APPENDIX B

Photos

Photo 1 – Overview of impoundment when drained (9/13/2018)

Photo 2 – Overview of impoundment when partially-filled (9/26/2018)

Photo 3 – Overview of spillway from downstream (11/08/2018)

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Photo 17 – View of spillway crest (7/10/2019); note separation of cap from adjacent concrete

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Photo 19 – Overview of right training wall (7/10/2019)

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Photo 24 – Deteriorated right upstream wall (7/10/2019)

Photo 25 – Right section of right upstream wall (7/10/2019)

Photo 26 – Right downstream wall ; note large spall with exposed rebar (7/10/2019)

Photo 27 – Deteriorated outlet structure; note missing facing concrete (7/10/2019)

Photo 28 – Overview of downstream side of spillway at right walls; note deteriorated concrete and gap along crest (7/10/2019)

Photo 29 – Right portion of spillway looking right; note wear on face and gap at crest (7/10/2019)

Photo 30 – Center portion of downstream face of spillway looking left; note wear on face and gap at crest (7/10/2019)

Photo 31 – Gap below crest of spillway and wear at apparent joint (7/10/2019)

Photo 32 – Center portion of downstream face of spillway looking right; note wear on face, gap at crest, and spalls (7/10/2019)

Photo 33 – Left portion of downstream face of spillway looking left; note wear on face and gap at crest (7/10/2019)

Photo 34 – Downstream face of spillway at right training wall; note large spall and heavy wear (7/10/2019)

Photo 35 – Upstream slope of embankment looking right (11/8/2018)

Photo 36 – Upstream slope of embankment looking left (11/8/2018)

Photo 37 – Northerly shore of pond; note signs of beaver activity (11/8/2018)

Photo 38 – Former penstock pipeline, surrounded by wetland flag series 1D (11/8/2018)

Photo 39 – Inlet of Sanborn Street Bridge (11/8/2018)

Photo 40 – Weir at inlet of Sanborn Street Bridge (11/8/2018)

Photo 41 – View through south bay of Sanborn Street bridge; note weir at inlet (11/8/2018)

Photo 42 – View through north bay of Sanborn Street bridge; note weir at inlet (11/8/2018)

Photo 43 – View of Phillips Brook downstream of Sanborn Street (11/8/2018)

APPENDIX C

Dam Term Definitions

Tighe&Bond

COMMON DAM DEFINITIONS

To provide a better understanding of this report, definitions of commonly used terms associated with dams are provided below. The terms are presented under the following common categories:

1) Orientation;
2) Dam components;
3) Size classification;
4) Hazard classification; and
5) General.

Orientation

Upstream – Shall mean the side of the dam that borders the impoundment.

Downstream – Shall mean the high side of the dam, the side opposite the upstream side.

Right – Shall mean the area to the right when looking in the downstream direction.

Left – Shall mean the area to the left when looking in the downstream direction.

Dam Components

Abutment – Shall mean that part of the valley side against which a dam is constructed. An artificial abutment is sometimes constructed as a concrete gravity section, to take the thrust of an arch dam where there is no suitable natural abutment.

Appurtenant Works – Shall mean any ancillary feature of a dam and shall include but not be limited to, such structures as training walls, spillways, either in the dam or separate there from and low-level outlet works; also water conduits such as tunnels, channels, pipelines, or penstocks, either through the dam or its abutments.

Crest – Shall mean the top of the dam, usually provides a road or path across the dam.

Cut-off – A low-permeability barrier within, below, or surrounding a dam to reduce seepage

Cyclopean Concrete - an unreinforced concrete that uses large stones (called plums) to reduce concrete use and provide some reinforcement

Dam – Shall mean any artificial barrier, including appurtenant works, which impounds or diverts water.

Embankment – Shall mean the fill material, usually earth or rock, placed with sloping sides, such that it forms a barrier that impounds water.

Ogee – A spillway shape with a continuous S curve

Riprap – Shall mean a loose assemblage of broken stones erected in water or soft ground as erosion protection.

Toe – Shall mean the protruding base of the dam on the downstream side either natural or man-made.

Weir – Shall mean the top of the spillway where the water flows to the downstream side

Size Classification
(as listed in Commonwealth of Massachusetts, 302 CMR 10.00 *Dam Safety* Regulations, revised February 10, 2017)

Large – Structure with a height greater than 40 feet and/or a storage capacity greater than 1,000 acre-feet.

Intermediate – Structure with a height between 15 and 40 feet and/or a storage capacity of 50 to 1,000 acre-feet.

Small – Structure with a height between 6 and 15 feet and/or a storage capacity of 15 to 50 acre-feet.

Non-Jurisdictional – Structure less than 6 feet in height and having a storage capacity of less than 15 acre-feet.

Hazard Classification
(as listed in Commonwealth of Massachusetts, 302 CMR 10.00 *Dam Safety* Regulations, revised February 10, 2017)

High Hazard (Class I) – Shall mean dams located where failure or misoperation will likely cause loss of life and/or serious damage to homes, industrial or commercial facilities, important public utilities, or major transportation arteries.

Significant Hazard (Class II) – Shall mean dams located where failure or misoperation may cause loss of life and/or damage to homes, industrial or commercial facilities, secondary highways or railroads, or cause the interruption of the use or service of important facilities.

Low Hazard (Class III) – Dams located where failure or misoperation may cause minimal property damage to others and loss of life is not expected.

General

DCR – Department of Conservation and Recreation, formerly the Department of Environmental Management (DEM).

EAP – Emergency Action Plan; shall mean a predetermined plan of action to be taken to reduce the potential for property damage and/or loss of life in an area affected by an impending dam break.

O&M Manual – Operations and Maintenance Manual; document identifying routine maintenance and operational procedures under normal and storm conditions.

Normal Pool – Shall mean the elevation of the impoundment during normal operating conditions.

Acre-foot – Shall mean a volume equal to one foot of water over a one-acre area.

Structural Height of Dam – Shall mean the vertical distance from the lowest portion of the natural ground, including any stream channel, along the downstream toe of the dam to the crest of the dam.

Spillway Design Flood (SDF) – Shall mean the flood used in the design of a dam and its appurtenant works particularly for sizing the spillway and outlet works.

APPENDIX D

Sediment Management Plan

Sediment Management Plan McTaggart's Pond Dam Fitchburg, MA

TO: Mr. Lenny Laakso, P.E. – Commissioner of Public Works, Fitchburg, MA

FROM: Jason M. Perry, Sr. Env. Scientist; Daniel R. Buttrick, P.E., Sr. Engineer

DATE: October 8, 2019

In accordance with our scope of work dated August 10, 2018, Tighe & Bond has prepared this sediment management plan for McTaggarts Pond Dam in Fitchburg, Massachusetts that details the following:

- The findings of our due diligence research,
- The collection and laboratory analysis of sediment samples,
- Laboratory analytical results,
- Sediment management options based on the laboratory results.

Summary of Due Diligence Review

Tighe & Bond reviewed available local, state, federal and historical records to identify current or past releases of oil or other hazardous materials (OHM) that have the potential to impact the sediments within McTaggarts Pond. These sediments must be managed appropriately should future removal, reduction or rehabilitation of the dam be performed. Tighe & Bond commissioned the services of Environmental Data Resources, Inc. (EDR) of Shelton, Connecticut to search state and federal databases for records related to the site and vicinity. In addition, EDR was commissioned to provide available historical aerial photographs, historical topographic maps, city directories and Sanborn Fire Insurance maps (Sanborns) for the site. A Copy of the EDR report is attached. The results of our due diligence research are summarized below.

EDR Radius Report - Multiple state-listed hazardous waste sites were identified within a one-mile radius of the site. Records were reviewed to identify documented releases of OHM that have the potential to impact the sediments within McTaggarts Pond, including searching the on-line Massachusetts Department of Environmental Protection (MassDEP) listed waste site database for supplemental information. None of the sites reviewed are expected to impact the sediments within McTaggarts Pond for the following reasons: the relatively small amount of oil or other hazardous materials (OHM) released to the environment, the site is hydrologically either cross-gradient or downgradient of McTaggarts Pond or the site has been "closed" with the MassDEP and the documented release site boundaries do not extend to McTaggarts Pond.

Sanborn Fire Insurance Maps - Historical Sanborn Fire Insurance maps (Sanborns) from the following years were provided by EDR and reviewed: 1887, 1897, 1902, 1936, 1950 and 1971. A summary of our review of the Sanborns is provided below:

1887: The Jas. Mc. Taggart Jr. Woolen Mill is shown on the eastern portion of Mc. Taggart's Pond and adjacent to the dam. Multiple buildings are shown associated with the woolen mill. The mill is reportedly powered by wood and coal and kerosene is used for lighting.

1897: The mill is identified as the J.M. Valentine Woolen Mill.

1902: The mill is identified as the Suv. Mills Manufacturing Co. Woolen Mill.

1936, 1950 and 1971: The Sanborn maps do not show a mill on the eastern shore of the pond.

Historical Aerial Images - Aerial photographs for the following years were provided by EDR and reviewed: 1938, 1952, 1967, 1970, 1975, 1980, 1985, 1993, 1995, 2008, 2012 and 2016. A summary of our review of the aerial photographs is provided below.

1938, 1952: Mc. Taggart's Pond and the associated dam is shown. A mill complex is not visible on the eastern portion of the pond, adjacent to the dam.

1967: Mc. Taggart's Pond appears mostly drained.

1970, 1975, 1980, 1985, 1993, 1995: Mc. Taggart's Pond and the associated dam is shown. A mill complex is not visible on the eastern portion of the pond, adjacent to the dam.

2008, 2012 and 2016: Residential structures are present in the general location of the former woolen mill complex.

City Directories - Historical city directories for the following years were provided by EDR and reviewed: 1931, 1965, 1967, 1992, 1995, 2000, 2005, 2010 and 2014. None of the historical directories reviewed listed the subject site or identified the historical woolen mill or dam.

Historical Topographic Maps - Historical topographic maps for the following years were reviewed as part of this due diligence research: 1889, 1893, 1935, 1936, 1943, 1946, 1949, 1953, 1954, 1970, 1979, 1987, 1988 and 2012. A summary of our review of the historical topographic maps is provided below.

1889, 1893, 1935 and 1936: McTaggarts Pond is shown and buildings (presumably the woolen mill) are shown on the eastern shore, adjacent to the dam. There are no other buildings or structures shown upgradient of the pond on the Nookagee River (currently named Phillips Brook).

1943: McTaggarts Pond is shown. The resolution of this historical map is poor and does not show any buildings or structures adjacent to the pond or dam.

1946: McTaggarts Pond is shown. There are no buildings or structures shown adjacent to the pond, dam or immediately upgradient of the pond.

1949: McTaggarts Pond and the dam are shown. There are no buildings or structures shown adjacent to the pond, dam or immediately upgradient of the pond.

1953, 1954: McTaggarts Pond is shown. Buildings or structures (presumably houses) are shown adjacent to the southeastern shore of the pond. There are no other buildings or structures shown adjacent to the pond, dam or immediately upgradient of the pond.

1970, 1979, 1987, 1988 and 2012: McTaggarts Pond is shown. These maps do not depict buildings or structures adjacent to, or upgradient of, the pond.

Due Diligence Summary - Based on the findings of the due diligence research summarized above, Tighe & Bond did not identify nearby sites or documented releases of

OHM that have the potential to impact the sediment within McTaggarts Pond. However, heavy metals have historically been used in woolen manufacturing. Our research indicates that coal and wood may have been used as fuel, and kerosene was used for lighting fuel, in the woolen mill that was previously located adjacent to the dam. Heavy metals and extractable petroleum hydrocarbons (EPH) with polycyclic aromatic hydrocarbons (PAHs) are included within suite of laboratory analyses described within our August 10, 2018 scope of work and these analyses would detect potential metals and PAHs associated with ash or petroleum in sediment samples submitted for analysis.

Sediment Sampling Program

Five sediment samples were collected from the project area. The sediment sample locations are shown on the attached Figure 1 Orthophotograph, and included:

- One sample from the stream upgradient of McTaggart's Pond (sample S-5),
- Two samples collected from within McTaggart's Pond (samples S-3 and S-4), and;
- Two samples collected in depositional areas downstream of McTaggart's Pond dam (samples S-1 and S-2).

Each in-pond sample was a composite sediment sample (samples S-3 and S-4) composed of three aliquots each, collected within a ten-foot radius. Each aliquot was collected using a manual/hand-held stainless-steel bucket auger and placed into a stainless-steel bowl. The bucket auger and each stainless-steel bowl was decontaminated with water and biodegradable detergent before and after each sample/aliquot was collected. The location of each sample was collected in the field using GPS technology with sub-meter accuracy. The three aliquots were combined in one bowl and homogenized prior to being placed into laboratory-supplied containers. Samples analyzed for volatile organic compounds (VOCs) were collected directly from an individual aliquot, prior to being composited, to minimize volatilization. The samples were transported to TestAmerica Analytical Laboratory of Westfield, Massachusetts (TestAmerica) for analysis under proper chain of custody.

In addition, a series of sediment probes were performed within McTaggart's Pond. The probes were advanced to gauge thickness and used to calculate the estimated volume of sediment within the pond. The probes included six transects across the pond with the top and bottom of sediment elevations being measured at each probe location. Sediment thickness and estimated volumes are further discussed below.

Sediment Analytical Results

The sediment analytical results are presented in the attached Table 1. A copy of TestAmerica analytical laboratory report number 480-145058-1 is also attached.

In general, the two sediment samples collected downgradient of the dam (S-1 and S-2) contained the highest concentrations of contaminants and samples collected from the impoundment (S-3 and S-4) and the upgradient sample (S-5) contained lower concentrations. Within Table 1, the analytical results are compared to the following criteria:

- **401 Water Quality Criteria Reporting Limits** - These are the necessary reporting limits, not standards, the lab needs to meet per 314 CMR 9.07.

- **MCP S-1 and S-2 Reportable Concentrations (RCs)** from the Massachusetts Contingency Plan (MCP, 310 CMR 40.0000) – These standards are applicable to soil, not sediment. However, we have included them in Table 1 as a known reference standard. Note that if the sediment were excavated/removed from the impoundment, the material would be considered soil and must then be managed as soil (some MCP standards may then be applicable).
- **Stage I Freshwater Sediment Screening Criteria** for performing environmental risk characterizations under the MCP.
- **Massachusetts Comm-97 Disposal Criteria** for disposing of soils at lined-landfills in Massachusetts.

Concentrations of metals, volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), extractable petroleum hydrocarbons (EPH) and polycyclic aromatic hydrocarbons (PAHs) were detected above the laboratory reporting limits in the downgradient (S-1 and S-2) samples.

In general, low to residual contaminant concentrations were detected in the two samples collected within the pond (S-3 and S-4) and the upgradient sample (S-5) with concentrations generally decreasing between S-3 and S-5. The PAH dibenzo(a,h)anthracene was the only analyte detected in S-3, S-4 and S-5 above reference values included in the table. In summary, we did not identify contaminant concentrations within the pond sediment samples that would indicate significant contamination or dictate that the sediment requires special handling or management.

The grain size distribution results from the sediment samples indicate mostly gravel-sized particles upstream of the pond, consistent with a moving stream-bed and fine to sandy sized particles within the pond, with finer sediment located closer to the dam. Greater than 10% of the material in the two samples collected from within the pond (S-3 and S-4) passed the number 200 sieve, which distinguishes fine particles from sand-sized particles. MassDEP is generally less concerned about the potential for sediment contamination if less than 10% of the material is finer than sand.

Based on our assessment and measurements, the average sediment thickness within the pond was 2.9 feet and the estimated volume is between 35,000 and 40,000 cubic yards. Additional assessment would be required to further refine our volume calculation.

Sediment Management Recommendations

The City is currently evaluating options for the future of McTaggart's Pond. The future sediment management approach will depend on the selected option. The following sediment management recommendations should be considered as part of the evaluation process.

Dam Removal - In-stream sediment management, where sediment is allowed to migrate downstream from the impoundment when a dam is removed, is the option widely preferred by environmental professionals as it serves to allow restored stream channels in former impoundment bottoms to evolve naturally while restoring more natural riverine sediment dynamics.

The characterization samples collected from McTaggart's Pond indicate relatively low levels of contamination compared to those present downstream in Phillips Brook and the Nashua

River. For this reason, sediment management by an in-stream processes is not expected to increase downstream sediment contaminant concentrations. However, the estimated volume of sediment present in McTaggart's Pond is significant and could have negative downstream impacts if released quickly by reducing channel capacities and potentially covering the downstream river substrate.

The opened low-level outlet gate of the dam has resulted in the formation of an eroded channel through the pond bottom. The restriction currently provided by the dam limits the width of the eroded channel. Should the dam be removed, it may be necessary to remove some of the sediment from the pond to reduce the overall rate of potential sediment erosion that would occur. In addition, sediment would need to be removed from upstream of the spillway to accommodate the dam removal. Excess sediment may be reused on-site within the former impoundment, along the northern shoreline, and seeded for stability and erosion control. Over time, sediment will continue to migrate downstream, but the strategic on-site reuse of some sediment may slow the rate of downstream migration to a more acceptable level. The relatively low-level of contamination within the sediment samples also suggests that no significant extra precautions would be needed to manage the sediment during construction activities.

Dam Rehabilitation – Rehabilitation of McTaggart's Pond dam would require the removal of sediment in areas around the dam's spillway and outlet structure to allow access for construction and rehabilitation activities. The volume of sediment to be removed will need to be refined during the design process. Dewatering and disposal of sediment can be costly, and, although the contaminant levels are below MassDEP thresholds for landfill disposal (the MassDEP COMM-97 policy included in the table), it would be more cost-effective to temporarily remove the sediment from work areas, stockpile it on site, then strategically reuse it on-site following construction and rehabilitation activities. If the sediment is to be removed from the pond for off-site disposal, additional characterization would be necessary.

Attachments: EDR Reports
Figure 1 Orthophotograph
Table 1 Sediment Analytical Results
TestAmerica analytical laboratory report number 480-145058

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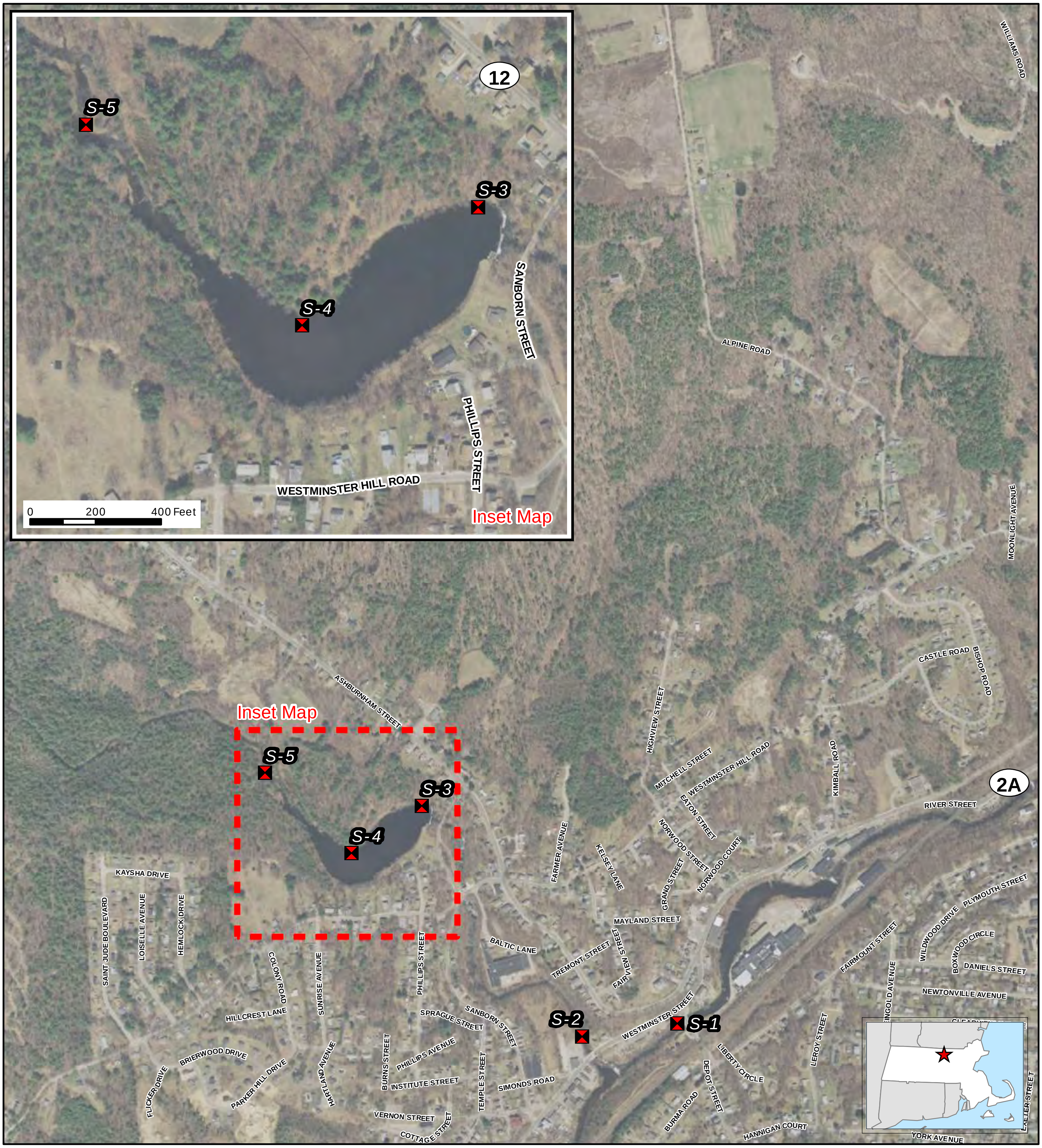
ATTACHMENT 1

EDR Reports

PAGES OMITTED
DUE TO FILE SIZE

ATTACHMENT 2

Orthophotograph



Legend

Composite Sediment Sample Locations

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2014)

1:12,000

0 500 1,000
Feet

N

FIGURE 1
SEDIMENT SAMPLE
COLLECTION LOCATIONS

MA00879
McTaggart's Pond Dam
Fitchburg, Massachusetts

October 2019

ATTACHMENT 3

Sediment Analytical Results

TABLE 1
Sediment Analytical Results
McTaggart's Pond Dam
Fitchburg, MA

Sample ID	S-1	S-2	S-3	S-4	S-5	401 Water Quality Criteria Reporting Limits	MCP Reportable Concentrations (Soil) [1]		Stage I Freshwater Sediment Screening Criterion (mg/kg) [2]	Comm-97 Disposal (Lined Landfills)
Date Collected			11/8/2018				S-1	S-2		
Total Metals (mg/kg)										
Arsenic	3.8	4.6	5.8	9.7	3.3	0.5	20	20	33.0	40.0
Cadmium	0.38	0.041	0.32	0.075	0.042	0.1	70	100	5.0	80.0
Chromium	8.6	6.2	6.3	4.7	3.2	1.0	100	200	110	1000
Copper	48	990	10	5.3	2.4	1.0	1,000	10,000	150	-
Lead	100	1500	19	6.5	3.3	1.0	200	600	130	2000
Nickel	3.7	8.2	5.4	4.0	2.6	1.0	20	700	49	-
Zinc	280	62	47	21	14	1.0	1,000	3,000	460	-
Mercury	67	0.046	0.056	0.025	<0.037	0.02	20	30	0.18	10
Total Organic Carbon (mg/kg)	11000	12000	23000	10000	1800	0.1%	-	-	-	-
Percent Moisture (%)	26.9	19.0	39.9	29.1	4.9	1.0	-	-	-	-
Grain Size Distribution (ASTM D422) (%) [3]										
Gravel	38.2	34.0	9.4	15.3	64.8	No. 4	-	-	-	-
Coarse Sand	4.8	15.7	3.1	14.3	10.7	No. 10	-	-	-	-
Medium Sand	35.1	41.9	11.8	33.6	20.1	No. 40	-	-	-	-
Fine Sand	19.2	6.1	38.5	20.2	2.8	No. 60	-	-	-	-
Fines	2.7	2.3	37.2	16.6	1.6	No. 200	-	-	-	-
PCBs by NOAA Summation of Congeners (mg/kg)										
PCB-8	<0.0014	<0.0012	0.0024	<0.0014	<0.0011	-			-	
PCB-18	0.0012	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-28	0.0022	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-44	0.0015	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-52	0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-66	0.0025	0.00042	<0.0016	<0.0014	<0.0011	-			-	
PCB-77	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-81	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-101	0.00079	0.00033	<0.0016	<0.0014	<0.0011	-			-	
PCB-105	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-114	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-118	0.00049	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-123	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-126	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-	1	4	-	<2
PCB-128	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-138	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-153	0.0023	0.00038	<0.0016	<0.0014	<0.0011	-			-	
PCB-156	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-157	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-167	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-169	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-170	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-180	0.0064	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-187	0.0056	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-189	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-195	0.0012	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
PCB-206	0.0059	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
DCB Decachlorobiphenyl	<0.0014	<0.0012	<0.0016	<0.0014	<0.0011	-			-	
Total PCBs	0.031	0.0011	0.0024	<0.0014	<0.0011	0.01	1	4	0.06	<2
Volatile Organic Compounds (VOCs) (mg/kg) [4]										
2-Butanone	0.0096	0.012	0.018	0.014	0.011		-	-	-	
Acetone	0.062	0.074	0.130	0.110	0.051		6	50	-	
Benzene	<.0058	<.0058	0.00076	<0.0069	0.00048		2	200	-	
Methylene Chloride	<.0058	0.0029	<0.0078	<0.0069	0.0023	0.1	-	-	-	10.00
Tetrahydrofuran	<0.012	<0.012	<0.016	<0.014	<0.0099		500	5,000	-	
Toluene	0.00089	0.00085	0.0058	0.00081	0.0053		30	1,000	-	
Vinyl acetate	<0.012	<0.012	<0.016	<0.014	<0.0099		-	-	-	
Extractable Petroleum Hydrocarbons (mg/kg)										
C9-C18 Aliphatics	12	<5.9	<8.3	<6.8	<4.9		1,000	3,000	-	-
C19-C36 Aliphatics	69	<5.9	14	<6.8	<4.9	25	3,000	5,000	-	-
C11-C22 Aromatics (Adjusted)	23	130	20	10	<5.3		1,000	3,000	-	-
Polycyclic Aromatic Hydrocarbons (PAHs) (mg/kg)										
2-Methylnaphthalene	**<0.65**	**<0.59**	**<0.83**	**<0.68**	**<0.49**		0.7	80	-	-
Acenaphthene	**<0.65**	**<0.59**	**<0.83**	**<0.68**	**<0.49**		4	3,000	-	-
Acenaphthylene	**<0.65**	1.5	**<0.83**	**<0.68**	**<0.49**		1	10	-	-
Anthracene	**<0.65**	3.4	**<0.83**	**<0.68**	**<0.49**		1,000	3,000	0.057	-
Benzo[a]anthracene	0.87	6.6	**<0.83**	**<0.68**	**<0.49**		7	40	0.110	-
Benzo[a]pyrene	0.92	5.8	**<0.83**	**<0.68**	**<0.49**		2	7	0.150	-
Benzo[b]fluoranthene	1.1	6.9	**<0.83**	**<0.68**	**<0.49**		7	40	-	-
Benzo[g,h,i]perylene	1.2	2.7	**<0.83**	**<0.68**	1.1		1,000	3,000	-	-
Benzo[k]fluoranthene	**<0.65**	2.7	**<0.83**	**<0.68**	**<0.49**	0.02	1,000	3,000	-	-
Chrysene	1.1	7.3	**<0.83**	**<0.68**	**<0.49**		70	400	0.170	-
Dibenz(a,h)anthracene	1.1	3.4	4.2	1.4	0.75		0.7	4	0.033	-
Fluoranthene	2.0	17	**<0.83**	**<0.68**	**<0.49**		1,000	3,000	0.420	-
Fluorene	**<0.65**	2.7	**<0.83**	**<0.68**	**<0.49**		1,000	3,000	0.077	-
Indeno[1,2,3-cd]pyrene	**<0.65**	0.98	**<0.83**	**<0.68**	0.51		7	40	-	-
Naphthalene	**<0.65**	**<0.59**	**<0.83**	**<0.68**	**<0.49**		4	20	0.180	-
Phenanthrene	1.4	18	**<0.83**	**<0.68**	**<0.49**		10	1,000	0.200	-
Pyrene	2.0	15	**<0.83**	**<0.68**	**<0.49**		1,000	3,000	0.200	-
Total Detected PAHs	11.69	93.98	**4.20**	**1.40**	**2.36**	0.02				100

< - Not detected above laboratory reporting limit.
[1] - MCP Soil Reportable Concentrations do not apply to sediment and are included simply as a known reference.
[2] - Freshwater Sediment Screening Benchmarks for Use Under the MCP, MassDEP (1996).
[3] - See laboratory report attachment for percentage of particles passing through sieves.
[4] - Only VOCs detected above laboratory reporting limit. See laboratory report attachment for complete list of VOCs.
Bold values exceed the 401 Water Quality Criteria Reporting Limits (1,4-dioxane, isobutyl alcohol, and all PAH analytes).
Boxed values exceed the Stage I Freshwater Sediment Screening Criterion.

ATTACHMENT 4

Analytical Laboratory Report

Report omitted for brevity

APPENDIX E

Hydrology & Hydraulic Memorandum

McTaggarts Pond Dam Hydrologic & Hydraulics Analysis, Spillway Capacity Analysis, and Alternatives Analysis

TO: Mr. Lenny Laakso, Fitchburg Commissioner of Public Works

FROM: Daniel R. Buttrick, PE; William M. Yan; David L. Azinheira, PE, CFM

COPY:

DATE: October 9, 2019

Tighe & Bond performed a hydrologic and hydraulic (H&H) analysis as part of the preliminary design phase to evaluate repair alternatives available for McTaggarts Pond Dam. The existing spillway capacity was evaluated to determine its ability to safely pass the 100-year Spillway Design Flood (SDF).

The results of the H&H analysis suggested the existing spillway at McTaggarts Pond Dam can adequately pass the 100-year storm frequency event without overtopping the dam. The dam spillway capacity is adequate to pass the SDF with approximately 1.2 feet of freeboard to the top of dam meeting the minimum freeboard that is typically considered acceptable. The dam is currently reported as being in unsafe condition so alternatives to either remove the dam or partially remove the dam to reduce the hazard class to non-jurisdictional were evaluated. The spillway capacity and alternatives evaluation are provided in detail within this report.

1 Description of Dam

McTaggarts Pond Dam is an approximately 430-foot long and 24-foot tall earthen embankment and concrete dam. The left side of the dam is an approximately 60-foot long earthen embankment that extends from the left of spillway to natural grade. The right side of the dam is an approximately 210-foot long earth embankment that extends from the right of spillway to residential properties. The dam was first built to impound McTaggarts Pond for industrial application, but is currently used for recreational purposes. Figure 1 in Attachment A is a site aerial overview of McTaggarts Pond Dam and adjacent areas.

A concrete gatehouse structure is located on the right of the primary spillway, containing a low-level outlet and penstock. Trash racks were installed at the intake side of both structures. A manual gate operator within the gatehouse was reportedly used to control the abandoned penstock that is 42-inches at the intake and reduced to 12-inches at the discharge side. The low level outlet is controlled by a wooden slide gate but can only be operated by an external mechanical equipment such as a backhoe.

The primary spillway is an approximately 160-foot long concrete broad-crested weir with concrete training walls. The originally spillway was reportedly constructed of stone masonry but was later encapsulated in concrete forming the currently spillway geometry. Both the primary spillway and low level outlet discharge into the downstream Phillips Brook. The impounded is currently drained for field investigation purposes.

2 Hydrology

McTaggarts Pond Dam is categorized as Intermediate size dam based on height with Significant hazard (Class II), in accordance with Commonwealth of Massachusetts 302 CMR 10.00 Dam Safety, revised November 4, 2004. Based on its size and hazard classification, the Spillway Design Flood (SDF) is the 100-year frequency storm event, or the inflow discharge equivalent to an annual exceedance probability of 0.01 (see 302 CMR 10.14). It is typically recommended that the peak SDF water surface elevation to be at least one to three feet below the elevation of dam components that would be subject to damage from overtopping flow (e.g. the embankment crest).

2.1 HEC-HMS Model Development

The hydrologic analysis for McTaggarts Pond Dam was performed using HEC-HMS (v. 4.2.1), a tool developed by the United States Army Corps of Engineers (USACE) for rainfall-runoff modeling. The United States Department of Agriculture's (USDA) Technical Release 55 (TR-55) methods (e.g., the curve number methodology) were used within HEC-HMS to develop the storm flow hydrographs for the 2-, 5-, 10-, 25-, 50-, 100- and 500-year frequency storm events. Principal hydrologic input values for this modeling approach program include: rainfall depth; the total contributing watershed area; land use; hydrologic soil types based on USDA Natural Resources Conservation Service (NRCS) soil surveys; and time of concentration. Impoundment storage estimate relationship such as an elevation-area curve was developed using surveyed data from December 2018 in conjunction with ArcGIS for McTaggarts Pond. Elevation-volume data for Winnekeag Lake and Factory Village Pond were collected from available Phase I Dam Inspection reports.

The contributing drainage area to McTaggarts Pond Dam is approximately 15.4 square miles. The drainage area was delineated using the StreamStats program[1], an online tool developed by the United States Geological Survey (USGS). Figure 2 in Attachment A shows the drainage area delineation, as well as the delineation of sub-drainage areas. The majority of the land-use within the drainage basin, calculated from MassGIS Land Use (2005) 0.5-meter resolution digital ortho-imagery, consists of mostly forest (~75%), low/very low residential (~6%), cropland (~5%), and pasture (~3%).

The soil type in the watershed were determined by the SCS soil group classification method, which are grouped into four different hydrologic soil group (HSG) categories based on their infiltration rates and, subsequently, runoff potential. The most common hydrologic soil group rating in the McTaggarts Pond watershed was D (~56%), which has the lowest infiltration rate of the other soil groups. The percentage of area in the watershed was with type A, B, and C soils were approximately 2%, 18%, and 24% of the total drainage area, respectively.

The 24-hour precipitation for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year frequency storm events were estimated using the National Oceanic and Atmospheric Administrations (NOAA) Atlas 14 Volume 10 data. A Northeast Regional Climate Center (NRCC) Type C rainfall distribution was used based on guidance from the NRCC. Table 2-1 provides the precipitation amounts used for the range of storms analyzed.

[1] U.S. Geological Survey, 2016, The StreamStats program, online at http://streamstats.usgs.gov, accessed May 1, 2019.

Table 2-1
24-hour Precipitation Values used in H&H Analysis

Storm Return Frequency	Precipitation Values (inches)
2-Year	3.08
5-Year	3.95
10-Year	4.67
25-Year	5.66
50-Year	6.42
100-Year	7.19
500-Year	9.70

The time of concentration (Tc) was determined using the empirical SCS lag formula method, which is a function of the length of the watershed, the average slope of the watershed, and the SCS curve number (CN). The total drainage area of McTaggarts Pond was separated into four (4) sub-drainage areas to improve model accuracy. A summary of the hydrologic information for the HEC-HMS model input values are presented in Table 2-2. Attachment B provides a detailed summary of the HEC-HMS input.

Table 2-2
Watershed Characteristics Used in HEC-HMS Modeling

Basin ID	Drainage -Area (acres)	Average Slope (%)	Longest Flow Path (feet)
1	1,367.85	8.3	9,388
2	115.96	0.001	4,795
3	1840.03	10.1	17,902
4	6,577.51	9.3	35,149

2.2 Hydraulics

The hydraulic analysis for this project was performed using HEC-RAS (v 5.0.6), a U.S. Army Corps of Engineers (USACE) riverine hydraulics computer model. The HEC-RAS model was developed using MassGIS Lidar data, field surveyed elevation data, HEC-HMS model results, and Massachusetts Bridge Inspection data. The top and bottom of McTaggarts Pond sediment was field measured during sediment probing by pushing a rod into the sediment until refusal was encountered. The field measured pond sediment elevations and depths were combined with MassGIS Lidar data to create a Triangular Irregular Network (TIN). TIN files were created for top and bottom of pond sediment to represent existing and potential future pond bathymetry, respectively. Cross section information was extracted from the TIN files using the HECgeoRAS ArcGIS plugin. Values of peak flows determined during the hydrologic analysis for McTaggarts Pond were used as input in the HEC-RAS model. The HEC-RAS model takes downstream conditions and structures into consideration when determining the hydraulic response of the spillway caused by various storm frequency events and has more sophisticated riverine hydraulic computation capabilities than HEC-HMS.

A steady state HEC-RAS model was developed for McTaggarts Pond Dam and extended from approximately 750 feet upstream of the dam to 1,700 feet downstream of the dam. This model extent was considered reasonable to capture anticipated tailwater conditions. A total of 27 cross sections were included in the HEC-RAS model. The model also included geometric data for McTaggarts Pond Dam, Sanborn Street bridge (located immediately downstream of the dam spillway), and Westminsiter Hill Road bridge. The Manning's roughness coefficients (Manning's n) varied from 0.035 to 0.04 within the channel and were 0.1 for the overbank areas. Figure 3 of Attachment A shows the location of the cross sections used for the HEC-RAS model.

A summary of the hydraulic information used for the HEC-RAS model input values for McTaggarts Pond Dam are as follows:

- Primary Spillway Structure
  a) Weir Length – 160 feet
  b) Weir Coefficient – 3.6
- Opening through Sanborn Street Bridge
  a) Deck Width – 22 feet
  b) Opening Span – 36 feet
  c) Opening Height – 7.5 feet
- Opening through Westminster Hill Road Bridge
  a) Deck Width– 52 feet
  b) Opening Span – 50 feet
  c) Opening Height – 18 feet

2.3 Model Scenarios

Model geometry scenarios were developed for both hydrologic and hydraulic models to evaluate the following:

1. Existing spillway capacity to safely meet the Storm Design Flood (100-year storm).
2. Proposed partial spillway removal to provide less than 15 acre-feet of impounded storage during a 100-year frequency storm.
3. Proposed dam removal with McTaggarts Pond existing sediment conditions.
4. Proposed dam removal assuming the channel within McTaggarts will extend to the observed refusal elevation over time.

Model scenarios 3 and 4 are modeled as one HEC-HMS scenario as the storage below the normal pool does not have an impact on hydrograph routing.

3 Results

The results from the H&H model and methodology described above are presented in the following sections.

3.1 HEC-HMS Parameter Adjustment

No nearby stream gauge or measured spillway flow data were available for comparison at the time of this HEC-HMS model development. USGS StreamStats reported peak flows calculated with a regression analysis using the Zarriello, P.J., 2017[2] method was used to validate initial HEC-HMS modeled peak flows of the various frequency storms. Table 3-1 shows the initial

[2] Zarriello, P.J., 2017, Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016-5156, 99 p. (https://dx.doi.org/10.3133/sir20165156)

flow rates developed using the HEC-HMS model and using the regression analysis. The model predicted peaks flows were significantly higher even when compared to the upper interval of the USGS regression predicted peak flows. This indicated that the Tc and CN used for each respective basin were likely to be overly conservative, resulting in an overestimated hydrologic response of the watershed during the different storm events.

Incremental adjustments to Tc and CN values were performed to better match the overall watershed response with the USGS regression analysis predicted peak flows. The Tc and CN values for each basin were iteratively adjusted by no more than a 10% increase and a 15% decrease, respectively, with the final adjusted model parameters as shown in Table 3-2. Sub-Drainage Area 2 is Winneakeag Lake, therefore the CN and Tc values were not adjusted because the response time was assumed to be instantaneous with all precipitation converted to runoff.

Table 3-1
Initial HEC-HMS and StreamStats Design Storm Peak Flow Comparison for McTaggarts Pond Dam.

Storm Return Frequency	HEC-HMS Initial Peak Flow Rate (cfs)	Regression Analysis Prediction Interval - Lower* (cfs)	Regression Analysis Prediction* (cfs)	Regression Analysis Prediction Interval – Upper* (cfs)
2-Year	1,504	246	491	979
5-Year	2,595	405	819	1,660
10-Year	3,584	524	1,090	2,260
25-Year	5,035	691	1,490	3,190
50-Year	6,202	820	1,820	4,050
100-Year	7,417	951	2,180	5,010
500-Year	11,487	1,330	3,160	7,520

*Regression analysis completed using “Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016–5156” (Zarriello 2017)

Table 3-2
Incremental adjustments to empirical model parameters

Sub-Drainage Area ID	Original CN*	Original Tc† (minutes)	CN* Increase (%)	Tc Increase (%)	Adjusted CN*	Adjusted Tc† (minutes)
1	75.6	45.4	10	5	68.0	47.7
2	98.0	1.0			98.0	1
3	73.8	72.5			66.4	76.2
4	72.4	134.7			65.1	141.5

* CN = Curve Number

† Tc = Time of Concentration

Collection of water level and flow data within the pond in combination with rain data could be used to further calibrate the model, which could result in further reduction of predicted storm flows. This calibration would be recommended if Alternative 1 were to be pursued further.

3.2 Existing Condition

Hydrologic Analysis

Figure 3-1 shows the results of the regression analysis and the HEC-HMS model results (original values, and values used for modeling). Results from the HEC-HMS model with adjusted parameters showed better agreement between the upper interval of peak flow from regression analysis and the HEC-HMS computed peak flows. The model results are still considered conservative as the HEC-HMS parameters were modified to more closely match the upper limit of the 90-percent confidence interval of the regression analysis, and not the median value. The model still slightly overestimated peak flows for higher frequency storms compared to the upper limit of the 90-percent confidence interval. Attachment B provides additional HEC-HMS output.

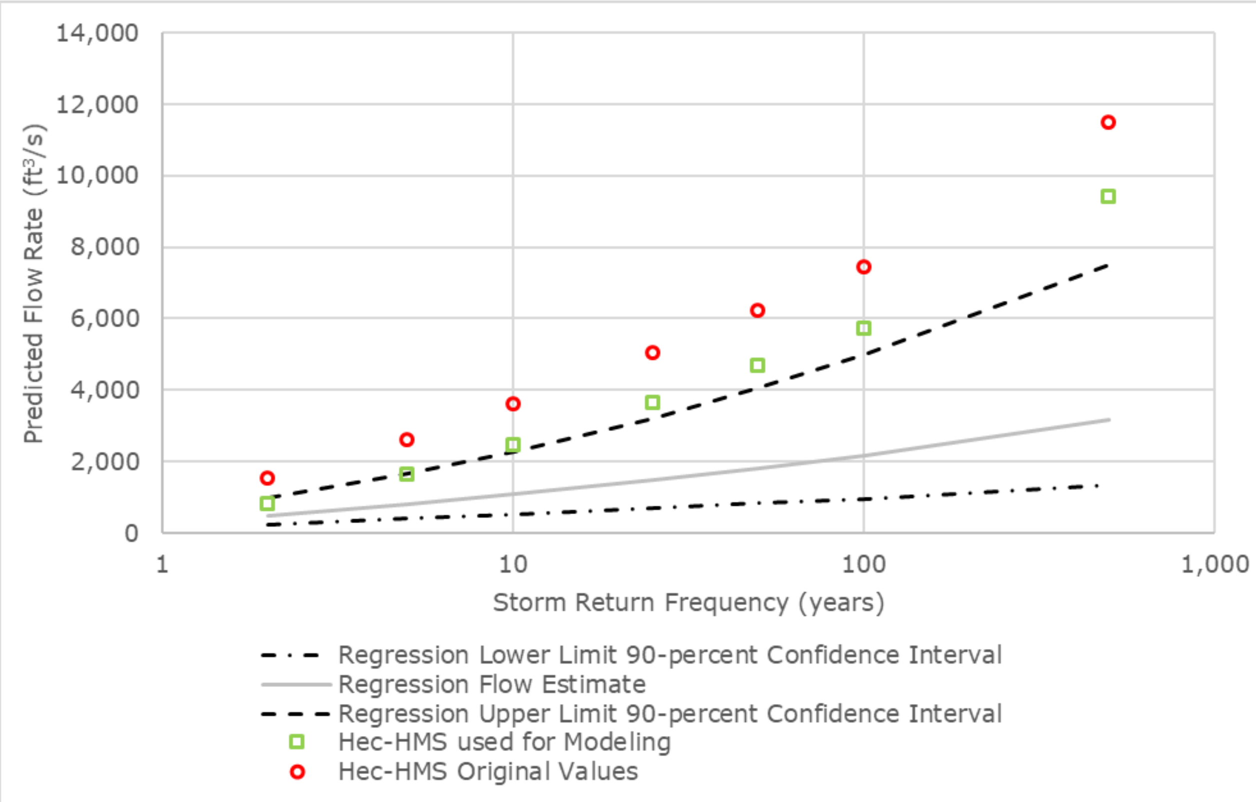


Figure 3-1. Peak flow rate predictions at McTaggarts Pond Dam using regression equations and HEC-HMS model results.

A condensed summary of the HEC-HMS model results for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year frequency storm events are presented in Table 3-3 below:

Table 3-3
Hydrologic Analysis Results for McTaggarts Pond Dam – Existing Conditions

Storm Return Frequency	Peak Inflow to McTaggarts Pond (cfs)	Peak Discharge from McTaggarts Pond (cfs)
2-Year	818.8	816.8
5-Year	1643.8	1639.5
10-Year	2435.6	2431.9

25-Year	3650.1	3644.2
50-Year	4657.2	4650.3
100-Year	5726.7	5718.3
500-Year	9399.6	9395.4

These results show that McTaggarts Pond Dam provides negligible flood-flow attenuation benefit since the peak calculated discharges are nearly the same as the peak calculated inflow. This finding makes sense since the storage volume of the pond is low and the spillway is wide.

Hydraulic Analysis

HEC-RAS was used to compute the dam freeboard with the peak flow input from HEC-HMS. The hydraulic model results suggested the existing spillway structure can provide a freeboard of 1.2 feet, during a 100-year storm. While HEC-HMS computes elevations as part of the hydrologic analysis, only HEC-RAS results are shown as it typically provides more accurate results, as it takes potential downstream backwater and channel geometry into account and performs a more sophisticated hydraulics analysis when calculating water surface elevations (and corresponding freeboard). Attachment C provides a summary of HEC-RAS results.

Table 3-4
Hydraulic Analysis Results for McTaggarts Pond Dam – Existing Conditions

Storm Return Frequency	Peak Water Surface Elevation of McTaggarts Pond (feet, NAVD88)	Available Freeboard (feet)*
25-Year	636.5	2.3
50-Year	637.1	1.7
100-Year	637.6	1.2
500-Year	639.1	-0.3

* The Top of dam is at 638.8 feet North American Vertical Datum of 1988 (NAVD88), a negative value represents overtopping of dam.

Generally-accepted dam safety design practice dictates that at least 1 foot of freeboard be available during peak SDF storm conditions unless wave run-up is thought to be a concern, I which case a wave run-up analysis should be performed. In the case of McTaggarts Pond Dam, the impoundment is small and the potential for large wind-induced waves is low. Therefore, McTaggarts Pond Dam has adequate spillway capacity in its current configuration.

3.3 Alternatives Analysis

McTaggarts Pond spillway has adequate discharge capacity to meet the minimum available freeboard required during a 100-year storm SDF, so an alternative to improve dam performance was not evaluated. Alternatives were evaluated to perform a partial dam removal (to reduce the hazard class) and to perform a full dam removal.

Alternative 1 – Partial Dam Removal

Alternative 1 consists of partial spillway removal by lowering the existing spillway elevation to meet the Massachusetts ODS 302 CMR, 10.06.2 Size and Hazard Potential Classification for a non-jurisdictional dam. The criterion a dam must satisfy to become a non-jurisdictional dam is having either a maximum storage of 15 acre-feet during a 100-year storm event or a maximum dam height of 6 feet.

This alternative assumes that the existing top of dam elevation and spillway width would the same as existing conditions, while the existing spillway elevation would need to be reduced from an average of 633.2 feet to a level determined by modelling to achieve the peak storage of 15 ace-feet or less during a 100-year storm. By trial and error, the updated spillway elevation was determined to be 627.2 feet, corresponding to a reduction in normal pool elevation of 5.6 feet. Table 3-5 shows the anticipated inflows, outflows, water surface elevations, storage, and anticipated storage for the partial dam removal scenario. The lowering of the spillway crest would not significantly change downstream flood discharge rates or elevations.

Table 3-5
Hydrologic and Hydraulic Model Results for McTaggarts Pond Dam – Alternative 1: Partial Dam Removal

Storm Return Frequency	Peak Inflow to Pond (cfs*)	Peak Discharge from Pond (cfs*)	Increase in Peak Discharge Compared to Existing Conditions	Peak Pond Storage (acre-feet)	Peak Water Elevation of Pond (feet, NAVD88)	Available Freeboard (feet)†
25-Year	3650.1	3650.1	5.9	4.1	630.1	8.9
50-Year	4657.2	4652.6	2.3	5.4	630.6	8.4
100-Year	5726.7	5724.7	6.4	13.5	632.3	6.8
500-Year	9399.6	9398	2.6	21.3	633.5	5.5

* cfs = cubic feet per second
†The Top of dam is at 638.8 feet North American Vertical Datum of 1988 (NAVD88), a negative value represents overtopping of dam.

Alternative 2 – Dam Removal

Alternative 2 involves removing the dam by constructing a breach starting at elevation 619 with a width of 70 feet, that extends up to the existing spillway elevation with a 1 unit horizontal to 1 unit vertical (1H:1V) side slopes.

Table 3-6 shows the hydraulic and hydrologic results for the dam removal assuming that the channel bottom through the dam breach erodes or is constructed to the elevation of refusal encountered during the sediment probing. It is unknown whether this refusal elevation relates to bedrock, stones and cobbles, or a firmer soil layer. As such, Table 3-7 shows results if the channel were graded through refusal to create a more consistent slope through the breach.

With either approach, there would be almost no attenuation in peak flows at the dam, although downstream flows would not significantly increase since there is little attenuation under existing conditions. This alternative would also result in 100-year speak storage volumes of less than 15-acre feet, which would result in non-jurisdictional hazard classification for McTaggarts Pond Dam. This alternative would remove the impoundment capacity of the dam allowing the Philips Brook to begin to revert back to natural riverine conditions.

Table 3-6
Hydrologic and Hydraulic Model Results for McTaggarts Pond Dam – Alternative 2: Dam Removal with Existing Sediment Conditions within McTaggarts Pond

Storm Return Frequency	Peak Inflow to Pond (cfs*)	Peak Discharge from Pond (cfs*)	Increase in Peak Discharge Compared to Existing Conditions	Peak Pond Storage (acre-feet)	Peak Water Elevation of Pond (feet, NAVD88)
25-Year	3650.1	3650.1	28.5	1.8	629.0
50-Year	4657.2	4656.3	6	3.7	630.0

100-Year	5726.7	5726.7	12.3	6.8	631.0
500-Year	9399.6	9399.6	5	21.6	633.5

Table 3-7
Hydrologic and Hydraulic Model Results for McTaggarts Pond Dam – Alternative 3: Dam Removal Assuming the Channel Sediment in McTaggarts Pond Extends to Refusal

Storm Return Frequency	Peak Inflow to Pond (cfs*)	Peak Discharge from Pond (cfs*)	Increase in Peak Discharge Compared to Existing Conditions	Peak Pond Storage (acre-feet)	Peak Water Elevation of Pond (feet, NAVD88)
25-Year	3650.1	3650.1	28.5	1.2	628.6
50-Year	4657.2	4656.3	6	2.1	629.3
100-Year	5726.7	5726.7	12.3	3.4	629.9
500-Year	9399.6	9399.6	5	11.1	631.9

4 Conclusion

The H&H analysis, spillway capacity analysis, and alternatives analysis methodology and results described above will be used to support the Alternatives Analysis being developed for McTaggarts Pond Dam. The analysis confirms that the dam can pass the 100-year frequency storm event spillway design flood (SDF) for existing conditions with over 1-foot of freeboard. The analysis also finds that a partial removal of the dam to create a small, non-jurisdictional dam impounding a smaller body of water, would provide relatively little attenuation of peak flows and therefore little hydraulic benefit compared to a full dam removal. A full dam removal by implementing a breach in the existing dam is considered preferable to a partial dam removal as it will provide substantial ecological improvement while significantly reducing potential risk associated with a potential dam failure, with increases in peak discharge of less than 1-percent compared to existing conditions.