PINE HILL RESERVOIR DAM

PHASE I

INSPECTION / EVALUATION REPORT

Dam Name:	Pine Hill Reservoir Dam
State Dam ID#:	3-14-134-6
NID ID#:	MA 00623
Owner:	City of Worcester
Owner Type:	Municipal
Town:	Holden, Massachusetts
Consultant:	CDM Smith Inc.
Date of Inspection:	September 24, 2015

CDM Smith

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Executive Summary

The Pine Hill Reservoir Dam is located in Holden, Massachusetts and is owned and operated by the City of Worcester, Massachusetts. On September 24, 2015, this structure was inspected by Tyler C. Dunn, P.E. and Elizabeth A. Wroe, E.I.T., representatives from CDM Smith Inc. Their observations are summarized below.

The condition of the dam was judged by the Massachusetts Office of Dam Safety criteria and was found to be in **Fair** condition.

The deficiencies that were noted include:

1. Spalled concrete on the upstream and downstream faces of the dam and on the spillway slab and training walls. Seepage through the concrete dam is considered to be a contributing factor to the continuing deterioration of this concrete.
2. Cracks and efflorescence in concrete in the crest, upstream face, and downstream face of the dam and in the spillway slab and training walls. Vegetation needs to be removed from some cracks.
3. Brush and vegetation growing in riprap and in the embankment where it adjoins the concrete dam and spillway.
4. Outlet drain for infiltration gallery is blocked so that seepage water floods the gallery and flows out through top of access manhole for the gallery.
5. Depressions and slightly damp ground surface on the right downstream slope between the dam and outlet gate house, which may be attributable to possible seepage through the face of the concrete dam.
6. Exposed reinforcing steel (rebar) on the right training wall, baffle blocks, and right downstream face, and exposed mesh on left downstream face.
7. Tractor ruts and bare spots parallel to the slope on the left downstream embankment slope.
8. There is no Operations and Maintenance Manual for this dam.
9. There is no updated seepage or stability analysis for the concrete masonry dam and the embankment for a revised spillway design flood analysis. Stability and seepage analyses are currently underway for an engineering assessment and preliminary rehabilitation design by CDM Smith.
10. Broken steps on access ladder in right access manhole to drainage gallery.

CDM Smith has recommended that the following actions be taken, many of which have been implemented for the preliminary rehabilitation design currently underway, to address the deficiencies found at the dam during this inspection and evaluation and/or comply with current regulations:

Studies and Analyses

1. Update the Emergency Action Plan (in progress).
2. Prepare an Operations and Maintenance Manual.
3. Prepare a stability and seepage analysis of the dam. (underway)
4. Perform an updated hydrologic and hydraulic analysis of the dam. (underway)
5. Perform an underwater inspection of the upstream face of the dam to determine the condition of the concrete. (underway)

Maintenance and Repairs

1. Perform regular maintenance to control and limit growth of vegetation on the dam.
2. Perform monthly monitoring and inspection of the dam.
3. Check operation of all gates.
4. Perform crack repair and filling annually.
5. Monitor for erosion and animal burrows on the embankments and repair as needed.
6. Inspect the seepage infiltration gallery annually.
7. Repair downstream dam face.
8. Repair concrete spalling and cracking on upstream and downstream dam faces, spillway slab, and training walls.
9. Regrout areas of spalled and damaged concrete to control seepage.
10. Construct a new drainage outlet for the seepage infiltration gallery.

Dam Evaluation Summary Detail Sheet

1. NID ID:	MA00623	4. Inspection Date:	September 24, 2015
2. Dam Name:	Pine Hill Reservoir Dam	5. Last Insp. Date:	April 11, 2012
3. Dam Location:	Holden, MA	6. Next Inspection:	September 24, 2017
7. Inspector:	Tyler C. Dunn, P.E.		
8. Consultant:	CDM Smith		
9. Hazard Code:	High	9a. Is Hazard Code Change Requested?:	No
10. Insp. Frequency:	2 Years	11. Overall Physical Condition of Dam:	FAIR
12. Spillway Capacity (% SDF)	>100% SDF w/ no actions by Caretaker		

E1. Design Methodology:	3	E7. Low-Level Discharge Capacity:	4
E2. Level of Maintenance:	4	E8. Low-Level Outlet Physical Condition:	5
E3. Emergency Action Plan:	4	E9. Spillway Design Flood Capacity:	5
E4. Embankment Seepage:	3	E10. Overall Physical Condition of the Dam:	3
E5. Embankment Condition:	5	E11. Estimated Repair Cost:	$1,316,000 - $1,804,000
E6. Concrete Condition:	3		

Evaluation Description

E1: DESIGN METHODOLOGY
1. Unknown Design – no design records available
2. No design or post-design analyses
3. No analyses, but dam features appear suitable
4. Design or post design analysis show dam meets most criteria
5. State of the art design – design records available & dam meets all criteria

E2: LEVEL OF MAINTENANCE
1. Dam in disrepair, no evidence of maintenance, no O&M manual
2. Dam in poor level of upkeep, very little maintenance, no O&M manual
3. Dam in fair level of upkeep, some maintenance and standard procedures
4. Adequate level of maintenance and standard procedures
5. Dam well maintained, detailed maintenance plan that is executed

E3: EMERGENCY ACTION PLAN
1. No plan or idea of what to do in the event of an emergency
2. Some idea but no written plan
3. No formal plan but well thought out
4. Available written plan that needs updating
5. Detailed, updated written plan available and filed with MADCR, annual training

E4: SEEPAGE (Embankments, Foundations, & Abutments)
1. Severe piping and/or seepage with no monitoring
2. Evidence of monitored piping and seepage
3. No piping but uncontrolled seepage
4. Minor seepage or high volumes of seepage with filtered collection
5. No seepage or minor seepage with filtered collection

E5: EMBANKMENT CONDITION (See Note 1)
1. Severe erosion and/or large trees
2. Significant erosion or significant woody vegetation
3. Brush and exposed embankment soils, or moderate erosion
4. Unmaintained grass, rodent activity and maintainable erosion
5. Well maintained healthy uniform grass cover

E6: CONCRETE CONDITION (See Note 2)
1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns
2. Cracks with misalignment inclusive of transverse cracks with no misalignment but with potential for significant structural degradation
3. Significant longitudinal cracking and minor transverse cracking
4. Spalling and minor surface cracking
5. No apparent deficiencies

E7: LOW-LEVEL OUTLET DISCHARGE CAPACITY
1. No low level outlet, no provisions (e.g. pumps, siphons) for emptying pond
2. No operable outlet, plans for emptying pond, but no equipment
3. Outlet with insufficient drawdown capacity, pumping equipment available
4. Operable gate with sufficient drawdown capacity
5. Operable gate with capacity greater than necessary

E8: LOW-LEVEL OUTLET PHYSICAL CONDITION
1. Outlet inoperative needs replacement, non-existent or inaccessible
2. Outlet inoperative needs repair
3. Outlet operable but needs repair
4. Outlet operable but needs maintenance
5. Outlet and operator operable and well maintained

E9: SPILLWAY DESIGN FLOOD CAPACITY
1. 0 - 50% of the SDF or unknown
2. 50-90% of the SDF
3. 90 - 100% of the SDF
4. >100% of the SDF with actions required by caretaker (e.g. open outlet)
5. >100% of the SDF with no actions required by caretaker

E10: OVERALL PHYSICAL CONDITION OF DAM
1. UNSAFE – Major structural, operational, and maintenance deficiencies exist under normal operating conditions
2. POOR - Significant structural, operation and maintenance deficiencies are clearly recognized under normal loading conditions
3. FAIR - Significant operational and maintenance deficiencies, no structural deficiencies. Potential deficiencies exist under unusual loading conditions that may realistically occur. Can be used when uncertainties exist as to critical parameters
4. SATISFACTORY - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result in deficiencies.
5. GOOD - No existing or potential deficiencies recognized. Safe performance is expected under all loading including SDF

E11: ESTIMATED REPAIR COST

Estimation of the total cost to address all identified structural, operational, maintenance deficiencies. Cost shall be developed utilizing standard estimating guides and procedures

Changes/Deviations to Database Information since Last Inspection

Executive Summary

Preface

The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigations and analyses involving topographic mapping, subsurface investigations, testing and detailed computational evaluations are beyond the scope of this report.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection, along with data available to the inspection team. In cases where an impoundment is lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions, which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is critical to note that the condition of the dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Prepared By:

CDM Smith Inc.

9/30/15

Tyler C. Dunn, P.E.
Senior Geotechnical Engineer
MA #47767 Civil

Elizabeth A. Wroe, E.I.T.
Geotechnical Engineer

Section 1

Section 1
Description of Project

1.1 General

1.1.1 Authority

The City of Worcester retained CDM Smith Inc. to perform a visual inspection and develop a report of conditions for the Pine Hill Reservoir Dam located on the Asnebumskit Brook in Holden, Massachusetts. This inspection and report were performed in accordance with MGL Chapter 253, Sections 44-50 of the Massachusetts General Laws as amended by Chapter 330 of the Acts of 2002.

1.1.2 Purpose of Work

The purpose of this investigation was to inspect and evaluate the present condition of the dam and appurtenant structures in accordance with 302 CMR 10.07. This inspection is intended to provide information that will assist in both prioritizing dam repair needs and planning/conducting maintenance and operation.

The investigation is divided into four parts: 1) obtain and review available reports, investigations, and data previously submitted to the owner pertaining to the dam and appurtenant structures; 2) perform a visual inspection of the site; 3) evaluate the status of an emergency action plan for the site and; 4) prepare and submit a final report presenting the evaluation of the structure, including recommendations and remedial actions, if warranted, and opinion of probable costs. Photographs taken during the inspection are included in **Appendix A**. Inspection checklists are included in **Appendix B**. Available references or reports used to supplement the inspection are included in **Appendix C**.

1.1.3 Definitions

To provide the reader with a better understanding of the report, definitions of commonly used terms associated with dams are provided in **Appendix D**. Many of these terms may be included in this report. The terms are presented under common categories associated with dams which include: 1) orientation; 2) dam components; 3) size classification; 4) hazard classification; and 5) miscellaneous.

1.2 Description of Project

1.2.1 Location

Pine Hill Reservoir Dam is located on the Asnebumskit Brook in the town of Holden, Worcester County, Massachusetts. It is accessed by an approach road located approximately 1.5 miles west of Route 122 A (Main Street). The dam access road is North of Kendall Road and is approximately 1.1 miles in length. A locked gate that is controlled by the City of Worcester is located at the beginning of the access road approximately 0.75 mile along Kendall Road adjacent to the Kendall reservoir dam. This site is located at coordinates N42.3510/W71.9050 and is upstream from Jefferson, MA as indicated on the **Figure 1**, Locus Plan. An aerial photograph of the reservoir and surrounding area is shown on **Figure 2**, Aerial Map. The contributing watershed is shown on **Figure 3**, and a general map of the downstream area is shown on **Figure 4**.

1.2.2 Owner/Caretaker

See Table 1.1 for current owner and caretaker data (names and contact information) presented at the end of this section.

1.2.3 Purpose of the Dam

The Pine Hill Reservoir provides part of the water supply for the City of Worcester. Water can be pumped from Kendall Reservoir (MA 00622) to Pine Hill Reservoir through a 24-inch diameter main that connects with the 30-inch diameter outlet pipe at the lower gatehouse at the downstream toe of the dam. The main is also used to transfer water by gravity from Pine Hill Reservoir to Kendall Reservoir. In addition, if needed, water can be gravity fed down the Asnebumskit Brook to the Headworks Dam (MA02326) and down the Asnebumskit Canal to Kendall Reservoir.

1.2.4 Description of the Dam and Appurtenances

As shown on Figure 5, Field Sketch and Notes, the dam system is comprised of the concrete dam and spillway, the earthen embankments, and conduits with underwater inlets.

The information provided regarding the details of the dam and appurtenances is based on observations and measurements performed during the September 24, 2015 inspection by CDM Smith, and is supplemented by data contained in previous reports.

The Pine Hill Reservoir Dam is a concrete masonry dam faced with concrete, and flanked by earth embankments constructed against the natural left and right abutments. The masonry dam section is 370 feet long, and the left and right embankments are 300 and 170 feet long, respectively. The dam is a cyclopean masonry structure, which is a combination of massive quarry run stones of irregular shape and size embedded in concrete.

A concrete masonry core wall is located within the left and right earth embankment sections. The crests of the earth embankment sections are about 25 feet wide. The upstream slopes are protected with hand-placed riprap ranging in size from 6 inches to 4 feet. The upstream slope on the right embankment is approximately 2.4H:1V. The upstream slope on the left embankment varies from approximately a 3.3H:1V slope at the top of the embankment and changes to approximately a 1.7H:1V at the mid slope between the crest and the normal pool elevation. The crest and downstream slope of each embankment is covered with grass. The downstream slopes vary from a 1.7H:1V to a 2H:1V slope. Measurement of the slopes was performed during the inspection. On the left embankment, there is an approximately 8-foot wide bench at about El. 890.0 on the downstream slope. The width of the bench diminishes near the face of the concrete dam. The earth embankments tie into natural higher ground at each abutment. Bedrock is exposed at the right abutment. It is reported that rock was quarried from the right abutment area to provide the masonry blocks for the main dam. The dam was founded on bedrock.

The concrete crest of the masonry dam section is generally flat at approximately EL. 920 National Geodetic Vertical Datum of 1929 (NGVD 29). The crest is 15 feet wide on the arch bridge over the spillway, widens to 20 feet for the main portion of the dam, and widens to 25 feet at the abutments. There is an iron pipe railing along both sides of the crest and a small concrete building to the right of the spillway to access the gate chamber. The structural height of the dam is approximately 70 feet, based on the concrete structure/rock subgrade interface at approximately El. 850. The upstream face of the dam is vertical. The downstream face is curved, and varies from about 0.75H:1V at the toe to near vertical at the top.

The primary spillway is located near the middle of the masonry dam section. It is a concrete ogee weir divided by two concrete pillars forming three arched bays. Each bay is 25 feet wide and 8.5 feet high at the centerline of a semi-circular arch. The crest of the weir is at El. 910.0. The upstream face of the spillway is vertical. The downstream face of the spillway is bounded by concrete training walls, 2-foot high and 4-foot wide. Concrete baffle blocks at the toe of the spillway dissipate energy as water discharges into a semi-circular concrete stilling basin. The floor of the stilling basin has an elevation of El. 848.5. The side walls of the basin are an extension of the spillway training walls and are 10 to 12 feet high at the end of the wall. The stilling basin is approximately 83 feet wide at the base of the spillway, and extends about 76 feet downstream along the spillway centerline to the semicircular basin wall. The downstream end of the stilling basin descends in two broad steps from elevation El. 853 to El. 851.0. Downstream of the basin steps is the stream channel which narrows from 70 to approximately 50 feet. The channel is lined with natural stones, with some vegetation growth.

There is a drainage gallery inside the base of the concrete dam. The gallery is accessible through two manholes. One access manhole is on the dam crest at about El. 920 near the right abutment and has a metal ladder providing access down to the right end of the drainage gallery. The second access manhole is located at the downstream toe of the dam at the left side of the stilling basin. This second manhole also contains a metal ladder for access down to the bottom of a perpendicular "T" gallery that connects to the main gallery within the dam. The manhole rim at the toe of the dam is set at about El. 858, and the invert of the gallery at the base of this manhole is about El. 848. The US Army Corps of Engineers (COE) (1978) reported that the gallery is about 335 feet long, 6.5 feet high with vertical walls and an arch ceiling, and about 4 feet wide. For about half its length, the floor is level at approximately El. 855.0 and then slopes up to El. 878.0 at the location of the first manhole near the right abutment of the dam. Fifteen vertical drainage wells collect seepage from the interior of the dam and conduct it directly to the gallery through the arch ceiling. Some vertical drainage wells are rectangular in section, about 6-inch by 12-inch, and some are circular in section, about 12-inch diameter. Inside the gallery, the seepage collects and flows in a shallow trough along the upstream edge of the gallery floor. The trough collects flow from the left and right portions of the concrete dam and meets at the perpendicular "T" that directs the flow downstream to an 8-inch-diameter cast iron outlet pipe. The 8-inch diameter cast iron pipe is intended to discharge collected water to a point downstream of the lower gallery manhole into the Asnebumskit Brook.

The outlet works for the dam are located in the gate chamber on the upstream face of the dam right of the spillway. The US Army Corps of Engineers (COE) (1978) reported the chamber is constructed over a well or intake chamber with an invert at approximately El. 850.0. There are three intakes to the well at different elevations. The sluice gates are operated by handwheels in the gate chamber. The water from the intakes discharges through a 30-inch diameter cast iron pipe and is then conducted to the gatehouse at the right side of the stilling basin. A valve inside the gatehouse regulates flow through the 30-inch-diameter pipe out into the stilling basin, and then into the channel.

The COE (1978) reports that a low-level outlet, with an invert at approximately El. 850.0, is located on the upstream face of the dam. Flow is regulated by a 24-inch by 26-inch sluice gate that is operated by a handwheel in the gate chamber. The outlet for this pipe is not visible.

Water can be pumped from Kendall Reservoir (MA 00622) to Pine Hill Reservoir through a 24-inch diameter main that connects with the 30-inch diameter outlet pipe at the lower gatehouse. The main is also used to transfer water by gravity flow from Pine Hill Reservoir to Kendall Reservoir. In addition, if needed, water

can be gravity fed down the Asnebumskit Brook to the Headworks Dam (MA02326) and down the Asnebumskit Canal to Kendall Reservoir.

1.2.5 Operations and Maintenance

General operating procedures include measuring and recording daily water levels and pumping rates. A daily security check is also performed.

The sluice gates in the intake chamber are opened and closed as required for drawing water from the Pine Hill Reservoir to supply the lower reservoirs with additional water. Flow through the 30-inch-diameter outlet pipe is regulated by the valve located in the gatehouse at the toe of the spillway. When an additional supply is needed in the lower reservoirs, this valve is opened and water flows down the spillway channel into the Asnebumskit Brook to the Headworks Dam and down the Asnebumskit Canal to Kendall Reservoir. The gate and valve operations are recorded and documented in a monthly report stored in the same office as mentioned above.

General maintenance of the dam is performed on an annual basis. The reservoir shoreline is mowed and fertilized once a year. Vegetation is cleared to a distance of 50 feet from the reservoir shoreline and a distance of 30 feet on either side of the feeder streams. The low-level outlet is kept closed under normal conditions. Other maintenance is performed as required. Repair work is done as the need arises, and when funds are available from the City.

The maintenance procedures at the dam typically include the following:

1. Regulate water in the reservoir as seasonal variations and reservoir levels warrant.
2. Measure reservoir level daily.
3. Perform site visits to inspect the dam daily.
4. Inspect gatehouse and appurtenant structures as needed. Exercise control valves regularly.
5. Mowing of grass on the embankments 2 to 3 times per year, and the removal of trees and brush is performed as needed.
6. Trees and brush are removed from within 50 feet of the reservoir shoreline every other year.
7. Identify, remove animals, and fill animal burrows when found.

1.2.6 DCR Size Classification

Pine Hill Reservoir Dam has a maximum structural height of approximately 70 feet and a maximum storage capacity of 13,023 acre-feet. Therefore, in accordance with Department of Conservation and Recreation Office of Dam Safety classification, under Commonwealth of Massachusetts dam safety rules and regulations stated in 302 CMR 10.00 as amended by Chapter 330 of the Acts of 2002, Pine Hill Reservoir Dam is a **Large** size structure.

1.2.7 DCR Hazard Potential Classification

Pine Hill Reservoir Dam is located upstream of a wooded and undeveloped area along the Asnebumskit Brook that lies upstream from Eagle Lake. Should a dam failure occur, the impacted area would extend

from the dam along Asnebumskit Brook to the Quinapoxet River and then to the Wachusett Reservoir some 10 miles downstream. The dam failure wave would first flow through Eagle Lake in Holden about one mile downstream of the dam affecting many properties bordering the lake. Properties along Rte. 122A and Princeton Street in the Jefferson Village area would be affected by flooding. A number of properties along Quinapoxet Street would be affected by flooding. After the confluence of Asnebumskit Brook and the Quinapoxet River, a cluster of homes in the Quinapoxet and Lovellville villages section where Rte. 31 crosses the river about 4 miles downstream of the dam would be impacted by flooding. Additionally, there are several more properties along River Street that would be impacted by flooding where the river runs along River Street for more than a mile. It appears that a failure of the dam at maximum pool will likely cause loss of life and serious damage to homes, industrial or commercial facilities, public utilities, highways, or railroads.

Therefore, in accordance with Department of Conservation and Recreation classification procedures, under Commonwealth of Massachusetts dam safety rules and regulations stated in 302 CMR 10.00 as modified amended by Chapter 330 of the Acts of 2002, Pine Hill Reservoir Dam is classified as a **High** hazard potential dam. The Hazard Potential Classification recommendation is consistent with the Hazard Potential Classification on record with the Office of Dam Safety for Pine Hill Reservoir Dam. An Emergency Action Plan (EAP) exists for the dam.

1.3 Pertinent Engineering Data

The pertinent engineering data presented is based on observations and measurements performed during the September 24, 2015 inspection by CDM Smith, and are supplemented by data contained in previous reports.

1.3.1 Drainage Area

The COE (1978) reported a drainage area of 6.7 square miles. CDM Smith measured the drainage area for Pine Hill Reservoir Dam from USGS maps as approximately 7.14 square miles, extending through the communities of Rutland and Paxton. The drainage area is indicated on Figure 3. Outside of these small population centers, the drainage area is wooded and has little development.

1.3.2 Reservoir

The information in the table below was estimated based on field measurements, web-based GIS measurements, USGS maps, and an elevation reference of El. 920 (NGVD 29) on the dam crest surface. The normal pool elevation is based on the highest controllable water surface determined by the top of the spillway crest. The maximum pool elevation is controlled by the elevation of the dam crest.

	Elevation (feet)	Length (feet)	Width (feet)	Surface Area (acres)	Storage Volume (acre-feet)
Normal Pool	910.0	6,400	5,100	336	9,398
Maximum Pool	920.0	6,500	5,250	389	13,023
Spillway Design Flood (SDF) Pool	918.0	6,380	5,120	378	12,254

1.3.3 Discharges at the Dam Site

It has been reported by Mr. Bruce Blanchard, caretaker of the dam, that this dam has never been overtopped. Discharges at Pine Hill Reservoir Dam occur over the spillway and through three upper gates or two lower gates controlled at the gate house. The three upper gates connect to a 30-inch diameter pipeline that connects to a 24-inch diameter pipeline that runs from Pine Hill Reservoir to Kendall to Quinapoxet Reservoir. The two lower gates flow through a 30-inch pipe to the stilling basin. The following is a summary of relevant discharge information provided in the COE (1978) Phase I Report and on the CVP (1978) Inspection Report.

1.3.4 General Elevations

All elevations are in feet and are based on NGVD 29. Elevations for the Pine Hill Reservoir Dam and applicable reservoir information are estimated based on field measurements or taken from the referenced reports.

A.	Top of Dam	920.0
B.	Spillway Design Flood Pool	918.0
C.	Normal Pool	910.0
D.	Spillway Crest	910.0
E.	Stilling Basin Floor	848.5
F.	Upstream Water at Time of Inspection	904.2
G.	Downstream Water at Time of Inspection	850.6
H.	Streambed at Toe of the Dam	848.7
I.	Low Point along Toe of the Dam	848.5

1.3.5 Main Spillway

A.	Type	Concrete Ogee Weir
B.	Length of Weir	Three 25-foot bays
C.	Weir Crest Elevation	910.0

D.	Upstream Channel	Pine Hill Reservoir
E.	Downstream Channel	Stilling Basin discharges to riprap and bedrock channel
F.	Downstream Water	Channel leads to Headworks Dam to Eagle Lake or to Kendall Reservoir

1.3.6 Outlet Structures

A.	Type	Cast iron water mains
B.	Pipe Invert	N/A
C.	Pipe Size	24-inch diameter and 30-inch diameter
D.	Valve type	Three sluice gates and two lower gates

1.3.7 Design and Construction Records and History

Based on information provided in COE (1978), construction of the dam began in 1916 and was completed in 1924. Spalling of the concrete on the dam and spillway has been a problem since at least 1934, when it was first mentioned in a county inspection report. These reports cited the poor condition of the concrete and the appearance of a longitudinal crack across one arch of the spillway, as potentially dangerous conditions. The first reference of repair to the surface appears in a 1960 report, which states that gunite was applied to the spillway face 5 to 6 years earlier.

Subsequent repair work on the concrete structure was undertaken around 1962. According to the referenced report, the Supervisor of Water Supply reported the outlet for draining the inspection gallery was probably damaged by equipment on site during the repair work. Field investigations were started in December 1980 to locate the 8-inch cast iron drainage pipe. It was reported in the field inspector's notes that the possible end of the 8-inch drainage pipe was identified using dye tests performed by Coffin & Richardson consulting engineers. The location of the end of the drainage pipe was shown to be about 380 feet downstream of the lower access manhole in the Asnebumskit Brook on a drawing for repairs to Pine Hill Reservoir Dam by Coffin & Richardson dated July 1980. It was reported in the field inspector's notes that the pipe was found just downstream of the access manhole. The pipe had little pitch leaving the manhole and the alignment turned downward about 45 degrees. A section of the pipe was cut and it was found to have some build-up of calcium deposits. A few test pit holes were excavated further downstream and it was found that the pipe had shallow pitch and it was speculated that the pipe was clogged by the accumulation of calcium. Attempts to clear some lengths of the pipe using a pressure hose were successful, but it was found that a 6-inch drain line originating at the old gatehouse tied into the 8-inch line at some locations and prevented the insertion of the hose. The gallery has been generally flooded since that time except during previous inspections.

Spalled concrete on the upstream and downstream dam faces and training walls were sandblasted and re-covered with shotcrete between 1981 and 1982. Reinforcement mesh was attached to the sandblasted surface before shotcrete was applied. This now exposed reinforcement mesh was observed on the September 24, 2015 inspection. The spillway slab was sandblasted and re-covered with steel fiber

shotcrete. Waterproofing was applied to the upstream face of the dam, and cracks in the upstream face and along the crest were grouted with epoxy. The iron pipe rail along the length of the dam crest was sandblasted and painted. In some areas on the lower downstream side of the dam, holes were drilled into the concrete surface and 1-inch diameter seepage drains were grouted into place. These drains were observed during the inspection and no flow was occurring.

1.3.8 Operating Records

Operation records are kept at the Department of Public Works & Parks office in Worcester. These records include water levels and rainfall. In addition, grass slopes are mowed two to three times per year and vegetation in the riprap slopes is cut once a year.

1.4 Summary Data Table

See Table 1.1 Summary Data Table on the following page at the end of this section.

1.1 Summary Data Table

Required Phase I Report Data	Data Provided by the Inspecting Engineer
National ID #	MA00623
Dam Name	Pine Hill Reservoir Dam
Dam Name (Alternate)	None
River Name	Asnebumskit Brook
Impoundment Name	Pine Hill Reservoir
Hazard Class	High
Size Class	Large
Dam Type	Cyclopean Concrete Gravity Dam/Earthen Embankment
Dam Purpose	Water Supply
Structural Height of Dam (feet)	70
Hydraulic Height of Dam (feet)	60
Drainage Area (sq. mi.)	6.7
Reservoir Surface Area (sq. mi.)	0.525
Normal Impoundment Volume (acre-feet)	9,398
Max Impoundment Volume ((top of dam) acre-feet)	13,023
SDF Impoundment Volume* (acre-feet)	12,254
Spillway Type	Ungated overflow ogee weir
Spillway Length (feet)	75
Freeboard at Normal Pool (feet)	10
Principal Spillway Capacity* (cfs)	6,546
Auxiliary Spillway Capacity* (cfs)	Not applicable
Low-Level Outlet Capacity* (cfs)	Unknown
Spillway Design Flood* (flow rate - cfs)	1/2 PMF/ 4,641 cfs
Winter Drawdown (feet below normal pool)	unknown
Drawdown Impoundment Vol. (acre-feet)	unknown
Latitude	N42.3510
Longitude	W71.9050
City/Town	Holden
County Name	Worcester
Public Road on Crest	No
Public Bridge over Spillway	No
EAP Date (if applicable)	June, 2007
Owner Name	City of Worcester DPW&P
Owner Address	20 East Worcester Street
Owner Town	Worcester, MA 01604
Owner Phone	(508) 799-1476
Owner Emergency Phone	(508) 929-1300 ext. 2113
Owner Type	Municipality or Political subdivision
Caretaker Name	Bruce Blanchard
Caretaker Address	55 Moy Ranch Road
Caretaker Town	Holden, MA 01520
Caretaker Phone	(508) 829-4811
Caretaker Emergency Phone	(508) 829-4811
Date of Field Inspection	9/24/2015
Consultant Firm Name	CDM Smith
Inspecting Engineer	Tyler C. Dunn, P.E.
Engineer Phone Number	(617) 452-6431

*In the event a hydraulic and hydrologic analysis has not been completed for the dam, indicate "No H&H" in this table, recommendation section shall include specific recommendation to hire a qualified dam engineering consultant to conduct analysis to determine spillway adequacy in conformance with 302 CMR 10.00.

Section 2

Section 2
Inspection

2.1 Visual Inspection

Pine Hill Reservoir Dam was inspected on September 24, 2015. At the time of the inspection, the weather was mostly sunny with the temperature of about 70°F. A field sketch and notes are shown on **Figure 5**. Photographs to document the current conditions of the dam were taken during the inspection and are included in **Appendix A**. The photograph locations are shown on **Figure 6**. Underwater portions of the dam were not inspected. A copy of the inspection checklist is included in **Appendix B**.

2.1.1 General Findings

In general, Pine Hill Reservoir Dam was found to be in **Fair** condition. Deficiencies observed include upstream face concrete cracking and efflorescence, spalling and delamination of the shotcrete on the downstream face of the dam, exposed wire mesh on the face of the dam with some vegetation growing in the cracks, spalling and efflorescence of the concrete on the spillway, spalling and cracking of concrete on the dam crest, exposed rebar on the right training wall and right downstream face, calcium deposits and wet areas on the left concrete downstream face, depressions and slightly damp ground surface at the right toe of the dam, and accumulation of calcium deposits and some horizontal cracking in the walls of the drainage gallery. There is no operations and maintenance manual. Seepage and stability analyses, and hydrologic and hydraulic analyses which have not been performed previously, are being addressed currently for an engineering assessment and preliminary rehabilitation design by CDM Smith. Specific concerns are detailed in the sections below.

2.1.2 Dam

Abutments

The abutment contacts of the earth embankments at the dam appear to be good (Photos 4 and 5). The crests and downstream slopes of the natural abutments are covered with maintained grass. The left and right abutments are riprap-lined on the upstream faces. The left abutment ties into natural ground, and the right abutment ties into bedrock on the right embankment.

Upstream Face

The riprap on the upstream slopes of the earth embankments is in good condition. Removal of some vegetation and brush is needed along the right embankment (Photo 1). The upstream portions of the concrete dam have some cracking and spalling of the shotcrete coating which has allowed some vegetation to root in its surface (Photo 18). Mineral deposits were noted below many of these cracks.

Crest

The concrete dam crest is generally in fair condition. Cracking and spalling is exhibited along the length of the concrete crest, and a small amount of vegetation is taking root (Photos 12, 19 and 21). Moss and vegetation are also growing in joints along the concrete dam crest. In addition, there are longitudinal cracks along the steel pipe railing on the concrete crest (Photo 38). The crest of the left earth embankment is covered with maintained grass about 4 to 5 inches tall. The crest of the right earth embankment is

covered with an asphalt access road that has severe deterioration with ruts and cracks and is in need of repair (Photos 4 and 20).

Downstream Face

The grass-covered downstream slopes of the earth embankment are covered with maintained grass about 4 to 5 inches tall (Photos 6 and 7). Some tractor ruts and bare spots (Photo 37) were found parallel to the slope on the left downstream face. The area approximately 20-feet-wide by 40-feet-long at the base of the dam, right of the gate house, previously observed in 2012 as soft, damp ground, was much drier and firm during this inspection (Photo 14). Much of the shotcrete surface on the downstream face of the concrete dam is cracked, spalled and delaminated. Some vegetation has taken root in the cracks (Photos 29 and 30). Mineral deposits were noted below many of the spalled areas. One area has exposed wire mesh reinforcement from the shotcrete application performed between 1981 and 1982 (Photos 25 and 26). Calcium deposits were noted along the left concrete downstream face along with damp areas (Photo 27).

Drains

Several 1-inch diameter PVC pipes were observed on the downstream face of the concrete dam (Photo 31). These pipes were installed in the dam during the installation of shotcrete. A 9.5-inch deep weephole was observed on the downstream face of right dam section.

The seepage infiltration gallery was not observed during this inspection. A detailed structural inspection was performed in September 2014 as part of the field investigation for the preliminary rehabilitation design of the dam. It has been reported that the 8-inch diameter cast iron outlet drain has been blocked since the 1960's, causing the seepage water to flow out of the top of the infiltration gallery access manhole downstream of the dam (Photos 33 and 34).

Instrumentation

Instrumentation was installed as part of the field investigations for the preliminary rehabilitation design for Pine Hill Reservoir Dam. Nine observation wells were installed in completed borings and cores on the crest and downstream slope of the dam during September and October 2014.

Access Roads and Gates

The access road to the dam is a paved travel way along the southern side of Asnebumskit Canal and Asnebumskit Brook. The access road is in good condition and is only used by the City of Worcester DPW&P personnel. Connection to the access road from beyond the Kendall Reservoir and Pine Hill Reservoir limits is from Kendall Road. There are at least two gates controlled and maintained by the City of Worcester DPW&P personnel that restrict vehicle access to the dam.

2.1.3 Appurtenant Structures

The appurtenant structures at the dam consist of the overflow spillway and three upper gates and two lower gates with controls in the gate house.

Primary Spillway

In general, the condition of the spillway is similar to the condition reported during the last inspection with some additional deterioration of the concrete face. The upstream water level was 6 feet below the concrete ogee spillway crest at the time of inspection. Some cracking, spalling and efflorescence of the downstream face of the spillway and training walls was evident (Photos 2, 8, 9, 10, 11, 22, 23, and 24). Longitudinal cracks were observed along the stilling basin stone steps, over which water from the stilling

basin was flowing. Exposed rebar was observed on the top face of the baffle blocks at the base of the spillway (Photo 39).

Low-Level Outlets

The dam has five gates for water release at various levels below the spillway crest as previously described in Section 1.2.4. Two of these gates, the primary outlet and the mud gate, are constructed at relatively low levels. The upper three gates are intakes for water supply. It was reported by Mr. Blanchard in the 2006 inspection that the mechanisms for all five gates and the upper gate house itself were renovated in 2001.

2.1.4 Downstream Area

The water that is discharged from the dam spillway flows into a bedrock channel (Photo 13) and then enters Asnebumskit Brook. Water flows in this brook downstream to the Headworks Dam. Water that flows over the spillway of the Headworks Dam flows to Eagle Lake while water that passes through the Headworks Dam sluice gate is diverted to the Asnebumskit Canal leading to Kendall Reservoir. The area downstream of the dam is heavily wooded (Photo 13) and undeveloped until reaching Eagle Lake and the village of Jefferson.

2.1.5 Reservoir Area

The Pine Hill Reservoir has no residential or commercial uses. The surrounding area consists of wooded hills. These areas are maintained by the City of Worcester. The trees and brush are cleared within about 50 feet of the shoreline about every other year.

2.2 Caretaker Interview

Mr. Bruce Blanchard is the official caretaker of Pine Hill Reservoir Dam. At the time of this inspection, Mr. Blanchard was not available for an interview. Mr. Matthew Dufresne, representative of the caretaker, accompanied the inspection team during the inspection. Mr. Dufresne described the normal operations and the site history. Information provided by Mr. Dufresne has been incorporated into this report and included:

1. The slopes and downstream area are mowed two to three times a year.
2. Trees and brush are cut back away from the reservoir shoreline approximately every other year.
3. The reservoir level is adjusted to maximize water storage.
4. The three upper gates are connected to the 30-inch diameter outlet pipe, which connects Pine Hill Reservoir to Kendall Reservoir to Quinapoxet Reservoir.
5. Pine Hill Reservoir Dam has never been overtopped.
6. The operators for all five gates and the upper gate house itself were renovated in 2001.
7. Shotcrete was applied to the dam and spillway as previously described in Section 1.3.7.
8. Field investigations were begun in 2014 for the preliminary rehabilitation design.

2.3 Operation and Maintenance Procedures

2.3.1 Operational Procedures

The three upper gates in the inlet gate house are regulated as needed to withdraw water from the reservoir. This water then flows through a 30-inch diameter discharge pipe to a valve in the outlet gatehouse at the toe of the spillway. Opening this valve allows water to flow into the stilling basin (Photo 12), down the spillway channel, into the Asnebumskit Brook, and then into the Kendall Reservoir or Eagle Lake. A 24-inch diameter pipeline from Kendall reservoir is also connected to the 30-inch diameter outlet pipe at the Pine Hill Reservoir Dam so that water may be drained from Pine Hill Reservoir to Kendall Reservoir to Quinapoxet Reservoir or it may be pumped to Pine Hill Reservoir via Kendall Reservoir from Quinapoxet Reservoir utilizing the Quinapoxet Reservoir pumps.

2.3.2 Maintenance of Dam and Operating Facilities

Mr. Dufresne reported that maintenance of the dam is performed on an annual basis. The grass embankments are mowed two to three times per year. About every other year, trees and vegetation are cleared about 50 feet from the reservoir shore. Repair work is performed as needed.

2.4 Emergency Warning System

There is no Emergency Warning System. An Emergency Action Plan was prepared by CDM Smith in June 2007, and is currently being updated.

2.5 Hydraulic/Hydrologic Data

A new hydrologic and hydraulic analysis is currently underway for the preliminary rehabilitation design.

COE (1978) reported the PMF flow can be discharged over the spillway with about 2 feet of freeboard. COE (1978) reported the Probable Maximum Flood (PMF) was determined to be 1,300 cfs per square mile. According to the referenced report, this calculation was based on an average drainage area slope of 2.8 percent, a pond-plus-swap area to drainage area ratio of 11.4 percent, and the U.S. Army Corps of Engineers guide curves for Maximum Probable Flood Peak Flow Rates (dated December 1977). Applying the full PMF calculated by COE (1978) to the drainage area of 7.14 square miles results in a calculated peak flood flow of 9,280 cfs as the inflow test flood. By adjusting the inflow test flood for surcharge storage, the maximum discharge rate is estimated at 5,810 cfs (814 cfs per square mile), with a water surface at approximately El. 918.

Hydraulic analyses by the referenced report indicated that the three spillway bays can discharge a total of 6,546 cfs at El. 920, which is the top of the dam. Therefore, the spillway can discharge the full test flood without overtopping the dam. A hydraulic analysis of the 30-inch diameter discharge pipe has not been performed.

Analyses performed for the 1993 inspection indicated that the spillway could safely pass the current Spillway Design Flood (SDF) of ½ PMF. Based on the 1978 simplified analyses and the 1993 analyses, it appears that the spillway should be able to safely pass the ½ PMF. However, updated hydrologic and hydraulic analyses are currently underway by CDM Smith to confirm the maximum water surface and freeboard during the SDF and the discharge capacity of the 30-inch diameter discharge pipe.

2.6 Structural and Seepage Stability

2.6.1 Embankment Structural Stability

During the inspection, there was no evidence to indicate a potential sloughing/sliding of the embankment slopes. A detailed stability analysis that would include an evaluation of the dam under various loading conditions was not performed. Preliminary structural stability analyses of the concrete dam by COE (1978) indicated that the dam has an adequate factor of safety relative to overturning and relative to sliding along its base if it is keyed into bedrock. However, COE (1978) indicated the dam may be vulnerable to a shear failure in the masonry along a possible horizontal failure plane at the elevation of the bottom of the stilling basin pool, approximately El. 847.0. Embankment and structural stability analyses are currently underway by CDM Smith as part of the preliminary rehabilitation design.

2.6.2 Structural Stability of Non-Embankment Structures

The lower gatehouse located to the right of the stilling basin houses the gate valve control to regulate the flow through the 30 inch cast iron discharge pipe to the stilling basin. The concrete structure appeared to have no signs of structural defects or deterioration.

2.6.3 Seepage Stability

Possible seepage was noted on the right downstream slope near the gate house during previous inspections. Efflorescence was also observed below cracks and spalled shotcrete areas on the face of the dam. These conclusions are further supported by findings in previous Phase I reports.

Specifically, COE (1978) reported "cracking, seeping, and efflorescence at the dam could partially be related to the blockage and flooding of the inspection gallery and outlet pipe. This may have caused seepage to find other paths through the dam instead of being intercepted by the vertical drainage wells which discharge to the inspection gallery. When water flows through cracks in concrete, it brings to the surface the soluble calcium hydroxide that results from the reaction of cement and water. The stones used in the cyclopean masonry are rich in iron content hence the rust-colored stains at the leakage areas". A seepage and stability analysis of this structure is currently underway as part of the preliminary rehabilitation design by CDM Smith.

Section 3

Section 3
Assessments and Recommendations

3.1 Assessments

In general, the overall condition of the Pine Hill Reservoir Dam is **Fair.** The dam was found to have the following deficiencies:

1. Spalled concrete on the upstream and downstream faces of the dam and on the spillway slab and training walls. Seepage through the concrete dam is considered to be a contributing factor to the continuing deterioration of this concrete.
2. Cracks and efflorescence in concrete in the crest, upstream face, and downstream face of the dam and in the spillway slab and training walls. Vegetation needs to be removed from some cracks.
3. Brush and vegetation growing in riprap and in the embankment where it adjoins the concrete dam and spillway.
4. Outlet drain for infiltration gallery is blocked so that seepage water floods the gallery and flows out through top of access manhole for the gallery.
5. Depressions and slightly damp ground surface on the right downstream slope between the dam and outlet gate house, which may be attributable to possible seepage through the face of the concrete dam.
6. Exposed reinforcing steel (rebar) on the right training wall, baffle blocks, and right downstream face, and exposed mesh on left downstream face.
7. Tractor ruts and bare spots parallel to the slope on the left downstream embankment slope.
8. There is no Operations and Maintenance Manual for this dam.
9. There is no updated seepage or stability analysis for the concrete masonry dam and the embankment for a revised spillway design flood analysis. Stability and seepage analyses are currently underway for an engineering assessment and preliminary rehabilitation design by CDM Smith.
10. Broken steps on access ladder in right access manhole to drainage gallery.

Previously identified deficiencies and major recommendations from prior inspection reports are summarized in the table below. The table also indicates the present condition or resolution of the deficiencies and recommendations.

Previously Identified Deficiency	*Resolution or Current Condition*
Wet area at base of right abutment may be due to seepage through face of dam.	Saturated/depressed area being monitored. An engineering assessment and preliminary rehabilitation design by CDM Smith is underway.
Outlet pipe blocked with sedimentation and water flowing out of seepage gallery manhole cover.	Flow from seepage gallery being monitored. An engineering assessment and preliminary rehabilitation design by CDM Smith is underway.
Spalling and cracking of dam shotcrete and concrete on upstream and downstream face.	Condition of shotcrete and concrete continues to degrade. Exposed reinforcement wire mesh observed on downstream face. An engineering assessment and preliminary rehabilitation design by CDM Smith is underway.
Update Emergency Action Plan.	Prepared June 2007 by CDM Smith; currently being updated.
Prepare, update and follow procedures outlined in the Operation and Maintenance Manual.	An Operation and Maintenance manual has not been prepared.
Vegetation and debris on upstream embankments.	Vegetation and debris were removed except vines at left abutment, which appeared to be dead at the time of inspection. Minor amount of vegetation growing in riprap on right upstream slope, but otherwise, brush and trees have been cleared.
There is no stability analysis or seepage analysis for the dam.	Stability and seepage analyses have been started on the dam and embankments. An engineering assessment and preliminary rehabilitation design by CDM Smith is underway.

The following recommendations and remedial measures generally describe the recommended approach to address current deficiencies at the dam. Prior to undertaking recommended maintenance, repairs and remedial measure, the applicability of environmental permits needs to be determined prior to undertaking activities that may occur within resource areas under the jurisdiction of local conservation commissions, MassDEP, or other regulatory agencies.

3.2 Studies and Analyses

This section identifies studies that should be completed to evaluate concerns and/or comply with current regulations.

1. The Emergency Action Plan should be reviewed and updated to reflect any changes in property owners or new construction in the inundation zone to ensure the most current information. The EAP is currently being updated.

2. Prepare an Operations and Maintenance Manual. The manual should include periodic inspection schedules, operational and maintenance procedures required to ensure satisfactory operation of the dam to minimize deterioration to the facility.

3. Perform a seepage and stability analysis of the dam. Evaluate the downstream concrete surfaces and the concrete spalling that is likely associated with this seepage. This study should include recommendations to provide drainage for these areas to allow a protective surface treatment to maintain adherence to the concrete surface. This study should also include an investigation of the cause of the routine clogging of the infiltration gallery drainage system to facilitate remedial repairs. As part of the seepage analyses, packer testing should be performed. Additionally, concrete core samples should be analyzed and tested. The stability analysis of the concrete masonry dam and the embankment should be performed in accordance with current state requirements, and the structure should be evaluated under normal and extreme loading condition which should include seismic loading (Underway).

4. Perform an updated hydrologic and hydraulic analysis of the dam to evaluate the spillway design flood for a ½ PMF design storm in accordance with current dam safety regulations (Underway).

5. Perform underwater inspection of the upstream face of the dam to determine condition of concrete (inspection complete; results to be incorporated into a Preliminary Design Report).

3.3 Recurrent Maintenance Recommendations

This section discusses those activities that should be undertaken on a regular or yearly basis. Typically these activities are recurrent maintenance level activities that can be undertaken by the dam owner/caretaker and do not require engineering design.

1. Regular maintenance activities should be performed at least twice a year or as conditions warrant from the Spring to Fall to control and limit growth of vegetation on the dam.

2. Perform monthly monitoring and inspection of the dam, especially in areas of suspected seepage through the downstream concrete surfaces.

3. Check operation of all gates.

4. Perform crack repair and filling annually.

5. Monitor for erosion and animal burrows on the embankments and repair as needed.

6. The seepage infiltration gallery should be inspected annually.

3.4 Repair Recommendations

This section presents recommended activities to improve the overall condition of the dam that do not alter the current design of the dam. These recommendations may require design by a professional engineer and construction by a contractor experienced in dam repair.

1. Repair downstream dam face; remove shotcrete and deteriorated concrete, place new cast-in-place concrete.

2. Repair concrete spalling, cracking on upstream and downstream face of dam and on spillway slab and training walls.

3. Control seepage through the dam's concrete surfaces. Re-grout areas of spalled and damaged concrete on dam and on spillway slab and walls.

4. Construct a new drainage outlet for the seepage infiltration gallery and maintain the gallery in a drained condition.

3.5 Remedial Modifications Recommendations

There are no recommended remedial measures.

3.6 Alternatives

There are no alternatives to the recommendations presented above.

3.7 Opinion of Probable Construction Costs

The following conceptual opinions of probable construction costs have been developed for the recommendations and remedial measures noted above. The costs are based on a limited investigation and are provided for general information only. This should not be considered as an engineer's estimate as actual costs may be somewhat more or less than indicated.

Studies and Analyses

1. Update the EAP (underway)	N/A
2. Prepare Operations and Maintenance Manual	$ 6,000 - $ 9,000
3. Seepage Analysis and Stability Analysis (underway)	$ 80,000 - $120,000
4. Hydrologic and Hydraulics Analyses (underway)	$ 15,000 - $ 20,000
5. Underwater Inspection of Upstream Face of Dam (underway)	$ 17,000 - $ 19,000
	$118,000 - $168,000
Contingency (20%)	$ 23,600 - $ 33,600
Subtotal (rounded)	$142,000 - $202,000

Recurrent Maintenance Recommendations

Assumed to be performed by City of Worcester DPW & Parks personnel

1. Perform regular maintenance	$ N/A
2. Perform monthly monitoring and inspection	$ N/A
3. Check operation of all gates	$ N/A
4. Perform annual crack repair	$ N/A

5. Monitor & repair erosion and animal burrows		$ N/A
6. Inspect drainage gallery annually		$ N/A

Repair Recommendations

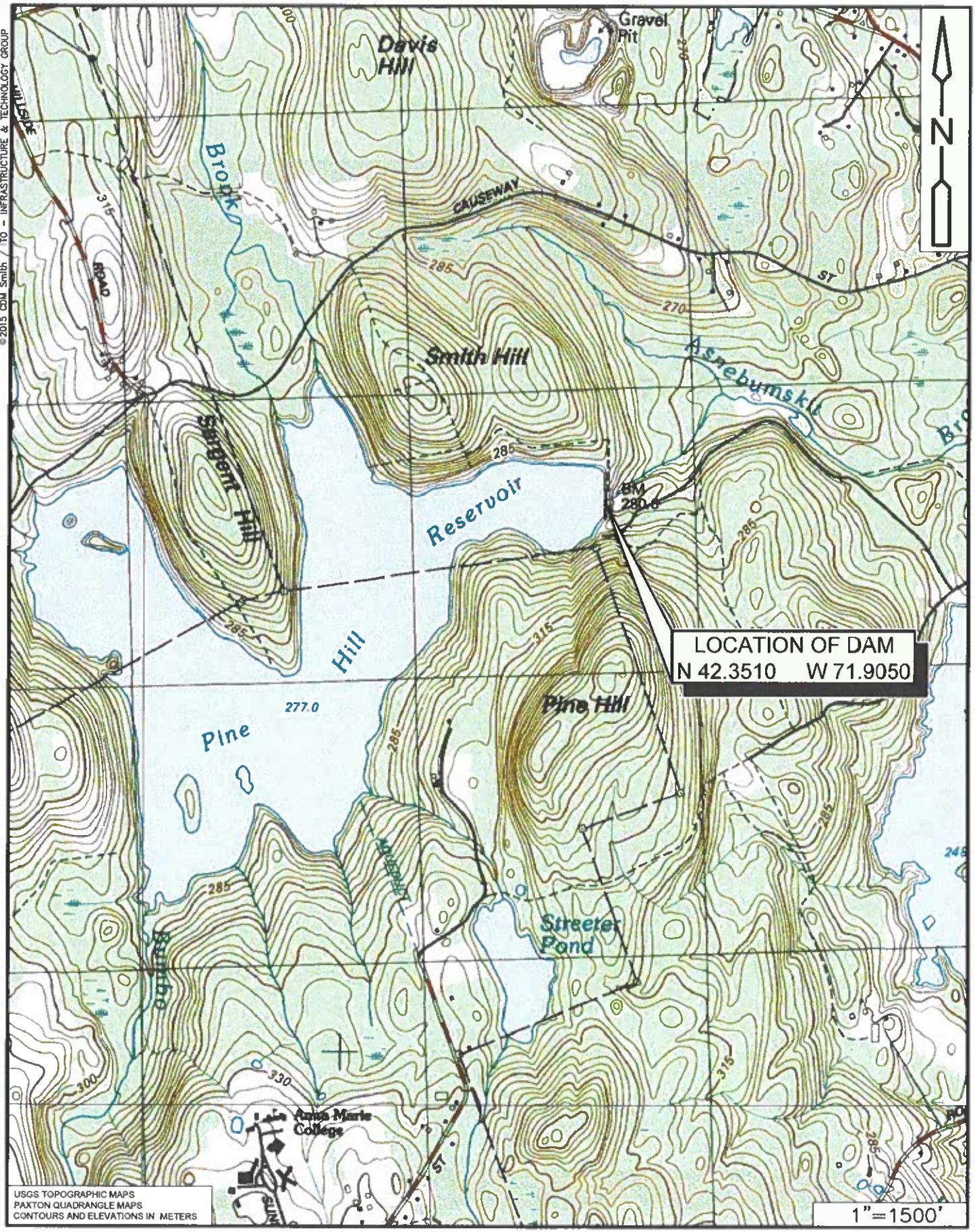
1. Remove shotcrete and remediate downstream dam face[1]		$ 700,000 - $ 900,000
2. Spillway surface remediation & Training Wall Repairs[1]		$ 150,000 - $ 195,000
3. Control seepage through concrete[1]		$ 110,000 - $ 215,000
4. Repair infiltration gallery outlet[1]		$ 18,000 - $ 25,000
5. Upstream dam face repair[2]		not included
		$ 978,000 - $1,335,000
	Contingency (20%)	$ 195,600 - $ 267,000
	Subtotal (rounded)	$1,174,000 - $1,602,000
	TOTAL (rounded)	**$1,316,000 - $1,804,000**

[1] Costs do not reflect results of preliminary design for rehabilitation, which is currently underway. Costs are escalated from April 2012 Phase I Report.

[2] Costs for the upstream face of the dam and approach spillway are not included based on limited information at this time. An underwater inspection (underway) and completion of preliminary design will provide information as to the extent of any repairs needed.

Appendices

Figures



CDM Smith

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS
PINE HILL RESERVOIR DAM
STATE DAM ID NO.: 3-14-134-6 NID ID NO.: MA00623

LOCUS MAP
FIGURE 1
SEPTEMBER 2015

AERIAL PHOTOGRAPH SOURCE:
GOOGLE EARTH PRO.

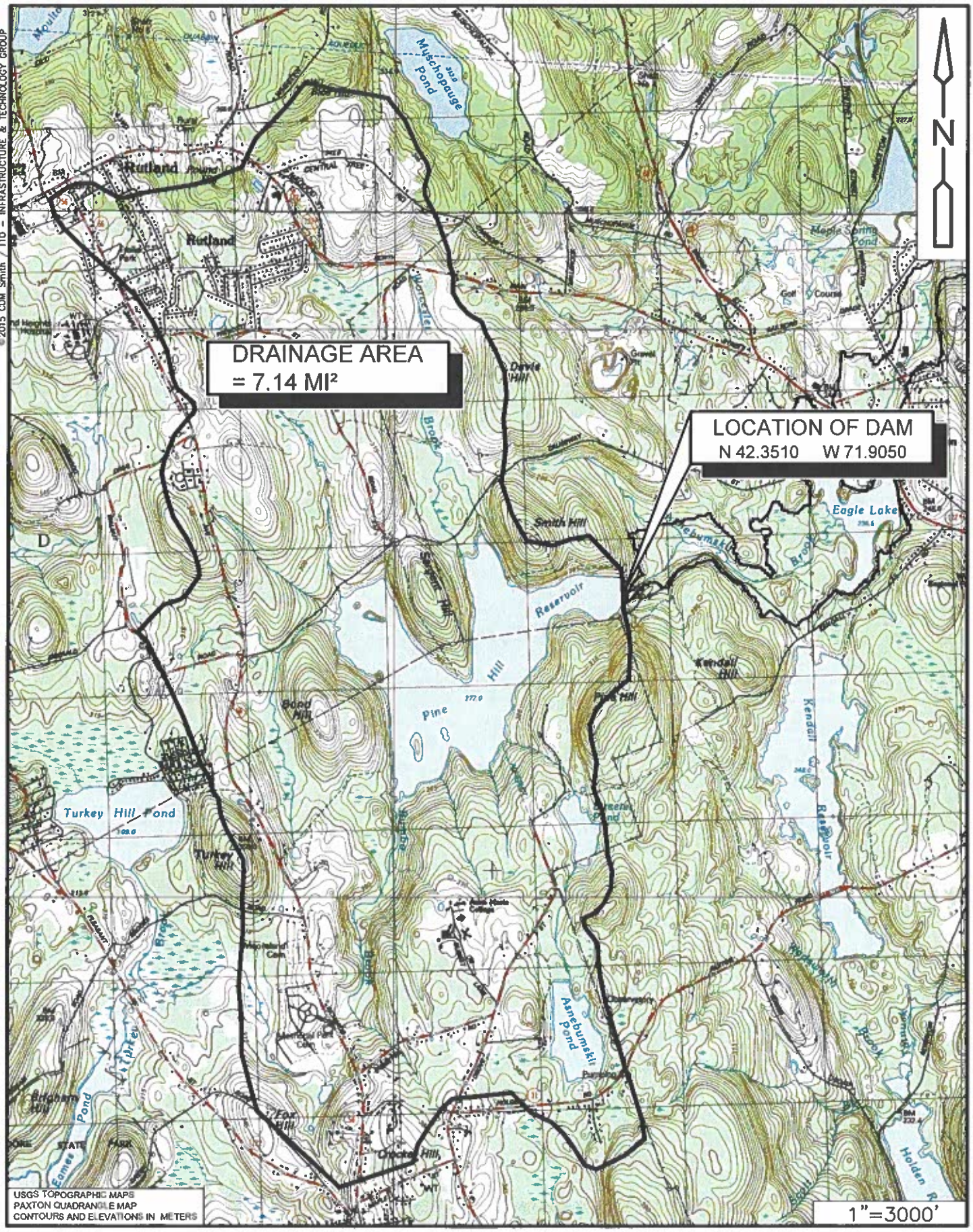
1"=1000'

PW_XM1\Documents\0198\91111\03 Reports and Studies\09 CADD Figures and Graphics\Pine Hill Reservoir Dam\B002AERL.dwg

CDM Smith

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS
PINE HILL RESERVOIR DAM
STATE DAM ID NO.: 3-14-134-6 NID ID NO.: MA00623

AERIAL MAP
FIGURE 2
SEPTEMBER 2015



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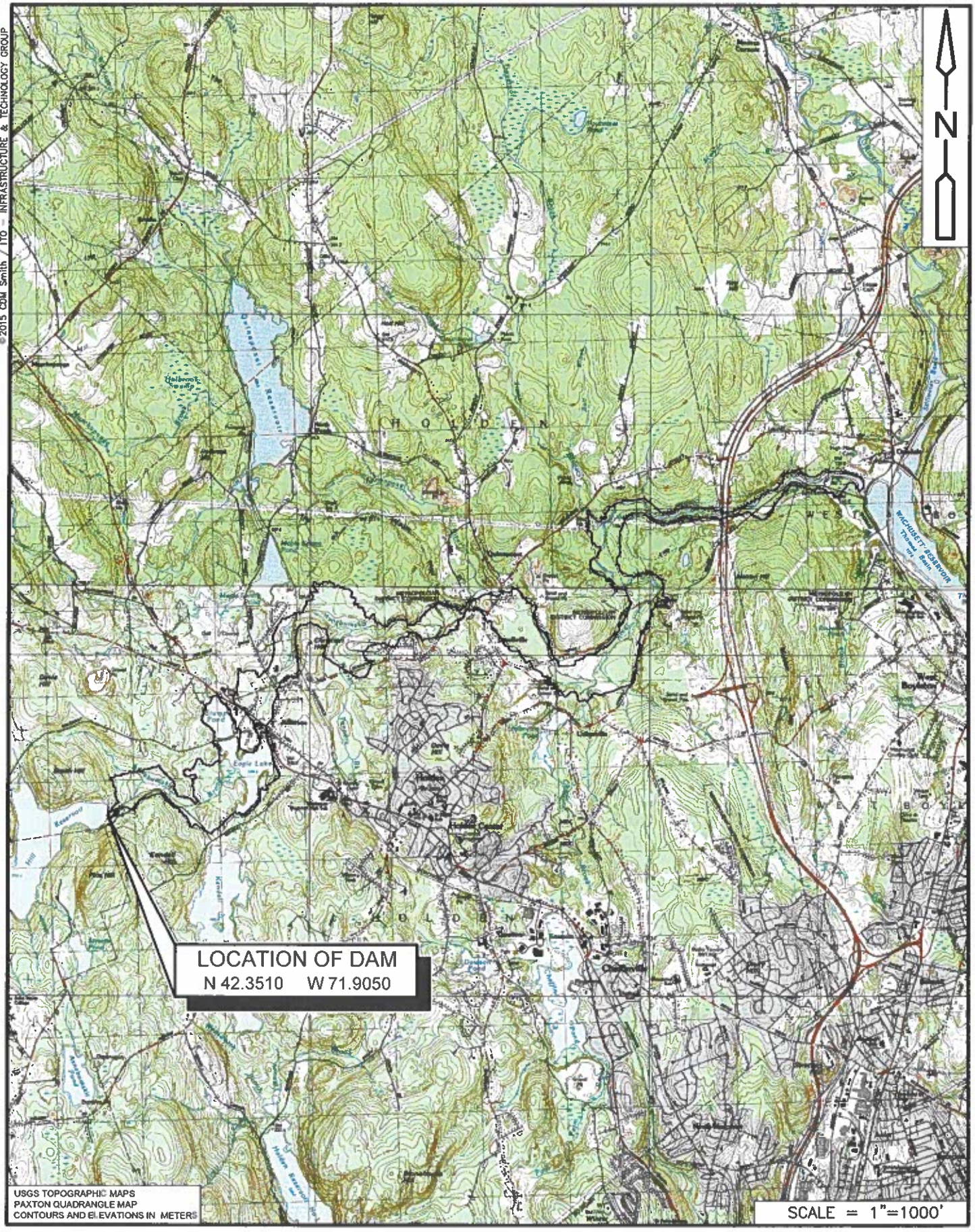
CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS
PINE HILL RESERVOIR DAM
STATE DAM ID NO.: 3-14-134-6 NID ID NO.: MA00623

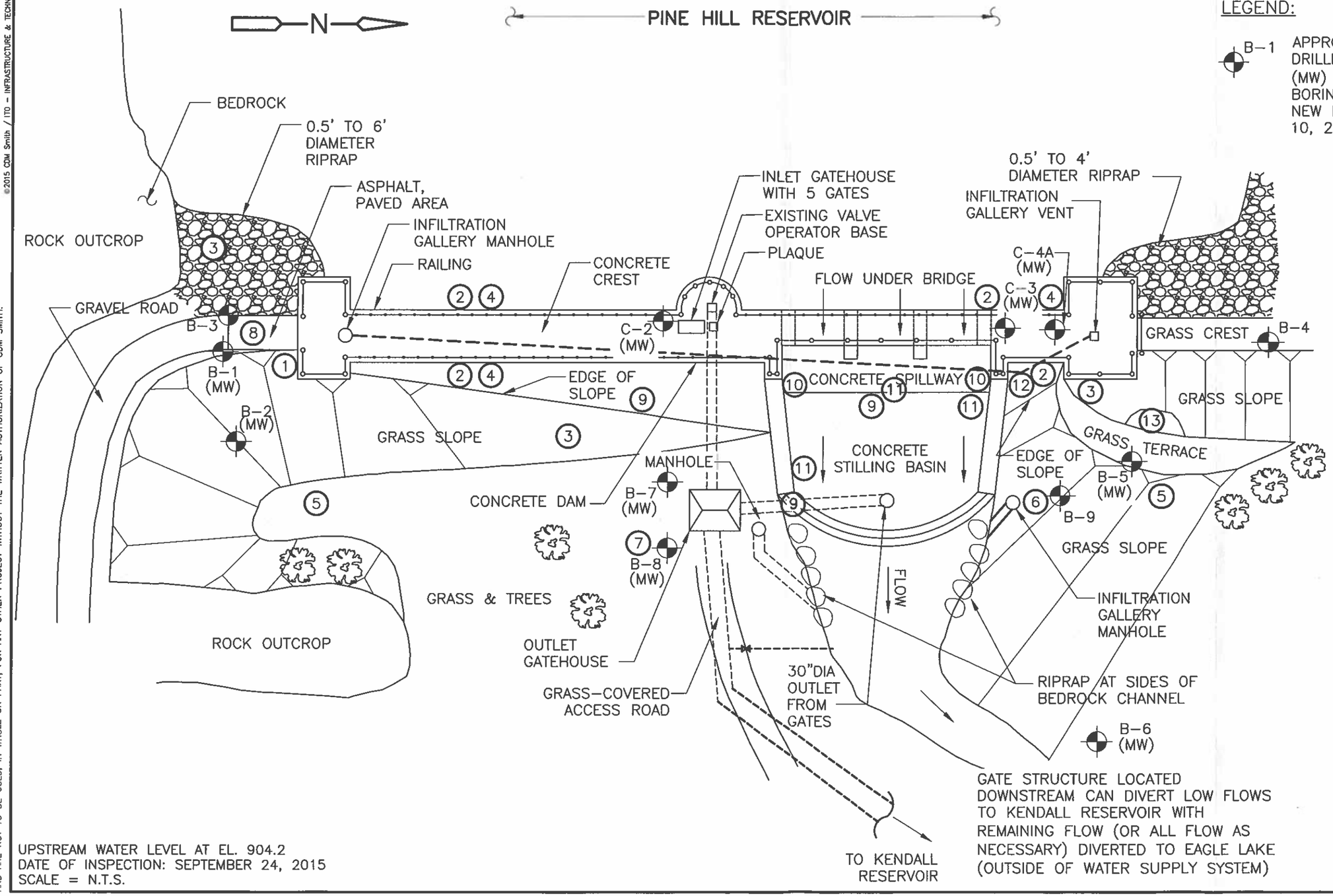
DRAINAGE AREA
FIGURE 3
SEPTEMBER 2015



CDM Smith

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS
PINE HILL RESERVOIR DAM
STATE DAM ID NO.: 3-14-134-6 NID ID NO.: MA00623

DOWNSTREAM AREA
FIGURE 4
SEPTEMBER 2015



LEGEND:

B-1 APPROXIMATE LOCATION OF BORINGS DRILLED AND MONITORING WELLS (MW) INSTALLED BY NEW ENGLAND BORING CONTRACTORS OF DERRY, NEW HAMPSHIRE FROM SEPTEMBER 10, 2014 TO OCTOBER 10, 2014

1. BROKEN GUARDRAIL
2. SHOTCRETE SLOUGHING FROM SOME CONCRETE SURFACES
3. SOME BRUSH, BUSHES, AND VINES
4. SOME CONCRETE CRACKING WITH MINERAL DEPOSITION
5. A FEW EROSION RILLS ON GRASS-COVERED SLOPE
6. WATER FLOWS OUT OF TOP OF INFILTRATION GALLERY MANHOLE
7. VEGETATION
8. RUTS AND CRACKS IN ASPHALT ON CREST
9. EXPOSED REBAR
10. CONCRETE FILLET MISSING FROM SPILLWAY
11. CONCRETE SPALLING AND EFFLORESCENCE
12. EXPOSED WIRE MESH
13. LARGE DEPRESSION IN SLOPE DUE TO DRILLING EQUIPMENT

UPSTREAM WATER LEVEL AT EL. 904.2
DATE OF INSPECTION: SEPTEMBER 24, 2015
SCALE = N.T.S.

CDM Smith

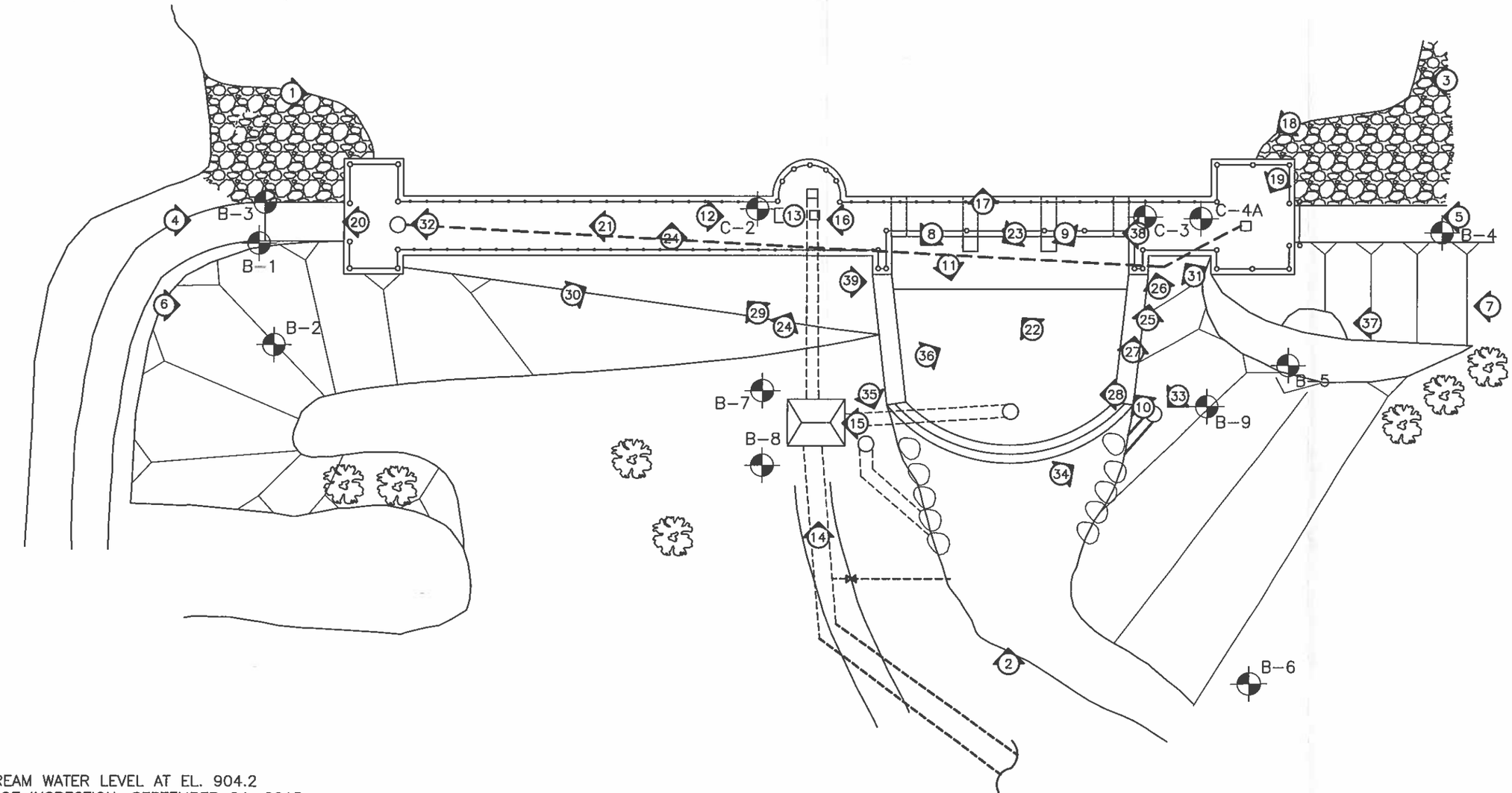
CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS
PINE HILL RESERVOIR DAM
STATE DAM ID NO.: 3-14-134-6 NID ID NO.: MA00623

FIELD SKETCH AND NOTES
FIGURE 5
SEPTEMBER 2015

LEGEND:

② PHOTOGRAPH NUMBER AND ORIENTATION

B-1 APPROXIMATE LOCATION OF BORINGS DRILLED AND MONITORING WELLS (MW) INSTALLED BY NEW ENGLAND BORING CONTRACTORS OF DERRY, NEW HAMPSHIRE FROM SEPTEMBER 10, 2014 TO OCTOBER 10, 2014



UPSTREAM WATER LEVEL AT EL. 904.2
DATE OF INSPECTION: SEPTEMBER 24, 2015
SCALE = N.T.S.

CDM Smith

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS
PINE HILL RESERVOIR DAM
STATE DAM ID NO.: 3-14-134-6 NID ID NO.: MA00623

PHOTOGRAPH LOCATION PLAN
FIGURE 6
SEPTEMBER 2015

Appendix A
Photographs

PINE HILL RESERVOIR DAM
MA00623

Photo No. 1: Overview of dam and upstream face from right abutment. Note vegetation and brush growing in upstream slope riprap.

Photo No. 2: Overview of dam and downstream face from discharge channel.

Photo No. 3: Overview of upstream face and crest from left abutment.

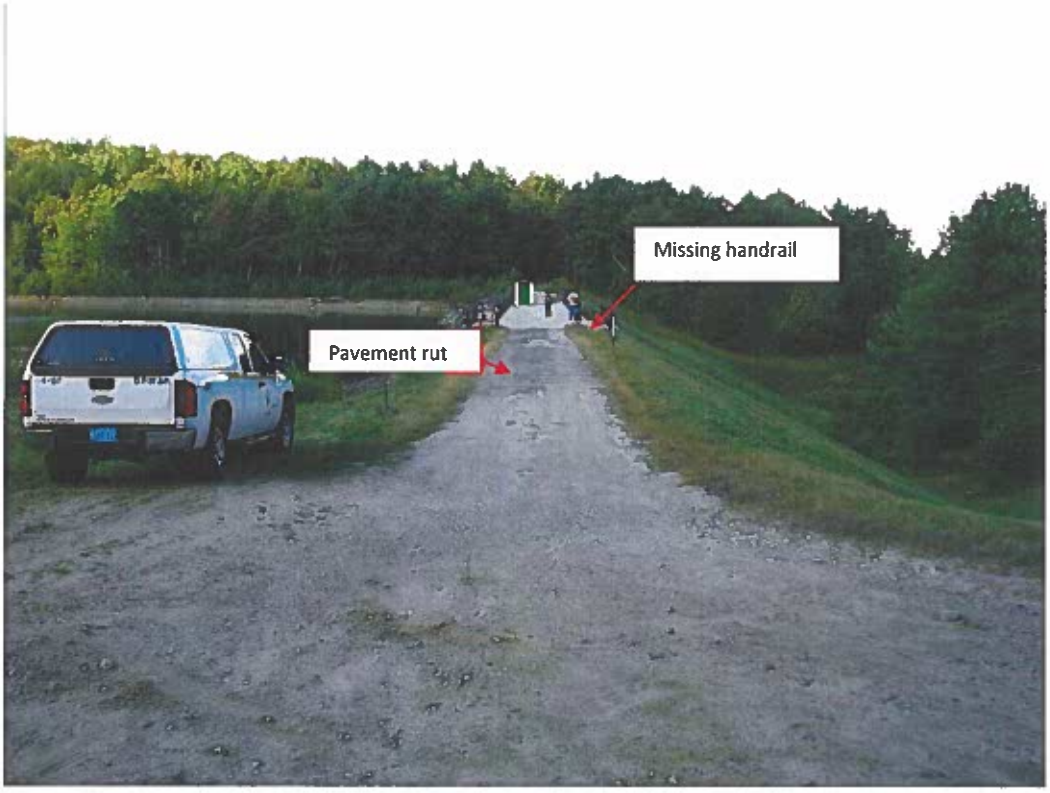


Photo No. 4: Overview of crest from right abutment.

Photo No. 5: Overview of crest from left abutment.

Photo No. 6: Overview of downstream slope from right abutment.

Photo No. 7: Overview of downstream slope from left abutment. Note ruts in grass due to mowing equipment.

Photo No. 8: Overview of right downstream spillway training wall. Note part of concrete fillet is missing and cracks and efflorescence are present.

Photo No. 9: Overview of left downstream spillway training wall. Note part of concrete fillet is missing and cracking and efflorescence are present on the wall.

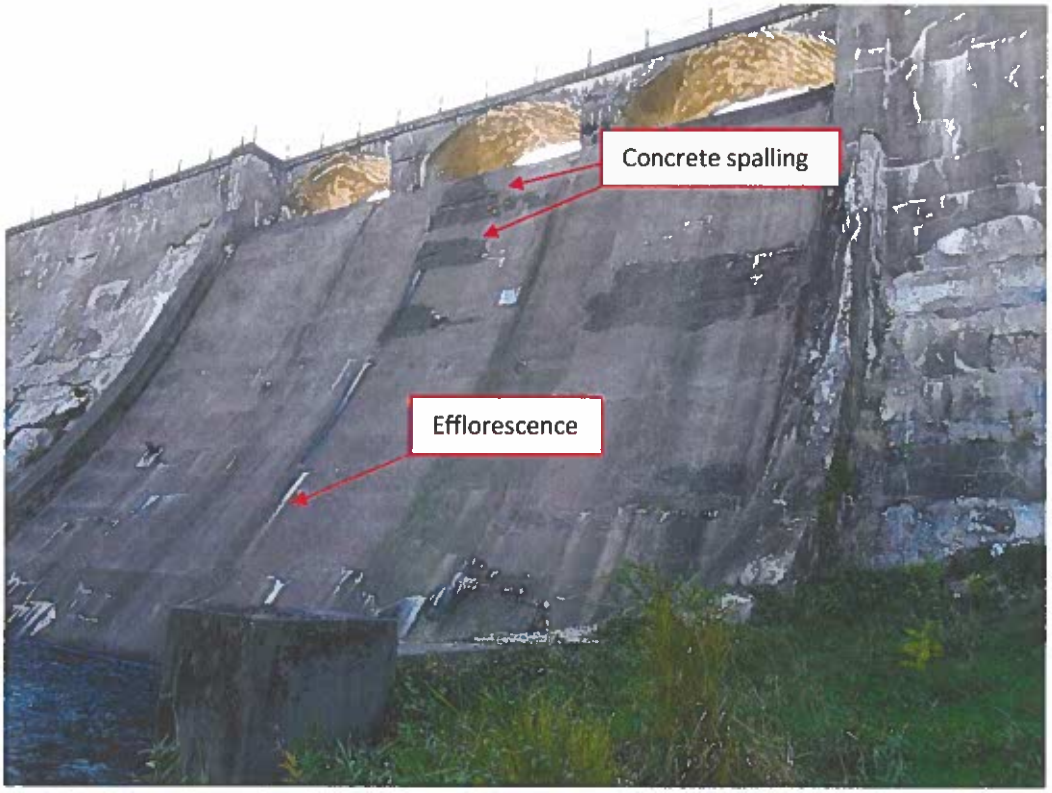


Photo No. 10: Overview of spillway from downstream. Note spalled sections of concrete and efflorescence on spillway weir.

Photo No. 11: Overview of stilling basin looking downstream from the crest. Note variation in elevation of the top of the downstream basin overflow weir. Also note trees along channel.

Photo No. 12: Overview of upper gatehouse exterior. Note cracking, spalling, and puddling along concrete deck.

Photo No. 13: Overview of upper gatehouse interior and gate operators – mudgate, 24" x 26" sluice gate low-level outlet, 3 different level gates at reservoir.

Photo No. 14: Overview of lower gatehouse exterior.

Photo No. 15: Overview of lower gatehouse interior.

Photo No. 16: Monument next to the gatehouse.

Photo No. 17: Overview of reservoir.

Photo No. 18: Cracks and efflorescence on upstream face of dam. Note that some weeds are growing in the cracks.

Photo No. 19: Cracks on crest near left embankment. Note minor weeds and moss growing in the cracks. Rectangular drain leads directly to left-most inspection gallery drainage well.

Photo No. 20: Pavement eroded, rutted, and cracked on right crest (looking towards right abutment).

Photo No. 21: Concrete spalled and cracked on right crest (looking towards right abutment).

Photo No. 22: Cracks/spalling and efflorescence on the spillway surface (view from downstream).

Photo No. 23: Spalling on the spillway surface (view from the crest).

Photo No. 24: A large piece of shotcrete spalled next to the right training wall on the right downstream face. Note weeds growing in the cracks.

Photo No. 25: Spalling of shotcrete left of the spillway (downstream face). Note calcium deposits forming to the left of the left training wall.

Photo No. 26: A large section of shotcrete spalled exposing wire mesh on the downstream face of dam next to left training wall.

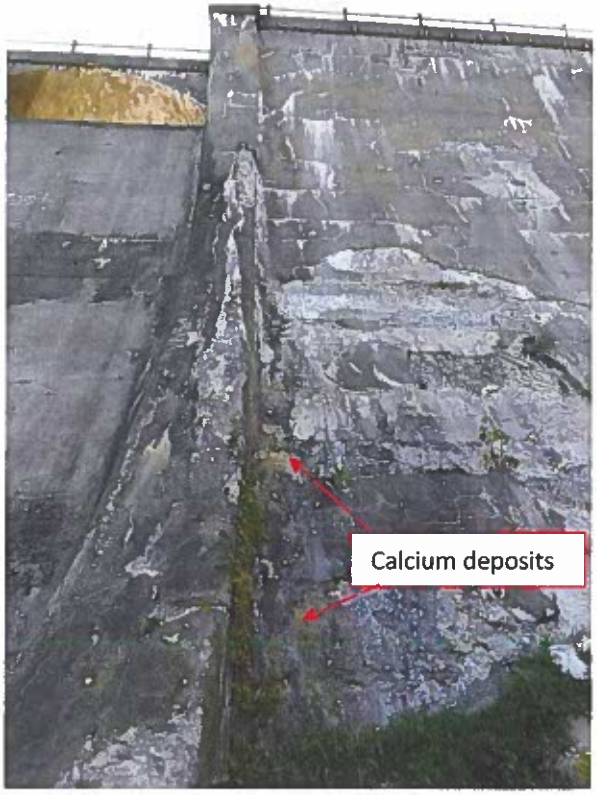


Photo No. 27: Efflorescence and spalling of concrete at toe of left training wall. Note calcium deposits on left downstream face.

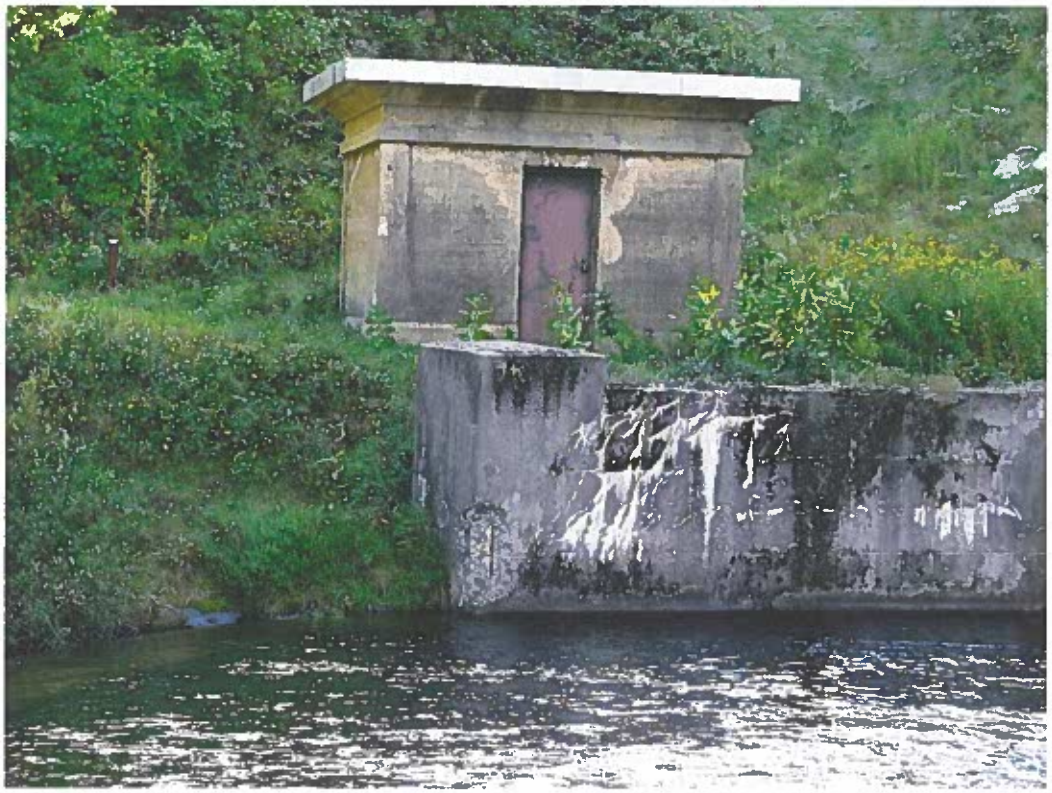


Photo No. 28: Concrete spalling and exposed rebar at the end of the right training wall.

Photo No. 29: Efflorescence, cracking, spalling and weeds growing in the cracks on the downstream face of the dam to right of spillway.

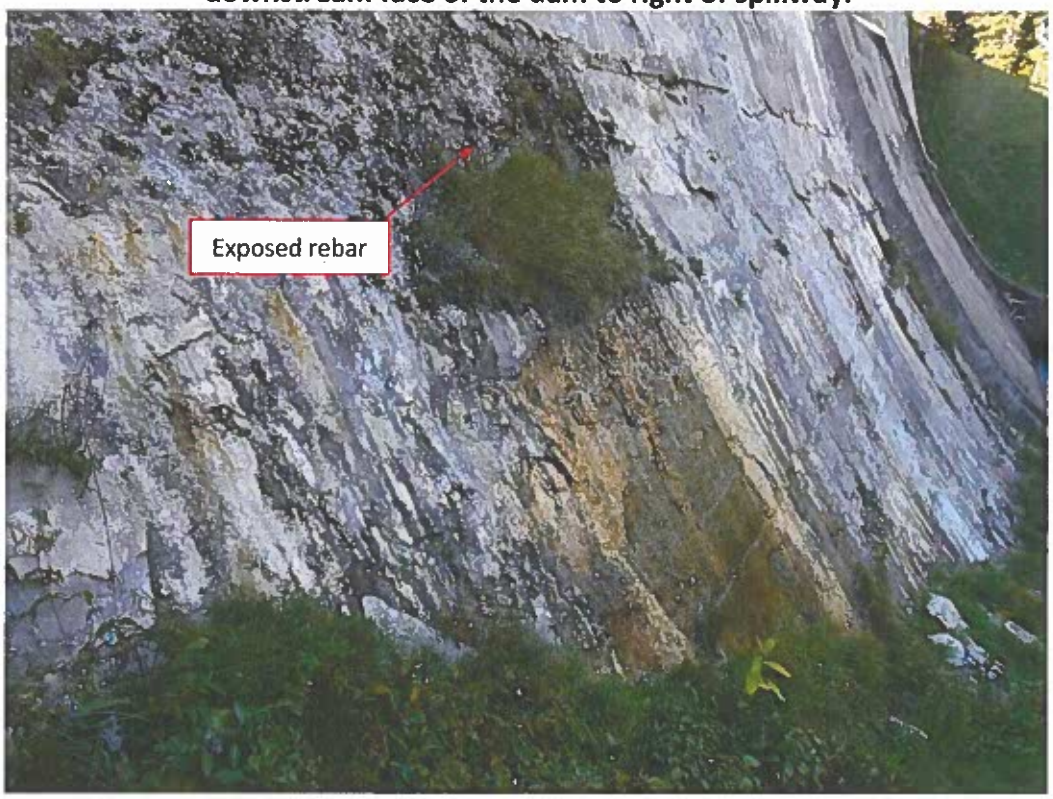


Photo No. 30: Exposed rebar intended to provide anchorage for shotcrete on the downstream face of the dam to right of spillway.

Photo No. 31: PVC weep holes on the downstream face of the dam to left of spillway. Weep holes were installed when dam face was sandblasted and shotcrete-covered in 1981 to 1982.

Photo No. 32: Entrance to the inspection gallery on dam crest. Note the broken ladder steps.

Photo No. 33: Manhole entrance to the inspection gallery under the dam. Water is flowing out of entrance.

Photo No. 34: Downstream manhole access to drainage gallery. Note that water draining from the top of the drainage gallery manhole is causing erosion of the downstream bank.

Photo No. 35: Manhole at the right downstream toe of the dam.

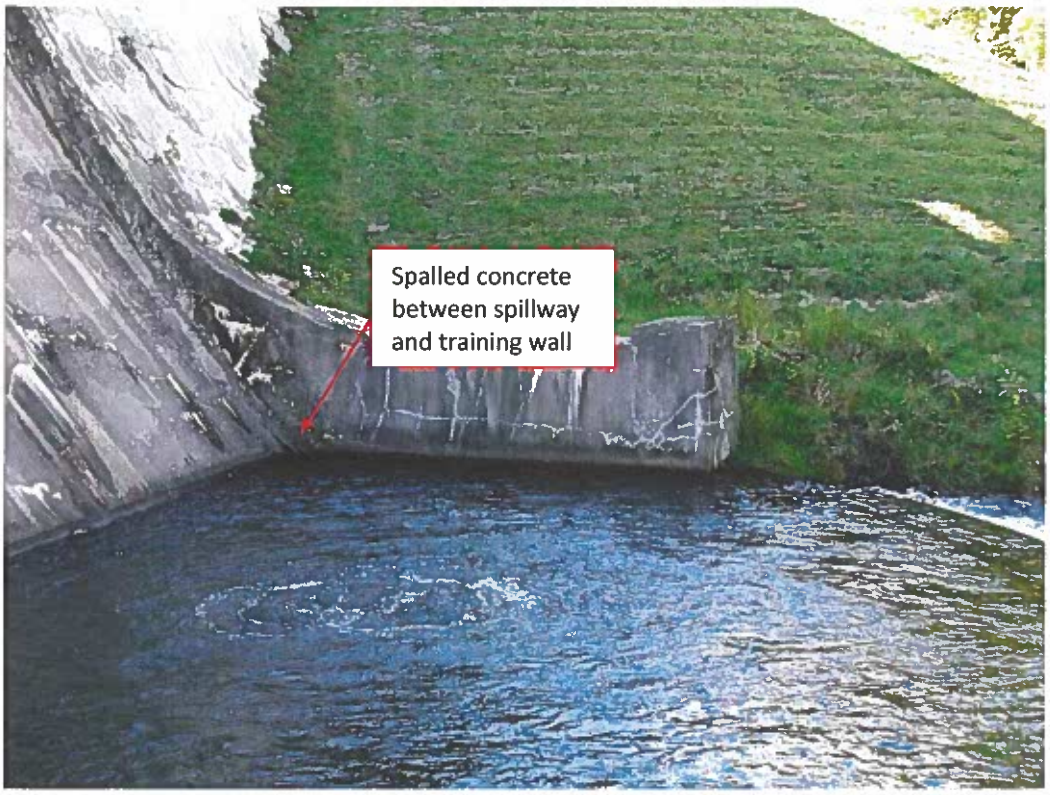


Photo No. 36: Concrete spalled between spillway and training wall at stilling basin. Cracking, spalling, and efflorescence on left training wall.

Photo No. 37: Tractor ruts and bare spots on left embankment downstream slope from mowing. Eroded zone remnant from monitoring well installation.

Photo No. 38: Longitudinal cracks along railing. Spalling, cracking, and efflorescence on concrete arch bridge over spillway. Weeds growing in cracks.

PINE HILL RESERVOIR DAM
MA00623

Photo No. 39: Exposed rebar on baffle blocks in stilling basin.

Appendix B
Inspection Checklists

DAM SAFETY INSPECTION CHECKLIST

NAME OF DAM: Pine Hill Reservoir Dam

STATE ID #: 3-14-134-6

REGISTERED: ☐ YES ☑ NO

NID ID #: MA00623

STATE SIZE CLASSIFICATION: Large

STATE HAZARD CLASSIFICATION: High

CHANGE IN HAZARD CLASSIFICATION REQUESTED?: No

DAM LOCATION INFORMATION

CITY/TOWN: Holden

COUNTY: Worcester

DAM LOCATION: Asnebumskit Brook, off Kendall Rd
(street address if known)

ALTERNATE DAM NAME: None

USGS QUAD.: Wachusett Mountain

LAT.: N42.3510

LONG.: W71.9050

DRAINAGE BASIN: Nashua

RIVER: Asnebumskit Brook

IMPOUNDMENT NAME(S): Pine Hill Reservoir

GENERAL DAM INFORMATION

TYPE OF DAM: Cyclopean Concrete Gravity Dam/Earthen Embankment

OVERALL LENGTH (FT): 840

PURPOSE OF DAM: Water Supply

NORMAL POOL STORAGE (ACRE-FT): 9,398

YEAR BUILT: 1924

MAXIMUM POOL STORAGE (ACRE-FT): 13,023

STRUCTURAL HEIGHT (FT): 70

EL. NORMAL POOL (FT): 910.0

HYDRAULIC HEIGHT (FT): 60

EL. MAXIMUM POOL (FT): 920.0

FOR INTERNAL MADCR USE ONLY

FOLLOW-UP INSPECTION REQUIRED: ☐ YES ☐ NO

CONDITIONAL LETTER: ☐ YES ☐ NO

NAME OF DAM:	Pine Hill Reservoir Dam	STATE ID #:	3-14-134-6
INSPECTION DATE:	September 24, 2015	NID ID #:	MA00623

OWNER:		CARETAKER:	
ORGANIZATION	City of Worcester DPW&P	ORGANIZATION	City of Worcester DPW&Parks
NAME/TITLE		NAME/TITLE	Bruce Blanchard
STREET	20 East Worcester Street	STREET	55 Moy Ranch Road
TOWN, STATE, ZIP	Worcester, MA 01604	TOWN, STATE, ZIP	Holden, MA 01520
PHONE	(508) 799-1476	PHONE	(508) 829-4811
EMERGENCY PH. #	(508) 929-1300 ext. 2113	EMERGENCY PH. #	(508) 829-4811
FAX	(508) 799-1448	FAX	(508) 829-6793
EMAIL	dpw@worcesterma.gov	EMAIL	blanchardb@worcesterma.gov
OWNER TYPE	Municipality or Political subdivision		

PRIMARY SPILLWAY TYPE	Ungated overflow ogee weir		
SPILLWAY LENGTH (FT)	75	SPILLWAY CAPACITY (CFS)	6,546
AUXILIARY SPILLWAY TYPE	Not applicable	AUX. SPILLWAY CAPACITY (CFS)	Not applicable
NUMBER OF OUTLETS	1	OUTLET(S) CAPACITY (CFS)	Unknown
TYPE OF OUTLETS	30-inch-diamter cast iron pipe	TOTAL DISCHARGE CAPACITY (CFS)	6,546
DRAINAGE AREA (SQ MI)	6.7	SPILLWAY DESIGN FLOOD (PERIOD/CFS)	1/2 PMF/ 4,641 cfs

HAS DAM BEEN BREACHED OR OVERTOPPED ☐ YES ☑ NO IF YES, PROVIDE DATE(S)

FISH LADDER (LIST TYPE IF PRESENT) No

DOES CREST SUPPORT PUBLIC ROAD? ☐ YES ☑ NO IF YES, ROAD NAME:

PUBLIC BRIDGE WITHIN 50' OF DAM? ☐ YES ☑ NO IF YES, ROAD/BRIDGE NAME:

MHD BRIDGE NO. (IF APPLICABLE)

NAME OF DAM: Pine Hill Reservoir Dam STATE ID #: 3-14-134-6

INSPECTION DATE: September 24, 2015 NID ID #: MA00623

EMBANKMENT (D/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS Left Embankment	Right Embankment	NO ACTION	MONITOR	REPAIR
D/S SLOPE	1. WET AREAS (NO FLOW)	None observed	None observed		X	
	2. SEEPAGE	None observed	See comment below*		X	
	3. SLIDE, SLOUGH, SCARP	None observed	None observed	X		
	4. EMB.-ABUTMENT CONTACT	Line of trees	Bedrock covered with brush	X		
	5. SINKHOLE/ANIMAL BURROWS	None observed	None observed	X		
	6. EROSION	Tractor ruts and bare spots parallel to slope from tractor.	None observed		X	
	7. UNUSUAL MOVEMENT	None observed	None observed	X		
	8. VEGETATION (PRESENCE/CONDITION)	Possibly dead vines growing up concrete wall at left abutment onto railing and crest of dam.	None observed			X

ADDITIONAL COMMENTS: *Possible seepage through the face of the concrete dam.

NAME OF DAM: Pine Hill Reservoir Dam STATE ID #: 3-14-134-6

INSPECTION DATE: September 24, 2015 NID ID #: MA00623

INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None			
	2. OBSERVATION WELLS	9 observation wells, on crest and downstream slope		X	
	3. STAFF GAGE AND RECORDER	None			
	4. WEIRS	None			
	5. INCLINOMETERS	None			
	6. SURVEY MONUMENTS	None			
	7. DRAINS	None			
	8. FREQUENCY OF READINGS	Not applicable			
	9. LOCATION OF READINGS	Not applicable			

ADDITIONAL COMMENTS:

NAME OF DAM: Pine Hill Reservoir Dam STATE ID #: 3-14-134-6

INSPECTION DATE: September 24, 2015 NID ID #: MA00623

UPSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S WALLS	1. WALL TYPE	Not applicable			
	2. WALL ALIGNMENT	Not applicable			
	3. WALL CONDITION	Not applicable			
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: Not applicable max: Not applicable avg: Not applicable			
	5. ABUTMENT CONTACT	Not applicable			
	6. EROSION/SINKHOLES BEHIND WALL	Not applicable			
	7. ANIMAL BURROWS	Not applicable			
	8. UNUSUAL MOVEMENT	Not applicable			

ADDITIONAL COMMENTS:

NAME OF DAM: Pine Hill Reservoir Dam STATE ID #: 3-14-134-6

INSPECTION DATE: September 24, 2015 NID ID #: MA00623

MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS
MISC.	1. RESERVOIR DEPTH (AVG)	Unknown
	2. RESERVOIR SHORELINE	Stable, woods
	3. RESERVOIR SLOPES	Moderate to steep
	4. ACCESS ROADS	Yes
	5. SECURITY DEVICES	Gated access road
	6. VANDALISM OR TRESPASS	☐ YES ☑ NO WHAT:
	7. AVAILABILITY OF PLANS	☑ YES ☐ NO DATE: Phase I report, October 1978
	8. AVAILABILITY OF DESIGN CALCS	☐ YES ☑ NO DATE:
	9. AVAILABILITY OF EAP/LAST UPDATE	☑ YES ☐ NO DATE: Jun-07
	10. AVAILABILITY OF O&M MANUAL	☐ YES ☑ NO DATE:
	11. CARETAKER/OWNER AVAILABLE	☑ YES ☐ NO DATE: April 11, 2012
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES ☑ NO PURPOSE:

ADDITIONAL COMMENTS:

Appendix C
Reports and References

Reports and References

The following is a list of reports that were located during the file review, or were referenced in previous reports and were utilized during the preparation of this report and the development of the recommendations presented herein:

1. Phase I Inspection/Evaluation Report, Pine Hill Reservoir Dam, prepared by CDM Smith, Cambridge, April 11, 2012.
2. Phase I Inspection/Evaluation Report, Pine Hill Reservoir Dam, prepared by CDM, Cambridge, October 9, 2009.
3. Emergency Action Plan, Pine Hill Reservoir Dam, prepared by CDM, June 2007.
4. Phase I Inspection/Evaluation Report, Pine Hill Reservoir Dam, prepared by CDM, Cambridge, August 2006.
5. DCR Dam Inspection Summary Report, prepared by Fuss & O'Neill, Holden, October 2005.
6. Department of Environmental Management, Office of Dam Safety, Municipally Owned Dam, Inspection/Evaluation Report, reported prepared by Pare Engineering Corporation, Holden, March 27, 1998.
7. Letter titled "Notice of Inspection" to Worcester Department of Public Works, prepared by Department of Environmental Management, Holden, May 2, 1994.
8. Department of Environmental Management, Office of Dam Safety, Municipally Owned Dam, Inspection/Evaluation Report, report prepared by Pare Engineering Corporation, Holden, June 1993.
9. Inspection Summary and Recommendations, prepared by Department of Environmental Management, Holden, March 4, 1992.
10. Dam Inspection Checklist, prepared by Office of Dam Safety, Holden, November 20, 1991.
11. Alternative for Repair for Pine Hill Reservoir Dam, Holden, report prepared by Coffin & Richardson, June 1989.
12. Department of Environmental Management, Office of Dam Safety, Municipally Owned Dam, Inspection/Evaluation Report, report prepared by CVP, Holden, July 27, 1987.
13. Design Drawings for Repair of Pine Hill Reservoir Dam, Coffin & Richardson Consulting Engineers, July 1980.
14. Phase I Inspection Report, National Dam Inspection Program, report prepared by Department of the Army Corps of Engineers, New England Division, Holden, October 1978.

Appendix D
Common Dam Safety Definitions

Common Dam Safety Definitions

For a comprehensive list of dam engineering terminology and definitions refer to 302 CMR 10.00 Dam Safety, or other reference published by FERC, Dept. of the Interior Bureau of Reclamation, or FEMA. Please note should discrepancies between definitions exits, those definitions included within 302 CMR 10.00 govern for dams located within the Commonwealth of Massachusetts.

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

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 permanent barrier that impounds water.

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

Abutment – Shall mean that part of a 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 structures, either in dams or separate there from. including but not be limited to, spillways; reservoirs and their rims; low level outlet works; and water conduits including tunnels, pipelines, or penstocks, either through the dams or their abutments.

Spillway – Shall mean a structure over or through which water flows are discharged. If the flow is controlled by gates or boards, it is a controlled spillway; if the fixed elevation of the spillway crest controls the level of the impoundment, it is an uncontrolled spillway.

Size Classification

(as listed in Commonwealth of Massachusetts, 302 CMR 10.00 *Dam Safety*)

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

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

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

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

Hazard Classification

(as listed in Commonwealth of Massachusetts, 302 CMR 10.00 *Dam Safety*)

High Hazard (Class I) – Shall mean dams located where failure will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).

Significant Hazard (Class II) – Shall mean dams located where failure may cause loss of life and damage to home(s), industrial or commercial facilities, secondary highway(s) or railroad(s), or cause the interruption of the use or service of relatively important facilities.

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

General

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 unit of volumetric measure that would cover one acre to a depth of one foot. It is equal to 43,560 cubic feet. On million U.S. gallons = 3.068 acre feet

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, and for determining maximum temporary storage and height of dam requirements.

Condition Rating

Unsafe – Major structural, operational, and maintenance deficiencies exist under normal operating conditions.

Poor – Significant structural, operation and maintenance deficiencies are clearly recognized for normal loading conditions.

Fair – Significant operational and maintenance deficiencies, no structural deficiencies. Potential deficiencies exist under unusual loading conditions that may realistically occur. Can be used when uncertainties exist as to critical parameters.

Satisfactory – Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result in deficiencies.

Good – No existing or potential deficiencies recognized. Safe performance is expected under all loading including SDF.