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
Date of Inspection:	October 9, 2009

CDM

Preface

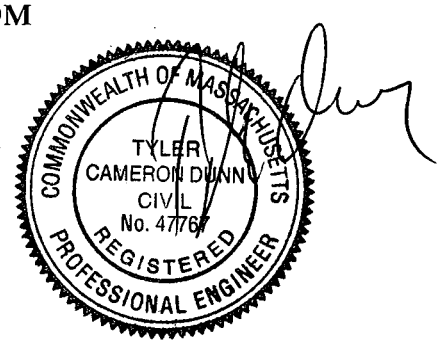
The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigations and analyses involving topographic mapping, subsurface investigations, testing and detailed computational evaluations are beyond the scope of this report.

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



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

Michael P. Smith, E.I.T.
Geotechnical Engineer

Executive Summary

The Pine Hill Reservoir Dam is located in Holden, Massachusetts and is owned and operated by the City of Worcester, Massachusetts. On October 9, 2009, this structure was inspected by Tyler C. Dunn, P.E. and Michael P. Smith, E.I.T., representatives from CDM of Cambridge, Massachusetts. 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 downstream face and training walls. Seepage through the concrete dam is considered to be a contributing factor to the continuing deterioration of this concrete.

2. Cracks 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. Trees and brush growing in riprap and in the embankment at the contacts with the concrete dam and spillway.

4. Outlet drain for infiltration gallery is blocked so that water flows out through top of access manhole for this gallery.

5. There is no Operations and Maintenance Manual for this dam. This should include regular maintenance of the gate operations.

6. There is no stability analysis for the concrete masonry dam and the embankment. The stability analysis should be performed in accordance with current state requirements and evaluate the structure under normal and extreme loading conditions which should include seismic loading.

7. A wet area on the right downstream slope between the dam and outlet gate house may be due to possible seepage through the face of the concrete dam.

CDM recommends the following actions be taken to address the deficiencies found at the dam during this inspection and evaluation:

1. Prepare a stability analysis, seepage analysis, hydrologic and hydraulic analysis, and Operations and Maintenance Manual for the dam.

2. Perform a confined space entry of the gallery in accordance with all applicable OSHA regulations as a follow up inspection of the gallery from the August 24, 2006 inspection.

3. Clear vegetation on the embankment slopes, crest, and the downstream area for a distance of at least 20 feet beyond the toe of the dam.

4. Regrout areas of spalled and damaged concrete on dam and on spillway slab and walls.

5. Remove loose materials and vegetation at concrete cracking on dam and on spillway slab and walls and regrout.

6. Construct a drainage system to control seepage through the dam's concrete surfaces.

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

Dam Evaluation Summary Detail Sheet

1. NID ID:	**MA00623**	**4. Inspection Date:**	**October 9, 2009**
2. Dam Name:	**Pine Hill Reservoir Dam**	**5. Last Insp. Date:**	**August 24, 2006**
3. Dam Location:	**Holden, MA**	**6. Next Inspection:**	**October 9, 2011**
7. Inspector:	**Tyler C. Dunn, P.E.**		
8. Consultant:	**CDM**		
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:**	**$320,000 - $580,000**
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

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Section 1
Project Information
1.1 General
1.1.1 Authority
The City of Worcester retained CDM 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 CMR10.07. 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, and opinion of probable costs.

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 ¾ of a mile down 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.

1.2.2 Owner/Operator

See Table 1.1 for current owner and caretaker data (names and contact information).

1.2.3 Purpose of the Dam

The Pine Hill Reservoir which provides part of the water supply for the City of Worcester. Water can be pumped from Kendall Reservoir (MA 00622) to Pine Hill Reservoir by a 24-inch-diameter main that connects with the 30-inch–diameter outlet pipe at the lower gatehouse. The main is also used to conduct water by gravity flow from Pine Hill Reservoir to Kendall Reservoir. In addition, if needed, water can gravity flow 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 the concrete dam and overflow spillways, 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 October 9, 2009 inspection by CDM, and is supplemented by data contained in previous reports.

The COE (1978) Phase 1 Report indicates that 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 embankment sections are about 25 feet wide at the crest. 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 terrace at elevation El. 890.0 on the downstream slope. The width of the terrace diminishes near the face

of the concrete dam. The earth embankments tie into natural 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. The crest is 15 feet wide on the arch bridge over the spillway, and widens to 20 feet wide for the main portion of the dam, and widens to 25 feet at the embankment. 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 has been reported to be 70 feet, with the crest at El. 920 National Geodetic Vertical Datum of 1929 (NGVD 29). CDM performed a level survey using a hand level and rod to confirm the approximate height from the crest of the dam to the floor of the discharge channel immediately downstream of the stilling basin. CDM measured an approximate height of 71.3 feet between these features, which corresponds well with the 70-foot height. 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 spillway is located near the middle of the masonry dam section. It is a concrete ogee weir divided into three arched bays by two concrete pillars. 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. On the sides of the spillway are 2-foot-high by 4-foot-wide concrete training walls. Concrete baffle blocks at the toe of the spillway dissipate energy as water discharges into a semi-circular concrete stilling basin. The bottom of the stilling basin has an elevation of El. 847. 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. 852 to El. 851.0. Downstream of the basin steps is the stream channel which narrows from 70 to approximately 50 feet wide. The channel is lined with natural stones, with vegetation growing in it.

There is an inspection gallery inside the base of the concrete dam (COE, 1978). The gallery is accessible through both a manhole at the top of the dam near the right abutment down through a riser with an aluminum ladder, and one at the toe of the dam at the left side of the stilling basin. The gallery, which is also used as a drainage conduit, is reported to be 335 feet long, and 6.5 feet high with arch ceilings. For about half its length, the floor is level at approximately El. 855.0 and then slopes up to El. 878.0 near the right abutment of the dam. Approximately nine vertical drainage wells collect seepage through the dam and conduct it directly to the gallery. These

vertical drainage wells are both 6-inch by 12-inch and 12-inch-diameter. Inside the gallery, the seepage flows in a shallow drain into an 8-inch-diameter cast iron outlet pipe. The 8-inch-diamter cast iron pipe discharges 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. COE (1978) reported the chamber is constructed over a well 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.

COE (1978) also reports that a low-level outlet with an invert at approximately El. 850.0 is also 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 by a 24-inch-diameter main that connects with the 30-inch–diameter outlet pipe at the lower gatehouse. The main is also used to conduct water by gravity flow from Pine Hill Reservoir to Kendall Reservoir. In addition, if needed, water can gravity flow down the Asnebumskit Brook to the Headworks Dam (MA02326) and down the Asnebumskit Canal to Kendall Reservoir.

1.2.5 Operations and Maintenance

According to the caretaker, Mr. Bruce Blanchard, of the City of Worcester, at the time of the telephone caretaker interview, there is no written operations and maintenance manual for the dam.

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 well 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 in a monthly report stored in the same office as mentioned above.

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According to the caretaker, Mr. Bruce Blanchard, of the City of Worcester, at the time of the telephone caretaker interview, there is no written operations and maintenance manual for the dam.

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 well 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 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 edges are mowed and fertilized once a year. Vegetation is cleared to a distance of 60 feet from the reservoir shoreline and a distance of 30 feet on either side of the feeder brooks. The reservoir drain 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 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 and fill animal burrows.

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.

1.3 Pertinent Engineering Data

The pertinent engineering data presented is based on observations and measurements performed during the October 9, 2009 inspection by CDM, and are supplemented by data contained in previous reports.

1.3.1 Drainage Area

COE (1978) reported a drainage area of 6.7 square miles. CDM measured on USGS maps the drainage area for Pine Hill Reservoir Dam to be approximately 7.14 square miles and to extend through the communities of Rutland and Paxton. Outside of these population centers, the drainage area is wooded and has little development.

1.3.2 Reservoir Area

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 (NVGD 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
SDF Pool	918.0	6,380	5,120	378	12,254

1.3.3 Discharges at the Dam Site

It has been reported by Bruce Blanchard that this dam has never been overtopped. Discharges at Pine Hill Reservoir Dam occur 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	852.0
F.	Upstream Water at Time of Inspection	904.8
G.	Downstream Water at Time of Inspection	849.3
H.	Streambed at Toe of the Dam	848.7
I.	Low Point along Toe of the Dam	850.0

1.3.5 Main Spillway

A.	Type	Concrete Ogee Weir
B.	Length of Weir	Three 25-foot bays
C.	Weir Crest Elevation	El. 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 Pipes
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 gunnite was applied to the spillway surface 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. The gallery has been completely flooded since that time. The gallery was not accessible for inspection due to flowing water in the gallery.

Mr. Bruce Blanchard indicated that spalled concrete on the downstream dam face, the spillway slab and training walls was sandblasted and re-covered with shotcrete in 1987. 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. It was reported by Bruce Blanchard that the previously spalled areas that continued to hold their recoating were those areas where a reinforcement mesh was attached to the sandblasted surface before shotcrete was applied. Exposed reinforcement mesh was observed on October 9, 2009 inspection in areas of spalled shotcrete.

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.

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.)	7.14
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 Department of Public Works & Parks
Owner Address	20 East Worcester Street
Owner Town	Worcester, MA 01608
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	10/9/2009
Consultant Firm Name	CDM
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
Inspection
2.1 Visual Inspection

Pine Hill Reservoir Dam was inspected on October 9, 2009. At the time of the inspection, the weather was partly cloudy with the temperature in the 60's°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**. The level of the impoundment was about 5 feet below the spillway crest on the day of inspection. Underwater areas and the flooded gallery area 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. The condition is based on the spalling of the shotcrete, exposed wire mesh on the face of the dam with some vegetation growing in the cracks, spalling of the concrete on the spillway, some excess vegetation and a need to repair the drain in the infiltration gallery. Photographs of these areas are located in Figure 5 and included in Appendix A. An Operations and Maintenance Plan, seepage analysis, stability analysis, and hydrologic and hydraulic analysis are needed for this dam structure. The specific concerns are identified in more detail in the sections below.

2.1.2 Dam

Abutments

Abutment contacts with embankments are generally in good condition except there were lines of trees observed on the left abutment (Photo 3). It is riprap-lined on the upstream faces and ties into bedrock on the right embankment.

Upstream Face

The riprap on the upstream slopes is in good condition but removal of some small trees and brush is needed along the embankment and at the contact with the concrete dam and spillway (Photos 1 and 3). 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 17). Mineral deposits were noted below many of these cracks.

Crest

The concrete dam crest also has cracking and spalling, and a small amount of vegetation taking root (Photos 4, 18 and 19). The crest of the left embankment is covered with grass about 6 to 12 inches tall. The crest of the right embankment is

covered with an asphalt access road that has severe deterioration with ruts and cracks and is in need of repair. On the right embankment crest, the asphalt access road had cracking, rutting, and the edges were eroded (Photo 4).

Downstream Face

The grass-covered downstream slopes of the earth portions of the embankment are covered with grass and milkweed about 6 to 15 inches tall (Photos 2, 6 and 7). Some tractor ruts and bare spots (Photos 2, 13 and 34) were found (Item 5 on Figure 5) parallel to the slope on the left downstream face. A saturated soil area approximately 20-feet-wide by 40-feet-long (Photo 33) at the base of the dam right of the gate house was observed (Item 7 on Figure 5). The shotcrete coating on the downstream faces of the concrete dam is cracked and spalled in numerous areas and has allowed some vegetation to take root (Photos 21, 22, 24, 26, 27 and 28). Mineral deposits were noted below many of these spalled areas. One area has exposed reinforcement wire mesh from the 1987 shotcrete application (Photo 26).

Drains

A 1-inch-diameter PVC pipes were observed on downstream face of the concrete dam (Photo 28). These pipes were installed in the dam during the installation of shotcrete. A 9.5-inch-deep weephole was observed on downstream face of right dam section.

The lower manhole cover to the seepage infiltration gallery (Photo 29) was locked during the October 9, 2009 inspection and water was flowing out of the cover. The flow was estimated to be 10 to 15 gpm. It has been reported that the 8-inch-diameter cast iron outlet drain has been blocked since the 1960's causing the seepage water flow out of the top of the infiltration gallery access manhole (Photo 29).

Instrumentation

There is no instrumentation for Pine Hill Reservoir Dam.

Access Roads and Gates

The site is restricted to the public by two locked gates. The access roads are in good condition.

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 face of the concrete. Water was about 5 feet below the concrete ogee spillway crest at the time of inspection. Some cracking and spalling of the spillway slab, and training walls was evident (Photos 8, 9, 10, 11, 12, 20, 31, 32, and 35).

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 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 Headworks Dam flows to Eagle Lake while water that passes through the 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 area surrounding consists of wooded hills. These areas are maintained by the City of Worcester. Mr. Bruce Blanchard stated that the trees and brush are cleared within about 50 feet of the shoreline at about 5-year intervals.

2.2 Caretaker Interview

On October 21, 2009, a telephone interview with Mr. Bruce Blanchard described normal operations and the site history. Information provided by Mr. Blanchard 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 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 seepage infiltration gallery's discharge pipe has been plugged with sediments for ten years and is no longer discharging to the downstream spillway channel but has been discharging through the top of the gallery's access manhole that is at a level about 5 feet above the stilling basin.

7. The operators for all five gates and the gate house itself were renovated in 2001.

8. Shotcrete was applied to the dam and spillway with mixed success as previously described in Section 1.3.7.

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. Bruce Blanchard reported that maintenance of the dam is performed on an annual basis. The grass embankments are mowed at two to three times a year. About every five years, trees and vegetation are cleared for 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 in June 2007.

2.5 Hydraulic/Hydrologic Data

Although the information from COE (1978) is believed to remain valid, a new hydrologic and hydraulic analysis should be performed to enhance and compliment the stability analysis recommended in the next section of this report.

COE (1978) reported the Probable Maximum Flood (PMF) rate 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. 918.0.

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 should be performed 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 Concrete Dam and 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. Such a failure plane would be caused by a shear crack in or degradation of the mortar of the cyclopean masonry.

2.6.2 Structural Stability of Non-Embankment Structures

COE (1978) reported the PMF flow can be discharged over the spillway with a freeboard of about 2 feet. Although the information is believed to remain valid, new overtopping estimates along with hydrologic and hydraulic analysis should be performed to enhance and compliment the stability analysis recommended in this report.

2.6.3 Seepage Stability

Possible seepage was noted on the right downstream slope near the gate house during the October 9, 2009 inspection. Efflorescence was also observed below cracks and spalled shotcrete areas on the face of the dam. Based on CDM's experience with similar concrete dams and the fact that a formal stability analyses has not previously been performed, a seepage and stability analysis of this structure should now be performed along with the previously described hydrologic and hydraulic analyses. 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".

Section 3
Assessments and Recommendations

3.1 Assessment

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

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 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. Trees and brush growing in riprap and in the embankment at the contacts with 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 this gallery.

5. There is no Operations and Maintenance Manual for this dam.

6. There is no stability analysis for the concrete masonry dam and the embankment.

7. A wet area on the right downstream slope between the dam and outlet gate house may be due to possible seepage through the face of the concrete dam.

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.	Wet area being monitored
Outlet pipe blocked with sedimentation and water flowing out of seepage gallery manhole cover.	Flow from seepage gallery being monitored.
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.
Update Emergency Action Plan	Updated June 2007 by CDM.
Prepare, update and follow procedures outlined in the Operation and Maintenance Manual.	A O&M manual has not been prepared
Vegetation and debris on upstream embankments.	Vegetation and debris were removed except vines at left abutment. New vegetation growing. Large tree trunk on left embankment.
No stability analyses.	No stability analyses have been performed on the dam and embankments.

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, MADEP, or other regulatory agencies.

3.2 Studies and Analyses

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

1. Perform a confined space entry in accordance with all applicable OSHA regulations and inspect the condition of the infiltration gallery.

2. The Emergency Action Plan should be reviewed to track any changes in property owners or new construction in the inundation zone to ensure the most current information. The EAP should be updated annually.

3. Prepare an Operations and Maintenance Manual. This manual should include procedures for maintaining the level of the impoundment, including criteria for adjustment in the pool level seasonally to provide more freeboard during

the winter months. In addition, 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.

4. Perform a seepage analysis of the dam and evaluate the downstream concrete surfaces and the concrete spalling that is likely associated with this seepage. This study should include a procedure 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, piezometers should be installed through the dam.

5. Perform a stability analysis for the concrete masonry dam and the embankment. The stability analysis should be performed in accordance with current state requirements and evaluate the structure under normal and extreme loading condition which should include seismic loading.

6. Perform an updated hydrologic and hydraulic analysis of the dam to confirm the maximum water surface, the discharge capacity of the 30-inch-diameter discharge outlet, and freeboard during the SDF.

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 yearly.

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

6. After gallery drainage repairs are completed, the seepage infiltration gallery should be inspected yearly.

3.4 Recommendations, Maintenance and Minor Repairs

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. Clear brush and vegetation on the embankment slopes, crest, and the downstream area for a distance of at least 20 feet beyond the toe of the dam.

2. Repair concrete cracking on dam and on spillway slab and walls.

3. Construct a drainage system to control seepage through the dam's concrete surfaces. Regrout areas of spalled and damage 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 Modification 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.

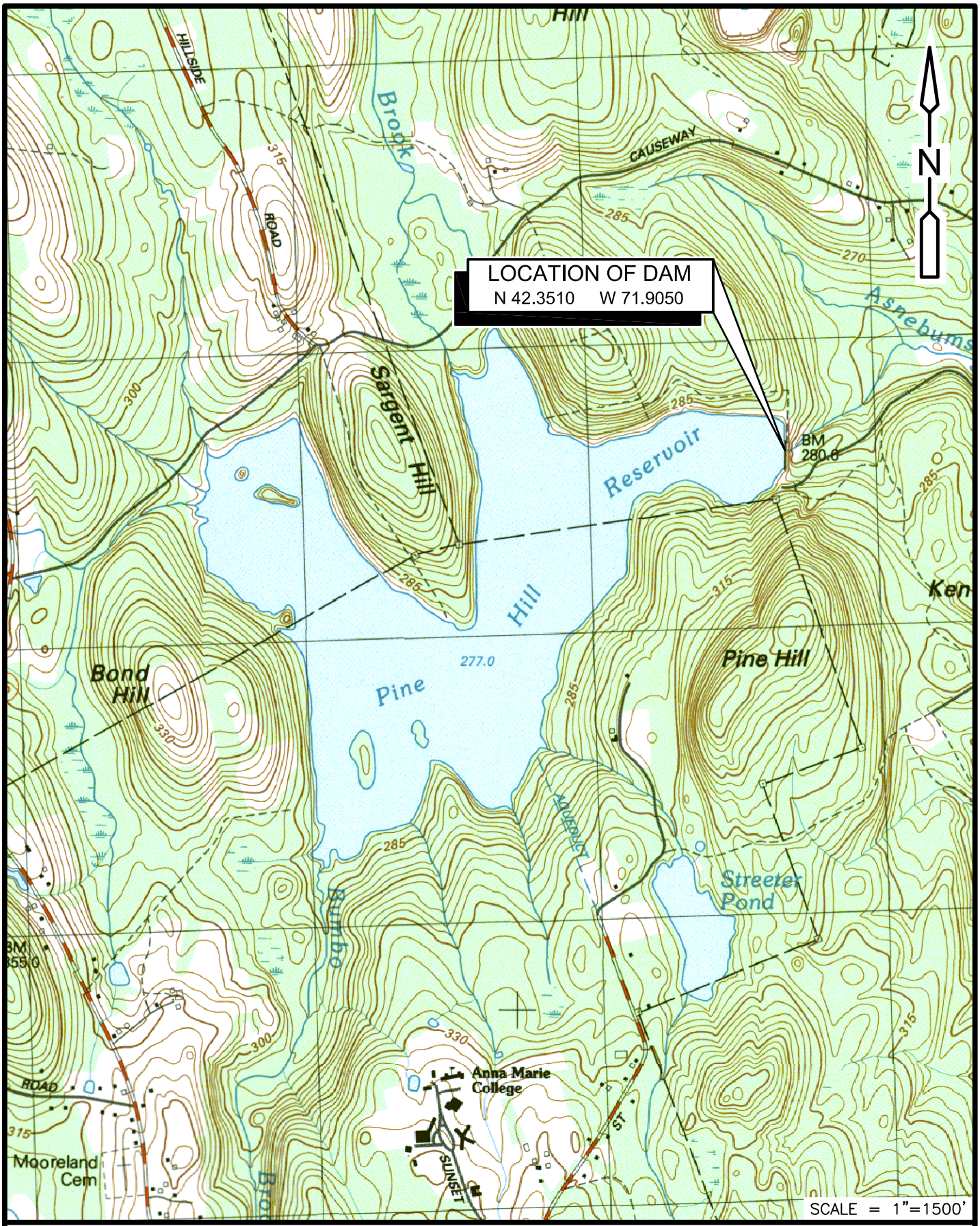
Studies and Analyses

1.	Update the EAP	N/A (in-house personnel)
2.	Operations and Maintenance Manual	N/A $ 9,000
3.	Seepage Analysis and Stability Analysis	$60,000 - $100,000
4.	Hydrologic and Hydraulics Analyses	$11,000 - $13,000
		$80,000 - $122,000
	Contingency (20%)	$16,000 - $24,400
	Subtotal	$96,000 - $146,400

Recommendations
(Determine the applicability of site permits before starting these repairs)

1.	Repair spalling of dam and spillway	$ 32,000 - $ 64,000
2.	Repair cracking of dam and spillway	$ 32,000 - $ 64,000
3.	Control seepage through concrete	$107,000 - $213,000
4.	Repair infiltration gallery outlet	$ 16,000 - $ 22,000
		$187,000 - $363,000
	Contingency (20%)	$37,400 - $72,600
	Subtotal	$224,400 – $435,600
	Total	**$320,400 – $582,000**

Figures



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USGS TOPOGRAPHIC MAPS
PAXTON
CONTOURS AND ELEVATIONS IN METERS

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS

PINE HILL RESERVOIR DAM

STATE DAM ID NO.:3-14-134-6 NID ID NO.:MA00623

CDM
consulting • engineering • construction • operations

LOCUS PLAN

OCTOBER 2009 FIGURE 1

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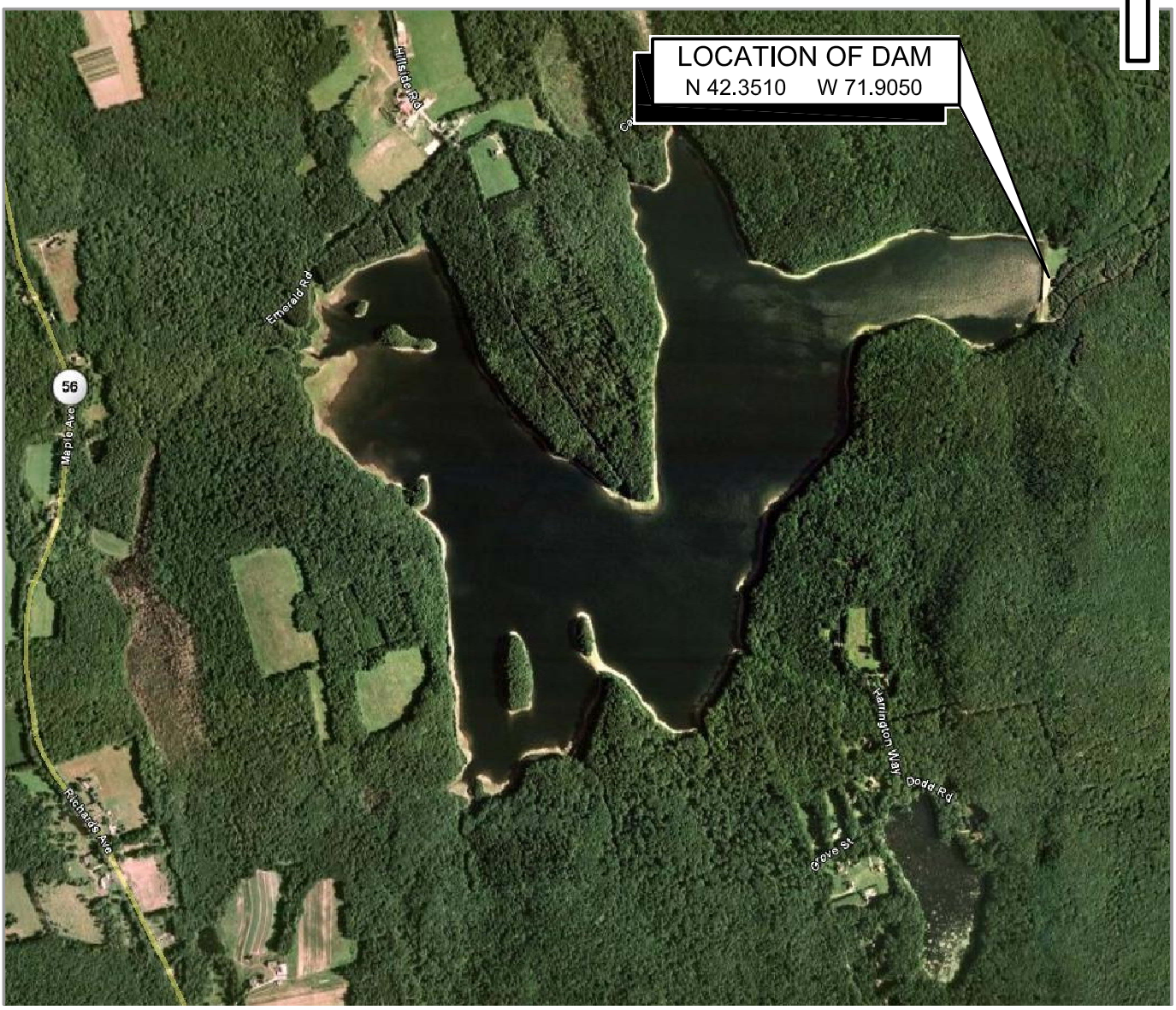

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USGS TOPOGRAPHIC MAPS
PAXTON
CONTOURS AND ELEVATIONS IN METERS

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS

PINE HILL RESERVOIR DAM

STATE DAM ID NO.:3-14-134-6 NID ID NO.:MA00623

CDM

consulting • engineering • construction • operations

AERIAL MAP

OCTOBER 2009 FIGURE 2

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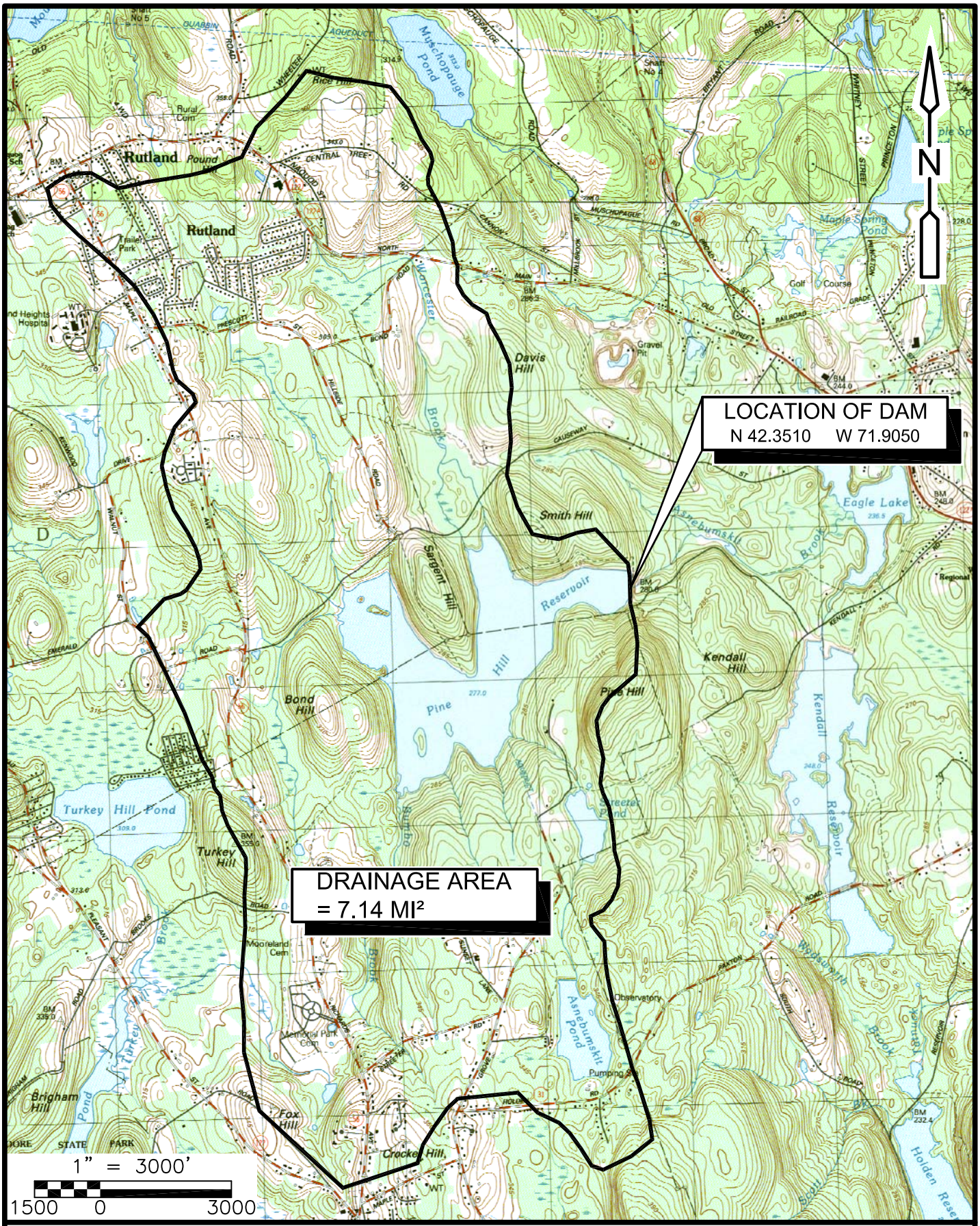

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USGS TOPOGRAPHIC MAPS
PAXTON
CONTOURS AND ELEVATIONS IN METERS

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS

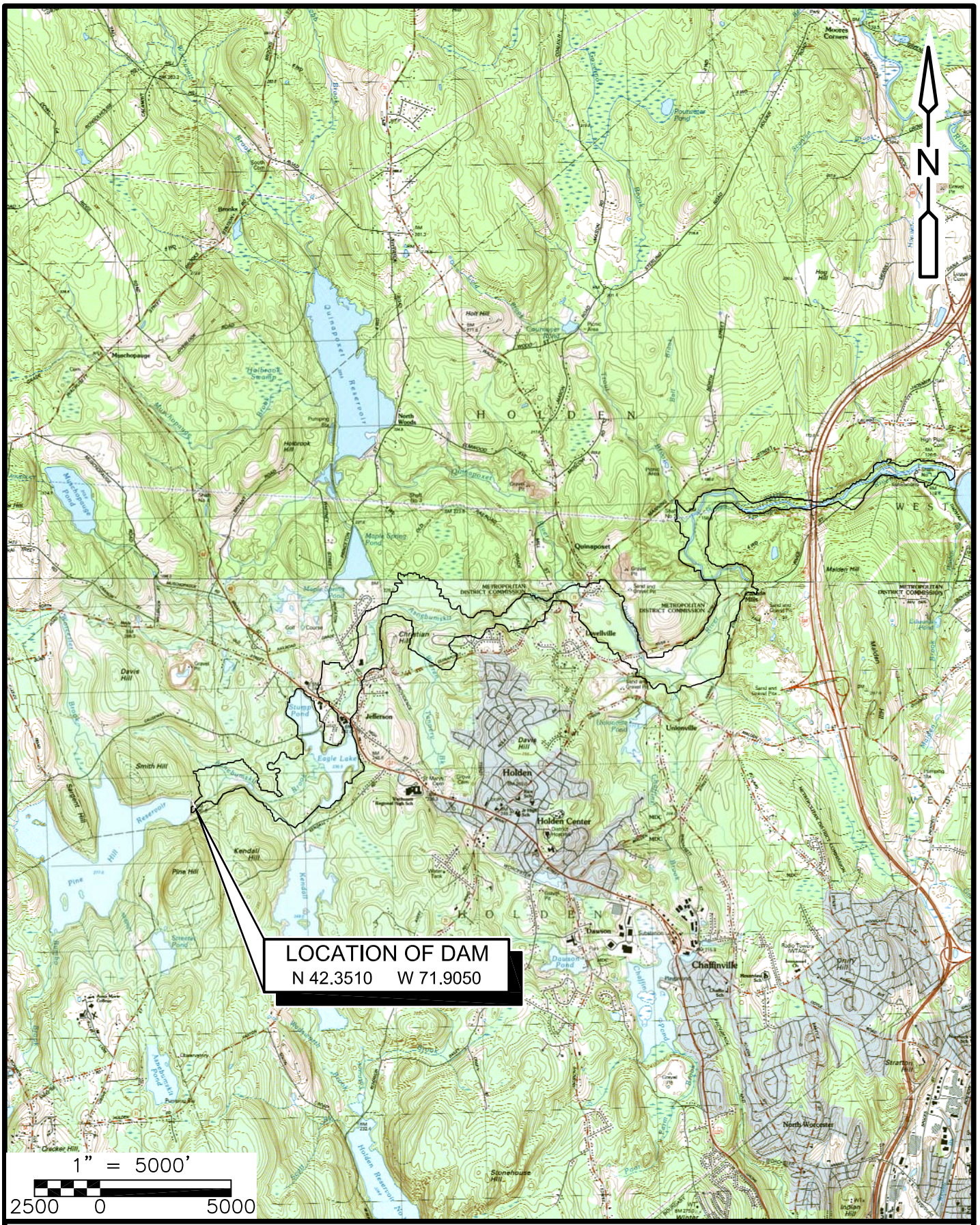
PINE HILL RESERVOIR DAM

STATE DAM ID NO.:3-14-134-6 NID ID NO.:MA00623

CDM
consulting • engineering • construction • operations

DRAINAGE AREA

OCTOBER 2009 FIGURE 3



USGS TOPOGRAPHIC MAPS
PAXTON
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CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS

PINE HILL RESERVOIR DAM

STATE DAM ID NO.:3-14-134-6 NID ID NO.:MA00623

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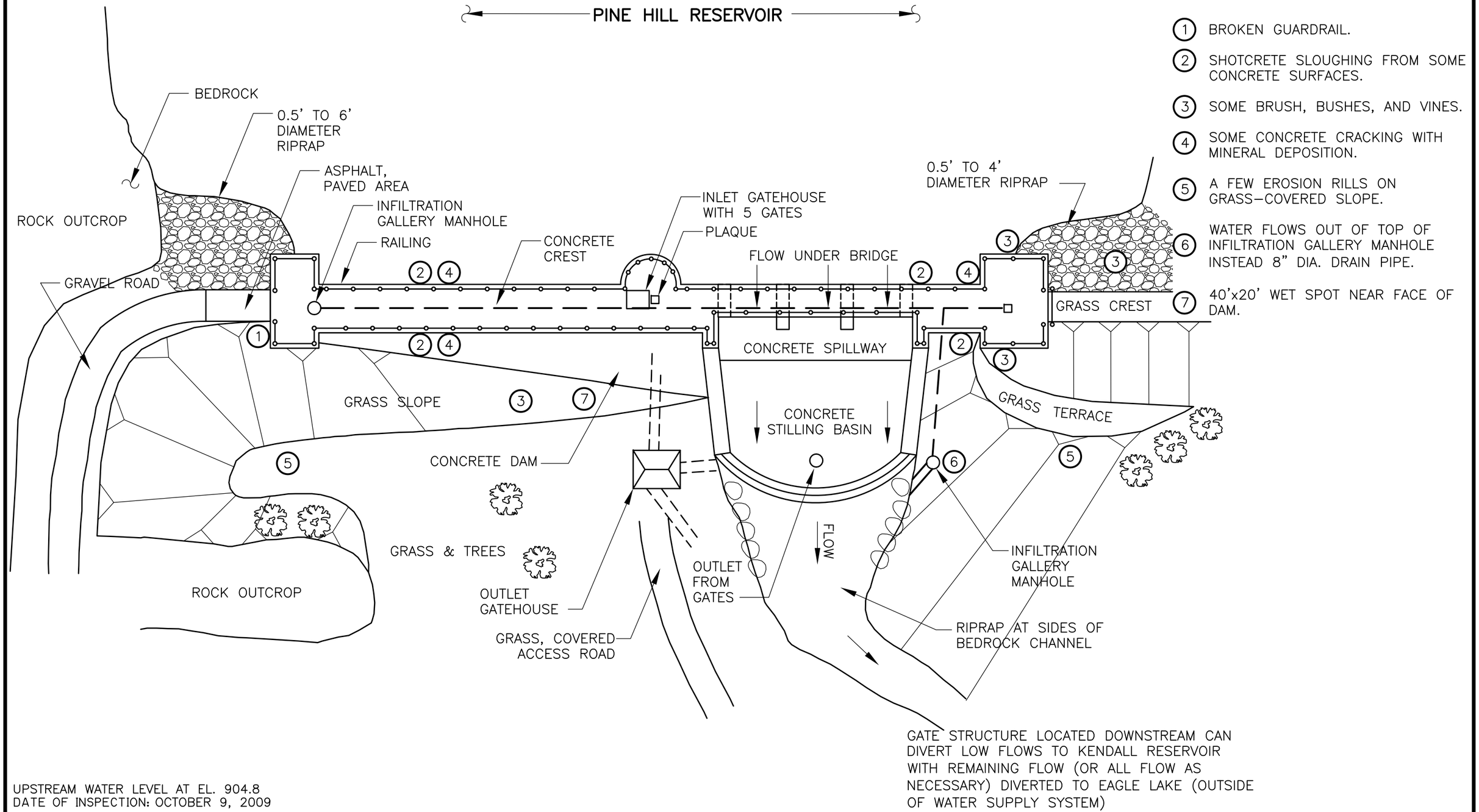
DOWNSTREAM AREA

OCTOBER 2009 FIGURE 4

\\Camsvr04\DAM INSPECTIONS\0198-70600\Pine Hill Reservoir Dam\Geotech\TDSFG001.DWG



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 INSTEAD 8" DIA. DRAIN PIPE.
7. 40'x20' WET SPOT NEAR FACE OF DAM.

UPSTREAM WATER LEVEL AT EL. 904.8
DATE OF INSPECTION: OCTOBER 9, 2009

SCALE = N.T.S.

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

FIELD SKETCH AND NOTES
OCTOBER 2009 FIGURE 5

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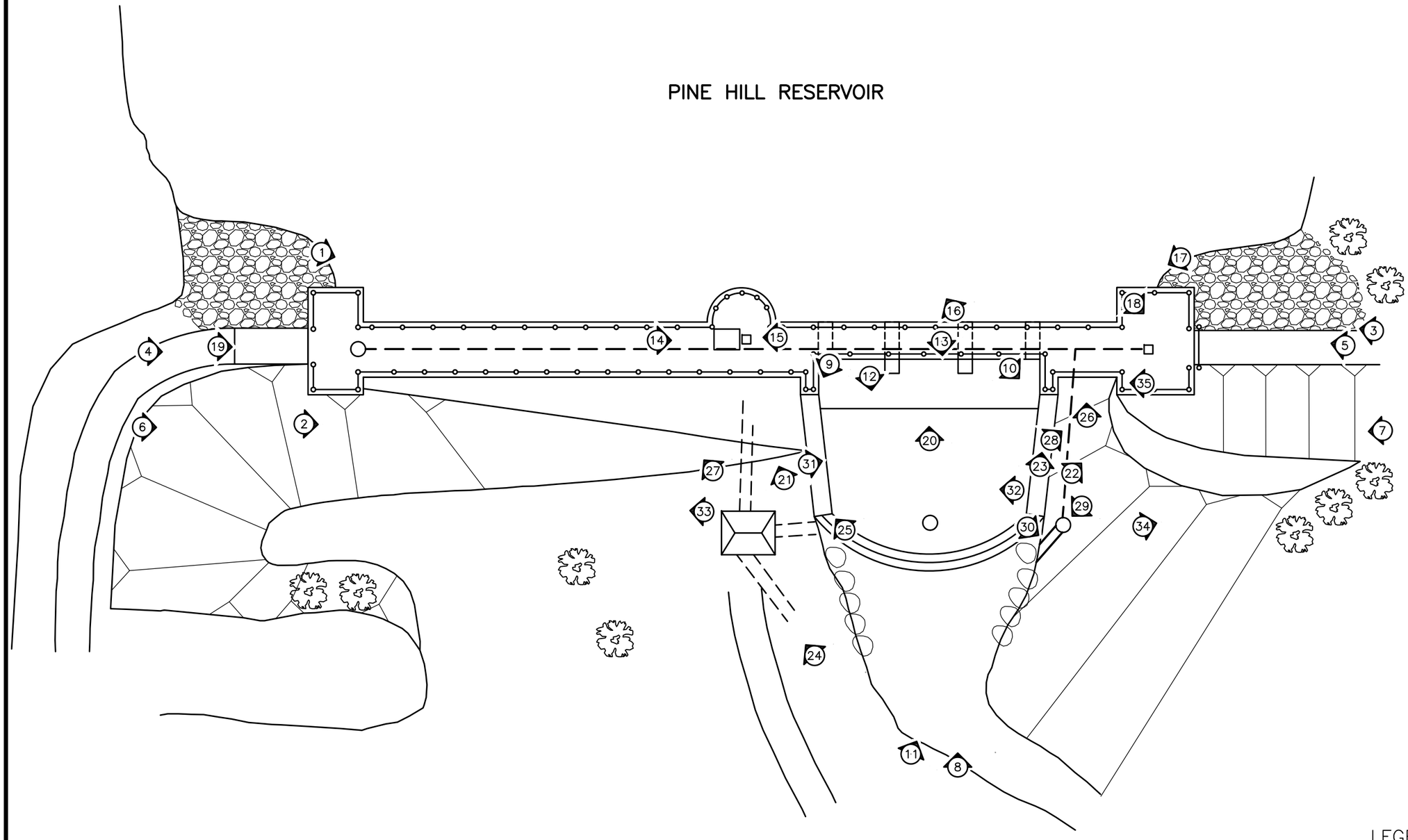
PINE HILL RESERVOIR



LEGEND:

(2) PHOTOGRAPH NUMBER AND ORIENTATION

UPSTREAM WATER LEVEL AT EL. 904.8
DATE OF INSPECTION: OCTOBER 9, 2009

SCALE = N.T.S.

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

PHOTOGRAPH LOCATION PLAN
OCTOBER 2009 FIGURE 6

Appendix A
Photographs

PINE HILL RESERVOIR DAM
MA00623

Photo No. 1: Overview of dam and upstream face from right abutment. Note brush on riprap near concrete dam contact.

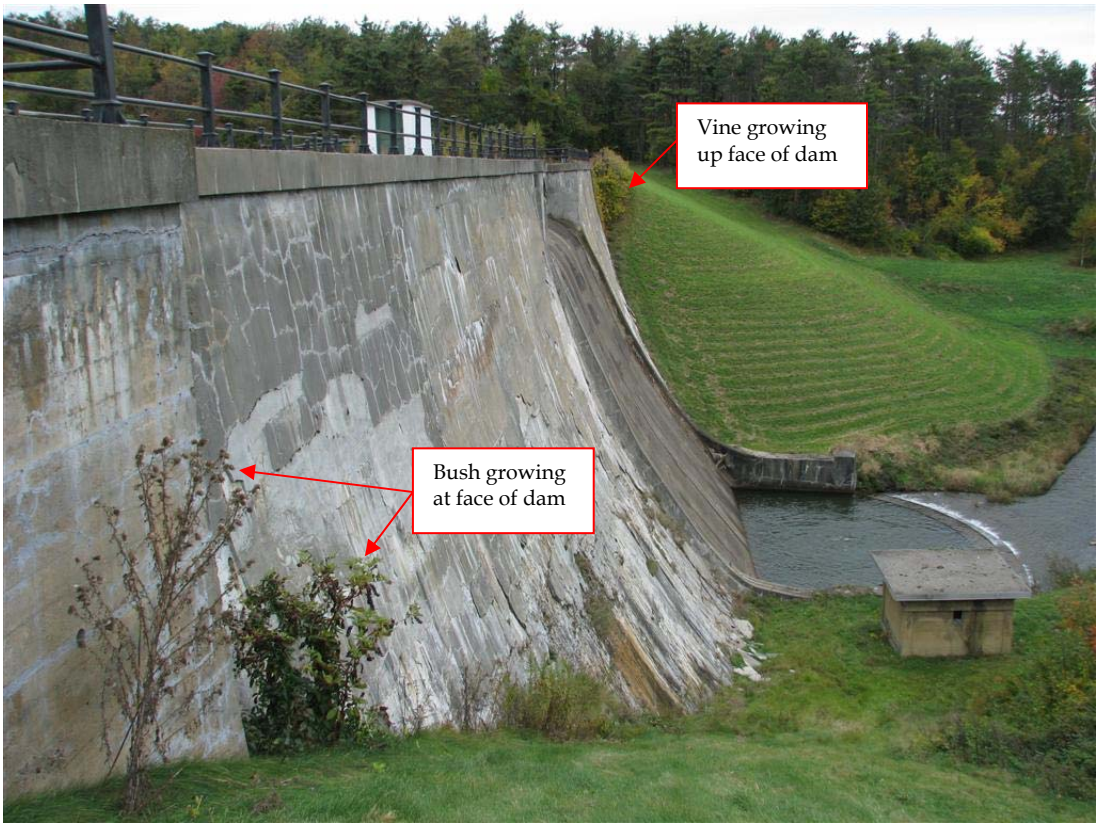

Photo No. 2: Overview of dam and downstream face from right embankment.

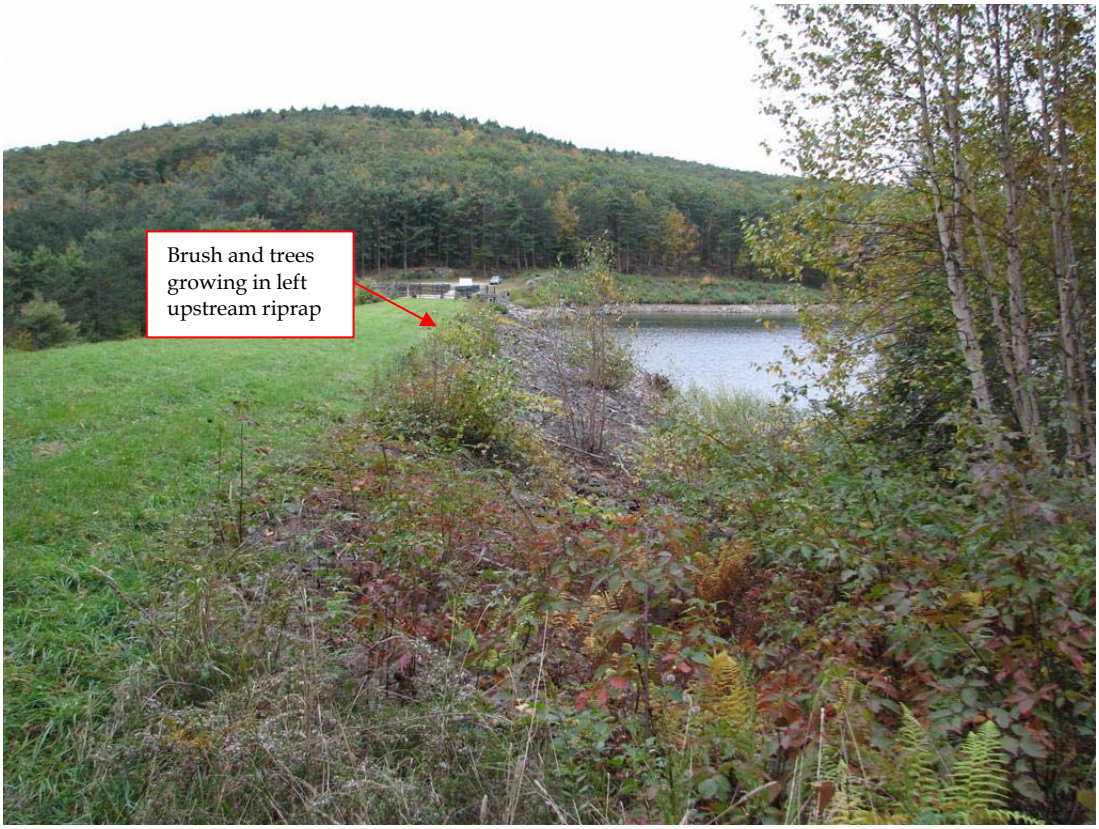

Photo No. 3: Overview of upstream face and crest from left abutment.

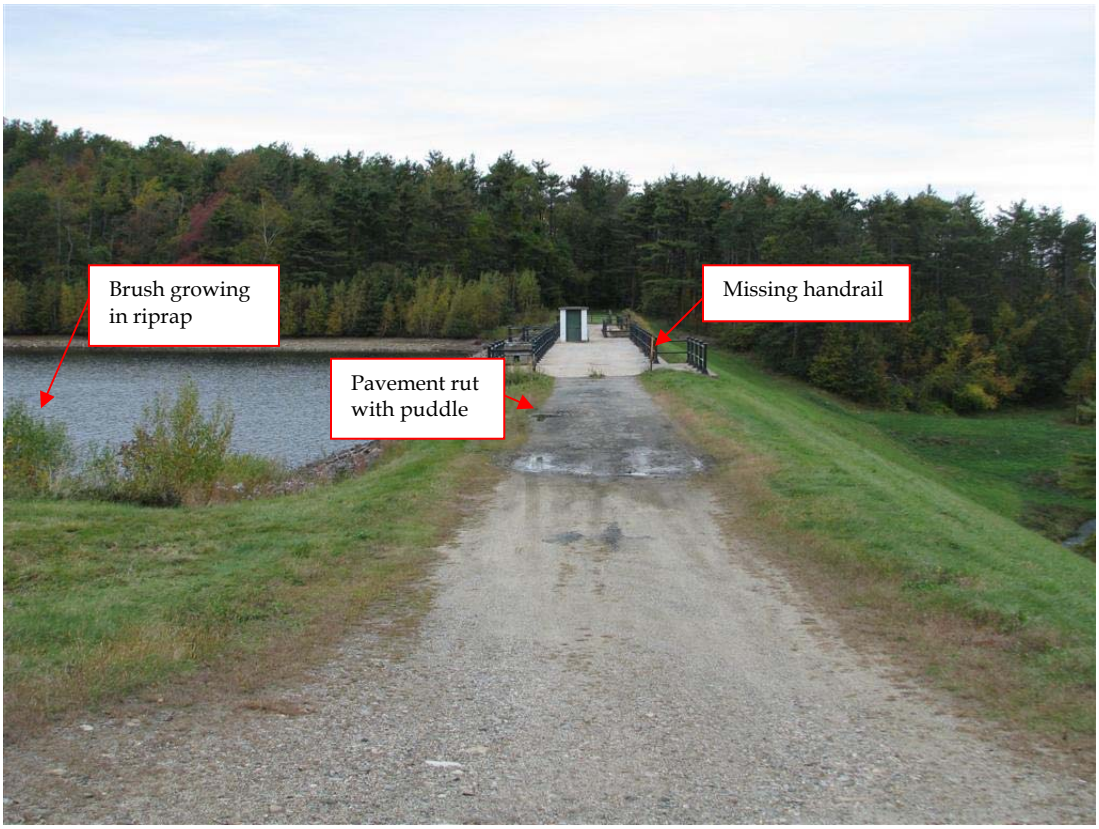

Photo No. 4: Overview of crest from right abutment.

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.

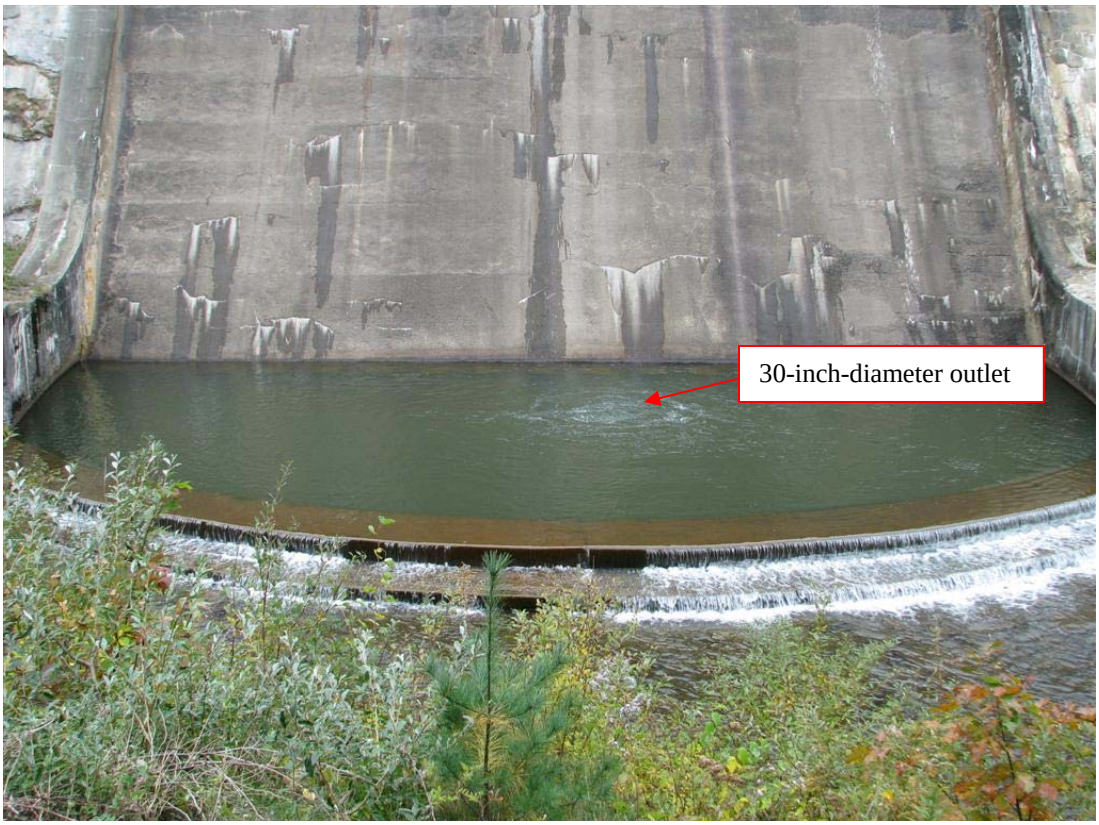

Photo No. 8: Overview of spillway.

Photo No. 9: Overview of right downstream spillway training wall. Note part of concrete fillet is missing.

Photo No. 10: Overview of left downstream spillway training wall.

Photo No. 11: Overview of spillway weir.

Photo No. 12: Overview of stilling basin. Need to label the arrow.

Photo No. 13: Overview of downstream channel (Note trees along channel).

Photo No. 14: Overview of gatehouse exterior.

PINE HILL RESERVOIR DAM
MA00623

Photo No. 15: Monument next to the gatehouse.

Photo No. 16: Overview of reservoir.

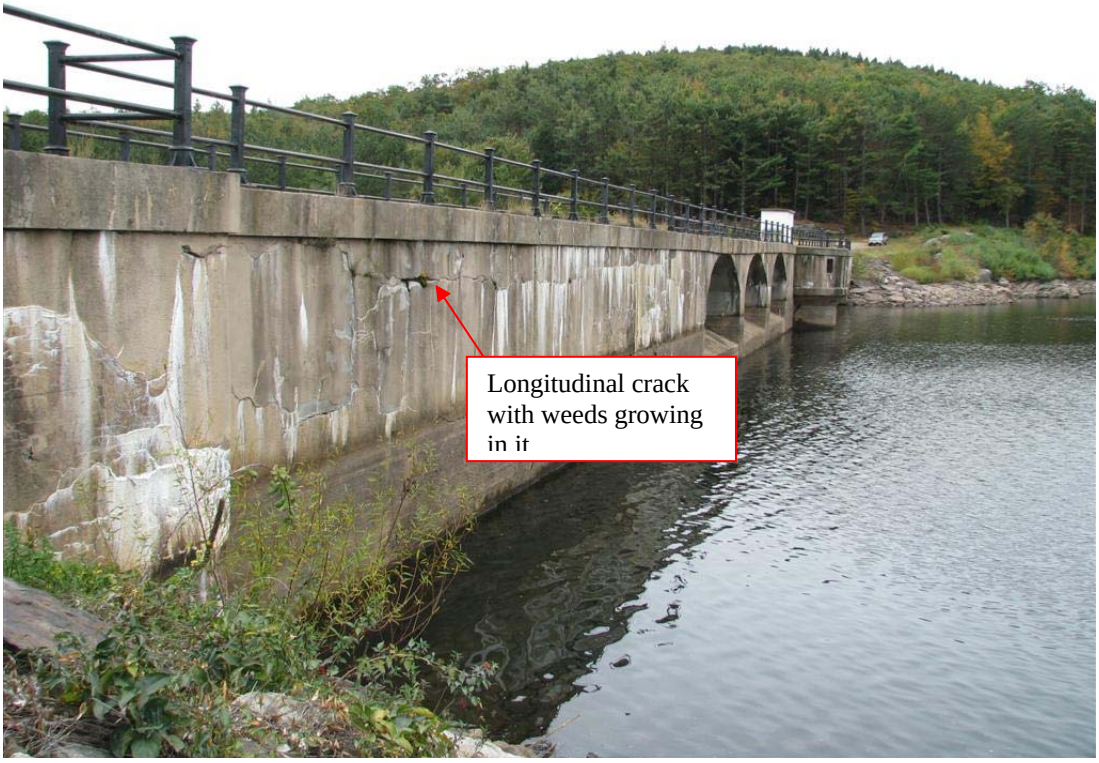

Photo No. 17: Cracks and efflorescence on upstream face of dam. Note that some weeds are growing in the cracks.

Photo No.18: Crack on crest near left embankment. Note weeds and moss growing in the crack.

Photo No. 19: Pavement eroded, rutted, and cracked on right crest.

Photo No. 20: Cracks and efflorescence on the spillway surface (View from downstream).

Photo No. 21: A large piece of shotcrete spalled next to the right training wall. Note weeds growing in the cracks.

Photo No. 22: Spalling of shotcrete left of the spillway (downstream face).

Photo No. 23: Efflorescence and spalling of concrete at toe of left training wall.

Photo No. 24: Large areas of spalling on downstream face of the dam to the right of the spillway.

PINE HILL RESERVOIR DAM
MA00623
Weeds growing in some cracks.

Photo No. 25: Exposed rebar at the end of the right training wall.

Photo No. 26: A large piece of shotcrete spalled exposing wire mesh in downstream face of dam next to left training wall. Weeds growing in cracks.

Photo No. 27: Efflorescence, cracking, spalling and weeds growing in the cracks on the downstream face of the dam to right of spillway.

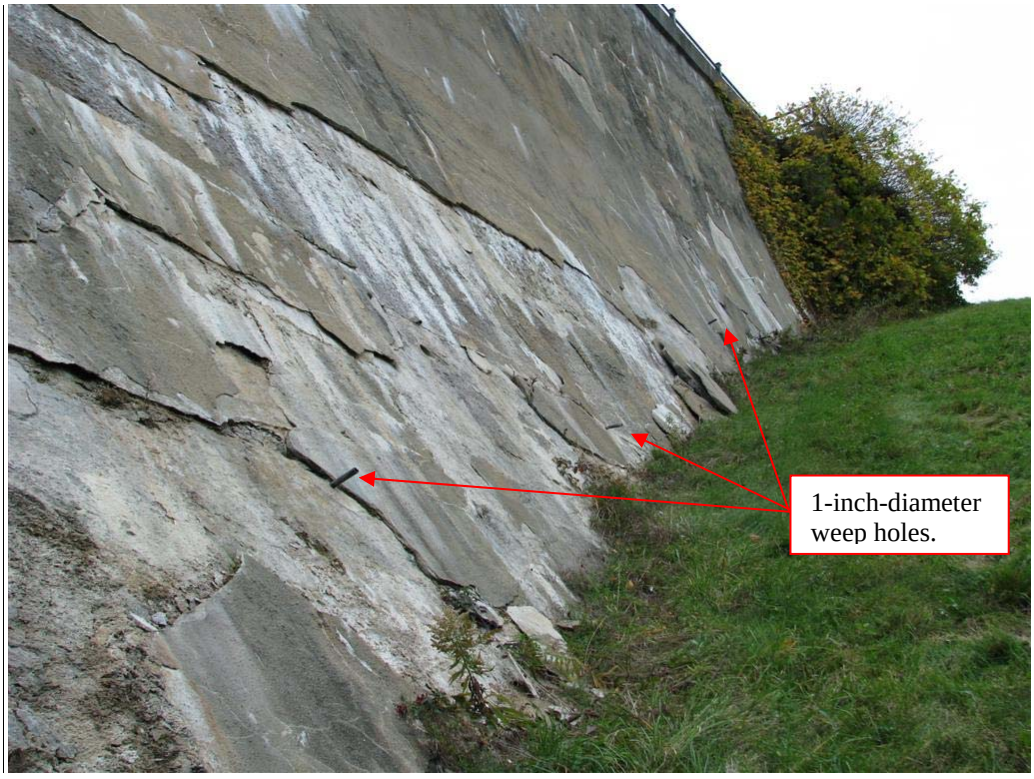

Photo No. 28: PVC weep holes on the downstream face of the dam to left of spillway. weep holes were installed when dam face was sandblasted and shotcrete-covered in 1987.

Photo No. 29: Entrance to the gallery under the dam. Note the manhole cover is locked and water is flowing out of holes in cover.

Photo No. 30: Outlet from drainage gallery clogged and overgrown. Water overflowing from manhole cover above.

Photo No. 31: Concrete spalled between spillway and training wall at stilling basin. Cracking, spalling, and effloresence on left training wall.

Photo No. 32: Cracking, spalling, and effloresence on right training wall at stilling basin.

Photo No. 33: Wet area on right slope between dam face and outlet gatehouse.

Photo No. 34: Tractor ruts and bare spots on left embankment downstream slope from mowing.

PINE HILL RESERVOIR DAM
MA00623

Photo No. 35: Longitudinal cracks along railing. Spalling, cracking, and efflorescence on concrete arch bridge over spillway. Weeds growing in cracks.

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: October 9, 2009 | NID ID #: MA00623

INSPECTION SUMMARY

DATE OF INSPECTION: October 9, 2009 | DATE OF PREVIOUS INSPECTION: August 24, 2006

TEMPERATURE/WEATHER: 60's cloudy | ARMY CORPS PHASE I: ☑ YES ☐ NO | If YES, date October, 1978

CONSULTANT: CDM | PREVIOUS DCR PHASE I: ☑ YES ☐ NO | If YES, date March 27, 1998

BENCHMARK/DATUM: NVGD 1929

OVERALL PHYSICAL CONDITION OF DAM: FAIR | DATE OF LAST REHABILITATION:

SPILLWAY CAPACITY: >100% SDF w/ no actions by Caretaker

EL. POOL DURING INSP.: 904.8 | EL. TAILWATER DURING INSP.: 849.3

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Tyler C. Dunn, P.E.	Sr. Geotechnical Engineer	CDM
Michael P. Smith, E.I.T.	Geotechnical Engineer	CDM

EVALUATION INFORMATION

	Click on box to select E-code		Click on box to select E-code
E1) TYPE OF DESIGN	3	E8) LOW-LEVEL OUTLET CONDITION	5
E2) LEVEL OF MAINTENANCE	4	E9) SPILLWAY DESIGN FLOOD CAPACITY	5
E3) EMERGENCY ACTION PLAN	4	E10) OVERALL PHYSICAL CONDITION	3
E4) EMBANKMENT SEEPAGE	3	E11) ESTIMATED REPAIR COST	$320,000 - $580,000
E5) EMBANKMENT CONDITION	5	ROADWAY OVER CREST	NO
E6) CONCRETE CONDITION	3	BRIDGE NEAR DAM	NO
E7) LOW-LEVEL OUTLET CAPACITY	4		

NAME OF INSPECTING ENGINEER: Tyler C. Dunn, P.E. | SIGNATURE:

NAME OF DAM: Pine Hill Reservoir Dam

STATE ID #: 3-14-134-6

INSPECTION DATE: October 9, 2009

NID ID #: MA00623

OWNER:		CARETAKER:	
ORGANIZATION	City of Worcester Department of Public Works & Parks	ORGANIZATION	City of Worcester Department of Public Works & Parks
NAME/TITLE		NAME/TITLE	Bruce Blanchard
STREET	20 East Worcester Street	STREET	55 Moy Ranch Road
TOWN, STATE, ZIP	Worcester, MA 01608	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	labovitesm@worcesterma.gov	EMAIL	blanchardb@worcesterma.us
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): 7.14

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: October 9, 2009 NID ID #: MA00623

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS Left Embankment	Right Embankment	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	grass on left	Paved on right (10' wide) with grass on sides			X
	2. SURFACE CRACKING		Poor condition (see comment below)			X
	3. SINKHOLES, ANIMAL BURROWS	None Observed	None Observed	X		
	4. VERTICAL ALIGNMENT (DEPRESSIONS	None Observed	Irregular			X
	5. HORIZONTAL ALIGNMENT	Good condition	Good condition	X		
	6. RUTS AND/OR PUDDLES	None Observed	Some observed (see comment below)			X
	7. VEGETATION (PRESENCE/CONDITION)	Good condition	Weeds in cracks in and on both sides of pavement		X	
	8. ABUTMENT CONTACT	Good condition	Good condition (ties well into bedrock)	X		

ADDITIONAL COMMENTS: Major alligator cracking, rutting, and missing sections of pavement on right embankment crest. Puddles in ruts.

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

INSPECTION DATE: October 9, 2009 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	40' x 20' area observed between gatehouse & dam		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	None observed	tractor ruts and bare spots parallel to slope from tractor mowing grass		X	
	7. UNUSUAL MOVEMENT	None observed	None observed	X		
	8. VEGETATION (PRESENCE/CONDITION)	Vines growing up concrete wall at left abutment onto railing and crest of dam. Some sparse areas				X

ADDITIONAL COMMENTS: 40' x 20' saturated area observed between gate house and dam on right embamkment. Sheen observed in the water. Estimated flow <1 gpm. Possible seepage through the face of the concrete dam.

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS Left Embankment	Right Embankment	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	None observed	None observed	X		
	2. SLOPE PROTECTION TYPE AND COND.	Hand-placed riprap (6"-4'), largest near dam	Hand-placed riprap (6"-6')		X	
	3. SINKHOLE/ANIMAL BURROWS	None observed	None observed	X		
	4. EMB.-ABUTMENT CONTACT	Good condition, riprap-lined	Riprap-lined, ties into bedrock	X		
	5. EROSION	None observed	None observed	X		
	6. UNUSUAL MOVEMENT	Slope of riprap varies	None observed		X	
	7. VEGETATION (PRESENCE/CONDITION)	Small trees growing in riprap. Vines growing at left abutment onto concrete wall and onto crest. At end of embankment 1"-6" trees.	Brush and small trees where slope ties into bedrock			X

ADDITIONAL COMMENTS: Riprap slope on left embankment is flatter on top, becomes steeper midslope between water and crest.
Large tree trunk on left embankment.

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None			
	2. OBSERVATION WELLS	None			
	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: October 9, 2009 NID ID #: MA00623

DOWNSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/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. SEEPAGE OR LEAKAGE	Not applicable			
	6. ABUTMENT CONTACT	Not applicable			
	7. EROSION/SINKHOLES BEHIND WALL	Not applicable			
	8. ANIMAL BURROWS	Not applicable			
	9. UNUSUAL MOVEMENT	Not applicable			
	10. WET AREAS AT TOE OF WALL	Not applicable			

ADDITIONAL COMMENTS:

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

INSPECTION DATE: October 9, 2009 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: October 9, 2009 NID ID #: MA00623

DOWNSTREAM AREA

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S AREA	1. ABUTMENT LEAKAGE	None observed	X		
	2. FOUNDATION SEEPAGE	None observed	X		
	3. SLIDE, SLOUGH, SCARP	None observed	X		
	4. WEIRS	None observed	X		
	5. DRAINAGE SYSTEM	None observed	X		
	6. INSTRUMENTATION	None	X		
	7. VEGETATION	Trees about 15-20' downstream from the left and right earth embankment	X		
	8. ACCESSIBILITY	Accessible from unpaved road on the right abutment	X		
	9. DOWNSTREAM HAZARD DESCRIPTION	Asnebumskit Brook to the Quinapoxet River, to the Wachusett Reservoir some 10 miles downstream. Flow through Eagle Lake in Holden affecting properties along Rte. 122A, Princeton Street in the Jefferson Village area, a number of properties along Quinapoxet Street, a cluster of homes in the Quinapoxet and Lovellville villages section where Rte. 31 crosses the river. Several more properties along River Street that would be impacted by flooding where the river runs along River Street for more than a mile.			
	10. DATE OF LAST EAP UPDATE	June, 2007			

ADDITIONAL COMMENTS: Trees located 15-20' downstream from the middle to upper face of the embankment slopes. Trees further away near bottom of embankment slopes near Asnebumskit Brook and the distilling basin.

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

INSPECTION DATE: October 9, 2009 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: Not onsite for inspection
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES ☑ NO PURPOSE:

ADDITIONAL COMMENTS: Gallery flooded and not inspected. A confined-space entry is required for a follow up inspection to the August, 2006 inspection.

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Concrete			
	WEIR TYPE	Concrete ogee			X
	SPILLWAY CONDITION	Spalling, cracks, some effloresence			X
	TRAINING WALLS	Cracks and spalling. Concrete missing on left side between wall and spillway			X
	SPILLWAY CONTROLS AND CONDITION	Not applicable	X		
	UNUSUAL MOVEMENT	None observed	X		
	APPROACH AREA	None observed	X		
	DISCHARGE AREA	Semi-circular stilling basin, bedrock channel	X		
	DEBRIS	None observed	X		
	WATER LEVEL AT TIME OF INSPECTION	5.2' below top of spillway			

ADDITIONAL COMMENTS: Arch bridge over spillway crest has three 25-foot bays. There was spalling at bridge pillars. Cracking, spalling, and deterioration of concrete on deck of arch bridge near the gatehouse.
Concrete missing on left side between the training wall and the spillway at stilling basin water level.

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

AUXILIARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Not applicable			
	WEIR TYPE	Not applicable			
	SPILLWAY CONDITION	Not applicable			
	TRAINING WALLS	Not applicable			
	SPILLWAY CONTROLS AND CONDITION	Not applicable			
	UNUSUAL MOVEMENT	Not applicable			
	APPROACH AREA	Not applicable			
	DISCHARGE AREA	Not applicable			
	DEBRIS	Not applicable			
	WATER LEVEL AT TIME OF INSPECTION	Not applicable			

ADDITIONAL COMMENTS:

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE	5 sluice gates			
	INTAKE STRUCTURE	Gatehouse on upstream face of dam			
	TRASHRACK	None observed, under water	X		
	PRIMARY CLOSURE	Sluice gates			
	SECONDARY CLOSURE	Downstream gatehouse			
	CONDUIT	Mud gate to channel downstream			
	OUTLET STRUCTURE/HEADWALL	None observed, under water			
	EROSION ALONG TOE OF DAM	None observed	X		
	SEEPAGE/LEAKAGE	None observed	X		
	DEBRIS/BLOCKAGE	None observed	X		
	UNUSUAL MOVEMENT	None observed	X		
	DOWNSTREAM AREA	Bedrock channel			
	MISCELLANEOUS	Control mechanism has been replaced in 2001			

ADDITIONAL COMMENTS: Sluice gates at 5 levels (mud gate, low level 24"×26" sluice gate outlet, 3 different intake levels from reservoir). Water from the intakes discharges through a 30-inch-diameter cast iron pipe that goes to the gatehouse at the right side of the stilling basin. Inlet and lower outlet fatehouse doors locked. Gatehouses not inspected.

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

CONCRETE/MASONRY DAMS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
GENERAL	TYPE	Cyclopean concrete			
	AVAILABILITY OF PLANS	Some plans available in COE (1978) Phase I Report			
	AVAILABILITY OF DESIGN CALCS	None			
	PIEZOMETERS	None			
	OBSERVATION WELLS	None			
	INCLINOMETERS	None			
	SEEPAGE GALLERY	Within the spillway and the dam. Seepage flow estimated to be about 50 gpm			X
	UNUSUAL MOVEMENT	None	X		

ADDITIONAL COMMENTS:

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

CONCRETE/MASONRY DAMS (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	TYPE	Shotcrete-overed concrete			
	SURFACE CONDITIONS	Cracking & spalling. Weeds coming out from cracks. Effloresence around hand rails. Concrete degraded near gatehouse and on spillway bridge.			X
	CONDITIONS OF JOINTS	Caulked	X		
	UNUSUAL MOVEMENT	None observed	X		
	HORIZONTAL ALIGNMENT	Good condition	X		
	VERTICAL ALIGNMENT	Good condition, slight depression on the bridge (near center)		X	

ADDITIONAL COMMENTS: Possible air intake to gallery found near left embankment.

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

CONCRETE/MASONRY DAMS (DOWNSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S FACE	TYPE	Concrete-covered with shotcrete (curved surface)			X
	SURFACE CONDITIONS	Shotcrete and concrete spalling, cracks, efflorescence (both sides with significant spalling). Weeds growing in cracks on right and left side.			X
	CONDITIONS OF JOINTS	Not visible			
	UNUSUAL MOVEMENT	None observed	X		
	ABUTMENT CONTACT	Good condition. Embankment wraps around the dam	X		
	DRAINS	1" diameter PVC drains, weeds observed.			X
	LEAKAGE	None observed	X		

ADDITIONAL COMMENTS: Some PVC drain pipes were installed in the dam when they installed shotcrete.
Severe spalling in some areas. Wire mess exposed left of the spillway near training wall.
Water flowing out of downstream gallery manhole cover adjacent to left training wall of stilling basin.

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

INSPECTION DATE: October 9, 2009 NID ID #: MA00623

CONCRETE/MASONRY DAMS (UPSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S FACE	TYPE	Concrete covered with shotcrete			
	SURFACE CONDITIONS	Shotcrete covered, crack at normal pool level, weeds growing in cracks, efflorescence. Longitudinal cracks along upstream face.			X
	CONDITIONS OF JOINTS	Mostly covered by shotcrete. The exposed one looks tight	X		
	UNUSUAL MOVEMENT	None observed	X		
	ABUTMENT CONTACTS	Earth embankments riprap-lined	X		

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. Emergency Action Plan, Pine Hill Reservoir Dam, prepared by CDM, June 2007.

2. Phase I Inspection/Evaluation Report, Pine Hill Reservoir Dam, prepared by CDM, Cambridge, August 2006.

3. DCR Dam Inspection Summary Report, prepared by Fuss & O'Neill, Holden, October 2005.

4. Department of Environmental Management, Office of Dam Safety, Municipally Owned Dam, Inspection/Evaluation Report, reported prepared by Pare Engineering Corporation, Holden, March 27, 1998.

5. Letter titled "Notice of Inspection" to Worcester Department of Public Works, prepared by Department of Environmental Management, Holden, May 2, 1994.

6. Department of Environmental Management, Office of Dam Safety, Municipally Owned Dam, Inspection/Evaluation Report, report prepared by Pare Engineering Corporation, Holden, June 1993.

7. Inspection Summary and Recommendations, prepared by Department of Environmental Management, Holden, March 4, 1992.

8. Dam Inspection Checklist, prepared by Office of Dam Safety, Holden, November 20, 1991.

9. Alternative for Repair for Pine Hill Reservoir Dam, report prepared by Coffin & Richardson, Holden, June 1989.

10. Department of Environmental Management, Office of Dam Safety, Municipally Owned Dam, Inspection/Evaluation Report, report prepared by CVP, Holden, July 27, 1987.

11. 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 CMR10.00 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 therefrom. 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 acreto 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.