rise due to dam failure is greater than one foot;*
- *(c) Structural damage to an interstate highway which could render the roadway impassable or otherwise interrupt public safety services;*
- *(d) The release of a quantity and concentration of materials which qualify as "hazardous waste" as defined by RSA 471-A:2 VI; or*
- *(e) Any other circumstance which would more likely than not cause one or more deaths."*

As stated in the NHDES Dam Bureau's 2010 LOD to the Town, the Macallen Dam is classified as a high hazard dam because the dam's right abutment is integral to the foundation of the historic brick mill building (Durham Book Exchange) on river right. The NHDES Dam Bureau's concern is that if the dam were to breach or overtop, its failure could impact the foundation of the historic brick mill building. This building is a commercial structure that is occupied under normal conditions[21], as described in term (a) above.

NHDES requires that each dam classification must pass a specific discharge capacity, which means "*the amount of water which can safely pass the structure through its normal discharge channels*" (Env-Wr 101.16).

NHDES regulations (Env-Wr 303.11) state the following relative to discharge capacity:

- *(a) All Class A, Class B, or Class C dams constructed prior to February 19, 1981 shall pass the flows indicated below with one foot of freeboard and without manual operations:*
  - *(1) Class A dams shall pass a 50-year flood, or at the owner's option, the site specific inflow design flood;*
  - *(2) Class B dams shall pass the 100-year flood, or at the owner's option, the site specific inflow design flood; and*

[21] Past inspections (prior to 2010) did not take this building into account because it was previously uninhabited.

(3) Class C dams shall pass 250% of the 100-year flood, or at the owner's option, the site specific inflow design flood.

As a Class C dam, the Macallen Dam must pass 250% of the 100-year flood, or at the owner's option, the site specific inflow design flood (IDF)[22]. Wright-Pierce conducted a detailed study of the site specific IDF and concluded that the IDF is equivalent to the 100-year flood at the Macallen Dam. This effectively means that for flows above the 100-year flood, failure of the dam is not anticipated to cause any additional loss of life or property beyond what would already have occurred from a flood of that magnitude. The Macallen Dam's 100-year flood flow is 10,259 cfs after taking the Lamprey-Oyster "flow split" into account[23]. It is worth noting that the dam's previous classification as a Class B dam (i.e., significant hazard dam) prior to 2008 would still require passage of the 100-year flood or the IDF. Since the IDF is being used as the design flood, and it is the same as the 100-year flood, the dam's discharge capacity requirement would not change even if the dam was considered a significant hazard dam rather than a high hazard dam.

The "one foot of freeboard" requirement means that the water depth over the dam spillway under the 100-year flood must be at least one foot below the lowest abutment. For the Macallen Dam, the right abutment (elevation 28.47 feet) is the lower abutment. This means that the 100-year flood flow must pass with a WSE of 27.47 feet or less at the dam. The estimated spillway discharge capacity with one foot of freeboard under existing conditions is 2,637 cfs as described in Section 9.2, which represents only 26% of the 100-year flood flow of 10,260 cfs (see Section 7.1.2 for 100-year flood flow).

The term "without manual operations" is not explicitly defined in the dam safety regulations. Based on our experience with NHDES Dam Safety, this means that any structure requiring human intervention is considered manual operations. The three gates at the dam's left abutment require a person to either physically or electrically open the gates. Thus, these gates are not counted toward the dam's discharge capacity even though the Town would normally open them during a flood event. If the gates were permanently removed (eliminating the "manual operation"), leaving three unobstructed 7-foot wide openings, the NHDES Dam Bureau would consider the openings as additional discharge capacity. It should be noted that removal of the gates would result in a lower impoundment elevation, similar to that experienced during the October 2013 drawdown. In addition, even with the gate opening discharge counted towards the overall dam's discharge capacity, it would still have insufficient spillway capacity to pass the 100-year flood. The estimated spillway discharge capacity with the gates removed and one foot of freeboard (no abutment raising) is 4,286 cfs as described in Section 9.3, which represents 42% of the 100-year flood flow of 10,260 cfs.

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[22] The IDF is the flow at which dam failure is not anticipated to cause any additional impacts to life or property.

[23] Under extreme floods, the Lamprey River water surface elevation rises high enough to flow over the typical watershed boundary. When this happens, some of the Lamprey River's flow diverts into the Oyster River watershed, rather than passing downstream to the Macallen Dam. This phenomenon is explained in Section 7 of this document.

3.2 Letter of Deficiency and Past Studies

The NHDES Dam Bureau regularly conducts dam safety inspections. Following the inspections, the Dam Bureau typically issues dam owners follow-up information, which may include general comments or a LOD if necessary. Following a November 7, 2007 inspection, NHDES sent the Town a LOD regarding Macallen Dam in May 2008. The LOD noted a spillway capacity deficiency and other items not addressed in the 2004 LOD, among other items. Since then, there has been a series of follow-up studies, a new LOD in September 2010, and other correspondence between NHDES and the Town. The purpose of this section is to summarize the actions and correspondences that occurred since the 2008 LOD was issued up through the issuance of the most recent Wright-Pierce letter report dated February 6, 2013.

2008 Hazard Reclassification (April 7, 2008): Based on NHDES's April 7, 2008 Macallen Dam inspection report, the Macallen Dam's hazard classification was changed from a Significant Hazard (Class B) dam to a High Hazard (Class C) dam. The classification change at the time was based on anticipated flooding in downstream apartments in the event of a dam breach. The hazard reclassification increased the dam's required design flow from the 100-year flood or the IDF to 2.5 times the 100-year flood or the IDF. The inspection did not note any sign of habitation in the historic mill building (current proprietor, Durham Book Exchange) that appears to be structurally tied to the right abutment, and that building was thus not considered in the hazard classification as part the 2008 reclassification and LOD.

NHDES 2008 Letter of Deficiency (May 5, 2008): The NHDES sent the Town a LOD on May 5, 2008. This LOD superseded a previously issued LOD from 2004. The 2008 LOD noted that some items from the 2004 LOD were not addressed. The LOD included a timeline for addressing the deficiencies, which included submitting an Operations, Maintenance and Response (OMR) form to NHDES, developing an Emergency Action Plan (EAP) and inundation maps, and various other structural and maintenance-related items. The LOD also indicated that the Town must submit a permit application with plans and specifications to increase the dam's discharge capacity so that it can "*safely pass the design flow (2.5 Q100 or IDF) with one foot of freeboard and no operations*."

Wright-Pierce Dam Assessment (began in 2009): In 2009, the Town hired Wright-Pierce to conduct an overall assessment of Macallen Dam, including a structural inspection and analysis of the dam, drafting an EAP, dam breach modeling and inundation mapping.

Wright-Pierce Structural Analysis and Recommendations (March 8, 2010): Wright-Pierce's letter report summarized the results of their November 7, 2009 inspection. Several repairs and rehabilitation measures were suggested to be undertaken within two years. The report indicated that Wright-Pierce did not perform a structural or stability analysis of the dam.

Wright-Pierce Structural Repair Cost Estimate (April 1, 2010): The document provided a cost estimate for the repairs and rehabilitation measures indicated in the March 8, 2010 letter. The costs were broken down into two phases, where Phase I repairs were recommended near-term fixes, while Phase II repairs were recommended to be completed concurrent with dam hydraulic capacity improvements. The estimates were $215,000 for Phase I and $290,000 for Phase II. The letter report did not include a cost estimate to bring the dam into compliance with the spillway flow capacity requirement.

Wright-Pierce Initial Dam Breach Results (May 24, 2010): Wright-Pierce sent a letter report summarizing the dam breach analysis to the Newmarket Town Administrator at that time. The report objectives were to verify the dam's hazard classification and provide initial inundation mapping for use in the EAP. The dam breach analysis was conducted for a 100-year flood flow of 8,302 cfs and a "Sunny Day"[24] flow of 272 cfs. The 100-year flow used in the analysis was cited as the same flow indicated in the April 2007 inspection report.

The report indicated that neither the downstream apartments nor any other habitable structure would be impacted by the dam breach. Thus, Wright-Pierce concluded that the dam should be reclassified as a significant hazard dam. The Town sent NHDES a reclassification request letter on June 7, 2010 asking to change the dam's classification from High Hazard to Significant Hazard.

NHDES Review of Initial Dam Breach Results (September 8, 2010): NHDES provided comments to the Town on the initial dam breach results and the hazard reclassification request.

The letter noted that the historic mill building (current proprietor, Durham Book Exchange) abutting the dam's right abutment appeared to be habited, and that a failure of the dam may impact the building's foundation. Thus, regardless of potential impacts to the downstream apartments, it was necessary to maintain the dam's High Hazard classification.

Other key points from the letter included:

1) The 100-year inflow used in the initial report (cited in the 2007 inspection report) dated back to a February 1999 inspection report. The 100-year flood flow was determined by using the USGS streamflow gage (Gage No. 01073500) located on the Lamprey River at Packers Falls and adjusting the 100-year flood at that location, based on drainage area, to the Macallen Dam. NHDES recommended developing a new 100-year inflow for Lamprey River at Macallen Dam.

2) NHDES suggested conducting an IDF analysis, which may result in a lower design flood than 2.5 times the 100-year flood. Because the High Hazard classification is solely due to the historic mill building next to the right abutment, the IDF may be as low as a 100-year flood event.

NHDES 2010 LOD (September 27, 2010): NHDES issued a new LOD. The LOD included a timeline for addressing the deficiencies, which included submitting an OMR form to NHDES, developing an EAP and inundation maps, and various other structural and maintenance-related items. The LOD also indicated that the Town must submit a permit application with plans and specifications to increase the dam's discharge capacity so that it can "*safely pass the design flow (2.5 Q100 or IDF) with one foot of freeboard and no operations*" by September 1, 2012. On January 2, 2011, the Town responded to the LOD and signed a form agreeing to address the deficiencies. The Town's 1/3/2011 response also noted that "we are proceeding with a warrant article on the May Town Meeting warrant to seek a bond to undertake noted repairs." Although dam removal was not specifically mentioned in the Town's response, a warrant article was passed in May 2011 authorizing the partial funding of a dam removal feasibility study.

[24] The term Sunny Day is used to reflect a dam breach or failure during a non-flood event or a "sunny day".

Wright-Pierce Final Dam Breach Results (February 6, 2013): Wright-Pierce revisited the initial dam breach analysis based on comments received by NHDES. There was a series of communications between Wright-Pierce and NHDES concerning the hydrology and hydraulics components of the dam breach analysis. The hydrology discussions focused on the rainfall-runoff analysis[25] for the Lamprey River watershed. The hydraulics discussions focused on the Lamprey River/Oyster River "flow split". Ultimately, the Town and NHDES agreed on a 100-year flood flow (which is also the IDF) at the Macallen Dam of 10,259 cfs.

The letter report resulting from this analysis was sent to the Town on February 6, 2013. In addition to describing the final inundation maps and modeling results, the report included a conceptual cost estimate to bring the Macallen Dam into compliance. The costs were broken down into dam repairs costs from the April 2010 letter and dam modification costs necessary to meet the spillway flow capacity requirements.

3.3 Wright Pierce Conceptual Level Cost Estimates to Bring Dam into Compliance

In Wright-Pierce's February 2013 report, the costs associated with dam repairs unrelated to the spillway capacity deficiency were provided and broken into Phase 1 and Phase 2 as follows:

<u>Phase 1</u>
Near term recommendation including:

- gate structure improvements;
- eastern upstream retaining wall repairs;
- Cost estimate was $215,000 (April 2010 dollars), $234,000 (in February 2013 dollars).

<u>Phase 2</u>
Repairs that may be impacted by spillway capacity improvements including:

- Dam structure improvements;
- Western upstream retaining wall repairs;
- Cost estimate was $290,000 (April 2010 dollars), $315,500 (February 2013 dollars).

The total cost for Phase 1 and 2 was $505,000 in April 2010 dollars or $549,500 in February 2013 dollars.

In the same February 6, 2013 report, Wright-Pierce included several potential dam modifications to address the insufficient spillway capacity issue. The alternatives included:

- permanently lowering the dam spillway by removing the upper portion of the spillway;
- widening the spillway beyond its current 70 feet;
- raising the dam abutments; and,
- combinations of the above three alternatives.

[25] NHDES required that a rainfall-runoff analysis be conducted to estimate the 100-year flood flow, rather than relying on the Lamprey River USGS gage. This is consistent with other recent dam safety assessments.

Due to site constraints, Wright-Pierce considered any alternative requiring widening of the spillway crest beyond 140 feet to be infeasible. The report listed five alternatives as potentially feasible. The dam modification cost estimates included the $290,000 (2012 dollars) for Phase 1, but did not include costs for Phase 2 or potential improvements or modifications to the fish ladder.

Table 3.3-1 summarizes the spillway improvement alternatives that Wright-Pierce deemed potentially feasible. Note that the estimated costs in Table 3.3-1, obtained from the Wright-Pierce February 6, 2013 report, had the following footnote: *"The costing presented here is conceptual in nature and is based on data collected from across the nation"*. Wright-Pierce refers readers to Appendix G of its report which lists six dams in NH, OR, and VT where estimates to modify or remove the dams were developed. The estimates do not reflect the actual construction costs to remove the dams. Wright-Pierce then unitized the estimates to include the cost per vertical foot of dam removed and the cost per vertical foot of raising an abutment. Unitized high end and low end estimates were included in the report's appendix. Average unitized costs were computed and then applied to the Macallen Dam to develop the budgetary numbers in Table 3.3-1.

Table 3.3-1: Potentially feasible dam spillway alternatives from February 2013 Wright-Pierce report.

Alternative	Description	Crest Elevation (feet)	Reduction in Crest Elevation (feet)	Crest Length (feet)	Estimated Cost ($2013 dollars)
Existing	Existing conditions – NOT FEASIBLE, included for comparison purposes	22.18	-	70	-
1	Increase spillway crest length	22.18	0.00	350	Not Feasible
2	Lower spillway crest	12.59	9.59	70	$1,100,000
3	Increase crest length, lower crest elevation	17.30	4.88	140	$2,900,000
4	Raise west abutment 1.8 feet, increase spillway crest length	22.18	0.00	265	Not Feasible
5	Raise right (west) abutment 1.8 feet, lower crest elevation	14.39	7.79	70	$1,300,000
6	Raise right abutment 1.8 feet, lower crest elevation, increase crest length	19.10	3.08	140	$3,000,000
7	Raise right abutment 1.8 feet, lower crest elevation, increase crest elevation, add 3 foot tall crest gate	22.18	0.00	140	$4,600,000

Only two alternatives did not require widening the spillway. These scenarios, Alternatives 2 and 5, called for permanently lowering the spillway crest by 7.8 feet to 9.6 feet, respectively. As a frame of reference the maximum drawdown during October 2013 was approximately 6.6[26] feet as measured at the dam relative to pre-drawdown conditions. Thus, the reduction in the width and depth of the impounded reach observed during the October 2013 drawdown would be greater under Alternatives 2 and 5.

[26] This is greater than the maximum drawdown listed above because the pre-drawdown water level was several inches above the spillway crest.

4.0 Existing Conditions Plan and Bathymetric Mapping

4.1 Existing Conditions Plan

An existing conditions plan (Figure 2.1-3) shows the dam, the timber-crib legacy dam, surrounding buildings, planimetrics (utilities, overhead wires, etc.) and topography in plan view. The purpose for developing an existing conditions plan is to assist in preparing a conceptual level dam removal plan showing access routes, and the general construction sequencing.

The plan was developed using several survey datasets. These included field survey data collected by Gomez and Sullivan, existing Light Detection and Ranging (LiDAR) data and aerial photographs. Field survey data collected by Gomez and Sullivan included use of a Sokkia Real Time Kinematic-Global Positioning System (RTK-GPS), a Trimble robotic total station and manual measurements (vertical rod, tape measure. The accuracy of the Gomez and Sullivan survey data was approximately ± 0.1 feet. The LiDAR data was obtained from NH GRANIT (www.granit.sr.unh.edu) and has a listed accuracy (root mean square error) of ±15 centimeters (approximately ±0.5 feet).

4.2 Bathymetric Mapping

Bathymetric[27] mapping of the Macallen Dam impoundment, extending up the Piscassic and Lamprey Rivers to the full impoundment extents, was conducted on September 23, 2013. The impoundment was at normal levels (i.e., not drawn down) when the survey was conducted. The mean daily flow for that day, as recorded at the USGS gage on the Lamprey River near Packer Falls Road, was 223 cfs (provisional data) or approximately 260 cfs at Macallen Dam when accounting for the additional drainage area. The bathymetric survey provides information on the depth of water and slopes from the river banks to the channel thalweg[28].

To develop the bathymetric map, a motorized boat equipped with an echosounder (Sontek RiverSurveyor M9) and an RTK-GPS (Sokkia GRX1) was used to obtain depth and location measurements throughout the impoundment. All water depth measurements were measured relative to the WSE elevation adjacent to the boat, which was continuously recorded by the RTK-GPS. The difference in the WSE at the dam and at the most upstream end of the impoundment, below Packers Falls, was approximately 0.2 feet. Thus, the impoundment's WSE is relatively flat under normal flow conditions.

Water depth measurements were collected using a Sontek RiverSurveyor M9, equipped with one 500-KHz vertical beam, four angled 1 MHz beams and four angled 3 MHz beams. The primary function of the 1 MHz and 3 MHz beams is to measure water velocities, but they also provide a redundant depth measurement. The RiverSurveyor has an accuracy of approximately 1% of the water depth (e.g., 0.1 feet accuracy in 10 feet of water, 0.25 feet accuracy in 25 feet of water). System accuracy was checked before and after the survey by comparing echosounder water depth measurements to known water depths. Known water depths were obtained using a survey rod in relatively flat and calm locations at

[27] A bathymetric map is the same as a topographic map, but reflects underwater elevation contours.
[28] The thalweg is the lowest point (deepest) along a cross-section of the river, where the cross-section is cut perpendicular to the river's flow direction.

various depths. As noted above, measured depths were converted to bottom elevations by subtracting the recorded water depth from the recorded WSE.

Figure 4.2-1 includes a colored bathymetric map of the impoundment. Figure 4.2-2 is a zoomed-in version of the bathymetric map from just above Veterans Bridge to Macallen Dam. Figure 4.2-3 is a profile of the Lamprey River showing the thalweg and the elevation of the spillway crest.

5.0 Sediment

5.1 Background

An issue common to most dam removal feasibility studies is how to manage sediment that is accumulated behind dams. Rivers not only transport water, but also sediment (e.g., sand, silt, clay) as either bed load (moving along the channel bed) or suspended load (transported in the water column). In upland areas of the watershed, physical, chemical, and biological erosive forces provide a continuous source of sediment for transport. Glacial deposits can also become mobilized. The sediment is collected by runoff and eventually enters tributaries and the mainstem of the river. From here the sediment is degraded until it is small enough to be transported by moving water. A river's velocity varies with the channel gradient (slope), width, and depth and the magnitude of flow, which is always changing. Usually, sediment deposits exhibit a range of sediment sizes from fine clays to boulders because the river passes through a varied geologic deposits. This range of sediment sizes leads to armoring, whereby fine particles are carried away and coarser sediment remains in place, protecting the channel bed from further erosion.

As a river carrying water and sediment transitions from a free-flowing condition (higher velocities) to an impoundment (slower velocities), sediment will start to drop out of the water column and accumulate in the impounded reach. For projects where sediment accumulates behind the dam, there are various steps needed to help inform sediment management alternatives should the dam be removed. A description of these steps is summarized below.

5.2 General Steps for Evaluating Sediment Volume, Testing, and Transport

The NHDES has established general protocols for evaluating the quantity, quality, and transport of sediment accumulated behind dams. These steps (in no particular order) include:

- conducting due diligence;
- pending due diligence results, develop a sediment sampling plan;
- if warranted, conducting sediment sampling/laboratory analysis;
- evaluating sediment quality;
- quantifying total sediment volume; and if needed
- quantifying mobile sediment volume.

The findings of these steps are used to inform sediment management alternatives. NHDES is in the process of revising these protocols. This section summarizes the various steps used to assess sediment and whether it was conducted as part of this feasibility study. Section 5.3.2 includes a description of what sediment activities were conducted as part of this project and recommended next steps.

5.2.1 Due Diligence

This step involves researching existing databases and contacting the Town for potential contaminant spills or historical use of the river by mills in the project area, as these contaminants can become attached to the surrounding sediments and then be transported down river. Historic mills, such as tanneries, were known to dispose of waste material directly into the river or bury the waste on-site. The purpose of a due diligence investigation is to determine if sediment sampling is warranted, and if so, to have a better understanding of the potential suite of contaminants to test.

A due diligence memo is developed summarizing the findings and recommendations for the next steps, which could range from recommending no sediment testing to developing a sediment sampling plan. In cases where the drainage area to the dam is small and the watershed is not highly developed, no sediment sampling may be recommended. In contrast, in larger more urban watersheds some level of sediment sampling is typically recommended—which would the case for this project.

In either case, the due diligence memo is provided to the NHDES Water Quality Section and Environmental Health Program. NHDES will review the memo and make a determination of a) concurrence with the recommendation (which could entail some or no sediment sampling), b) if sampling is proposed, modification to the proposed sampling or c) request additional information prior to making a determination. Typically, the due diligence memo is also sent to NHFGD and other relevant state and federal agencies for their review and comment.

A due diligence analysis was completed as part of this study as summarized later in this section, however a due diligence memo has not been prepared or submitted to NHDES or other state or federal agencies.

5.2.2 Develop Sediment Sampling Plan

Sediments found in streams, rivers, lakes and estuaries are habitat for many forms of aquatic life. Bottom-dwelling aquatic life such as insects and crustaceans are intimately linked via nutrient and energy webs to higher trophic level organisms such as fish, birds and other wildlife. Sediments can serve as a repository and source of persistent and potentially toxic inorganic and organic chemicals. Contaminated sediment may adversely impact these ecological resources or humans who consume these resources.

If the due diligence analysis suggests the potential for contaminated sediment, sediment sampling is recommended. The NHDES has established protocols for sampling sediments for contaminants before dam removals occur (as noted above, NHDES is currently in the process of updating their protocols). The NHDES adopted the USEPA Sediment Quality Triad Approach to assess adverse impacts on sediment aquatic life. This methodology integrates both chemical and biological data to assess ecological risk and includes three components that are applied sequentially. The components are:

1. Sediment chemical analysis
2. Sediment toxicity bioassays
3. Benthic community assessment (this step is typically not conducted for dam removal projects)

Essentially the findings of the chemical analysis (step 1) inform whether step 2 is necessary. If an ecological risk assessor interprets the laboratory results for the chemical testing and finds no ecological/human risk, then no further testing may be required. However, if the ecological risk assessor finds that the laboratory results exceed certain screening level thresholds (representing potential ecological/human risk), then step 2 may be conducted or further step 1 testing may be recommended.

Assuming the due diligence recommends sediment sampling, a sediment sampling plan must be developed to include the following:

- Proposed locations for collecting sediment cores for laboratory sampling,
- Proposed sampling methods , procedures and techniques for collecting the sediment cores,
- Listing of proposed chemicals to be evaluated in the laboratory,
- Laboratory detection limits; and
- Chain-of-custody forms.

The standard suite of chemical testing (see bullet 3 above) includes the following parameters:

- Total organic carbon (TOC);
- Grain size distribution via sieve and hydrometer, bulk density and porosity- these parameters are needed for sediment transport analysis;
- Polynuclear aromatic hydrocarbons (PAHs);
- Polychlorinated biphenyls (PCBs) Pesticides;
- Selected Metals (arsenic, barium, cadmium, chromium (total), copper, lead, mercury, nickel, and zinc);
- Volatile Organic Compounds (VOCs);
- Semi-Volatile Organic Compounds (SVOC).

Per the NHDES sediment guidance document, the laboratory chemical results are to be compared to screening criteria to determine if any contaminants exist at elevated levels or if any contaminants pose an ecological/human risk. For this work, it is highly recommended that an ecological risk assessor evaluate the laboratory findings, sediment volume data, and any sediment transport findings to help inform next steps.

The sediment sampling plan would be developed in consultation with state, federal and local agencies. It is also recommended that the NHDES and other federal/state agencies involved in the project approve the plan prior to its implementation.

A sediment sampling plan was not developed part of this feasibility study.

5.2.3 Sediment Sampling and Laboratory Analysis

This step entails executing the sediment sampling plan, which requires collecting sediment cores at various locations and sending the cores to a NH certified laboratory for testing. The sediment sampling results are then compared to screening level thresholds to help inform the potential for ecological/human risk.

No sediment sampling or laboratory analysis was conducted as part of this study.

5.2.4 Quantify Total Sediment Volume

This step entails quantifying the approximate total sediment volume in the impoundment. Note that there is a difference between total sediment volume and mobile sediment volume. If the dam were removed, not all of the sediment contained within the impoundment would mobilize as discussed later. One method to quantify the approximate total sediment volume is to establish transects through the length of the impoundment. Then, at each transect, a steel rod is hammered to refusal with a sledge hammer at several stations across the transect to measure the sediment thickness. The sediment thickness area is subsequently computed and then multiplied by the representative length of the impounded reach to yield an approximate total sediment volume. Sediment thickness probing at select locations was conducted as part of this study and is summarized later in this section.

5.2.5 Quantify Mobile Sediment Volume- Sediment Transport Analysis

As noted above, a preliminary estimate of total sediment volume is developed based on sediment thickness measurements. When dams are removed, the sediments most likely to mobilize (if any) are those contained within the new flowing channel. Newly exposed sediment on the impoundment fringes could potentially be stabilized in place with natural re-vegetation or proactive planting (re-vegetation is dependent on the substrate composition and seed mix), depending on what season (e.g., summer, fall, etc.) the dam removal occurs.

If a dam removal is proposed and the sediments are determined to pose no ecological/human risk, sediment transport studies are sometimes conducted to estimate the mobile sediment volume under various flows. The sediment transport analysis requires a hydraulic model (such as the model already developed in this study to assess flooding), as well as grain-size information to predict the mobile sediment volume moving out of the system and where it could deposit downstream. Note that sediment transport modeling is not an exact science and offers only an approximation of sediment movement and deposition. If sediments do pose an unacceptable ecological/human risk, the most likely scenario would call for full or partial dredging, in which case a sediment transport analysis may not be necessary.

No sediment transport modeling was conducted for this study.

5.2.6 Sediment Management Plan

A sediment management plan is developed using previously collected information on the sediment quality, total quantity, and mobile quantity. The plan is highly contingent on the laboratory testing and specifically if the risk assessor deems there is a potential ecological/human risk. Sediment management plans can include the following:

- Assuming the sediments pose no ecological/human risk, and there are no major impacts to aquatic resources below the dam, then it may be possible to allow the accumulated sediment to naturally mobilize and move downstream. This alternative could be supplemented with aggressive planting or seeding of exposed river banks, or allowing for exposed banks to naturally reseed. Ideally, the goal is to re-vegetate the exposed banks so the bank sediment stabilizes and remains in place when higher flows having higher sediment transport capacity moves through the reach.

- Assuming the mobile sediments are slightly contaminated and are considered a manageable risk by the ecological risk assessor, the material could be dredged and disposed of on-site (with an Activity Use Restriction (AUR)). For this project, no evaluation was conducted to determine if there are lands available to potentially bury the sediment on-site with an AUR.

- Assuming the sediments are deemed a significant risk, partial or full sediment dredging and proper off-site disposal may be required. The extent of dredging would likely require additional chemical testing to narrow the "hot spot(s)".

No sediment management plan was developed as part of this project.

5.3 Sediment Analyses and Proposed Next Steps

5.3.1 Due Diligence Results

To evaluate the potential for sediment contamination and to help inform what contaminants to test in the future, due diligence was conducted based on reviewing the following readily available data sources:

- NHDES One-Stop;
- USEPA Superfund Sites, Remediation Sites, Hazardous Waste Generators;
- USEPA's National Coastal Assessment Program;
- Town of Newmarket (Health Office and Fire Department) was contacted directly to obtain information on potential spills;
- Historic Information gathered by PAL.

<u>NHDES One-Stop</u>
Shown in Table 5.2.1-1 is a summary of the known spill events as recorded on the NHDES One-Stop website. In addition, the approximate spill locations are shown in Figure 5.2.1-1. The majority of spill events are related to petroleum based products such as oil or gasoline or a catch-all category listed as "hazardous waste".

Table 5.3.1-1: Summary of NHDES One-Stop listed sites near the Macallen Dam impoundment.

Master ID	Status	Description
40773	Inactive	Carlisle Construction, hazardous waste generation, ceased in 2004
66991	Closed	Wojnowski Residence, petroleum remediation in 2012 (#2 fuel oil release)
57418	Closed	Cyr residence, 2 teaspoons of #2 fuel oil release from storage tank
61521	Closed	Duplex, Fuel oil released during flooding event
40780	Inactive	Durham Newmarket Animal Hospital, hazardous waste generation (x-ray solution)
43909	Inactive	KB&M Excavating, hazardous waste generation
43901	Inactive	Lamprey River Screen Print, hazardous waste generation (photo silver solution)
43902	Inactive	Great Bay Dental Care, Hazardous Waste Generation (silver)
4362	Closed	Lamprey River Bowling Lanes, leaking underground storage tank, hazardous waste generator, remediation
61653	Closed	Huntington property
60069	Closed	Labone residence, petroleum discharge 2005
51029	Closed	Nichols Ave residence, spill/release
17253	Closed	New Hampshire Fish and Game site remediation, closed 1991
17258	Closed	Public Service Company of New Hampshire substation, closed 2005
17261	Closed	Marquis residence, petroleum discharge 2001
4363	Active	Jays Newmarket Convenience, site remediation, vapor recovery
54332	Closed	Dover Sugar House, #2 fuel oil release

USEPA Superfund Sites

The USEPA's Superfund program was established in 1980 to locate, investigate and clean up hazardous waste sites throughout the United States. Based on reviewing the USEPA's Superfund website, there are 21 Superfund sites in NH. One site is located in Epping [29] which is within the Lamprey River watershed.

This Superfund site, referred to as Keefe Environmental Services, is located on Exeter Road in Epping. The 7-acre site operated as a chemical waste storage facility from 1978 until 1981. Waste storage containers present on site included 4,100 drums, four 5,000-gallon and four 10,000-gallon above ground storage tanks, and a 700,000-gallon synthetically lined lagoon. Solvents, acids, caustics, heavy metals, paint sludges, waste oils, and organic chemicals were disposed of at the site. The site is located in a state-protected watershed (the Lamprey River) with wetland areas draining to the Piscassic River. The site is located within approximately 500-600 feet of the Piscassic River. As a side note, the Town of Newmarket had a water supply intake on the Piscassic River approximately seven (7) miles downstream from the site that was outside the influence of this Macallen Dam impoundment. The water treatment plan was mothballed in 2004.

Per the USEPA website, the groundwater at the site is contaminated with chlorinated volatile organic compounds (VOCs) including trichloroethene (TCE), perchloroethene (PCE), 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), 1,4-dioxane and benzene. Soils adjacent to the lagoon were

[29] All or portions of the following towns are located in the Lamprey River watershed: Candia, Deerfield, Durham, Epping, Lee, Northwood, Nottingham, Newmarket and Raymond

contaminated before cleanup was completed. As reported on the website, drinking contaminated groundwater poses a potential threat.

USEPA National Coastal Assessment

The USEPA's National Coastal Assessment (NCA) surveys the condition of the Nation's coastal resources by creating an integrated, comprehensive monitoring program among the coastal states. To answer broad-scale questions on environmental conditions, EMAP[30] and its partners have collected estuarine and coastal data from thousands of stations along the coasts of the continental United States. EMAP's NCA comprises all the estuarine and coastal sampling done by EMAP beginning in 1990. The NCA data was reviewed and two samples were collected in Great Bay downstream of the Macallen Dam. Data was collected from one location in 2000 and a different location in 2001 which included the following parameters: temperature, salinity, dissolved oxygen and mean number of benthic samples, but no information on contaminants.

Town of Newmarket

The Town's Fire Department was contacted to determine if they were aware of any known contaminant spills in Newmarket above the dam. GSE was informed that based on recent memory there were contamination spills below the dam, but not above the dam. The Town Health Officer was also contacted and was not aware of any spills.

Historic Information Gathered by PAL

PAL's Request for Project Review (RPR) Form completed for the NH Division of Historical Resources (NHDHR) is discussed in Section 8. The RPR Form was reviewed to gain additional insight of historical use and activities in the Project area. The RPR Form notes the Newmarket Manufacturing Company, built 1823–1920, was a former textile plant located below the footbridge and consisted of two- to four-story stone and brick mill buildings that now house commercial offices, light manufacturing facilities, and residential condominiums.

5.3.2 Sediment Thickness Measurements

As noted above, one of the first steps in evaluating sediment is conducting sediment thickness measurements within the reach impounded by the dam. The length of the impoundment created by Macallen Dam up the Lamprey River is 2.5 miles; from the Piscassic/Lamprey River confluence to the first dam on the Piscassic River is 0.75 miles.

To identify where sediment thickness transects would be obtained, the bathymetric mapping results were evaluated. Figure 4.2-3, shown previously, is a profile of the channel bed and WSE as measured at the Macallen Dam. On this same figure is the predicted WSE if the dam is removed. As Figure 4.2-3

[30] EMAP- Environmental Monitoring and Assessment Program (EMAP). EMAP was a research program run by the USEPA's Office of Research and Development to develop tools necessary to monitor and assess the status and trends of national ecological resources. EMAP collected field data from 1990 to 2006.

shows, if the dam is removed, new hydraulic controls[31] would become present in the Lamprey River impounded reach. There are several locations where there is a relatively sharp drop in the WSE; these locations would likely experience higher channel velocities and would be more susceptible to scour and sediment mobilization. Given this, sediment thickness measurements were targeted at those locations where scour and erosion are most likely to occur. Note that sediment thickness in numerous bays and arms off-shooting from the mainstem Lamprey River impoundment were not measured. In the many backwater coves that offshoot from the Lamprey River mainstem, such as around Moat Island, sediment mobilization is not likely to occur given that there would be little flowing water (velocity) to transport sediment, although it is possible that some bank sloughing may still occur in those areas.

Based on the locations of sharp drops in the WSE, eleven (11) transects were selected for sediment thickness measurements as shown in Figure 5.3.2-1. Five (5) sediment thickness transects were located above the Piscassic/Lamprey River confluence, one (1) was located in the Piscassic River below the Railroad Crossing, and the remaining five (5) transects were located between the dam and Piscassic/Lamprey River confluence.

The methods for collecting the sediment depth measurements were as follows:

Pre-marked ropes, in two foot increments, were strung across the eleven (11) transects. The endpoints, or tie-off locations for the ropes, were set on the left and right banks by attaching the ropes to eyebolts secured into rocks or trees. At each transect, ropes were secured to the right and left eyebolts and pulled taught. By establishing monumented endpoints, if in the future additional monitoring of sediment within the impoundment is desired, it can be compared to the sediment measurements collected as part of this survey. GPS coordinates were also obtained at each of the transects' left and right starting stations. Starting at the left bank and moving to the right bank in approximately ten (10) foot station increments, a stainless steel pre-marked rod measured the water depth. At the same station, the rod was then hammered to refusal and the water/sediment depth was recorded. The difference between the water depth and the water/sediment depth represents the sediment depth.

Sediment thickness measurements (see inset for measurements in Macallen impoundment) occurred on October 7 for Transects T1-T7 (during the fall 2013 drawdown) and October 24 for Transects T-8-T10 (when the impoundment was at normal levels). The mean daily flows (provisional) on October 7 and 24, as recorded at the USGS gage on the Lamprey River near Packers Falls was 60 cfs and 104 cfs, respectively, or approximately 70 cfs and 121 cfs, respectively at the Macallen Dam. Note that the October 7 sediment thickness occurred during the drawdown when the water level was maintained near the crest gate elevation, hence the WSEs were low. During the October 24 sediment thickness measurements, the gates were closed and thus the WSE was closer to the spillway crest elevation.

[31] A hydraulic control in a river is a horizontal (e.g., the river width narrows) or vertical constriction (e.g., the channel bed has an inverse slope) which creates a backwater effect.

Figures 5.3.2-2 (Transect 1) through Figure 5.3.2-12 (Transect 10) show cross-section plots (looking in a downstream direction) of the water line (blue), top of sediment (red) and bottom of sediment (green). The WSE at each transect was surveyed and all water and sediment depth measurements were made relative to the surveyed WSE. The cross-sectional area of sediment was computed at each transect as shown in Table 5.3.2-1.

Table 5.3.2-1: Cross-Sectional Area of Sediment at Each Transect

Transect No.	Cross-Sectional Area of Sediment (ft^2)	Notes/Comments
1	14	These cross-sections are located between the dam and Veterans Bridge, which includes the legacy dam. There is minimal sediment deposition in this area. Transect 3 was located beneath the Veterans Bridge and contained no sediment. Sediment probes in this area suggest either large boulder or bedrock. Some sediment deposition is apparent along river right upstream of the dam.
1-A	109	
2	49	
3	0	
4	318	Deep supply of sediment in center of channel. Primarily sand or soft sand (indicating some organics or fines).
5	540	Soft/fine material along channel edges, with sandy material in the center of the channel. Sediment deeper along the left third of cross-section.
6	1,350	Highest sediment cross-sectional area is located in Piscassic River. Only one sediment thickness transect was obtained in the Piscassic River. Probes reached maximum depth (12 feet) several times along this transect, indicating very deep and fine-grained/soft substrate.
7	655	Soft/fine material across this transect, indicating primarily fine substrate. Substrate deposits generally 4-6 feet thick.
8	779	Primarily silt with some sandy material mixed in. Sediment deposits much thicker along left half of cross-section (6-9 feet) than the right half (0.5 to 5 feet).
9	1,142	Generally thick (6+ feet) silty deposit throughout the transect. Appears to be underlying more consolidated material where refusal was reached. Some locations did not reach refusal.
10	665	Generally sandy bottom, with some silt and gravel. Sediment thickness averaged about 6 feet in mid-channel.

The sediment thickness measurement results generally indicate a pattern of increasing sediment volume and decreasing sediment size from the Macallen Dam moving upstream, although the most upstream transect had a coarser and less thick sediment deposit.

In general, there was little to no sediment deposition near the dam, with bedrock and boulders composing most of the bottom material, although a small area of softer material was visually apparent between transects 1A and 2. The middle portion of the Lamprey River, from transect 4 through 9 (excluding transect 6, which was on the Piscassic River), had increasing total sediment volume as one traveled farther upstream from the dam. The material in this portion of river transitioned from a primarily sandy bottom to a more silty/fine bottom in the upper portion of this reach. The farthest upstream transect (transect 10) had less sediment compared to the downstream transects. This is likely due to the shallower depths in this reach, meaning that relatively higher velocities (and thus a higher sediment transport capacity) are already experienced under certain flow conditions. While this portion of the river showed active sediment transport of primarily sand-sized material during the fall 2013 drawdown, the relatively shallow depth to refusal (likely armoring from the pre-dam bed elevation) suggests that while there may be some downcutting in the upper reach, it is likely self-limiting due to the underlying material.

Although the upstream extent of the impoundment was not formally probed, visual inspections during our field visits and during the drawdown suggest the river bed is primarily bedrock. This bedrock-controlled reach will prevent any potential headcut (e.g., erosion traveling upstream over time as sediment is transported) from traveling upstream of the large pool at the upper end of the current impoundment.

Sediment thickness measurements were made along only one transect in the Piscassic River. The findings showed extensive fine sediment deposits of 6 to 12+ feet deep, where sediment refusal was never reached. Visual inspections also revealed similar-looking material throughout the Piscassic River, though the depth of substrate upstream of transect 6 is unknown. Similar to the Lamprey River, there is a bedrock control located at the upstream extent of the impounded reach of the Piscassic River. There is also a dam located along the top of the bedrock outcrop. If the Macallen Dam were to be removed, this bedrock control and dam will prevent any potential headcut.

5.4 Summary and Recommended Next Steps

Based on the review of available information, petroleum and gas spills of various magnitudes have occurred in the past suggesting the potential for contaminated sediment. If the dam removal project were to proceed, a due diligence memo should be sent to the NHDES Water Quality Section and Environmental Health Program, which would include a recommendation of conducting sediment sampling. It may also be prudent to also analyze for any chemicals potentially associated with the Superfund site in the Piscassic watershed, if any of the constituents detected at that site are not already part of the standard suite of contaminants.

If the NHDES agreed that sediment sampling is warranted, and if the feasibility study proceeds, we recommend developing a sediment sampling plan for NHDES and other federal/state agency approval. Preliminary locations for collecting sediment samples are listed below.

On the Lamprey River (in downstream to upstream order), preliminary sediment sampling locations include:

- typically a sediment sample is obtained immediately below the dam being considered for removal in a fine-grain depositional area; however, further discussions with NHDES and other agencies is recommended since the reach below the Macallen Dam is tidally influenced;
- between Veterans Bridge and the Macallen Dam;
- above the confluence with the Piscassic River, but within the impounded reach of the Lamprey River;
- in a free-flowing section of the Lamprey River above the head of the impoundment in a fine-grain depositional area.

On the Piscassic River (in downstream to upstream order), preliminary sediment sampling locations include:

- between the Railroad Bridge spanning the Piscassic River and the first dam on the Piscassic River;
- in a free-flowing section above the Macallen Dam's influence in a fine-grain depositional area.

The purpose for obtaining sediment cores above and below the project, in these free-flowing sections, is to determine background conditions and compare the concentration of contaminants at these locations with those in the impoundment and below the dam.

6.0 Summary of Existing Environmental and Infrastructure Information

6.1 Environmental Information

6.1.1 Migratory Fish Passage Estimates

The Macallen Dam's denil-style fish ladder is owned and operated by the NHFGD, and began operation in 1972. The NHFGD annually monitors diadromous[32] and resident fish passing through the fish ladder. The most prominent fish species enumerated are river herring[33] migrating upstream through the ladder to reach freshwater spawning habitat above the dam from April through June. Passage of other species has also been tracked approximately since 1980. The Macallen Dam fish ladder passage numbers were provided by the NHFGD (NHFGD, unpublished data[34]). The number of fish passed each year varies greatly, but recent years have seen all-time high passage numbers for river herring. Figure 6.1.1-1 shows the number of river herring passing through the Macallen Dam fish ladder, by year, since 1972. The NHFGD estimates indicate approximately 1,400,000 river herring have passed through the Macallen Dam fish ladder since it was first opened in 1972. The NHFGD has documented several species other than river herring also passing through the ladder. These species include Atlantic salmon, sea lamprey, American shad, American eel and various trout, sunfish and perch species, among others. These species are native to the project area.

Efficiency studies have not been completed for the Macallen Dam fish ladder. However, some generalities about passage efficiency at the dam were provided (Personal Communication, NHFGD, 1/15/2014). These generalities include:

1) The Macallen Dam Denil fish ladder is a 3-foot wide design. This is appropriate for many species such as river herring, but is not for some other migratory fish. For example, American shad prefer a wider (4 feet or greater) structure even though some may use a 3-foot Denil fish ladder. Other species, however, such as sturgeon, cannot pass through this type of ladder or most fish ladder designs.
2) Young-of-the-year American eels cannot effectively navigate an operating fish ladder because the water velocities inside the ladder are too high for their swimming ability. Therefore, the existing ladder is likely ineffective for passing this life stage of American eel.
3) Denil fishway entrances are designed to constrict access at the structure entrance to provide attraction flows. Therefore, when large schools of fish arrive at once there can be delayed access to the structure. This delay can therefore create an opportunity for increased predation on the population.

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[32] Diadromous fish spend a portion of their life cycle within both freshwater and saltwater.

[33] River herring consist of two species: blueback herring and alewife. NHFGD records indicate that the river herring passing through the Macallen Dam fish ladder are almost exclusively alewife. The percentage of blueback herring migrating through the fish ladder has varied between 0% and 12%. However, there is a large blueback herring spawning population below the Macallen Dam that may move upstream under more favorable passage conditions.

[34] Current reports can be found on the NHFGD website: http://www.wildlife.state.nh.us/marine/marine_div_projects.html

4) Fish ladders are generally seasonally operated to accommodate diadromous fish spawning runs (typically coinciding with higher seasonal flows) and are closed to maintain impoundment levels for the rest of the year. Therefore, the potential for fish to utilize the structure for passage is not year-round. Freshwater fish species that may end up below the dam during high flows may not have the ability to regain access into freshwater when the passage system is closed.
5) Even though a fish ladder is installed to allow freshwater access, native migratory fish populations may still perish due to habitat changes that have occurred within an impoundment or because of successive dams creating many impoundments on a river system. This type of habitat destruction and limited upstream access has eliminated Atlantic salmon from most east coast rivers.
6) The fish ladder at the Macallen Dam provides for upstream migration passage, but it is not designed for downstream passage.

The hydraulic modeling results in Section 7.2.10 discuss potential dam removal impacts on fish passage, noting that dam removal may create vertical or velocity passage barriers in-between the Macallen Dam and the Veterans Bridge and possibly at the upstream extent of the current impoundment.

6.1.2 Water Quality Information

Background water quality data was obtained from various sources and is summarized below.

<u>USEPA/NHDES 303(d) List of Impaired Waters</u>

The goal of the Clean Water Act (CWA) is "*to restore and maintain the chemical, physical, and biological integrity of the Nation's waters*". Under Section 303(d) of the CWA, states, territories and authorized tribes, collectively referred to in the act as "states", are required to develop lists of impaired waters. One approach to developing the list of impaired water is water-quality based, which requires the collection of water quality data.

Water quality standards are the foundation of the water-quality based program mandated by the CWA. Water quality standards define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. A water quality standard consists of four basic elements:

1. Designated uses of the waterbody (e.g. recreation, water supply, aquatic life, agriculture),
2. Water quality criteria to protect designated uses (numeric pollutant concentrations and narrative requirements),
3. An anti-degradation policy to maintain and protect existing uses and high quality waters, and
4. General policies addressing implementation issues (e.g., low flows, mixing zones)

The NHDES Watershed Management Bureau is responsible for conducting the water quality assessment to determine if there are any water quality impairments. Research of the 2012 draft 303(d) list for the impacted reaches of the Lamprey River was conducted. The list of impairments are listed in Table 6.1.2-1, while the assessment segments are shown in Figure 5.2-2. Note that three sections were evaluated as follows: the impoundment denoted as IMP, the river denoted as RIV, and the estuary denoted as EST.

Based on Table 6.1.2-1 in the estuary, Great Bay, there are impairments to aquatic life due to a variety of chemicals including pesticides, metals, and PAH's. In addition, there are impairments to fish consumption and shellfishing in the Great Bay due to PCBs. In the impounded reaches, there are impairments to aquatic life due to dissolved oxygen (DO), DO saturation, and pH. Finally in the Piscassic River, there is also an impairment to aquatic life due to DO and pH and (only pH in the Lamprey).

Table 6.1.2-1: Water quality impairments in the NH DES 2012 303(d) list.

NH DES Assessment Unit ID	Assessment Unit Name	Use Description	Impairment Name
NH EST 600030709-01-01	Lamprey River North	Aquatic Life	2-Methylnaphthalene, Acenaphthylene, Aluminum, Anthracene, Arsenic, Benzo(a)pyrene (PAHs), Benzo(a)pyrene (PAHs), Benzo[a]anthracene, Benzo[a]anthracene, Cadmium, Chlorophyll-a, Chrysene (C1-C4), Chrysene (C1-C4), Copper, DDD, DDE, DDT, Dibenz[a,h]anthracene, Dibenz[a,h]anthracene, Dissolved oxygen saturation, Fluoranthene, Fluoranthene, Fluorene, Lead, Mercury, Naphthalene, Nickel, Nitrogen (Total), Dissolved Oxygen, Phenanthrene, Pyrene, pH, trans-Nonachlor
NH EST 600030709-01-01	Lamprey River North	Fish Consumption	Polychlorinated biphenyls
NH EST 600030709-01-01	Lamprey River North	Primary Contact Recreation	Chlorophyll-a, Nitrogen (Total)
NH EST 600030709-01-01	Lamprey River North	Shellfishing	Dioxin (including 2,3,7,8-TCDD), Polychlorinated biphenyls
NH EST 600030709-01-02	Lamprey River South	Aquatic Life	Chlorophyll-a, Estuarine Bioassessments, Light Attenuation Coefficient, Nitrogen (Total)
NH EST 600030709-01-02	Lamprey River South	Fish Consumption	Polychlorinated biphenyls
NH EST 600030709-01-02	Lamprey River South	Primary Contact Recreation	Chlorophyll-a, Nitrogen (Total)
NH EST 600030709-01-02	Lamprey River South	Shellfishing	Dioxin (including 2,3,7,8-TCDD), Polychlorinated biphenyls
NH IMP 60030708-03	Piscassic River	Aquatic Life	Dissolved oxygen, Dissolved oxygen saturation, pH
NH IMP 60030709-03	Lamprey River - Macallen Dam Impoundment	Aquatic Life	pH
NH RIV 60030708-07	Piscassic River, PWS, CLS-A	Aquatic Life	Dissolved Oxygen, pH
NH RIV 60030709-09	Lamprey River	Aquatic Life	pH

6.1.3 State and Federal Threatened, Endangered and Species of Concern

A review of the New Hampshire National Heritage Bureau (NHNHB) records indicate there are several federal and state threatened, endangered species, and species of concern located in Newmarket and Durham. A list of the species, by town, is included in Appendix A. Some of these species may live along or be impacted by changes to the river reach impounded by Macallen Dam. If the feasibility study is advanced to evaluate additional steps, it is recommended that letters be sent to the NHNHB, NHGFD, National Marine Fisheries Service (NMFS) and USFWS along with a map showing the area of potential of impact which would include the impounded reaches, the area around the dam, and a distance below the dam. The agencies would subsequently provide more detail on specifically what, if any, species could potentially be impacted requiring additional analysis.

6.2 Infrastructure Information

6.2.1 Hoyle Tanner and Associates Assessment of Veterans Bridge, Retaining Walls and Buildings

Veterans Bridge crosses the Lamprey River approximately 250 feet upstream of the Macallen Dam. The New Hampshire Department of Transportation (NHDOT) Bureau of Bridge Design provided the most recent bridge inspection report from 2011 with photographs (personal communication, NHDOT, 6/29/2012). NHDOT also provided drawings of the bridge superstructure. Appendix B contains the information provided by the NHDOT. NHDOT indicated that they did not have any information on the bridge's substructure (i.e., the stone block abutments/foundation). They indicated that no formal scour calculations had been completed on the bridge, but that screening-level assessments indicated that the bridge was at low risk for scour. NHDOT's 2011 underwater inspection indicated that the river bed around the bridge consists of bedrock with cobbles.

The inspection report indicated that the bridge's clear span is approximately 61 feet. GSE's field survey data confirmed this measurement. While the roadway (and the 61 foot clear span) is skewed relative to the river, the openings are parallel to the river flow direction. Field data from the October 2013 drawdown indicate that depths are relatively shallow beneath the bridge relative to reaches upstream and downstream of the bridge. Hydraulic modeling results, described in Section 7, indicate that the shallow bedrock beneath the bridge acts as a hydraulic control if the dam were to be removed.

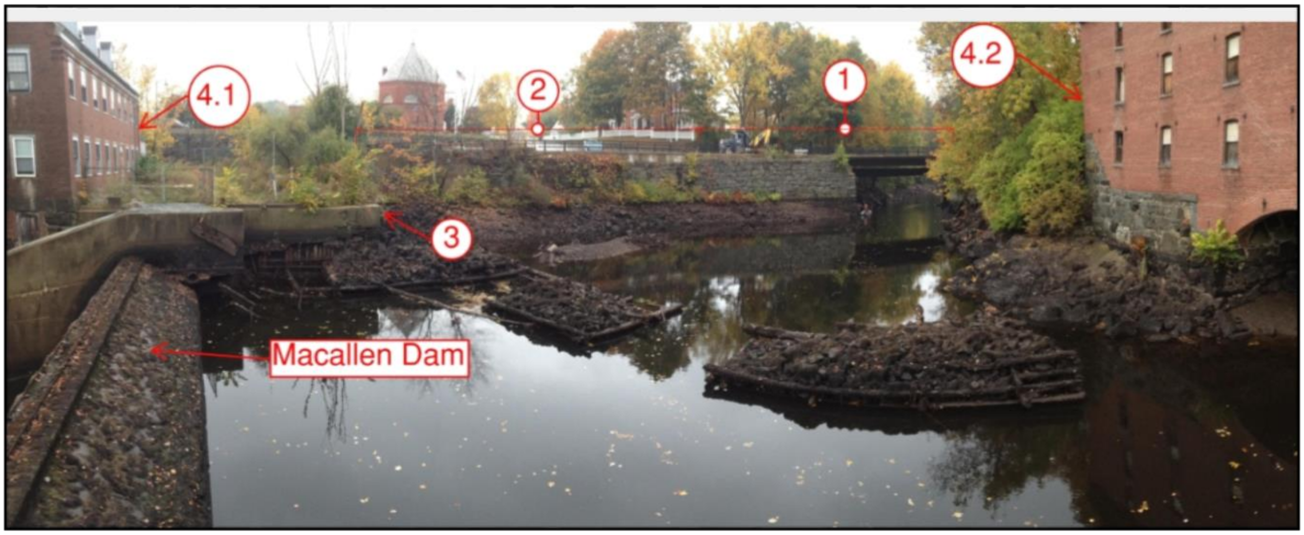
HTA Assessment

On October 7, 2013 two representatives of Hoyle, Tanner & Associates, Inc. (HTA) visited the Veterans Bridge over the Lamprey River (NHDOT Bridge No. 127/097) in Newmarket, NH as well as the area immediately downstream of the bridge. The purpose of the site visit was to gather field data as part of an evaluation of potential effects of the removal of the Macallen Dam on infrastructure in close proximity to the dam. Access was on foot using waders when the water level was low due to a planned October drawdown.

The limits of HTA's inspection consisted of Veterans Bridge, retaining walls located downstream of the bridge and building foundations located downstream of the bridge and adjacent to the dam. Only visual observations were included as part of HTA's evaluation; no structural calculations or testing was completed. For the purpose of this section, north is considered upstream. HTA's findings are discussed first as they relate to the bridge, retaining walls and then the building foundations.

In preparation of this study section, HTA relied upon the following information:

- NHDOT Bridge Inspection Report dated 6/29/2012 (inspection conducted November 2011).
- Existing bridge plans dated April 1954, Project Number S 35(1).



View Upstream of Dam (Numbering Refers to the Following Sections)

1- Veterans Bridge (1.1- West Abutment, 1.2- East Abutment, 1.3 Southwest Wall
2- Retaining Wall (2.1- Section I, 2.2- Section II, 2.3- Section III, 2.4- Section IV, Traverse Wall Adjacent to Dam)
3- Building Foundations
4.2- Selectwood Building
4.1- Durham Book Exchange Building

1-Veterans Bridge

Downstream Elevation of Veteran's Bridge

Veterans Bridge was built in 1955. Based on the existing 1954 bridge plans, it appears that the original superstructure was replaced and the existing substructure was rehabilitated to accommodate a roadway widening upstream. The existing bridge is a single span carrying two lanes of traffic and one sidewalk located on the downstream side of the bridge. The bridge superstructure consists of steel I-beams with a reinforced cast-in-place concrete deck. The substructure consists of dry-laid cut granite stone masonry abutments and wingwalls that bear on ledge. Concrete caps consisting of bridge seats and backwalls were constructed on top of the stone abutments during the 1954 construction and were not doweled into the existing stone. The concrete cap at the east abutment cantilevers upstream to accommodate the roadway widening. The abutment stone is laid in such a way that the front face is battered. The upstream wingwalls are u-back (parallel to the roadway) and the downstream wingwalls are flared. The existing southwest wingwall was raised with dry squared stone masonry during the 1954 rehabilitation and a concrete cap was constructed on top of the existing northwest wingwall. A concrete facing was constructed on the northeast wingwall to support the steel I-beam carrying the cantilever concrete cantilever cap beyond the east abutment. The concrete facing begins approximately 60 feet from the face of the east abutment. The existing southeast wingwall was not modified.

Upstream banks on both sides of the river consist of natural stream bank. The downstream bank east of the river consists of ledge and extends to a building foundation. The downstream bank west of the river consists of a stone retaining wall and transitions into a concrete retaining wall.

Upstream Elevation of Veteran's Bridge

1.1-West Abutment

West Abutment

The west abutment consists of rectangular stone varying in height from 16 to 30 inches and a 12-inch wide stone footing where the abutment is not directly on ledge. Stone has been placed in front of the wall at the upstream corner and upstream wingwall. There is no vegetation in the abutment and no signs of bulging stones. A three (3) foot void is located at the downstream end of the abutment, between the ledge and footing and extends five (5) feet diagonally into the abutment. It is unclear if the gap is due to a missing stone or the abutment was constructed with the gap; however, the abutment does not appear to be undermined. Chinking stones placed throughout the abutment are loose and ineffective. Two sizable voids were observed in the abutment; a 28 inch wide void one course above the water level at the downstream corner and a 42 inch wide void in the middle of the abutment. At the downstream corner there are two cracked stones and the base stone has shifted three (3) to four (4) inches towards the river. The cracked stones are located over ledge and do not appear to have been cracked from settlement. The concrete cap has horizontal cracking at the upstream corner and extends from the fascia beam to the second interior beam. The wingwalls are of same construction and in similar condition as the abutment. The downstream wingwall, southwest wingwall, is discussed below.

1.2-East Abutment

The east abutment consists of rectangular stone and a few rhombus-shaped cut stone varying in height and a 12-inch to 20-inch wide stone footing. Stone has been placed along the full length of the abutment and both wingwalls. There is no vegetation in the abutment. The courses of stone do not appear to be level and there are gaps between courses at the upstream corner and in the upstream wingwall. Chinking stones has been placed throughout the abutment. Two stones located in the middle of the abutment are bulging approximately four (4) inches. There are no signs of settlement or distress. A drainage pipe runs through the concrete cap at the cantilever. The concrete cap has horizontal cracking at the downstream bearing and at the upstream cantilever section. The wingwalls are of same construction and in similar condition as the abutment.

East Abutment

1.3-Southwest Wingwall

The southwest wingwall consists of rectangular stones varying in height. At the base of the wall there are stones and cohesive soils varying in depth due to natural build up. Vegetation was observed in the wingwall and a beech tree is growing out the top of the wall, adjacent to the bridge rail. There are cracked stone adjacent to the abutment and a bulging stone at the top of the wall. Also adjacent to the abutment is a six (6) inch wide void between courses located three courses above the base of the wall, which extends approximately 3.5 feet into the wall. Two drainage pipes are located at the transition to the retaining wall.

Condition Summary

According to the latest NHDOT Bridge Inspection Report, the condition of the deck is listed as a condition rating of five (5) or 'Fair' and the superstructure and substructure are listed as a condition rating of six (6) or 'Satisfactory'. The bridge is not listed on the NHDOT Red[35] List and does not currently have a weight limit posting.

HTA's observations are in agreement with the latest NHDOT Bridge Inspection Report.

2-Retaining Wall

The southwest wingwall transitions to a retaining wall extending down Penstock Way and parallels the roadway. For the purpose of this section, the retaining wall has been divided into four sections, which are depicted below. Section I, Section II and Section III consist of dry-laid granite stone masonry and appear to have been constructed at the same time. During the 1954 construction, Section I of the retaining wall was raised with dry squared stone masonry and a concrete cap was constructed on top of the wall. It is unclear when the remaining sections of the retaining wall were rehabilitated or constructed. The stone retaining wall appears to have been constructed at a different time than the southeast wingwall as the quality of the construction is not as good as the wingwall; the bond is not regular and the stone size is variable. Section IV consists of concrete and appears to have been constructed after the stone retaining wall.

[35] Bridges on the red list require interim inspections due to known deficiencies, poor conditions, weight restrictions, or type of construction. These structures are inspected twice yearly.

Southwest Retaining Wall Elevation

Section I

Section I of the retaining wall begins at the end of the southwest wingwall and ends at the stop sign at Penstock Way. The bridge metal rail continues to the end of the concrete cap on top of this section of the stone retaining wall. There is heavy brush buildup at the base of the wall and vegetation and vines along the wall. A tree is growing out the top of the wall at midspan and is pushing the stone out at this location.

Section II

Section II of the retaining wall begins at the stop sign at Penstock Way and extends to the concrete facing on the stone retaining wall. There is a concrete cap on top of this section which continues along the length of the retaining wall to Section III. A two bar metal rail and a chain link fence is mounted to the concrete cap and extends along the length of the retaining wall to Section IV. There is stone fill at the base of the wall and vegetation with trees adjacent to the concrete facing of Section III. There is a slight bulge in the stones at the beginning of this section and gaps between stones towards the end of this section.

Section III

Section III is the remaining portion of the stone retaining wall and has a concrete facing and concrete cap. The concrete facing appears to be older construction than the concrete cap. A drainage pipe is located adjacent to Section IV and just beyond the pipe the concrete facing is cracked. There is honeycomb cracking and efflorescence[36] at the base of the concrete facing. At the base of the wall is stone fill and tress.

Section IV

Section IV begins at the end of the stone retaining wall and consists of sound concrete. It appears that the concrete retaining wall is of new construction as noted by the use of concrete forms and was

[36] Efflorescence is the usual terms for deposit of soluble salts, formed in or near the surface of a porous material, as a result of evaporation of water in which they have been dissolved. It is the white powdery material on the surface of the concrete.

constructed at the same time as the concrete cap that extends from Section II to Section III. There is stone in front of the base of the wall.

Transverse Wall Adjacent to Dam

The transverse wall adjacent to the dam abuts the old timber crib, which is filled with stone. The section of wall near the retaining wall consists of stone with a regular bond and transitions to a stone base with a concrete cap. There are tilted stones and many chinking stones throughout locations adjacent to the cribbing. There is a pipe through the base of the stone wall. Behind the wall are trees and heavy vegetation and in front of the wall, except at the cribbing end, are large stones.

Transverse Wall Adjacent to Dam

Condition Summary

Overall the southwest retaining wall and transverse wall adjacent to the dam are in satisfactory condition. Although there is minor local bulging of the stones, the walls remain stable. The stone in front of the walls appears stationary and provides some protection from scour.

3-Building Foundation

Two buildings are located immediately downstream of the bridge and adjacent to the dam. The Durham Book Exchange building is located to the west of the dam and the Selectwood Building is located to the east of the dam. HTA personnel were granted access to the buildings by their respective owners.

Durham Book Exchange Foundation

Durham Book Exchange

The owner noted that the building was built in 1840. The masonry building has a stone foundation and water has leaked through during high flows. The transverse wall adjacent to the dam is shorter than the gate system west of the dam; therefore, during high flows the water overtops the transverse wall and flows towards the building. Town personnel have been placing sandbags behind the transverse wall to divert the overflow water away from the foundation during high flows, which has prevented water from leaking into the building foundation.

Selectwood Building

The masonry building (built in 1860) has a stone foundation with a sand floor and is partially supported on ledge at the upstream side. It is unknown what the downstream side of the foundation is supported on. Penstocks are built into the foundation and the penstock adjacent to the parking lot has been boarded up and filled with stone. The first level of the building is supported on wood columns and concrete footings supported on the sand foundation floor.

The concrete columns supporting the penstock closure, adjacent to the parking lot, are severely deteriorated at the normal water elevation. The owner has recently filled a sink hole that formed adjacent to the closed penstock and parking lot with stone fill. At the open penstock, sunlight was observed coming through the downstream corner bearing stone. This would indicate that the masonry arch is moving and settling. The concrete footings supporting the first floor wood columns exhibit minor concrete spalling and are undermined.

Selectwood Building Foundation

The owner is fully aware that the building foundation will need to be repaired prior to any use and mentioned that an engineer has recently looked at the building.

Condition Summary

The condition of the Durham Book Exchange building foundation is good as no concerns related to scour were observed.

The condition of the Selectwood Building foundation is poor and appears to be settling and unstable. Scour protection should be investigated for this building. As mentioned above, the owner is aware that the foundation will require further evaluation.

Selectwood Building Foundation (Upstream)

<u>Potential Structural Issues</u>

The structures discussed above were evaluated for vulnerability to scour for existing and proposed conditions. The Hydraulic Engineering Circular No. 18 (HEC-18), "*Evaluating Scour at Bridges*", 5th Edition, published by the Federal Highway Administration (FHWA) was used as a guide for the scour evaluation. A detailed scour analysis was not performed; however, Chapter 10 of HEC-18 "*Scour Evaluation, Inspection, and Plan of Action*" was used to assess the visual observations.

Existing Conditions

According to the latest NHDOT Bridge Inspection Report, the National Bridge Inventory (NBI) appraisal rating for the bridge scour critical status is 'Stable for extreme flood'. From the underwater inspection that took place on July 14, 2011 inspectors noted that the submerged portions of the substructure are in satisfactory condition with no significant defects. One void was observed near the south end of the west abutment at the stream bottom and the area on the backside of the void appeared solid. It was suggested that a masonry unit at this location may have been displaced since the last inspection. A portion of the footing on the east abutment is visible and the river bottom is bedrock with cobbles. Chink stones appear to be missing, approximately 40%, at several locations below the waterline.

Upstream Banks

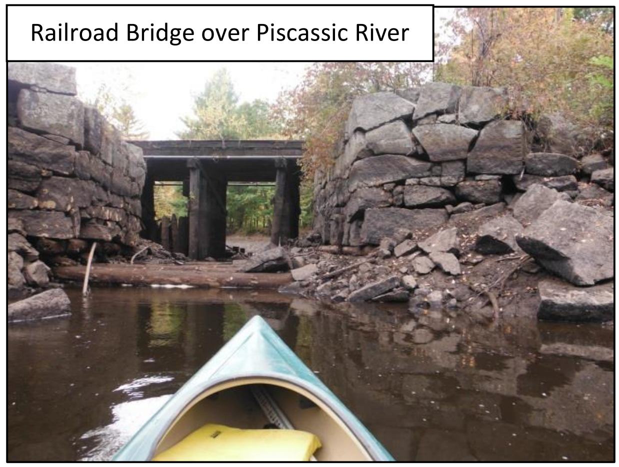
Downstream Banks

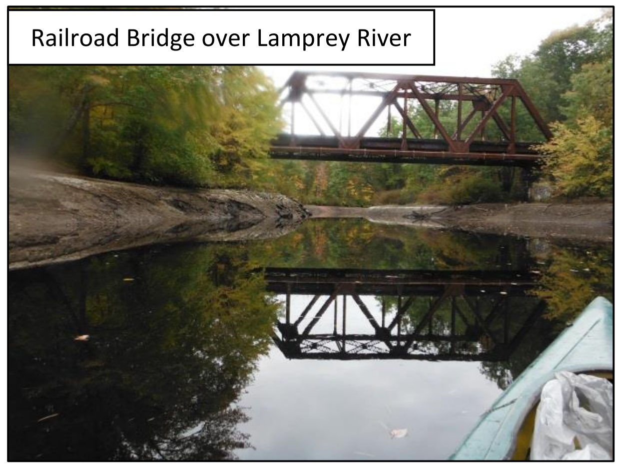
HTA's observations of Veterans Bridge are in agreement with the latest NHDOT Bridge Inspection Report. The upstream conditions appear stable with natural vegetation and trees on the stream banks. Rip rap has been placed immediately upstream of the bridge and there is no evidence of aggradation or degradation of the streambed. The downstream conditions appear stable with exposed ledge of the east stream bank and rip rap on the west stream bank. There appears to be some natural build up on the west stream bank as cohesive soils were observed. The Macallen Dam is downstream of the bridge, which currently controls the flow through the bridge. Although the bridge constricts the flow, due to the clear channel being narrower than the upstream and downstream channel, there is no evidence of scour or undermining of the substructure. Rip rap composed of well graded angular stone has been placed at the northern portion of the west abutment and along the entire length of the east abutment. The rip rap is not toed into the bedrock stream bed but the rip rap is not undermined. It is unknown whether rip rap was displaced at the south end of the west abutment or if rip rap was never placed at that location; however, there is no evidence of displaced rip rap along the downstream banks. No further investigation or scour countermeasure is recommended for the bridge and retaining wall.

No evidence of scour was observed at the foundation of the Durham Book Exchange. Provided that the Town continues to place sandbags behind the building, no further investigation or scour countermeasure is required. The foundation of the Selectwood Building has areas of concern which the owner is aware of as mentioned above. It is recommended that further evaluation for scour be completed for this building.

Other Bridges

HTA's assessment focused on the Veterans Bridge, however, there are two other railroad bridges traversing the impounded reach including the same active railroad line [37] passing over the Piscassic River and Lamprey River. The first inset shows the Railroad Bridge traversing the Piscassic River; the photograph was taken during the October 2013 drawdown. The bridge appears to be supported by piers and the stone abutments. If the dam removal alternative were advanced, further assessment of this bridge is needed to determine the potential for scour along the supporting piers and abutments. If there is the potential for scour, an evaluation of potential counter scour measures and costs would be developed. In addition, under the October 2013 drawdown and flow conditions present at the time, limited fish passage would occur due to the logs on the channel bed. Again, further evaluation is needed to ensure fish passage through the bridge opening.


Railroad Bridge over Piscassic River


Railroad Bridge over Lamprey River

The second inset shows the Railroad Bridge over the Lamprey River impounded reach; the photo was taken during the October 2013 drawdown. In this case, the abutments are located outside the existing channel. Even with the impoundment full, the width of the channel does not extend to either abutment. Further assessment is needed, but is it suspected that if the dam were removed, there would be no risk to scouring of the two abutments.

6.2.2 Well Survey

A dam of some measure has been in existence at the location of the Macallen Dam since at least 1832. Since its construction, residential homes and other dwellings have been constructed on properties abutting the impounded reach. The Town of Newmarket provides both public water and sewer; however, Durham does not provide public water or sewer to those properties abutting the Lamprey River impoundment.

One concern with dam removal and subsequent lowering of the impoundment level is the potential impact on wells located on Durham properties abutting the impoundment. If a property owner relied on a dug well for water supply, and if the well yield was hydraulically connected to the impoundment

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[37] It is our understanding that the railroad is used for passengers and freight.

elevation, removal of the dam could have an impact on the well yield. To investigate this issue, all Durham property owners abutting the impoundment were contacted via mail[38] (see December 30, 2013 letter in Appendix C) and asked to provide the following information, if available:

- The type of well (if known) - typically either overburden wells or bedrock wells.
- The approximate date the current well was placed into service.
- The depth to water within the well (in feet)
- The depth of the well (in feet).

The survey was provided to 50 Durham property owners, and 14 owners responded (28% return rate). Of the fourteen (14) respondents, twelve (12) indicated they had bedrock wells and two were uncertain. No respondents indicated they had a "dug" or unconfined well. Thirteen (13) owners had an approximate installation date for their wells, with the oldest well installed in 1956 and the most recent well installed in 1998. Eight (8) owners provided an estimate on the depth to water for their wells, with the elevations ranging from as little as six (6) feet up to an estimated 310 feet. Eight (8) owners provided an estimate on the total well depth, with a range of 190 feet to 600 feet. One survey respondent indicated a neighbor had a well on the range of 1,000 feet deep.

Groundwater aquifers, and in particular fractured bedrock aquifers, are hydraulically complex systems. Water in bedrock aquifers is often conveyed along bedrock fractures and fissures, which can follow highly irregular three-dimensional paths. The hydraulic link between the Lamprey River water levels and any individual well is difficult to characterize without conducting a long-term (i.e., weeks to months) study comparing well levels to river levels. Lowering the Lamprey River's long-term levels from either dam removal or spillway lowering would lower shallow groundwater aquifers in the vicinity of the river. This is why "dug" wells (i.e., shallow wells that draw from unconfined aquifers) are typically considered highly sensitive to changes in local water levels. The impact on deep bedrock aquifers, which all survey respondents likely[39] have, is less clear. In general, regardless of well type, those with static water levels at or near the level of the river would be most susceptible to any long-term lowering of the Lamprey River.

In the case of the survey respondents around the Macallen Dam impoundment, there were approximately six (6) wells having water levels within 20-30 feet (in the vertical plane) of the impoundment water level. While all of the wells are drilled to much deeper depths than the static water level (at least 100 feet below the static depth in most cases), there is a remote possibility that long-term changes in the level of the Lamprey River could impact some static well levels. It is unclear whether these changes in static well levels may ultimately impact the ability of any individual well to continue to yield an acceptable water flow.

[38] The Town of Durham provided us with the landowner parcel information.

[39] Two of the survey respondents were uncertain of their well type. Given the provided depths of the wells, however, they are almost certainly bedrock wells (total depth > 100 feet).

6.2.3 Sewer Line

Based on discussions with the Town DPW, there is a sewer line traversing the Piscassic River just below the first dam on the Piscassic River within reach impounded by Macallen Dam. If dam removal were to proceed, further investigation of this sewer line is needed to determine if it could be impacted by dam removal or lowering of the spillway crest elevation, particularly if sediment in the Piscassic reach is expected to mobilize, which is unknown at this time.

6.2.4 Hydroelectric Generation

Hydroelectric development is regulated by the Federal Energy Regulatory Commission (FERC). FERC is responsible for issuing operating licenses for hydroelectric developments across the nation. GSE has considerable experience with FERC licensing of hydroelectric projects, having been involved in this practice for 20+ years. We offer the following background information to the Town to help explain the hydroelectric licensing process.

There has been considerable discussion about resurrecting hydroelectric power at the Macallen Dam, which previously generated hydroelectric power until the 1950s. It is our understanding that at one time, there was a 500 kilowatt (KW) turbine on the left side of the river and a 50 KW turbine on the right side. It appears that the intake for the 500 KW turbine was located at the arch of the Selectwood Building located adjacent to the dam, and then conveyed flow via an underground penstock to a turbine located in the basement of a building located below the dam (see Figure 6.2.3-1).

The subject of resurrecting hydropower at the Macallen Dam has been pursued sporadically for the past few decades based on filings with the FERC. If an Applicant[40] seeks to develop hydropower at Macallen Dam they must file a preliminary permit application with FERC. If the preliminary permit application is approved by FERC, the Applicant is allowed three (3) years to study the site and file a License Application. The Applicant does not need to file a preliminary permit to study a site's hydropower potential, and screening-level work can be conducted under the risk of another entity filing a preliminary permit on the site. The Applicant, however, must file a preliminary permit with FERC to formally license the site. FERC has established regulations on specifically what must be contained within a preliminary permit application, which includes the following Exhibits:

- Exhibit 1: Project Description- includes a description of the proposed project and its operation.
- Exhibit 2: Study Plans- includes a list of studies proposed by the Applicant.
  Exhibit 3: Statement of Costs and Financing- includes the Applicants estimated study costs and source(s) of financing the project.
- Exhibit 4: Project Maps- includes project maps, and proposed layout of the proposed facility.

[40] Note that the Applicant can be any party- the Town, non-profit, individual, etc. Potential applicants can file a preliminary permit application on the Macallen Dam at any time. If a municipality (Town of Newmarket) files a competing preliminary permit application at the same time as another party, FERC will grant the preliminary permit application to the municipality due to what is termed "municipal preference".

Once the preliminary permit is filed with FERC, it's reviewed for completeness (i.e. does the application address the regulatory requirements). FERC will then "notice" the preliminary permit application and seek comment from federal and state agencies, non-government organizations and any interested parties (collectively referred to as stakeholders) on the proposed development. Typically, the comments will include concerns and issues with the potential development. Commonly stakeholders will request various studies to determine the impact of the proposed project on environmental (wetlands, wildlife, plants, fisheries, etc.), geology and soils, water quality, recreation, aesthetic, and cultural resources.

If an Applicant was to pursue a preliminary permit and went through the regulatory process culminating with the filing of a License Application with FERC, there are several milestones required; only the key milestones are listed below - the full process includes considerably more than noted below. These steps are described fully in the FERC regulations.

- A Pre-Application Document (PAD) must be filed with FERC describing the proposed project and all of its known environmental, recreation, water quality, recreation, and cultural resources based on research and input from stakeholders.
- Stakeholders will review the PAD and submit letters requesting studies needed to determine the impact of the proposed project on various resources.
- The Applicant must develop study plans addressing the issues and concerns raised by stakeholders.
- Numerous meetings are held with the stakeholders discussing the study plans and revising them, as needed.
- Once agreed upon, the studies are conducted and reports completed.
- Numerous meetings are held to review the various study findings.
- The Applicant files a Draft License Application, obtains comments, and then files a Final License Application.
- Assuming no issues, FERC will issue a License and the NHDES will issue a 401 Water Quality Certificate. Thereafter, the Applicant can start developing the site.

To our knowledge, preliminary permits were previously filed on the Macallen Dam as follows:

Preliminary Permit Docket No. P-6602

- DJ Pitman International Corporation filed a preliminary permit application in August 1982.
- Stakeholders filed comments on the permit application.
- FERC issued a Draft Environmental Assessment in March 1988.
- FERC notified the Applicant that the project could not be economically and financially feasible in June 1988.
- DJ Pitman International Corporation withdrew their preliminary permit application in July 1988.

Preliminary Permit Docket No. P-11823

- The Town of Newmarket filed a preliminary permit application in September 1999.
- Stakeholders filed comments on the preliminary permit application.

- The Town of Newmarket withdrew their preliminary permit application in March 2000.

Note that FERC maintains a website where more recent communications – like the information for preliminary permit Docket No. P-11823 -- is readily available on-line at the following website: http://elibrary.ferc.gov/idmws/search/fercgensearch.asp. Once on the website, enter the docket number- in this case “P-11823”. Included in Appendix D is all of the correspondence and filings with FERC relative to the Town’s preliminary permit application.

Relative to the preliminary permit filed in 1999, the Applicant proposed installing a turbine at the base of the existing gate structure and raising the impoundment elevation by installing 2-foot flashboards[41]. The permit application called for one 600 kilowatt (KW) turbine that could operate with flows between 80 and 400 cfs. The reported estimated annual generation was 2,300,000 kilowatt-hours (KWH).

The Applicant estimated the costs for conducting the studies related to engineering, environmental, economic and financing studies as $50,000 ($78,600 in June 2014 dollars).

Following the filing of the preliminary permit application with FERC, comments were filed by federal and state agencies, non-government organizations and citizens. Many issues and concerns were noted and presumably the Town came to the conclusion that it was not worth pursuing the project given that they withdrew the preliminary permit in March 2000.

It is not the intent of this dam removal feasibility study to evaluate the feasibility of hydropower development at Macallen Dam. However, if the Town opts to develop hydropower at Macallen Dam the following should be considered:

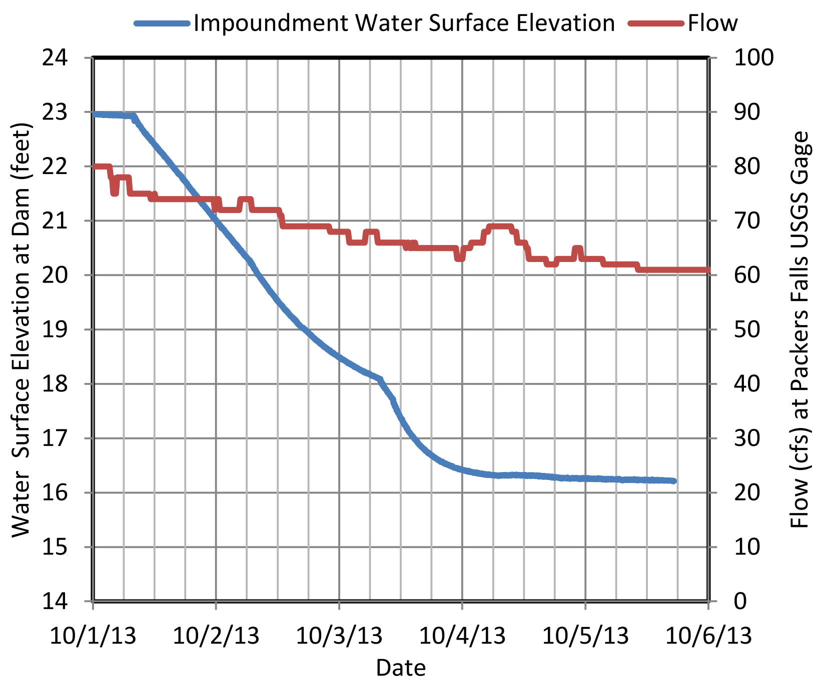
- There are still costs associated with modifications to the dam necessary to pass the 100-year flood per the NHDES. Developing hydroelectric generation will not ease these requirements.
- There are upfront costs associated with the FERC licensing process, including studies, as listed above. Based on GSE’s experience, the $50,000 estimate in the 1999 preliminary permit application is grossly underestimated.
- There are capital costs associated with developing the site (powerhouse, turbine, substation, transmission, etc.).
- The average annual electricity consumption for a US residential customer in 2011 was 11,280 KWh/year (US Energy Information Administration). Assuming that approximately 2,300,000 kWH/year could be produced annually (per the 1999 permit application), it would power approximately 204 homes.
- Assuming the wholesale price of power was $50 to $60/MWH (US Energy Information Administration), a facility producing approximately 2,300,000 kWH/year would yield between $115,000 and $138,000 annually if it was selling to the wholesale power market.
- Other issues could be investigated that could increase the value of the facility’s energy. These could include renewable energy credits, certified low-impact hydropower, etc.

[41] Raising the elevation of the impoundment by 2 feet increases the head available for generation. The greater the head, the higher the generation.

6.3 October 2013 Drawdown

In consultation with the NHFGD, NHDES and the Town, the water levels behind the Macallen Dam were purposely lowered starting on October 1, 2013 in order to evaluate the condition of the dam, to observe more of the building and retaining wall structures, to conduct the historic survey and to facilitate the sediment thickness mapping. Prior to this action, a legal notice was published on September 9, 2013 in the Portsmouth Herald and Foster's Daily Democrat, notifying the public of the impending drawdown. In the same notice it indicated that a public meeting would be held in the Newmarket Town Hall on September 16, 2013 to discuss the impending drawdown, answer questions, and provide an overview of the feasibility study. The purpose for lowering the water level was to photo document the impoundment, conduct sediment thickness mapping, and to allow structural engineers greater visibility of underwater structures in proximity to the dam.

Prior to the drawdown, a water level recorder was placed just upstream of the dam to record the rate of drawdown. The drawdown was initiated on October 1, 2013 and lasted until October 8. The impoundment was refilled by October 11, 2013. The WSE at the dam is shown in the inset as well as the flow estimated at the Macallen Dam based on prorating the flows at the Packers Falls USGS Gage to the dam (based on ratio of drainage area). The overall maximum drawdown was approximately 6.6 feet.



On October 5, 2013, when the WSE at the dam was approximately 16.3 feet, the entire impoundment was kayaked and photo documented. Shown in Appendix E are the photographs taken during the survey. An aerial map and ground photographs of some key areas are shown in Figure 6.3-1.

Observations made during the drawdown include:

- Some banks appeared to have significant sloughing.
- Some backwater areas became dewatered.
- The Piscassic impounded reach experienced a significant reduction in wetted width, particularly from the Piscassic boat launch and upstream. Gravel on the upstream end of the Piscassic railroad bridge crossing appears to create a hydraulic control preventing water levels upstream of the bridge from dropping any lower. There was significant debris and old construction material in this area, which would need to be addressed if dam removal or partial lowering is considered.

The bottom of the channel in this area was lined with timbers. Upstream of the bridge was a deposit of gravel that appeared to come from the railroad. This material created a hydraulic control that may or may not remain if the dam were to be removed.

- The Moat Island area showed a moderate decrease in width at first, but by about two-thirds of the way up the oxbow, it became too shallow to kayak upstream any farther.
- There appears to be a small waterfall at the head of the impoundment where Packers Falls enters the large pool at the upstream end of the impoundment. This may become a barrier to upstream fish passage under certain conditions.
- There appears to be a hydraulic control in the Lamprey River halfway between the upstream railroad crossing and Packers Falls. There was a sandy/gravel bottom bed at this location that included actively moving sediment. This hydraulic control looked like an over-widened riffle, and may be susceptible to downcutting or channel reformation over time.
- The drawdown exposed the old timber crib dam upstream of the existing dam.
- The maximum drawdown was approximately 6.6 feet at the dam. All of the alternatives considered by Wright-Pierce calling for lowering the spillway crest elevation would drop water levels even farther.
- Some isolated pools were observed during the drawdown. If the dam were to be removed or lowered, some of these mussels or fish inhabiting these smaller isolated pools may become stranded and would require relocation. Similarly a strategy to assess impacts to mussels located on the exposed banks would have to be developed, as there appeared to be large population of mussels throughout the impounded reach. The dwarf wedge mussel and brook floater mussel are listed as endangered in NH, but it is unknown if they exist in the project area.

7.0 Hydrology and Hydraulic Analysis

7.1 Hydrology

In this section, the mean daily flows and flood flows in the project area are quantified. The purpose for quantifying the hydrology at the site is for later simulation of these flows in a hydraulic model to predict the change in river depth and width if the dam were removed.

7.1.1 Mean Daily Flow

As shown in Figure 1.1-1 previously, there is a USGS gage (No. 01073500) located on the Lamprey River near Packers Falls upstream of the impoundment. The gage continuously records the river's WSE, which is converted to flow via a WSE versus flow (cfs) relationship, commonly called a rating curve. Table 7.1.1-1 provides information on the gage.

Table 7.1.1-1: USGS Gage Lamprey River near Packers Falls

Gage No.	Gage Name	Drainage Area	Period of Record	Comments
017073500	Lamprey River near Newmarket, NH	185 mi^2	10/01/1934-present	Some flow regulation may occur upstream of the Macallen Dam due to several impoundments throughout the Lamprey watershed, some of which experience seasonal drawdowns and refills.

The drainage area at the Packers Falls gage is approximately 185 mi^2. The Lamprey River at the Macallen Dam has a drainage area of approximately 212 mi^2, an increase of approximately 14%. Most of the incremental drainage area between the USGS gage and the Macallen Dam is due to the Piscassic River (drainage area = 23 mi^2), a major tributary to the Lamprey River. The Piscassic River has no USGS gage. To estimate flows at Macallen Dam, it is common practice in the field of hydrology to prorate the flows from a known location (e.g., the Packers Falls USGS gage) by a ratio of drainage area (212/185= 1.14) to estimate the flow at another location on the same river (e.g., at the Macallen Dam). The mean daily flows recorded at the USGS gage were prorated by 1.14 to estimate the mean daily flow at the dam. Using the estimated flows at the dam, annual and monthly flow duration curves were developed as shown in Figures 7.1-1 through 7.1.5 (three months/plot), respectively. The flow duration curves show the percent of time a given flow is equaled or exceeded on a monthly or annual basis. For example, in reviewing Figure 7.1-1, a flow of 100 cfs is equaled or exceeded 68% of the time on an annual basis.

Shown in Table 7.1.1-2 are the estimated minimum, maximum, mean, median and mean flows at the dam.

Table 7.1.1-2: Estimated Minimum, Maximum, Median, and Mean Monthly Flows at the Macallen Dam

Stat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Min	28	36	45	102	51	12	2	2	2	3	10	12	2
Max	3,224	5,210	7,266	8,572	9,230	5,003	3,606	2,492	3,344	7,346	2,181	2,696	9,230
Med	242	251	539	616	322	138	63	43	36	86	219	290	197
Mean	331	360	725	809	427	236	112	86	82	163	316	395	337
Drainage Area at Macallen Dam = 212 mi^2													

For hydraulic modeling purposes, the following flows for dam-in and dam-out conditions were simulated:

- Mean annual flow (337 cfs) at Macallen Dam. The purpose for simulating this flow is to have a sense of the new channel width and depth under "average" conditions if the dam were removed.
- 90% exceedance flow at Macallen Dam for the lowest flow month (September) (10 cfs) - the purpose of simulating this flow is to evaluate a "worst case scenario" from a wetted area perspective.
- The middle of the river herring migration period is from mid-April to early June. The mean flow for this period (April 15 to June 10) is 472 cfs, and was simulated in the hydraulic model to determine if fish passage is possible under dam-out conditions in proximity of the dam.

7.1.2 Flood Flows

Past studies have been conducted to predict flood flows on the Lamprey River including a) Federal Emergency Management Agency (FEMA) flood insurance studies (FIS), b) use of the Lamprey River USGS streamflow at Packers Falls and c) watershed rainfall-runoff modeling. A rainfall-runoff model was developed by Wright-Pierce to estimate the 100-year flood of the Lamprey River at the Macallen Dam to simulate a dam failure. Each of these sources is summarized below.

FEMA FIS

The FEMA FIS includes flood flow estimates on the Lamprey River at the Wiswall Road Dam, which has a drainage area of 182.1 square miles. Per the Strafford County FIS, it states the following "*In the Town of Durham and Newmarket, peak discharge computations for the Oyster River and the Lamprey River were based on log-Pearson Type III analysis of gage records at USGS gaging stations No. 01073000 and No. 01073500, respectively. Peak discharge computations for the Oyster River at Mill Pond Dam and the Lamprey River at gage No. 01073500 were based on discharge values that were determined in the 1990 Town of Durham FIS*". The 10-, 50-, 100- and 500-year flood flows at the Lamprey River USGS gage, as listed in the Strafford County FIS, are 4,120 cfs, 6,270 cfs, 7,300 cfs and 10,000 cfs, respectively. Note that these flood flows were conducted in 1990, **and thus do not include four (4) of the five (5) largest peak flows** recorded at the Lamprey USGS gage (1996, 2006, 2007, 2010).

Lamprey River USGS Gage at Packers Falls

The flood flows at the USGS gage at Packers Falls can be readily estimated; however, the flow at Macallen Dam is more difficult to estimate because there is a flow spilt downstream of the gage, whereby under high flows the WSE in the Lamprey River impoundment rises to the point of conveying flow to the Oyster River. Shown in Figure 7.1-6 are the instantaneous peak flows for each water year from 1935 to 2012. Note that the frequency and magnitude of peak flows has increased since 1990 (compared to the FIS), as the first and second greatest peak floods of record occurred on May 16, 2006 (8,970 cfs) and April 18, 2007 (8,490 cfs), respectively.

The same log-Pearson Type III flood frequency analysis used in the Strafford County FIS was conducted using the 79 instantaneous peak flows as measured at Packers Falls gage for water years[42] 1935 through 2012. Shown in Figure 7.1-7 is the flood frequency analysis for various return intervals (years). As expected with the increase in the frequency and magnitude of peak flows since 1990, the estimated flood flows increased. The 10-, 50-, 100- and 500-year floods at the Lamprey River USGS gage were estimated as 4,684, 7,954, 9,714 and 14,870 cfs, respectively. The 100-year flood flow estimate of 9,714 cfs is approximately 33% higher than FEMA's estimate in the Strafford County FIS of 7,300 cfs.

Wright-Pierce Rainfall Runoff Analysis

As described earlier, the Town initially requested Wright-Pierce to perform preliminary engineering studies to confirm the dam's hazard classification and provide initial inundation mapping for the Emergency Action Plan. The original 100-year flood flow used in the May 24, 2010 dam breach was 8,302 cfs, which was obtained from a NHDES's February 1999 inspection report. The NHDES Dam Bureau reviewed the analysis and indicated in a September 8, 2010 letter to the Town the following relative to the 100-year flood flow.

> *"The 100 year storm inflow estimate used in the analysis was 8,302 cfs. It appears this information is taken from NHDES's February 1999 inspection report. Using the recorded flows at the USGS gauging station #01073500, Lamprey River in Newmarket, the 100-year storm event of 8,302 cfs was estimated using the area-ratio technique and based upon the data available at the time. Current information from USGS (Scientific Investigations Report 2008-5206) at the same stream gauge shows a 2008 value of 9,270 cfs for the 100 year storm and when applying the area-ratio technique the resulting 100 year inflow to the dam is approximated as 10,688 cfs. This conversion is rough, but shows the difference for 15% more drainage area. Please update the 100 year inflow estimates in the analysis."*

In Wright-Pierce's February 6, 2013 report, in response to the above NHDES Dam Bureau letter stated the following:

[42] A water year extends from October 1 to September 30; for example Water Year 2012 extends from October 1, 2011 through September 30, 2012.

"An updated 100-year flood flow hydrologic analysis for the Lamprey River was conducted using the TR-20/Lag-CN method. The flood flow was also routed through an updated hydraulic analysis model that included a flow diversion near Route 108 in Durham. At this location, flood waters from the Lamprey River overflow Route 108 and exit the Lamprey River watershed through the Oyster River, effectively decreasing the downstream 100-year flood flow. The updated 100-year flood flow at the dam was determined to be approximately 10,260 cfs".

The NHDES Dam Bureau reviewed Wright-Pierce's February 6, 2013 report and concluded, relative to the 100-year flood flow, the following in a March 5, 2013 letter to the Town:

"The design flow rate and IDF established for the Macallen Dam is 10,259 cfs and corresponds to the calculated 100 year flow rate. Any proposal to retain the dam as a jurisdictional dam (see RSA 482:2II) must include provisions for the dam to pass this flow rate with a minimum of one (1) foot of remaining freeboard or otherwise meet the provisions of Env-Wr 303.12."

Based on the above communications, the NHDES Dam Bureau has agreed that the 100-year flood flow for evaluation of the dam's spillway capacity should be 10,259 cfs. This study is not intended to re-evaluate the Macallen Dam's 100-year flood flow. **Given this, for hydraulic modeling purposes the agreed upon 100-year flood flow of 10,259 cfs was simulated at the dam.**

7.2 Hydraulic Model

7.2.1 Purpose of Hydraulic Model

Hydraulic models of river systems are developed to predict WSEs, depths, and velocities under a range of flows. GSE developed a hydraulic model of the Lamprey River from just below the Macallen Dam to just below Packers Falls, including the lower Piscassic River, for the following purposes:

- To predict WSEs and velocities in the impoundment under dam-in and dam-out[43] conditions under a range of flows.
- If opted to evaluate in the future, the model can be used to determine whether impounded sediments could become mobilized if the dam is removed.
- If opted to evaluate in the future, the model can estimate water velocities under dam-out conditions to determine the potential of scouring existing infrastructure, including bridges and railroad lines spanning the impoundment.
- To determine whether depths and velocities will be sufficient to pass fish under dam-out conditions through the project area.

For this project, a program called Hydraulic Engineering Center River Analysis System (HEC-RAS) was used to develop a hydraulic model.

[43] Dam-out is referenced throughout this document and assumes that the abutments, gates and spillway would be fully removed, as would the timber crib legacy dam.

7.2.2 Hydraulic Model Description

This section provides a brief technical background on how HEC-RAS predicts water depths, velocities, and water surface profiles (WSP) and methods used in modeling the dam-out condition. This section contains technical terms relating to hydraulics and hydrology. Whenever possible, an effort was made to simplify hydraulic concepts presented; however, if further clarification or explanation is desired, the reader is referred to the HEC-RAS Hydraulic Reference Manual (Brunner, 2002) or any standard open channel flow text.

HEC-RAS is designed to perform one-dimensional, steady (flow does not change over time), gradually-varied flow calculations in natural and manmade channels, as well as to perform unsteady (flow over a time increment) flow routing, and elementary sediment transport computations. The model can simulate depths and velocities for a single reach, a branched system, or a full network of channels.

Hydraulic analyses performed by HEC-RAS are based upon a step-wise solution of the one-dimensional energy equation. In instances of rapid change in the WSE causing turbulence and energy loss, HEC-RAS uses the momentum equation. In HEC-RAS, rapid changes in the WSE may occur under the following conditions: bridge constrictions, inline structures (dams and weirs), confluence of two or more flows, rapid changes in the channel bed elevation, and hydraulic jumps. Energy losses in the channel are associated with friction (solved with Manning's equation) and with contraction and expansion (solved by multiplying a loss coefficient by the change in velocity head between transects) losses. Flows over weirs and other inline structures (dams) are determined with the standard weir equation. HEC-RAS also permits the modeler to include gate structures that accompany inline structures such as dams. All modeling efforts completed as part of this study were conducted assuming steady flow conditions.

7.2.3 Model Inputs

As noted above, the bathymetric data used in this model was collected as part of this study. Relative to upland topography, LiDAR (Light Detection and Ranging) data was obtained from an aerial flight of the NH coastline in 2011. LiDAR is a technology used to develop high-resolution maps. The LiDAR data have a root mean square error (RMSE) (analogous to accuracy) of approximately ±15 cm (±0.5 feet) (GRANIT, http://www.granit.sr.unh.edu/resourcelibrary/specialtopics/lidar/Status-November2013.pdf)

With the combined bathymetry and upland topography map, transects were "cut" in HEC-GeoRAS (a GIS extension of HEC-RAS). HEC-GeoRAS directly uploads transects' station and elevation data, as well as distance between transects, into HEC-RAS. There are two major benefits of using HEC-GeoRAS. First, there is the considerable time savings of locating and exporting the transects into HEC-RAS, as opposed to manually entering the station/elevation data. Second, once the HEC-RAS model is run for a flow event, the results can be loaded back into GeoRAS to produce inundation maps on top of aerial imagery. For example, the hydraulic model was run for the 100-year flood with and without the dam in place. The resulting inundation area maps were uploaded to the GIS and visually compared on using aerial imagery.

7.2.4 Manning's n Values

HEC-RAS requires the user to define Manning's n-values at each transect. Manning's n-values are used to describe the roughness of a channel; the higher the n-value, the rougher the channel. For example, a Manning's n-value of 0.03 (unitless) is representative of channel substrates such as sand, whereas a Manning's n-value of 0.05 is representative of cobbles which causes greater friction losses. There are also typical n-values associated with land use types. The HEC-RAS program requires the user to enter the Manning's n-values for at least the right overbank, main channel, and left overbank at each transect (further refinement along stations can be made). When flow moves beyond the right/left overbanks, which is typically defined as the top of bank, it may be conveyed through trees and upland vegetation. In these instances, the Manning's n-values in these overbanks are generally higher to reflect the greater flow resistance.

The Manning's n values for this study were initially assigned by using typical Manning's n values for an area's land use or channel description, as described in Chow (1959). Manning's n values were then adjusted as part of the calibration process to better fit observed WSEs until the final values were obtained. In-channel Manning's n values ranged from 0.045 to 0.055, depending on the channel substrate and bottom roughness. Out-of-channel or bank areas had Manning's n values ranging from 0.07 to 0.10, depending on land cover.

7.2.5 Expansion and Contraction Coefficients

HEC-RAS requires the user to define expansion and contraction coefficients at each transect. When a river constricts—meaning the width decreases—it creates a "bottleneck" and the water level upstream will rise due to increased energy losses. The coefficients for gradual transitions of contraction and expansion are 0.1 and 0.3, respectively. For a typical bridge, the values rise to 0.3 and 0.5, respectively. In most instances expansion and contraction coefficients of 0.1 and 0.3 were applied to the transects, while the typical bridge coefficients of 0.3 and 0.5 were used for the Veterans Bridge. The only exception to these coefficients was the reach between the Veterans Bridge and the Macallen Dam. Due to the rapid expansion of the channel and extreme bed elevation changes due to steep bedrock formations, coefficients of 0.2 and 0.4 were used instead of the typical 0.1 and 0.3.

7.2.6 Coefficients of Discharge at Macallen Dam

In HEC-RAS, dam spillways are typically modeled as broad-crested weirs. The amount of water passing over a weir (note weir and spillway are used interchangeably) is calculated using the following equation:

$Q = CLH^{1.5}$, where

Q = is quantity of flow passing over the weir (cfs),
C= is the weir coefficient (feet$^{0.5}$),
L= is the length of the weir (feet), in this case the length of the spillway is 70 feet, and
H= is the depth of water above the weir crest (feet).

Figure 7.2.6-1 shows the dimensions on an example broad-crested weir.

The weir coefficient typically varies based on the depth of water above the spillway crest and the spillway geometry. While the dam's geometry is different than a typical broad-crested weir, we believe it is prudent (and slightly conservative) to model the dam spillway as a broad-crested weir. A typical weir coefficient for a broad-crested weir with minimal depth of water (H) over the spillway is approximately 2.63. In general, however, weirs become more efficient (higher C values) as the depth of water above the spillway crest increases. For depths of water (H) less than 4.0 feet, the dam was modeled with a weir coefficient between 2.48 and 3.32. For water depths (H) greater than 4.0 feet, the dam was modeled with a weir coefficient of 3.32. The resulting stage[44] versus discharge curve for the Macallen Dam spillway is shown in Figure 7.2.6-2. A detailed description on the weir coefficient used for the Macallen Dam is included in Appendix F.

The dam's crest gates are typically only opened during high flow events, during which they are fully submerged (meaning the water moving through the gate openings is under pressure). Thus, they will be modeled as an orifice. Flow through an orifice is calculated using the equation:

$Q = CA\sqrt{2gh}$, where

- C= is an orifice coefficient (unitless),
- A= is the orifice area (feet^2), in this case, each gate has a usable orifice opening of 7 feet by 7 feet or 49 feet^2,
- G= is gravitational acceleration (32.2 feet/sec^2) and
- h= is the net head through the orifice (feet).

The orifice coefficient, C, was approximated as 0.5, which is conservative of the typical value range (0.5 – 0.7). The orifice area, A, is 49 feet^2 (7-ft wide x 7-ft high) per gate[45]. The net head, h, was calculated as if the orifice was submerged. A photograph from the March 2010 flood shows that flow through the gates is partially impeded (backwatered) by an angled wall on river left (Figure 7.2.6-3). The left and center gates are clearly impacted by the backwater, while it is unclear if the right gate is impacted by the backwater. It was conservatively assumed that downstream tailwater elevation is equal to the midpoint of the crest gates, rather than the bottom of the gates. This means there is less gate hydraulic capacity than if the angled wall was not causing a backwater effect. The resulting stage versus discharge curve for the Macallen Dam gates is shown in Figure 7.2.6-4.

Figure 7.2.6-5 shows a combined gate and spillway stage versus discharge rating curve for the Macallen Dam. The graph shows that at approximately one foot below the right abutment (28.47 feet), the dam can pass approximately 3,458 cfs over the spillway and 1,752 cfs through the gates, for a total of 5,210 cfs. The figure also shows that as the WSE increases, the gates pass an increasingly smaller proportion of the total flow passing over the spillway. At an impoundment elevation of 28.4 feet, the gates can pass a maximum of approximately 33% (1,752 cfs) of the total flow passing the dam (5,210 cfs).

[44] Stage refers to the WSE above the spillway crest.

[45] Prior to the installation of gate extenders in 2007, the gates could only open approximately 5.5 feet rather than 7 feet (Personal Communication, Town DPW Director, March 2014).

7.2.7 Upstream and Downstream Boundary Conditions

A mixed flow regime was used in the model to simulate hydraulic conditions in the study reach. The HEC-RAS program requires an upstream and downstream boundary condition for a mixed flow regime. For this model, the upstream boundary conditions were set to "normal depth" using approximate bed slopes for the applicable reaches, except for the Piscassic Reach, which was set as "critical flow" due to the steep falls where the river enters the impoundment. The downstream boundary of the Hamel Brook "flow split" reach was set as normal depth with a slope of 0.0049, based on survey data from the NHDOT indicating this was the average bed slope of Hamel Brook downstream of Route 108. The downstream boundary of the Lamprey River was set to 2.5 feet (approximate high tide elevation) for the low-flow modeled scenarios (low flow, daily average flow, fish passage season flow), while it was set to 7.0 feet (Wright-Pierce's estimated tailwater elevation for the 100-yr flood) for the 100-yr flow.

7.2.8 Lamprey-Oyster Flow Split

As described above, during high flows, water levels in the Macallen Dam impoundment rise considerably. When WSEs rise several feet above normal conditions, some of the water backwaters into the Moat Island area (see Figure 2.1-1) and diverts flow over Route 108 and Longmarsh Road in Durham. This water leaves the Lamprey River watershed and passes into Longmarsh Brook, then Hamel Brook, and finally the Oyster River and over the Oyster River Dam[46]. This diversion reduces the amount of water passing over the Macallen Dam during extreme flood events. Various studies have estimated the portion of this flow that is diverted. The most recent studies evaluating the Lamprey-Oyster flow split are the Wright-Pierce February 2013 study and the UNH Lamprey River study[47]. Most recently, the Wright-Pierce February 2013 study estimated the magnitude of flow diversion during a 100-year flood event was approximately 5,615 cfs of the 15,875 cfs flowing into the Macallen Dam impoundment and "flow split area", leaving 10,260 cfs to flow toward the Macallen Dam.

The proportion of water diverted from the Lamprey River into the Oyster River watershed during a flood is a function of the WSE at the Moat Island flow split. Under low to moderate flows, when WSEs in the Moat Island area are less than approximately 28.3 feet, there appears to be little to no diversion from the Lamprey River to the Oyster River watershed. Altering the hydraulic controls in either flow path (main stem Lamprey River or the flow diversion path) will change the amount of water remaining in the Lamprey River. Raising the hydraulic controls (and consequently WSEs) in the main stem Lamprey River will increase the diversion proportion, while lowering the WSE (such as removing or lowering the Macallen Dam) will decrease the diversion proportion. Similarly, raising the hydraulic controls (and consequently WSEs) in the flow diversion reach reduced the amount of flow diverted to the Oyster River and increased the proportion passing over the Macallen Dam.

This phenomena will be important for the Town to consider in any final hydraulic designs of the Macallen Dam under any removal or modification scenario, as lowering the Macallen Dam may decrease

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[46] The Oyster River Dam currently has an LOD for also having inadequate spillway capacity. The dam's estimated 100-year flood flow is 1,688 cfs. The drainage area at the dam is approximately 20 mi^2.

[47] The document describing this work is a Thesis titled "*Consequences of Changing Climate and Land Use to 100-Year Flooding in the Lamprey River Watershed of New Hampshire*" by Ann M. Scholz in December 2011.

the proportion of flow diverted into the Oyster River during flood events. This essentially creates a “moving target,” such that as the dam is lowered to meet the dam safety freeboard requirement, progressively more flow must be passed. The Wright-Pierce hydraulic calculations and cost-estimates do not appear to take this factor into account in their spillway alternatives.

The flow split was represented as a lateral weir in our model, where water was diverted from the Lamprey River watershed to the Oyster River watershed based on WSEs near Moat Island. Flows from the lateral weir were then routed through the “flow split” reach, which included passing over the “flats”’ area of Route 108, Longmarsh Brook and Longmarsh Road, an old class VI road approximately 1500 feet downstream of Longmarsh Road, and finally over Route 108 again at the Hamel[48] Brook crossing before entering the Oyster River Dam impoundment.

HEC-RAS determines how much flow passes through the ‘flow split’ via a manually entered flow versus river stage rating curve. The manually entered rating curve was calculated such that the water surface in the Lamprey River will typically match the water surface elevation in the ‘flow split’ area just north of the Durham Boat Company (DBC) building, within a small (~0.1 foot) tolerance. HEC-RAS equalizes the WSEs between the Lamprey reach and the ‘flow split’ reach via a ‘flow optimization’ function, where the program iterates the diversion amount until the WSEs match.

7.2.9 Model Calibration

Whenever possible, hydraulic models are calibrated to known conditions to help improve the accuracy of the model’s results. This model was calibrated to WSEs from several historic flow events (May 2006, April 2007, March 2010), as well as to measured flows and WSEs from an event that occurred during this study (March 31, 2014). No survey data were available for the historic flood events below the flow split area, but peak instantaneous flows were measured at the Packers Falls USGS gage for all of the events. In lieu of survey data for the historic flood events, WSEs have been estimated based on photographs from the NHDES Dam Bureau. These photographs are included in Appendix G. The available calibration data are described for each event below.

March 31, 2014 Flow Event

Gomez and Sullivan conducted a site visit on March 31, 2014, following a moderate flow event in the Lamprey River induced by a moderate amount of rain combined with melting snowpack. A flow measurement at the Veterans Bridge was obtained at approximately 4:30 PM of 2,495 cfs. Immediately following the flow measurement, several photographs of the dam and Veterans Bridge were taken. A field measurement indicated the river stage was approximately 2.9 feet below the Macallen Dam’s right abutment, which had been previously surveyed by Gomez and Sullivan as having an elevation of 28.47 ft. Thus, the WSE at the dam was approximately 25.57 feet. All three spill gates were fully open when the flow and stage measurements were taken.

[48] We have seen Hamel Brook spelled alternatively as Hamil Brook in some other documents and maps, but they are referencing the same stream.

March 2010 Flood

The March 2010 flood event is the fifth-largest recorded event at the Lamprey River Packers Falls USGS gage, with a peak flow of 6,760 cfs at the gage. NHDES conducted a site visit during the peak flow period (3/16/2010), and took several photographs of the Macallen Dam and Veterans Bridge. These photos were provided to Gomez and Sullivan, which were used to approximate WSEs at the Macallen Dam and on the downstream face of the Veterans Bridge. Due to the flow split, the actual flow at the Macallen Dam is not known. Our analysis of the photographs, which was limited to photographic scaling, indicated that the WSE at the dam was approximately 28.9 feet, while the WSE at the downstream face of the Veterans Bridge was approximately 29.3 feet.

April 2007 Flood

The April 2007 flood event is the second-largest recorded flow event on the Lamprey River, with a peak flow of 8,450 cfs recorded at the Packers Falls USGS gage. NHDES conducted a site visit just after the peak flow was reached at the gage. NHDES provided photographs taken during the site visit, which were used to approximate WSE's at the downstream face of the Veterans Bridge. Due to the flow split, the actual flow at the Macallen Dam at the time of the photographs is not known. Our analysis of the photographs, which was limited to photographic scaling, indicated that the WSE at the downstream face of the Veterans Bridge was approximately 29.7 feet. For hydraulic modeling purposes, flows entering the impoundment system via the Piscassic River and local tributaries were estimated by using a drainage-area proration method from the Packers Falls USGS gage.

May 2006 Flood

The May 2006 flood event is the largest recorded flow event on the Lamprey River, with a peak flow of 8,970 cfs recorded at the Packers Falls USGS gage. NHDES conducted a site visit around when the peak flow was reached at the gage. NHDES provided photographs taken during the site visit, which were used to approximate WSE's at the upstream and downstream face of the Veterans Bridge. Due to the flow split, the actual flow at the Macallen Dam at the time of the photographs is not known. Our analysis of the photographs, which was limited to photographic scaling, indicated that the WSE at the upstream face of the Veterans Bridge was approximately 32.4 feet, while the WSE at the downstream face of the Veterans Bridge was approximately 30.1 feet. While the elevations have a potentially large amount of uncertainty given the estimation method (photographic scaling), the estimated 2.3 foot WSE difference between the upstream and downstream face of the bridge indicate that the bridge was likely acting as a constriction, even though it is not visually apparent from any of the available photographs. For hydraulic modeling purposes, flows in the Piscassic River and other local tributaries were estimated by using a drainage-area proration method from the Packers Falls USGS gage.

Calibration Results

Table 7.2.9-1 compares modeled and observed WSEs for the four calibration events (March 31, 2014; March 2010; April 2007; May 2006). Note that the March 31, 2014 event is the only event with a direct flow measurement at Macallen Dam. The March 31, 2014 flow event was simulated with a weir C coefficient of 2.63, as the head at the dam was less than four (4) feet (the height at which data indicates the weir C coefficient is approximately 3.32). All other flow events were simulated with a weir C coefficient of 3.32 since the head was greater than four (4) feet. All events were simulated with the gates open, which was the actual condition. In May 2006 and April 2007 the gates did not have the extenders installed yet, so they were modeled with a vertical opening height of 5.5 feet. The March 2010 and March 31, 2014 flow events were modeled with the gates fully open and a vertical opening height of 7 feet.

In addition to the calibration data that Gomez and Sullivan collected/analyzed, Table 18 in Scholz (2011) included estimated WSEs at the Durham Boat Company (DBC) for the March 2010 and April 2007 events based on high water marks within the DBC building, with April 2007 having an elevation of approximately 33.6 feet NAVD 1988 and March 2010 having an elevation of approximately 32.4 feet NAVD 1988. The DBC also independently provided Gomez and Sullivan with relative elevation differences between the three recent large storms (May 2006, April 2007, March 2010), as measured from high water marks within their building, where the relative height of the March 2010 event was <6" (likely 5-6"), the April 2007 event was approximately 17"-18", and the May 2006 event was approximately 23". These readings are slightly different than those reported in Scholz (2011), as the DBC measurements indicate a difference of approximately one foot between April 2007 and March 2010, while the Scholz (2011) indicate a difference of approximately 0.8 feet. These differences, however, are not surprising given the uncertainty typically associated with surveying historic high water marks.

Table 7.2.9-1: Hydraulic Model Calibration Results

Event	Macallen Dam			Downstream Face of Veterans Bridge			Upstream Face of Veterans Bridge			Durham Boat Company Building		
	Obs. WSE (ft)	Model WSE (ft)	Delta (ft)	Obs. WSE (ft)	Model WSE (ft)	Delta (ft)	Obs. WSE (ft)	Model WSE (ft)	Delta (ft)	Obs. WSE (ft)	Model WSE (ft)	Delta (ft)
Mar 31, 2014	25.57	25.55	-0.02	N/A	N/A	-	N/A	25.87	-	N/A	26.50	-
March 2010	28.90	29.41	+0.49	29.20	29.49	+0.29	N/A	30.34	-	32.6	31.90	-0.70
April 2007	N/A	30.21	-	29.70	30.26	+0.56	N/A	31.16	-	33.4[49]	33.11	-0.29
May 2006	N/A	30.63	-	30.10	30.66	+0.56	32.4	31.65	-0.75	N/A	33.25	-

Note: "Obs." means observed

Given that the observed WSEs are estimated from photographs for the historic events, we believe that the model calibration is reasonable for these events. The WSEs at the Macallen Dam are slightly over-estimated. While the May 2006 photographic observations indicate we may be under-estimating the constriction due to the Veterans Bridge, NHDES field investigations during the May 2006, April 2007 and March 2010 events did not indicate any visually apparent signs of the bridge constricting flow.

[49] Flows at the Packers Falls gage were about 7,800 cfs or ~8% below the peak flow when the NHDES photographs were taken in April 2007, while the high water mark reflects the events peak flow. Therefore, the model WSE for the Macallen Dam and Veteran's Bridge locations reflects the 8% lower flow, while the modeled WSE at the Durham Boat Company reflects the events maximum flow.

7.2.10 Hydraulic Modeling Results

The hydraulic model was used to simulate water surface profiles and hydraulic conditions throughout the Lamprey River, Piscassic River and "flow split" area for a variety of flow scenarios, under both dam-in and dam-out conditions. The following scenarios were simulated in the hydraulic model:

a) Wright-Pierce 100-year flood, with dam-in conditions, no flow optimization[50];
b) Wright-Pierce 100-year flood, with dam-out conditions;
c) Average daily flow, with dam-in conditions;
d) Average daily flow, with dam-out conditions;
e) Low flow, with dam-in conditions;
f) Low flow, with dam-out conditions;
g) Average fish passage season flow, with dam-in conditions;
h) Average fish passage season flow, with dam-out conditions;

Model Scenario A: Wright-Pierce 100-year Flood, with Dam-In Conditions, Gates Closed, No Optimization

Scenario A simulated existing or baseline conditions and was developed to compare against other alternatives. To exactly match the Wright-Pierce 100-year flows on a reach-by-reach basis (such as above and below the flow split), Scenario A was not run using the HEC-RAS optimization function[51]. A breakdown of the flows in each model reach is shown in Table 7.2.10-1. Scenario A resulted in WSEs of 33.9 feet at Macallen Dam, 36.80 feet at the Moat Island flow split, and 38.5 feet at the large pool near the upper extent of the current impoundment.

Table 7.2.10-1: Flow Distribution in the Lamprey-Oyster Flow Split System for Dam-In Conditions, 100-yr flow.

River/Reach	Flow (cfs)
Lamprey River Upstream of Moat Island	12,670
Lamprey River Between Moat Island and Piscassic	8,410
Lamprey River Downstream of Piscassic	10,260
Piscassic River	1,850
Lamprey Local Tributaries	740
Oyster Flow Split Local Tributaries	615
Flow Diverted from Lamprey to Oyster River Watershed	4,260
Oyster Flow Split Total Flow (including Lamprey diversion)	5,615

[50] The hydraulic model is set up by default to optimize (i.e., iterate) the flows in the "flow split" reach and the mainstem Lamprey river such that the WSEs match. In order to model the exact flows Wright-Pierce modeled (i.e., preserve the balance between the flow diversion and the mainstem Lamprey River flows), we had to manually direct our model to pass specific flows on a reach-by-reach basis. Because of this, the WSEs for this scenario do not exactly line up between the "flow split" reach and the mainstem Lamprey River.

[51] Running the 100-year flow through our model resulted in a slightly different flow distribution between the Lamprey River and the flow split. For simplicity, we ran Wright-Pierce's exact flows through our model in this scenario.

A longitudinal WSE profile of Scenario A is shown in Figure 7.2.10-1. The profile indicates that the dam and the Veteran's Bridge both control upstream WSEs. WSEs are high enough to contact the water main running on the underside of the Veteran's Bridge (bottom elevation is estimated at ~33.4 feet). The Town may want to evaluate further into the potential risk or impact of this water main under extremely high flows. An inundation map under Scenario A is shown in Figure 7.2.10-2.

Model Scenario B: Wright-Pierce 100-year Flood, with Dam-Out Conditions

Scenario B is the same as Scenario A, but with the dam and gate structure removed. Scenario B was run to show the potential WSE reduction due to removing the dam under the 100-yr flood. Scenario B utilized the HEC-RAS optimization function. The flow distribution for Scenario B relative to Scenario A is shown in Table 7.2.10-2. It shows that when the dam is removed, approximately 1,265 cfs less (5,000 cfs – 3,735 cfs) flow is diverted to the Oyster River under the 100-year event compared to Scenario A. This flow increase in the Lamprey River (in combination with the Veterans Bridge constriction) somewhat reduces the flood WSE benefits of removing the dam. Scenario B showed WSEs of 17.8 feet at Macallen Dam (a drop of 16.1 feet compared to Scenario A), 34.8 feet at the Moat Island flow split (a drop of 2 feet compared to Scenario A), and 37.1 feet at the large pool near the upper extent of the current impoundment (a drop of 1.4 feet compared to Scenario A).

Table 7.2.10-2: Flow Distribution in the Lamprey-Oyster Flow Split System for Dam-In and Dam-Out Conditions, 100-yr flow.

River/Reach	Scenario B Dam-Out Flow (cfs)	Scenario A Dam-In Flow (cfs)
Lamprey River Upstream of Moat Island	12,670	12,670
Lamprey River Between Moat Island and Piscassic	9,675	8,410
Lamprey River Downstream of Piscassic	11,525	10,260
Piscassic River	1,850	1,850
Lamprey Local Tributaries	740	740
Oyster Flow Split Local Tributaries	615	615
Flow Diverted from Lamprey to Oyster River Watershed	3,735	5,000
Oyster Flow Split Total Flow (including Lamprey diversion)	4,350	5,615

A longitudinal WSE profile of Scenarios A and B is shown in Figure 7.2.10-1, while Table 7.2.10-3 compares river depths, widths and velocities at select locations throughout the modeled reach for both scenarios. The profile indicates that flood WSEs in the reach upstream of the Veteran's Bridge drops by approximately 1.4 feet to 3.5 feet, with the greater reductions at the dam and diminishing in the upstream direction. The profile also shows that the Veterans Bridge restricts flow under the dam-in and dam-out scenarios, with a greater impact when the dam is removed. This is due to the narrow (less than 60 foot wide) opening underneath Veterans Bridge as well as the shallow bedrock (approximately elevation 10.0 feet) that crests underneath the bridge structure. This flow restriction moderately reduces the flood reduction benefits of removing the Macallen Dam. Flood WSEs between the Macallen Dam and the Veteran's Bridge are reduced by 6 to 16 feet compared to Scenario A, with the greatest reductions occurring where the dam is currently located. An inundation map under Scenario B is shown in Figure 7.2.10-2. It shows that there is a moderate reduction in the inundation area around the lower

Lamprey River (below the Piscassic River) and around the Piscassic River. While this reduction in inundation area does not appear to reduce flooding along entire properties or buildings, some of the areas along the Piscassic River are particularly urbanized and may benefit from the reduction in flood WSEs.

Table 7.2.10-3: Comparison of river depths, widths and velocities at select locations for the 100-year flow under dam-in and dam-out conditions.

Location		Dam-In Conditions (Scenario A)			Dam-Out Conditions (Scenario B)			Diff. Between Dam-In and Dam-Out Conditions		
Model Sta.	Description	Depth (feet)	Width (feet)	Vel. (ft/s)	Depth (feet)	Width (feet)	Vel. (ft/s)	Depth (feet)	Width (feet)	Vel. (ft/s)
204	Macallen Dam Location	32.1	312	4.7	17.7	122	10.5	-14.4	-190	5.8
545	US of Veterans Bridge	27.5	113	5.8	24.0	98	8.0	-3.5	-15	+2.2
2954	DS Piscassic Confluence	32.1	1,345	1.5	29.6	1,128	2.4	-2.7	-217	+0.9
1288	Near Piscassic River Launch	23.9	1,945	1.2	21.6	1,537	1.3	-2.3	-408	+0.1
8029	Moat Island	26.7	751	1.1	24.8	578	1.4	-1.9	-173	+0.3
12719	Pool DS of Packers Falls	43.2	683	0.4	41.9	674	0.5	-1.3	-9	+0.1

Model Scenario C: Wright-Pierce 100-year Flood, with Dam Spillway Lowered 10 feet

Scenario C simulates the dam modification alternative #2 from the Wright-Pierce report. It was run to reflect the conditions that the river would experience if the dam's spillway were lowered by 9.6 feet so that it can pass the 100-year flood (as determined by Wright-Pierce). Because this study uses a higher C coefficient for the dam spillway than the Wright-Pierce calculations assumed, we calculate that in this scenario the dam has more freeboard (2.6 feet) than the one foot that is necessary to meet dam safety requirements, even when accounting for the reduced flow diversion to the Oyster River (Table 7.2.10-4). A longitudinal WSE profile of Scenarios A and C is shown in Figure 7.2.10-3. Scenario C showed WSEs of 25.9 feet at Macallen Dam (a drop of 8.0 feet compared to Scenario A), 34.9 feet at the Moat Island flow split (a drop of 1.9 feet compared to Scenario A), and 37.1 feet at the large pool near the upper extent of the current impoundment (a drop of 1.4 feet compared to Scenario A).

Table 7.2.10-4: Flow Distribution in the Lamprey-Oyster Flow Split System for Dam-In, Dam-Out and Dam-Modification Conditions, 100-yr flow.

River/Reach	Scenario C Dam-Mod Flow (cfs)	Scenario B Dam-Out Flow (cfs)	Scenario A Dam-In Flow (cfs)
Lamprey River Upstream of Moat Island	12,670	12,670	12,670
Lamprey River Between Moat Island and Piscassic	9,599	9,675	8,410
Lamprey River Downstream of Piscassic	11,449	11,525	10,260
Piscassic River	1,850	1,850	1,850

Lamprey Local Tributaries	740	740	740
Oyster Flow Split Local Tributaries	615	615	615
Flow Diverted from Lamprey to Oyster River Watershed	3,856	3,735	5,000
Oyster Flow Split Total Flow (including Lamprey diversion)	4,471	4,350	5,615

Model Scenario D: Average Daily Flow, with Dam-In Conditions, Gates Closed
Scenario D simulates dam-in conditions under the average daily flow and the gates closed. It was run to reflect existing conditions – the current width and depth of the river-- and to allow for comparison to the dam-out condition, Scenario D under the same flow. A breakdown of the flows in each model reach is shown in Table 7.2.10-5. Scenario D shows WSEs of 23.9 feet at Macallen Dam, 23.9 feet at the Moat Island flow split, and 24.0 feet at the large pool near the upper extent of the current impoundment. As expected, under average flow conditions, the impoundment is relatively flat.

Table 7.2.10-5: Flow Distribution in the Lamprey-Oyster Flow Split System for Dam-In Conditions, Average Annual Flow.

River/Reach	Scenario C Dam-In Flow (cfs)
Lamprey River Upstream of Moat Island	295
Lamprey River Between Moat Island and Piscassic	300
Lamprey River Downstream of Piscassic	337
Piscassic River	37
Lamprey Local Tributaries	5
Oyster Flow Split Local Tributaries	2.1
Flow Diverted from Lamprey to Oyster River Watershed	0
Oyster Flow Split Total Flow (including Lamprey diversion)	2.1

A longitudinal WSE profile of Scenario D is shown in Figure 7.2.10-4. The profile indicates that the dam appears to be the primary hydraulic control throughout the reach. An inundation map under Scenario D is shown in Figure 7.2.10-5.

Model Scenario E: Daily Average Flow, with Dam-Out Conditions
Scenario E is the same as Scenario D, but the dam and gates are removed. The purpose of this simulation is to show changes in river depth and channel width with the dam removed, relative to current conditions (Scenario D). The flow distribution is the same Scenario D. Scenario E shows WSEs of 3.5 feet at the site of the existing dam (a 20.4 foot drop compared to Scenario D), 15.8 feet at the Moat Island flow split (an 8.1 foot drop compared to Scenario D), and 18.7 feet at the large pool near the upper extent of the current impoundment (a 5.3 foot drop compared to Scenario D).

A longitudinal WSE profile comparing Scenarios D (Dam-in) and E (Dam-out) is shown in Figure 7.2.10-4, while Table 7.2.10-6 compares river depths, widths and velocities at select locations throughout the modeled reach for both scenarios. The profile indicates that WSEs upstream of the Veteran's Bridge (which acts as a hydraulic control if the dam is removed) drop between 5 to 9 feet, with the greater reductions closer to the dam and diminishing in the upstream direction. WSEs between the Macallen Dam and the Veteran's Bridge are reduced by 16 to 20 feet, with the greatest reductions occurring where the dam is currently located. An inundation map under Scenario E is shown in Figure 7.2.10-5. It shows that river widths in the Lamprey river mainstem are modestly reduced. There are also several backwater and bay areas (e.g., Piscassic River, Moat Island) that are severely reduced in terms of wetted width. A small channel appears to remain in the Moat Island portion of the river, but it is very shallow and susceptible to dewatering at lower flows.

Table 7.2.10-6: Comparison of river depths, widths and velocities at select locations for the daily average flow under dam-in and dam-out conditions.

Location		Dam-In Conditions (Scenario A)			Dam-Out Conditions (Scenario B)			Diff. Between Dam-In and Dam-Out Conditions		
Model Sta.	Description	Depth (feet)	Width (feet)	Vel. (ft/s)	Depth (feet)	Width (feet)	Vel. (ft/s)	Depth (feet)	Width (feet)	Vel. (ft/s)
204	Macallen Dam Location	22.1	122	0.4	3.3	34	10.0	-18.8	-88	+9.6
545	US of Veterans Bridge	16.1	73	0.4	7.2	54	1.3	-8.9	-29	+0.9
2954	DS Piscassic Confluence	19.7	148	0.2	10.9	104	0.4	-8.8	-44	+0.2
1288	Near Piscassic River Launch	11.4	217	0.0	8.7	43	0.9	-2.7	-174	+0.9
8029	Moat Island	13.9	307	0.2	5.7	129	0.9	-8.2	-178	+0.7
12719	Pool DS of Packers Falls	28.7	337	0.06	23.5	283	0.09	-5.2	-54	+0.03

Model Scenario F: Low Flow, with Dam-In Conditions, Gates Closed

Scenario F simulates current conditions under a low flow. A breakdown of the flows in each model reach is shown in Table 7.2.10-6. This scenario shows WSEs of 22.6 feet at Macallen Dam, 22.6 feet at the Moat Island flow split, and 22.6 feet at the large pool near the upper extent of the current impoundment.

Table 7.2.10-7: Flow Distribution in the Lamprey-Oyster Flow Split System for Dam-In Conditions, Low Flow

River/Reach	Scenario E Flow (cfs)
Lamprey River Upstream of Moat Island	8.8
Lamprey River Between Moat Island and Piscassic	8.9
Lamprey River Downstream of Piscassic	10
Piscassic River	1.1
Lamprey Local Tributaries	0.1
Oyster Flow Split Local Tributaries	1[52]
Flow Diverted from Lamprey to Oyster River Watershed	0
Oyster Flow Split Total Flow (including Lamprey diversion)	1

[52] A flow of 1 cfs was chosen to keep the models flow split reach stable. A drainage-area prorated flow for this scenario would have resulted in a flow of less than 0.1 cfs.

A longitudinal WSE profile for Scenario E is shown in Figure 7.2.10-6. The profile indicates that the dam is the primary hydraulic control throughout the reach. An inundation map under Scenario E is shown in Figure 7.2.10-7. It shows a similar, but slightly smaller, wetted area than the daily average flow scenario (with the dam in).

Model Scenario G: Low Flow, with Dam-Out Conditions

Scenario G is the same as Scenario F, but the dam and gates are removed. Scenario G was run to show the potential WSE reduction due to removing the dam under a "worst case" scenario. The flow distribution is the same as Scenario F. Scenario G shows WSEs of 2.5 feet at the site of the existing dam (a 20.1 foot drop compared to Scenario F), 12.4 feet at the Moat Island flow split (a 10.2 foot drop compared to Scenario F), and 17.0 feet at the large pool near the upper extent of the current impoundment (a 5.6 foot drop compared to Scenario F).

A longitudinal WSE profile for Scenarios F and G is shown in Figure 7.2.10-5. The profile indicates that WSEs upstream of the Veteran's Bridge (which acts as a hydraulic control if the dam is removed) drop from between 5 to 10 feet, with the greater reductions at the dam and diminishing in the upstream direction. WSEs between the Macallen Dam and the Veteran's Bridge are reduced by 16 to 20 feet, with the greatest reductions occurring where the dam is currently located. An inundation map under Scenario G is shown in Figure 7.2.10-7. It shows relatively large reductions in width along some portions of the Lamprey River, including a portion of the mainstem Lamprey River above the Piscassic confluence. The Piscassic River could not be mapped for the flow in this scenario due to the over-widened channel resulting in extremely shallow modeled depths[53]. The Moat Island area, other than perhaps some isolated (i.e., stagnant) pools, appears to be fully dewatered under this flow.

Model Scenario H: Fish Passage Season Flow, with Dam-In Conditions, Gates Closed

Scenario H was run to represent typical flow conditions during the migratory fish passage season (approximately mid-April through early-June). A breakdown of the flows in each model reach for Scenario H is shown in Table 7.2.10-8. This scenario shows WSEs of 24.3 feet at Macallen Dam, 24.3 feet at the Moat Island flow split, and 24.4 feet at the large pool near the upper extent of the current impoundment. Water velocities were consistently less than 1 foot per second throughout the impounded reach such that there were no velocity barriers to fish passage.

Table 7.2.10-8: Flow Distribution in the Lamprey-Oyster Flow Split System for Dam-In Conditions, Fish Passage Flow.

River/Reach	Scenario G Flow (cfs)
Lamprey River Upstream of Moat Island	413
Lamprey River Between Moat Island and Piscassic	421
Lamprey River Downstream of Piscassic	472
Piscassic River	51

[53] It is likely that the Piscassic channel's shape will change if the dam were to be removed, as most of the sediments are very fine and easily transported. The extent of this change will strongly influence post-removal widths and depths in the Piscassic.

Lamprey Local Tributaries	8
Oyster Flow Split Local Tributaries	3
Flow Diverted from Lamprey to Oyster River Watershed	0
Oyster Flow Split Total Flow (including Lamprey diversion)	3

A longitudinal water velocity profile for Scenario G is shown in Figure 7.2.10-8.

Model Scenario I: Fish Passage Season Flow, with Dam-Out Conditions

Scenario I is the same as Scenario H, but with the dam and gates removed. Scenario I was run to show the potential impacts that dam removal may have on migratory fish passage during the spring. The flow distribution is the same as Scenario H. A longitudinal water velocity profile for Scenario H and I are shown in Figure 7.2.10-8. Under Scenario I, water velocities increase to over 10 feet per second in the newly-exposed bedrock reach between the dam and the Veterans Bridge. In addition to the initial high velocity area near the legacy dam/Macallen Dam area, there is a second high-velocity area beneath the Veterans Bridge that may also act as a velocity barrier to fish passage if the dam is removed, as the velocities exceed 10 feet per second in some transects beneath the bridge. While there is some uncertainty on exactly how the flow patterns in the reach between the Veterans Bridge and Macallen Dam may change if the dam is removed, these results indicate that there is likely a velocity barrier to passing fish unless mitigating actions are taken.

In addition to the velocity barrier concerns, it is important to note that the river reach between the Veteran's Bridge and the Macallen Dam is very steep. The river bed drops nearly 10 feet (approximate thalweg elevation under the Veteran's Bridge), over approximately 250 feet of river length, which is equal to an average slope of 4%. The presence of the Macallen Dam and the legacy timber crib dam make it impossible to fully assess how the below-dam channel is shaped. Given that historic descriptions refer to this area as the "First Falls", it is possible that there are portions of the riverbed that are much steeper than the average slope. These steeper areas may present vertical barriers to fish passage unless mitigating actions are taken. Additionally, the small falls at the head of the existing impoundment that would be created if the dam were to be removed may also potentially act as a vertical passage barrier under some flow conditions.

Model Scenario J and K: 25-year Bulletin 17B Flow, Dam-In and Dam-Out

Scenario J and K were run to gain a better understanding of the potential flood impacts of dam removal under a more frequently-seen flood flow. These scenarios used a drainage-area prorated 25-year flow from the Packers Falls USGS gage, as determined by the Bulletin 17B procedure. This flood flow was modeled with the dam gates fully open to simulate likely real-world conditions. The flow distribution in each model reach is shown in Table 7.2.10-9. The results show that nearly all flow diversion to the Oyster River is eliminated under this flow, as the diversion amount goes from 1,034 cfs to 23 cfs. A longitudinal WSE profile for Scenarios J and K is shown in Figure 7.2.10-9. The WSE profile shows a decrease in flood water elevations between 1 and 3 feet in the river reach upstream of the Veterans Bridge relative to dam-in conditions with the gates open, even with the nearly eliminated diversion to the Oyster River and thus increased flow at the Macallen Dam location (6,274 cfs with dam-in conditions; 7,320 cfs with dam-out conditions).

Table 7.2.10-9: Flow Distribution in the Lamprey-Oyster Flow Split System for Dam-In and Dam-Out Conditions, under the 25-yr flow as determined by a Bulletin 17B analysis on the Packers Falls Gage.

River/Reach	Scenario J Dam-In Flow (cfs)	Scenario K Dam-Out Flow (cfs)
Lamprey River Upstream of Moat Island	6,420	6,420
Lamprey River Between Moat Island and Piscassic	5,478	6,524
Lamprey River Downstream of Piscassic	6,274	7,320
Piscassic River	796	796
Lamprey Local Tributaries	127	127
Oyster Flow Split Local Tributaries	47	47
Flow Diverted from Lamprey to Oyster River Watershed	1,034	23
Oyster Flow Split Total Flow (including Lamprey diversion)	1,116	70

8.0 Cultural Resources Studies

8.1 Consultation Requirements

The potential removal of the Macallen Dam must take into account potential impacts to historic resources including archaeological and architectural resources. Section 106 of the National Historic Preservation Act (NHPA) of 1966 requires federal agencies to take into account the effects of their undertakings (dam removal) on known or potential historic properties and afford the Advisory Council of Historic Preservation (ACHP) a reasonable opportunity to comment. Properties greater than 50 years old may be eligible for listing to the NRHP. Compliance with Section 106 of the NHPA is required of most dam removal projects that require a federal permit (such as a USACOE permit for activities involving the placement of fill in waters of the United States) or receive federal funding or assistance.

All federal agencies (e.g. United States Fish and Wildlife Service, United States Environmental Protection Agency, National Resource Conservation Services, National Oceanic and Atmospheric Administration) are responsible for addressing Section 106 of the NHPA. To make the process more efficient, typically a lead federal agency (LFA) is identified. For this project, the LFA is NOAA through completion of this feasibility study. The LFA is responsible for ensuring compliance with Section 106 of the NHPA. As part of that responsibility, the LFA must coordinate with the State Historic Preservation Office (in this case NHDHR) regarding the project affects, if any, on known or potential historic properties.

The purpose of the historic preservation review process as defined under state law RSA 227-C:9 and Section 106 of the NHPA of 1966, as amended (16 U.S.C. 470), implemented by ACHP procedures, is to balance the public interest in historic preservation with the public benefit from a variety of governmental initiatives.

Steps in the Section 106 Process

Step 1: Initiate Section 106 Process

The responsible federal agency(s) first determines whether it has an undertaking that could affect historic properties. Historic properties are properties that are included in the NRHP or that meet the criteria for the National Register. If so, it must identify the appropriate State Historic Preservation Officer (SHPO)/Tribal Historic Preservation Officer (THPO) to consult with during the process. It should also plan to involve the public, and identify other potential consulting parties. If the federal agency determines that it has no undertaking, or that its undertaking is a type of activity that has no potential to affect historic properties, the agency has no further Section 106 obligation.

Step 2: Identification/Evaluation of Historic Properties

If the federal agency's undertaking has the potential to affect known or potential historic properties, it determines the scope of appropriate identification efforts and then proceeds to identify historic properties in the area of potential effect (APE[54]). The agency reviews background information, consults

[54] The area of potential effect is defined as the area in which eligible properties may be affected by the undertaking, including direct effects (such as destruction of the property) and indirect effects (such as visual, audible, and atmospheric changes which affect the character and setting of the property).

with the SHPO/THPO and others, seeks information from knowledgeable parties, and conducts additional studies as necessary. Districts, sites, buildings, structures, and objects listed in the National Register are considered; unlisted properties are evaluated against the National Park Service's published criteria, in consultation with the SHPO/THPO any Indian tribe, consulting parties, Project Partners and the dam owner.

If questions arise about the eligibility of a given property, the agency may seek a formal determination of eligibility. Section 106 review gives equal consideration to properties that have already been included in the National Register as well as those that have not been so included but that meet National Register criteria and are eligible for listing.

If the agency finds that no historic properties are present or affected, it provides documentation to the SHPO/THPO and, barring any objection in 30 days, proceeds with its undertaking.

If the agency finds that historic properties are present, it proceeds to assess possible adverse effects.

Step 3. Determination of Effect

The agency, in consultation with the SHPO/THPO, makes an assessment of adverse effects on the identified historic properties based on criteria found in ACHP's regulations. If they agree that there will be **no adverse effect,** the agency proceeds with the undertaking and any agreed-upon conditions. If they find that there is an **adverse effect,** or if the parties cannot agree and ACHP determines within 15 days that there is an adverse effect, the agency begins consultation to seek ways to avoid, minimize, or mitigate the adverse effects.

Step 4. Resolve Adverse Effects

The agency consults to resolve adverse effects with the SHPO/THPO and others. Consultation usually results in a Memorandum of Agreement (MOA), which outlines agreed-upon measures that the agency will take to avoid, minimize, or mitigate the adverse effects. In some cases, the consulting parties may agree that no such measures are possible, but that the adverse effects must be accepted in the public interest.

It should be noted that if the Macallen Dam is found eligible for the NRHP, such a designation does not preclude removal of the dam.

8.2 PAL Investigation

PAL conducted the following aspects of the cultural resource study.

- A Pedestrian Survey and Recommended Delineation of the APE
- Completion of the NHDHR’s RPR Form

PAL’s report is included in Appendix H.

To begin review and consultation with the NHDHR, the Town must submit a RPR form to the NHDHR. The form requires background information on the Project specific to architectural and archaeological resources. PAL conducted a site file review at the NHDHR and summarized their findings in the RFR form that will be sent to the NHDHR in June 2014. PAL noted the following in their review:

Legacy Dam above Macallen Dam

- The Macallen Dam is not included in the NHDHR architectural inventory files. The dam is located within, but not listed as a contributing resource to the Newmarket Commercial and Industrial Historic District (the Historic District), which was listed in the National Register of Historic Places (NRHP) in 1980.

- Twenty-four (24) archaeological sites are recorded within a five-kilometer (km) radius of the proposed study area: nine pre-contact sites, six post-contact sites, and nine sites with pre- and post-contact components. None of the recorded archaeological sites are located within the study area.

PAL recommended the following next steps, should the dam removal feasibility study advance further:

- Intensive survey and National Register evaluation of the Macallen Dam is recommended to assess the significance and contributing status of the structure within the established Historic District.

- A Phase 1A Archaeological Survey is recommended to establish a final recommended archaeological APE for the dam removal feasibility study. The survey should include comprehensive pre- and post-contact histories of the study area, including any ethnographic or historical references to migratory fish being present upstream before a dam was located at the "First Falls;" detailed archaeological sensitivity statements; and recommendations for additional Phase 1B Archaeological Survey, as required.

After NHDHR reviews the RPR, it will make a recommendation to the LFA as to next steps.

8.3 Other Cultural Resource Tasks Not Studied

At this juncture, only the APE has been preliminarily identified and the RPR Form will be submitted to NHDHR in June 2014; however, there are many other required steps as described below. As noted above, Step 2 requires conducting various surveys and investigations that are summarized below, but have not been conducted as part of this feasibility study. If the Town opted to advance the dam removal alternative further, it is recommended that these studies be conducted.

<u>Archeological Resources</u>

If there are any modifications of the dam (including repair or removal), the impact on archeological resources is required per Section 106 of the NHPA. The typical sequence of steps is a) conduct Phase 1A archeological survey, b) pending the Phase 1A findings, conduct Phase 1B subsurface surveys and c) pending the Phase 1A and 1B findings, conduct Phase II investigation to evaluate National Register significance.

The purpose of the Phase 1A survey is to develop a detailed sensitivity assessment for pre- and post-contact archaeological resources within the APE that may be affected by dam removal, and to develop predictive statements for the types and locations of such resources. For this project, archeological sensitivity would be evaluated not only in proximity of the dam, but would include the impounded reach as well. If the Phase 1A survey results indicate that the project area is archeologically sensitive, Phase 1B surveys are typically required. Phase 1B investigations undertake intensive, systematic field-testing (test pits) of areas identified as archaeologically sensitive during Phase IA. Phase II investigation evaluates the National Register significance of the site through more extensive excavation, which samples and characterizes archaeological deposits.

Historic Structure Resources

The work products for the Phase I historic/architectural/engineering survey could consist of a Project Area Form (PAF) for the study area in accordance with the NHDHR's *Scope of Work for Proposed Dam Removals Pertaining to Historical and Archaeological Resources* guidelines. The PAF would serve to expand and supplement (as necessary) the information contained within the 1980 National Register documentation for the *Newmarket Commercial and Industrial District*, in which the Macallen Dam is included but not identified as a contributing resource. The PAF would include a discussion of the history of development in the area surrounding the Macallen Dam and would include photos of the study area, including the dam and historic properties in proximity to the dam.

A New Hampshire Individual Inventory Form must also be completed for the dam and its ancillary components. The form is used to record and understand the appearance, history, and significance of a building, structure, site, or object prior to listing on the State or National Registers of Historic Places, for a historic resources survey or planning project, or for review and compliance purposes.

9.0 Other Potential Alternatives

As noted in the introduction, we were asked by the Town and Project Partners to discuss other potential alternatives to dam removal based on reviewing past reports and hydraulic modeling, our hydraulic modeling and knowledge of the project. At the public meetings, many alternatives were mentioned, which have been addressed below as well as other alternatives we recommend the Town consider. Note that no engineering analysis has been conducted to determine if any of the alternatives are feasible. In addition, no costs have been included.

9.1 Review of Past Studies

As noted earlier, the amount of water passing over the spillway is a product of the spillway length (L), depth of water atop the spillway (H) and the weir coefficient (C). As shown earlier the equation is:

$$Q = CLH^{1.5}$$

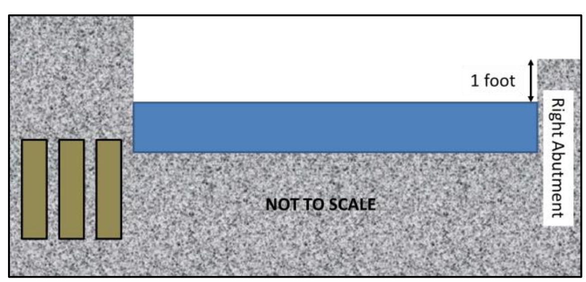
Based on the equation, increasing the weir coefficient or spillway length, increases the spillway discharge capacity. We reviewed the Wright-Pierce hydraulic model and noticed a few issues. First, as discussed in detail in Appendix F, we believe a rational case could be made that the weir coefficient of 2.63 used in the Wright-Pierce hydraulic model could be raised to 3.32 based on the calibration to observed data conducted as part of this study. What this means is the spillway can pass roughly 26% more water under flood flows (when the depth of water atop the spillway is greater than four (4) feet).

Based on our review of the Wright-Pierce modeling, it appears that the “flow split” calculations that were used to determine the Macallen Dam’s 100-year flood flow may have been conducted with the dam’s gates opened. If this is correct, then it is possible that this may slightly lower the dam’s 100-year flood flow.

Wright-Pierce developed three alternatives (Alternatives 2, 3 and 5) to lower the spillway or lower the spillway with other measures such as lengthening the spillway or raising the right abutment. As noted above, reducing the spillway crest elevation lowers the water surface profile at the flow spilt meaning that less water passes to the Oyster River and more passes to the Macallen Dam. In reviewing Appendix G of their report, Alternatives 2, 3, and 5 used the same 100-year flow of 10,259 cfs, but should have been higher to account for the flow spilt. This “moving target” should be accounted for in any final design that the Town conducts.

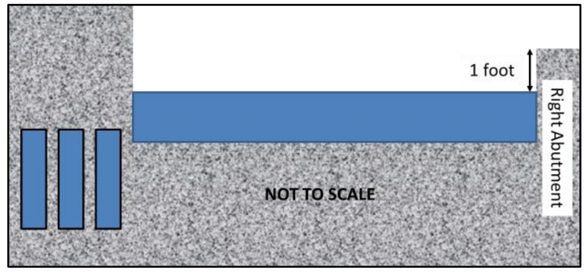
9.2 Existing Conditions- Maximum Discharge Capacity of Spillway

Based on our hydraulic model (weir coefficient of 3.32), under existing conditions and the gates closed, the dam’s maximum discharge capacity with one foot of freeboard is approximately 2,637 cfs. Thus, the current configuration can only pass 26% (2,637 cfs/10,259 cfs) of the 100-year flood. This flow is used as a reference point in evaluating other alternatives.



9.3 Removal of the Gates

A question raised at public meetings is if the gates were permanently removed to avoid manual operations, how much additional water can the dam pass? NHDES has indicated that permanent removal of the gates would count toward the dam's discharge capacity. The gate crest elevation is approximately 6.3 feet below the spillway crest (metal lip) elevation. We have addressed this question herein for purpose of analysis, but do not believe removing the gates is a plausible alternative given the following:

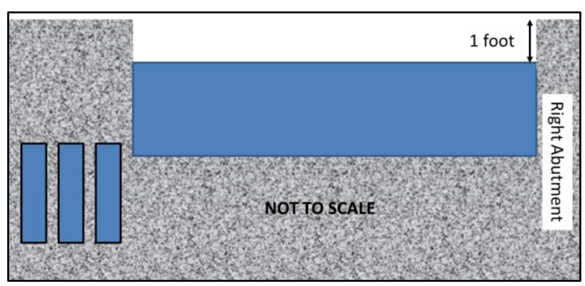


- To maintain the impoundment water elevation at the spillway crest, 6.3 foot-high flashboards would be needed. Flashboards are typically in the 1-3 foot range and are purposely designed to fail as flows increase.
- As described earlier and shown Figure 7.2.6-3, even if the gates are removed, under high flows the left and center gates are impacted by the backwater, while it is unclear if the right gate is impacted by the backwater. Thus, the gates cannot pass as much water as compared to if they were not backwatered under flooding conditions.
- As mentioned in the flow split section of this report, increasing the discharge capacity of the dam will result in a greater proportion of flow passing toward the Macallen Dam. Final design calculations must take this into account.
- As explained below, removal of the gates does not increase the overall dam discharge capacity considerably.

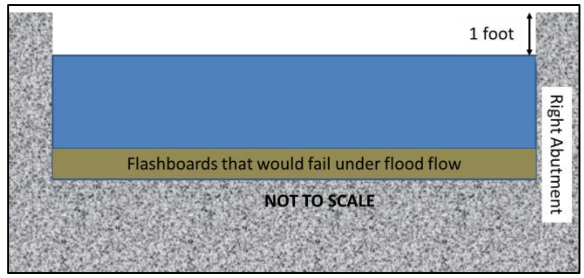
Assuming the gates were permanently removed (and excluding the issues identified above), the maximum discharge capacity of the spillway and gates with one foot of freeboard is approximately 4,286 cfs or 42% of the 100-year flood. Thus, the gates only provide approximately 1,745 cfs of additional discharge capacity.

9.4 Removal of the Gates and Raise Right Abutment

Based on the same scenario as above, the gates are permanently removed, but in addition the right abutment (elevation 28.47 feet) is raised to be the same elevation as the left abutment (elevation 30.20 feet) the maximum discharge capacity of the spillway and gates with one foot of freeboard is approximately 5,926 cfs or 58% of the 100-year flood. Thus, removing the gates and raising the right abutment gains approximately 3,289 cfs of additional discharge capacity. This is still not a viable alternative.



9.5 Remove Gate Structure, Raise Right Abutment, Lower Spillway Crest 3 feet



This alternative calls for a) removing the existing gate structure for purpose of lengthening the spillway crest from 70 feet to approximately 90 feet, b) raising the right abutment to elevation 30.20 feet, and c) lowering the spillway crest 3 feet (i.e., new crest elevation of 19.42 feet) and installing 3 foot-high flashboards that fail under flood flows (schematic shows flashboards in place, but they would fail under flood flow). Note that NHDES would likely require the installation of a low-level outlet as well. In addition, removing three feet from a gravity dam could influence the dam's stability, thus any measures calling for lowering the spillway crest would require a stability analysis. Another factor to consider is that when flashboards fail, flows must drop considerably before the flashboards can be replaced. While this is considered routine maintenance for most flashboard-equipped spillways, if the flashboards fail during the fish passage season, the fish ladder could be rendered unusable as the exit would be perched and no water would flow down the ladder. As a result, this issue would need further evaluation. Based on the above assumptions, the maximum discharge capacity of this alternative with one foot of freeboard is approximately 9,139 cfs or 89% of the 100-year flood. Thus, this alternative gains approximately 6,502 cfs of additional discharge capacity. While this scenario is much closer to compliance than the other alternatives, it is still approximately 11% shy of the required capacity. Additionally, this calculation does not consider the change in flow diversion due to a reduced WSE at Macallen Dam, as previously discussed. Thus, it is possible that the 100-year flood flow may increase above 10,259 cfs as WSEs at Macallen Dam are lowered[55].

9.6 Stability Analysis

Per NHDES Dam Safety Regulations Env-Wr 303.12 Meeting Discharge Capacity Requirements indicates the following:

Env-Wr 303.12 Meeting Discharge Capacity Requirements

(a) If a dam does not have adequate discharge capacity to pass the flood specified in Env-Wr 303.11 with one foot of freeboard, the owner shall submit a plan to the department to address the deficiency.

(b) The plan submitted pursuant to (a), above, shall:

(1) Specify the action to be taken, per (c), below;

(2) Specify the proposed timeframe for taking the action; and

(3) Include the results of hydrologic analyses completed pursuant to Env-Wr 403.05, assessing the floods and discharge capacity of the structure.

(c) The plan shall specify which of the following actions the owner intends to pursue:

[55] As described in Table 7.2.10-2, the 100-year flood in the Lamprey River downstream of the Piscassic River confluence increased to 11,525 cfs when the Macallen Dam is removed. Therefore, we do not expect the 100-year flood flow would increase beyond that flow under any dam modification scenario.

(1) *Increase the capacity of the dam to pass the flood with one foot of freeboard and without manual operations;*

(2) ***Submit a stability analysis to the department showing that the dam is safe against sliding, overturning, or erosion by overtopping, as applicable, during the specified flood, using the methods outlined in "Engineering Guidelines for Evaluation of Hydropower Projects" published by the Federal Energy Regulatory Commission (FERC), Chapter 3 dated 2002 and Chapter 4 dated 1991, available as noted in Appendix B****;*

(3) *Stabilize the dam so that it is safe under the specified flood conditions; or*

(4) *Modify the dam so that the hazard classification is lowered and the dam passes the appropriate flow for the new classification.*

(d) *The department shall approve the plan if the department determines that:*

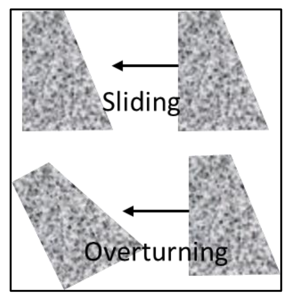
(1) *The proposed action will bring the dam into compliance with Env-Wr 303.11;*

(2) *The work can be done in a way that will not:*

a. *Endanger life or property downstream of the dam; or*

b. *Cause environmental losses that are not reversible environmental losses; and*

(3) *The time frame for the work is reasonable under the circumstances, including the risk posed by the deficiency, the owner's financial resources, and the timing of the work in relation to other uses of the impounded water.*



As noted above, the regulations permit conducting a stability analysis to demonstrate to the NHDES Dam Bureau that the dam is safe against sliding, overturning, or erosion by overtopping during the 100-year flood event. A stability analysis evaluates the forces acting on the dam.

The Macallen Dam is a stone gravity dam. The weight of the dam acts vertically downwards and is the major force maintaining the dam in place. A gravity dam is subjected to the following main forces (not all of the forces listed below are applicable to the Macallen Dam):

- Weight of the dam- downward forces due to the weight of the gravity dam structure.
- Water pressure- forces acting on the upstream side of the dam due to the depth of water and resisting forces on downstream side of the dam due to tailwater elevation.
- Uplift pressure- force of water pressure acting vertically upwards.
- Wave pressure-likely negligible for Macallen Dam.
- Earth and Silt pressure.
- Ice pressure.
- Wind pressure- likely negligible for Macallen Dam.
- Earthquake forces.
- Thermal loads- likely negligible for Macallen Dam.

These forces fall into two categories as: a) forces, such as weight of the dam and water pressure, which are directly calculable from the unit weights of the materials and properties of fluid pressures; and b) forces, such as uplift, earthquake loads, silt pressure and ice pressure, which can only be assumed on the basis of assumption of varying degree of reliability. It is in the estimating of the second category of the forces that special care must be taken and reliance placed on available data, experience, and judgment.

The Town could conduct a stability analysis to determine if the dam is safe from overturning or sliding under the 100-year flood flow. Our recommendation is that before moving forward with a stability analysis, the Town consult with the NHDES Dam Bureau to ensure the Dam Bureau agrees with the study's methods and assumptions. The Town should consider conducting the stability analysis incrementally and consult with the NHDES Dam Bureau after completing stages of the study as earlier findings may dictate different future steps. In addition, the incremental approach is recommended such that the Town can control costs as information learned earlier will inform the process. If the findings indicate the dam and its abutments are stable under the 100-year flood flow, then the Town may work with the Dam Bureau to assess any other outstanding safety concerns (e.g., impacts to the historic mill building on river right, etc.). If the findings indicate the dam is not stable, there may be options to stabilize the dam in-place; however, the costs of these measures are unknown at this juncture.

9.7 Other Alternatives

Setting aside costs, there are other alternatives the Town may wish to consider to maintain the same pond elevation as follows:

- The Town could buy and remove the Durham Book Exchange Building and raise the right abutment. As noted in the NHDES Dam Bureau's September 8, 2010 letter, the main concern with a potential dam failure is the habitation of this building. If this option were to be pursued, a stability analysis would still be required assessing whether the dam is stable under the 100-year flood event. Other structural modifications may still need to be made to alleviate any remaining Dam Bureau safety concerns.
- Various combinations of widening the spillway[56], partially or fully removing the gate structure[57], and adding flashboards.
- Recognizing this as a very remote alternative, a new dam could be constructed between the Veterans Bridge and Macallen Dam where the channel width is much wider as it would result in a spillway length closer to 130 feet in which to pass the 100-year flood. This option would need to take the hydraulic impact of the Veterans Bridge into account, as field investigations indicate the Bridge may prevent the full width of the river from effectively passing flow under high flows.

[56] Given the infrastructure on either side of the dam's abutment, there may be limited ability to substantially widen the dam spillway.

[57] As previously stated, the Dam Bureau would likely require the Town to install a new low-level outlet if the gate structure was removed.

10.0 Conceptual Plan for Macallen Dam Removal and Opinion of Probable Construction Cost

10.1 Conceptual Plans

This section includes a description of the conceptual level sequencing plan. Prior to any construction activities, all regulatory permits must be obtained. During construction, we have assumed that a police detail will be available for traffic control during the debris hauling stage.

The preliminary dam removal design is based on managing flows during the demolition period of up to 100 cfs (this flow is equaled or exceeded approximately 30% of the time in July, 20% in August and 15% in September). Shown in Figure 10.1-1 is a conceptual plan for removal. A visual rendering showing what the area around the dam potentially may look like after the dam is removed is shown in Figure 10.1-2. The general sequencing steps are described below.

Step 1: Lower the impoundment by approximately 6 feet[58] by opening all three crest gates[59]. A final drawdown schedule will be developed in consultation with the Town, NHFGD and NHDES.

Step 2: Install:

a) appropriate sediment and erosion control measures along the water's edge, and around all staging and work areas;
b) temporary construction entrance; and
c) an oil boom below the dam.

Step 3: Install vibration monitoring equipment (by others). Monitor vibration throughout the removal process (by others)

Step 4: Clear and grub, as needed, to establish staging area and access area on river right immediately upstream of the dam.

Step 5: Using an excavator, gradually lower the area adjacent to the dam and breach the spillway as low as possible. Cut the concrete block with a concrete saw from the existing concrete retaining wall prior to using the excavator on it. This is based on the assumption that the ground surface/fish ladder concrete block can be lowered to about elevation 24 feet with little problem (existing elevation 25 feet).

Step 6: Construct access ramp at 13% grade to elevation 15 feet from staging area (elevation 29 feet).

Step 7: Extend the access road over the existing thalweg with two 4-foot diameter culverts (flow = 122 cfs, velocity = 4.85 feet per second each). Extend the gravel road over the existing ledge material and remove the legacy dam as necessary.

[58] The metal lip affixed to the spillway crest is at elevation 22.42 feet; the gate sill elevation is 16.15 feet, thus the net drawdown resulting from opening the gates is approximately 6.3 feet.
[59] In addition to a construction sequencing plan, another plan will be needed to assess potential impacts to aquatic animals such as mussels, crawfish, and fish that are exposed or stranded in a pool or on an exposed river bank to the free-flowing section of the river.

Step 8: Remove the existing gate structure and plateau just downstream of the crest gates. Cut the concrete block first, cutting as close as possible to the existing retaining wall. The existing retaining wall will be left in place to avoid grading.

Step 9: Remove as much of the spillway as possible from the river left side of the thalweg, including the timber/crib framework and stone from the legacy dam components.

Step 10: Remove the existing access road along river left as well as the two 4-foot diameter culverts and begin moving the material into place for access to the remaining dam structure on river right. Set the elevation of the downstream end of the access road on river right at elevation 5.0 feet (roughly 18% grade from the "intersection" to the dam breach location). Remove components of the legacy dam with an excavator as the road is built and approaches the existing dam. Flow will have switched by now from passing through the original breach on river right to the center where the natural thalweg is located as a majority of the dam has been removed now on river left.

Step 11: Remove the remainder of the stone/concrete spillway structure.

Step 12: From the dam to the downstream end of the fish ladder construct a flat road at elevation 5 feet. Eventually design a transition for the 18-0% grade change.

Step 13: Cut the concrete fish ladder from the existing retaining wall and commercial building foundation. Proceed by removing the ladder with the crawler-mounted excavator and deposit debris into trucks for hauling.

Step 14: Remove the haul road/access ramp.

Step 15: Seed/stabilize the staging area.

Step 16: Remove oil boom, vibration monitoring equipment and temporary erosion controls once the area has stabilized.

10.2 Feasibility Study Costs

As noted above, not all of the issues and concerns typically included in a feasibility study were conducted as part of this study. To provide a complete picture, the Town requested a budget estimate to address outstanding issues. To comply with this request, budgetary estimates were developed for other aspects of the feasibility study that were not completed. Note that it is not possible to firmly estimate all feasibility-related costs as earlier findings will dictate the scope/cost of future steps. This is particularly relevant to sediment above the dam. As an initial step in evaluating sediment, standard procedure calls for obtaining sediment cores and sending the samples to a laboratory for chemical testing. However, after the chemical results are provided and interpreted by an ecological risk assessor it could lead to varying next steps such as a) no further testing, b) additional chemical testing to define the geographic range of potential contaminants, c) toxicity testing or d) some other step. If, for example, the chemical testing resulted in "clean" sediment, then perhaps no further testing is needed. If the sediment is contaminated, it could lead to other more costly steps. For now, we have provided a description and budgetary estimates for tasks where the scope of work can be reasonably defined. In those instances where the scope/budget is not as clear, we have described the potential additional work, but have not included a cost estimate due to the many unknowns. Table 10.2-1, at the end of this section, outlines recommended additional feasibility study steps and associated budgetary costs to develop a full feasibility report.

10.3 Costs for Dam Removal

As part of this study, we were requested to develop an opinion of probable construction cost (OPCC) for removing the Macallen dam, legacy dam, abutments, gate structure and fishway. The OPCC was based on our current understanding of the project. The OPCC will change pending further investigation and should be considered a starting point relative to overall project costs. Several assumptions were made in preparing the OPCC estimate including:

- The OPCC estimate assumes sediments do not pose an ecological/human risk and thus would be permitted to mobilize and transport downstream following dam removal. In contrast, if the sediments do pose an ecological/human risk and require dredging, the costs could escalate rapidly due to accessing, dredging, hauling, and disposing of the contaminated material.

- The OPCC estimate assumes the railroad bridge crossing the Piscassic River would not require any further restoration work such as scour protection, structural stabilization or restoration work to permit fish passage. HTA did not conduct a structural investigation or scour analysis of this bridge. Note that per discussions with the NHDES if it was determined that the railroad bridge requires scour protection or stabilization measures due to dam removal, the Town would not bear these costs. The Town would be responsible to notify the railroad bridge owner of any potential impacts.

- The OPCC estimate assumes no fish passage issues. However, as noted above there appears to be a velocity barrier to fish passage beneath Veterans Bridge, as well as a vertical barrier to fish passage, if the dam was removed. Additional mitigation alternatives would require investigation to enable fish to move through this reach.

- The OPCC estimate assumes dam removal would not impact the sewer line traversing the Piscassic River in the impounded reach. No assessment of this sewer line has been conducted and thus it is unknown if any measures are needed to protect the line.

- The OPCC estimate assumes no historic mitigation work will be necessary.

The OPCC for removing the dam is $743,000; a cost breakdown is shown in Table 10.3-1 at the end of this section. One of the more challenging issues on this project is access and the infrastructure development around the dam. The OPCC estimate does not include potential costs associated with modifying the bedrock beneath the dam, if needed, to allow for fish passage[60].

[60] Hydraulic model results indicate there is a potential for a velocity and/or depth barrier to form between the Macallen Dam and the Veteran's Bridge if the dam is removed.

10.4 Summary of Costs Associated with Dam Repair, Feasibility and Dam Removal.

The Town has requested having the costs associated with the various alternatives (those listed by Wright-Pierce and our dam removal estimate) in one location in this report. As such Table 10.4-1 includes the costs to repair and modify the dam to satisfy the LOD; these costs were obtained directly from previous Wright-Pierce Reports. Also included in Table 10.4-1 is a line item for the budget already expended by the Town for the work Wright-Pierce has conducted to develop the estimates for repairing and modifying the dam. The cost for this line item is unknown, but is included as a placeholder to provide a complete cost picture.

Table 10.4-2 includes the costs associated with the dam removal alternative, which also includes feasibility-related costs expended as part of the current contract, and estimated additional feasibility-related tasks. Finally, the OPCC for removing the dam, gates and fishway is also provided recognizing the various assumptions described earlier in this report (again, this cost should be considered a starting point).

Table 10.4-1: Summary of Costs Associated with Studying and Dam Repair/Modification Alternative

Item	Budgetary Cost
Town expenditures to develop cost estimates for maintaining the dam	Unknown
Dam Repairs, Phase II	$315,500[1] (2013 dollars)
Dam Repairs and Modification, Phase I work and Resolution of Inadequate Spillway Capacity	$1,100,000 to $3,000,000[1] (2013 dollars)
Required Fish Ladder Improvements[61]	Unknown
TOTAL	**$1,415,500 to $3,315,500 (2013 dollars)**
[1]Source: Wright-Pierce	

Table 10.4-2: Summary of Costs Associated with Feasibility Study and Dam Removal Alternative

Items	Budgetary Cost
Partial Feasibility Study	$81,700[1] (2014 dollars)
Completion to Full Feasibility Study	$171,000[2] (2014 dollars)
OPCC for Dam Removal	$743,000[2] (2014 dollars)
TOTAL	**$995,700 (2014 dollars)**
[1]Includes $40,000 from a grant. [2]Grants could be pursued to lower the cost to the Town. NOTE: OPCC for Dam Removal should be considered a starting point as the cost will likely increase as more is learned on the project.	

Grant Opportunities

Relative to the dam removal alternative, there are competitive grant opportunities to help fund feasibility-related tasks, design/engineering/permitting, and the actual dam removal costs. Generally, it

[61] Some alternatives called for lowering the spillway elevation. This would require modifications to the fish ladder as the ladder was designed to operate at the current spillway crest elevation.

is more challenging to secure grants for feasibility-related tasks and less challenging to secure grants for the actual dam removal. Many grantors prefer funding the actual dam removal cost to demonstrate that their monies are being expended on river restoration; however, as occurred already, funding is available to offset feasibility-related tasks. Typically, dam owners committed to removing a dam will apply for numerous grants with the goal of raising funds to help defray costs. It should be noted that the majority of funding opportunities are with federal entities and most of these require a 50-50 non-federal match. For example, if a federal agency awarded $50,000 to the Town to help remove the dam, they may require a $50,000 match – that match could come from the State, Town, Non-Governmental Organizations or in-kind services One of the factors in being awarded a grant is the level of commitment and interest expressed by the Town or dam owner in removing the dam. Funders are less apt to award grants to dam owners that are non-committal. In the applications, grantors ideally seek letters of support to study or remove the dam from the Town's governing body. Potential grant funding opportunities include: NOAA Habitat Conservation funds, American Rivers, Trout Unlimited, The Nature Conservancy, and several others. If the Town is interested in advancing the feasibility study and removing the dam the NOAA website below include information on funding opportunities (funding range, states available and deadlines) See http://www.habitat.noaa.gov/funding/northeast.html

Relative to the dam repair/modification alternative, funding opportunities may exist particularly for those that may preserve the historic character of the dam. These could include:

- NH Land and Community Heritage Investment Program (grant program)
- National Trust for Historic Preservation (loan fund)
- Society for Industrial Archeology (grant program)

Admittedly, we do not have considerable experience with these opportunities and are unsure of the success rate of securing loans, grant funds or whether this project would qualify for such assistance. It is recommended that the Town consult with NHDHR on any grant opportunities for repairing the dam.

Table 10.2-1: Recommended Additional Feasibility Study Steps and Associated Budgetary Estimates

Task	Summary of Study Needs	Budgetary Estimate
Survey		
Deed and Title Search	If the dam were removed, a deed and title search would be required to determine if easements are needed to access the dam for removal. Property boundaries and owner names are needed to show on design drawings and for future consultation with owners.	$500
Sediment		
Sediment Sampling Plan	Working with NHDES and Project Partners an approved sediment sampling plan would be developed. The budgetary estimate includes developing the sediment sampling plan, having a conference call with Project Partners, and revising the plan based on input.	$2,000
Sediment Sampling	Sediment sampling includes collecting sediment cores at various locations. It was assumed that, as a minimum, five (5) cores would be collected at the following locations: • two (2) in Lamprey impounded reach, • one (1) in Piscassic impounded reach, • one (1) on the Lamprey River above the impoundment and • one (1) downstream of the dam. The budgetary estimate is based on collecting five (6) sediment samples. Pending further analysis, additional sediment sampling may be required to further delineate the geographic extent of a potential contaminated area, but is not included in the budgetary estimate.	$7,500
Laboratory Analysis	The five sediment cores would be transported to a NH certified laboratory for chemical [total organic carbon (TOC), Polynuclear aromatic hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), pesticides, selected metals, Volatile organic compounds (VOCs), Semi-Volatile organic compounds (SVOCs)] and physical (grain-size, bulk density, porosity) testing. The costs reflect laboratory testing only.	$6,500
Ecological/Human Risk Assessment	The laboratory findings are compared to screening level criteria to determine if the constituents pose a risk to ecological and/or human health. Typically, the laboratory findings are compared to the MacDonald *et.* al 2000 threshold effects concentration (TEC) and probable effects concentration (PEC). Pending the ecological risk assessors findings, the following next steps relative to sediment could be conducted a) if the sediments pose no ecological and/or human risk, perhaps no additional sampling is needed, b) if the sediments pose no ecological/human risk, additional chemical testing may be warranted pending the estimated mobile sediment volume, c) if the sediments are above certain threshold levels, sediment toxicity[62] testing may be required, d) if sediments pose an ecological/human risk, additional chemical sampling may be required to define the geographic extent of contamination. For purposes of this estimate, a budgetary range is provided as the level of the ecological risk assessor's involvement can vary pending the laboratory findings. The cost estimate does not include time for consultation with agencies or time for reporting, as this will be highly variable depending on the sediment sampling results.	$3,000-$5,000
Sediment Transport Analysis	If one of the sediment management alternatives calls for allowing the accumulated sediment to transport downstream following dam removal, a sediment transport analysis may be required. Using the grain-size analysis data and the existing hydraulic model, a sediment transport analysis would be conducted to predict the quantity of mobile sediment. The budgetary estimate is for conducting the sediment transport analysis upstream and downstream of the dam. Costs also include time for collecting cross-section survey data downstream of Macallen Dam, as well as predicting where sediments may deposit downstream of the dam..	$15,000
Scour Analysis	A scour analysis is needed of the railroad bridge crossing the Piscassic River to determine if dam removal could scour the supporting structure and create structural concerns. Based on the probing conducted at the Veterans Bridge, scour is not anticipated given that the channel bed is comprised of either large rocks or bedrock. Also, it does not appear that a scour analysis is needed for the railroad crossing the Lamprey River as the abutments are outside the channel. The budgetary estimate is for conducting a scour analysis of the railroad bridge crossing the Piscassic River.	$3,800
Sediment Management Plan	The following evaluations would help inform and/or determine the need for a sediment management plan: • laboratory testing, • ecological/human risk assessment, • rare, threatened and endangered species assessment, and • sediment transport analysis and infrastructure evaluation • coordination with state and federal agencies Pending the finding of these studies, the sediment management plan could entail various alternatives including: • Instream management, meaning allowing the sediment to naturally mobilize and transport downstream. Allow exposed banks to re-vegetate naturally. • Instream management, but actively vegetate exposed banks to halt invasive plant species dominance.	$4,000-$6,000

[62] The toxicity testing typically includes a 10-day survival and growth test where a freshwater amphipod is exposed to the sediment.

Task	Summary of Study Needs	Budgetary Estimate
	• Partial sediment removal of mobile sediment and allow exposed banks to naturally re-vegetate or actively vegetate. Partial sediment removal could be conducted in certain "hot" spots or in key areas. • Install instream structures, such as rock vanes, to purposely limit sediment movement. • Full sediment removal of mobile sediment volume and allow exposed banks to naturally re-vegetate or actively vegetate. The cost of developing a sediment management plan can vary considerably, pending the sediment testing and risk assessment and thus a budget range has been provided.	
Infrastructure Assessment		
Structural Analysis	A structural assessment of the two railroad lines traversing the impounded reach needs to be undertaken, although as noted above, it does not appear that the railroad bridge crossing the Lamprey River is a concern (but should be confirmed). If it is found that scour is a concern, protective measures may be required and could add to the dam removal estimate. As noted earlier, the Town is not responsible for costs related to infrastructure impacts due to dam removal, but they must assess the potential impacts and notify the appropriate potentially impacted parties.	$5,000
Riverine Ice Survey	GSE is uncertain if sheet ice develops on the impoundment and if there have been reported ice jams on the Lamprey River. The scope would entail conducting a field study to document ice conditions in the impoundment and in the free-flowing section of the Lamprey River in the winter. Photo documentation and the type of ice observed (sheet, border ice, anchor ice, etc.) would be documented. In addition, any reported ice jams would be reported. This study would also involve coordination with the Cold Regions Research and Engineering Laboratory.	$2,500
Environmental Resources		
Wetlands Delineation	A wetland delineation of the impounded reach and the area around the dam is needed to determine the potential loss in wetland habitat if the dam were removed. In addition, if dam removal was the preferred alternative the wetlands delineation is needed for permitting and the design phase.	$7,000
Rare, Threatened and Endangered Species Survey	Letters need to be sent to the NH Natural Heritage Bureau, NH Fish and Game Department and the US Fish and Wildlife Service, along with a map showing the potential area of impact, to determine if there is any state or federal rare, threatened, endangered or species of concern (plant, reptile, amphibian, mammal, etc.) that could be impacted by removal. With feedback from these agencies, a walkover of the project area would be conducted to determine if any of these species or their habitat is present. Note that this is typically not an exhaustive search and is commonly done as part of the wetlands delineation.	$2,000
Aquatic Resource Assessment	The impact of dam removal on aquatic resources (fish, invertebrates, mussels, etc.) needs to be evaluated and methods to reduce impacts would be assessed. This could entail documenting current aquatic habitat in the impounded reach and sampling for mussels. If allowing mobile sediment to transport downstream is considered, the agencies may want some type of aquatic resources study conducted below the dam to determine the impact of a sediment release on downstream aquatic resources. Another issue that should be addressed is whether river herring and other migratory fish could negotiate the bedrock drop that is likely present beneath the Macallen Dam if it were removed. Per NHFGD the bulk of river herring passed at the dam are alewife and they prefer to spawn in slow-moving shallow sections of river and coves that are present with the dam in place. An evaluation of potentially lost alewife spawning habitat is needed.	$10,000
Recreation Resources		
Recreation Assessment	Some type of assessment is needed to document the current recreational use of the impounded reach. This could include conducting random surveys during the summer- weekday, weekend and holiday to document on-water use (no. of kayakers, canoeists, motor boats) and no. of cars at the Piscassic Boat Launch. The survey would also document the number of existing docks.	$10,000
Cultural Resources		
Archeological- Phase 1A Reconnaissance Survey	The purpose of Phase 1A survey is to develop a detailed sensitivity assessment for pre- and post-contact archaeological resources within the APE that may be affected by dam removal, and to develop predictive statements for the types and locations of such resources.	$4,500
Archeological- Phase 1B Subsurface Survey	Pending the findings of the Phase 1A assessment, subsurface testing may be needed. Because of the many unknowns, a budgetary number has not been provided.	Unknown
Archeological- Phase II	Pending the findings of the Phase 1B assessment, Phase II investigations may be required. Because of the many unknowns a budgetary number has not been provided.	Unknown
Historic Structures- Phase I Historic, Architectural, Engineering Survey	The purpose of a Phase I historic/architectural/engineering survey is to document the area and dam in a Project Area Form and Individual Dam Inventory Form, respectively. PAL has only recommended an Individual Dam Inventory Form be completed, however.	$4,500
Development of Section 106 MOA	If the dam or archeological site is deemed eligible for the NRHP and would be adversely impacted by dam removal, a Memorandum of Agreement would be developed. The Memorandum of Agreement specifies the mitigation requirements based on the site and preliminary findings.	$5,000
Mitigation	The cost associated with mitigation is unknown, but based on previous dam removal projects it has required documentation of the removal process, interpretative signage memorializing the dam, and potentially leaving a portion of the dam in place. It is premature to predict the cost of mitigation, but we have included a budgetary estimate.	$10,000
Aesthetic Resources		
Aesthetic Assessment	As part of the revised feasibility report, further evaluation of the aesthetic impact with and without the dam should be provided.	$2,000
Property Value and Tax Implications	It is beyond Gomez and Sullivan's area of expertise to develop budgetary estimates associated with impacts to property values and taxes if the dam were removed.	Unknown
Other		
Updated Feasibility	Once the additional feasibility –related tasks are complete, the study report would be updated accordingly.	$8,000

Task	Summary of Study Needs	Budgetary Estimate
Report		
Meetings	It is assumed that there would be several more Project Partner and public meetings associated with the conclusion of the feasibility study.	$15,000
Project Management	There is day-to-day management associated with the project including calls, grant reporting assistance, scheduling, and invoicing.	$5,000
Engineering & Permitting		
Dam Removal	The cost associated with engineering and permitting is shown on a separate line item later in this document.	Included in dam removal OPCC
Other Restoration	Based on the October 2013 drawdown and site inspection, there appears to be issues associated with the railroad bridge crossing the Piscassic River. Those issues could include: scour issues, structural issues with the bridge, and impacts to fish passage. Based on our review of the area, we are anticipating that some restoration work may be necessary here to ensure fish passage, and to remove barriers that will not compromise the bridge. Since no detailed studies (structural assessment, scour) has been conducted, it is unknown what restoration work is needed. As such, we have not provided an estimate, but are notifying the Town that this may be an additional cost item.	Unknown
Contingency		
25% Contingency	Based on the uncertainty with several of the tasks outlined here, we recommend that the town plan on a 25% contingency for the estimated costs to account for unforeseen costs. Based on a sub-total of $132,800-$136,800 for the above tasks.	$33,200-$34,200
TOTAL		$166,000-$171,000

Table 10.3-1: Opinion of Probable Costs- Macallen Dam Removal

Prepared by: KJC	Checked:	RLS			
Gomez and Sullivan Engineers, P.C.				Project No:	1612
Prepared for:					
Town of Newmarket, NH					
	OPINION OF PROBABLE CONSTRUCTION COST				3.27.14
Project:	**Macallen Dam - Dam Removal**				
Estimate for:	**Macallen Dam - Dam Removal**				

Item	Description	Quantity	Unit	Unit Price	Cost
Contractor Gen. Requirements[1] (mob/demob, on-site facilities, etc.)		10%	EA	$366,362.40	$36,636
Site	Erosion Control	1	LS	$3,000	$3,000
Site	Turbidity Curtain	100	LF	$25.00	$2,500
Site	Silt Fence	150	LF	$1.20	$180
Misc.	Vibration Monitoring Equipment	4	WK	$5,100.00	$20,400
Site	Clearing and Flush-Cut Small Trees and Vegetation	0.10	ACRE	$9,050.00	$905
Access	Stabilized Construction Entrance 1-1/4" Crushed Stone	40	CY	$50.00	$2,000
Access	Geotextile for Stabilized Construction Entrance	239	SY	$2.60	$621
Dam	Breach Dam with Excavator	1	DAY	$1,714.00	$1,714
Access	Access Ramp Geotextile	315	SY	$2.60	$819
Access	Trap Rock (Class C Stone) for Temporary Access Road	402	CY	$50.00	$20,100
Access	Haul Road (Class C Stone)	938	CY	$50.00	$46,900
Access	Haul Road Geotextile	820	SY	$2.60	$2,132
Access	Install and Remove Temporary 4' Diameter CMP Culvert	80	LF	$86.00	$6,880
Legacy Dam	Legacy Dam Demo.	655	CY	$10.00	$6,550
Dam	Saw Cut Concrete Crest Gate Structure from Wall	5	DAY	$529.20	$2,646
Dam	Remove Crest Gate Structure	291	CY	$180.00	$52,380
Dam	Dam Concrete Demolition	615	CY	$180.00	$110,700
Dam	Hauling	1,561	CY	$12.00	$18,732
Access	Move Geotextile On-Site	255	SY	$1.00	$255
Access	Move Haul Road Material On-Site	230	CY	$5.00	$1,150
Fish Ladder	Saw Cut Concrete Fish Ladder Structure from Wall	10	DAY	$529.20	$5,292
Fish Ladder	Fish Ladder Concrete Demolition	132	CY	$180.00	$23,760
Fish Ladder	Haul Fish Ladder Debris	132	CY	$12.00	$1,584
Access	Remove Haul Road (Class C Stone)	938	CY	$10.00	$9,380
Access	Remove Access Ramp (Class C Stone)	402	CY	$10.00	$4,020
Access	Remove Geotextile	1135	SY	$1.00	$1,135
Access	Remove Stabilized Construction Entrance 1-1/4" Crushed Stone	40	CY	$10.00	$400
Access	Remove Geotextile for Stabilized Construction Entrance	239	SY	$1.00	$239
Access	Hauling (8 CY Dump Truck and Driver)	1374	CY	$12.00	$16,488
Site	Seed Staging Area	1	LS	$500.00	$500
Site	Removal of Temporary Erosion Control Measures	1	LS	$3,000.00	$3,000
	Subtotal Direct Cost				**$402,999**
	Contingency Allowance (25%)[2]				$100,750
	Total Direct Cost[3]				**$504,000**
	Engineering, Administration, Permitting and Construction Management[4]				$210,000
	Total OPCC $2013				$714,000
	Total OPCC $2014				**$743,000**

Notes:

1. Contractor General Requirements taken as 10% of the remaining itemized costs totaled.
2. Contingency Allowance taken as 25%.
3. Rounded to the nearest $1,000.
4. Engineering & Administration =$115,000

Permits = $50,000

Bidding Phase = $10,000

Construction Management = $35,000

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