PARE CORPORATION

Pine Hill Reservoir Dam

Phase I Inspection / Evaluation Report

Holden, Massachusetts

Dam Name: **Pine Hill Reservoir Dam**
NID ID#: **MA00623**
Owner: **City of Worcester**
Town: **Holden**
Consultant: **Pare Corporation**
Date of Inspection: **June 15, 2022**

Dam Evaluation Summary Detail Sheet

1. NID ID:	**MA00623**	**4. Inspection Date:**	**June 15, 2022**
2. Dam Name:	**Pine Hill Reservoir Dam**	**5. Last Insp. Date:**	**September 24, 2015**
3. Dam Location:	**Holden, MA**	**6. Next Inspection:**	**June 15, 2024**
7. Inspector:	**Clarence C. Hutto, III, P.E.**		
8. Consultant:	**Pare Corporation**		
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:**	**$4.9M - $15.8M**
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

Spillway capacity increased from 6,546 cfs to 7,515 cfs. SDF increased from 4,641 cfs to 5,550 cfs.

EXECUTIVE SUMMARY

This Phase I Inspection/Evaluation Report details the inspection and evaluation of the Pine Hill Reservoir Dam located in Holden, Massachusetts. The inspection was conducted on June 15, 2022 by Pare Corporation (Pare) of Foxboro, Massachusetts. Pine Hill Reservoir Dam is an approximately 840-foot long, 70-foot high earthen and concrete structure with a concrete ogee weir spillway, an upper gatehouse structure equipped with gated low-level outlet and a lower gatehouse structure. The dam is currently classified as a Large size, High (Class I) hazard potential dam.

No formal Operation and Maintenance (O&M) Manual is known to exist for this structure.

An emergency action plan was developed for the dam in June 2007. As of the 2015, an update was reportedly in progress; however, the updated EAP was not available at the time of this inspection.

In general, Pine Hill Reservoir Dam was found to be in **Fair** condition with the following deficiencies noted:

1. Voids, erosion, developing vegetation, and areas of settlement within the upstream slope riprap.
2. Spalling, exposed reinforcing bar, cracks, and efflorescence on the upstream face of the dam, spillway slab, training walls, and baffle blocks.
3. Systemic failure of the previous concrete facing repair on the downstream face of the dam resulting in spalling, delamination, seepage, and fallen pieces of the facing repair.
4. Animal burrows and tire rutting along crest and downstream slope
5. Seepage through the downstream face of the dam
6. Misaligned cracks and flow through cracks on the end sill.
7. Unknown operability of the lower gates.
8. Ponded water to the right and saturation of the floor of the lower gatehouse
9. Calcification, blocked outlet, evidence of previous leaks, and damage to the ladder rungs within the access manhole on the crest of the seepage gallery.
10. No formal Operations & Maintenance Manual.
11. Other areas of additional maintenance and dam safety concerns, as reported herein.

More detailed descriptions, additional deficiencies, recommended repairs, and opinions of probable repair costs are provided within this report.

Based upon the size and hazard potential of this structure, the spillway design flood (SDF) for the dam is the ½ PMF storm event. Based upon hydraulic and hydrologic (H&H) evaluations completed as part of previous evaluations, the spillway can accommodate of the inflow associated with the SDF.

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

1. Develop and implement a concrete repair program to address areas of concrete deterioration.
2. Restrict access to the downstream toe of the dam to address safety concern of failure of previous downstream face repair (Immediate action item).
3. Remove calcium deposits, timber, and accumulated debris within the seepage gallery.
4. Update the Emergency Action Plan.
5. Inspect the low-level outlet to assess the condition of the outlet pipes, gates, and all components.

6. Complete an ROV inspection of the seepage gallery outlet; improve the conduit to maintain drainage capacity
7. Install chinking stone to fill the voids in the upstream slope riprap.
8. Fill the animal burrows within the embankment.
9. Conduct additional studies, evaluations, maintenance, and repairs as noted herein.

These repairs should be made in accordance with standard design practices, specifications, and construction methods. Design of the repairs, analyses to confirm the extent or the work, and observation to verify materials/methods used should be completed by a qualified engineer experienced in the design and rehabilitation of earthen dams throughout the evaluation, design, and construction process.

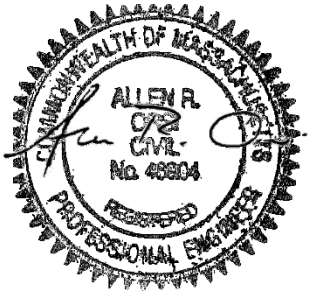
Prior to undertaking recommended maintenance, repairs and remedial measures, the applicability of environmental permits needs to be determined for activities that may occur within resource areas under the jurisdiction of the local conservation commission, MADEP, or other regulatory agencies.

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 is evolutionary in nature and depends on numerous and constantly changing internal and external conditions. 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.



Allen R. Orsi, P.E., Senior Vice President
Pare Corporation
Massachusetts License No.: 46904
License Type: Civil

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1.0 DESCRIPTION OF PROJECT

1.1 General

1.1.1 Authority

The City of Worcester, Massachusetts has retained Pare Corporation (Pare) to perform a visual inspection and develop a report of conditions for the Pine Hill Reservoir Dam in Holden, Worcester County, Massachusetts. This inspection and report were performed in accordance with MGL Chapter 253, Sections 44-50 of the Massachusetts General Laws.

1.1.2 Purpose of Work

The purpose of this investigation is to inspect and evaluate the present condition of the dam and appurtenant structures in accordance with 302 CMR10.04 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 and need for an emergency action plan for the site and; 4) prepare and submit a final report presenting the evaluation of the structure, including recommendations for remedial actions, and opinions 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; 5) general; and, 6) condition rating.

1.2 Description of Project

1.2.1 General

Sections of this report are based upon available documentation, including previous inspection reports and other available information as identified in Appendix C. Other historical information obtained during the inspection, including information provided by the caretaker has also been incorporated into this report. This material is intended to provide general information. The accuracy of this referenced information was not verified as it was outside the scope of work for this inspection.

The completion of detailed hydrologic/hydraulic studies, stability analyses, subsurface investigations, and underwater investigations is beyond the scope of this evaluation.

1.2.2 Location

Pine Hill Reservoir Dam is located within Worcester County in the Town of Holden, Massachusetts. The dam impounds water along the Asnebumskit Brook to create Pine Hill Reservoir. Discharges from the structure flow in an easterly direction. The structure and the impoundment are shown on the Paxton, Massachusetts USGS quadrangle maps near coordinates 42.35100ºN\71.90500ºW[1]. The dam is located at the eastern end of the impoundment, as indicated on Figure 1: Locus Plan.

From I-190 North, take Exit 2 toward Ararat St/Holden/Greendale and merge onto Frontage Road N. In approximately 0.2 miles, turn left onto Ararat Street and then in approximately 0.6 miles turn left onto Brattle St. In 300 feet, turn right onto Holden St and then in approximately 1.4 miles turn left onto Shrewsbury St. In 0.5 miles, turn right onto MA-122A N and follow that for 2.6 miles, then turn left onto Kendall Road. Follow Kendall Rd 0.7 miles to a security gate, then drive through the gate for about 0.1 miles and turn right at Dirt Rd. Follow the access road for approximately 1.1 miles to the right abutment of the dam.

1.2.3 Owner/Operator

The dam is owned and maintained by the City of Worcester Department of Public Works & Parks.

1.2.4 Purpose of the Dam

The Pine Hill Reservoir currently served as a part of the water supply for the City of Worcester. Water can be pumped from Quinapoxet Reservoir (MA00929) 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. Water can also be gravity fed down the Asnebumskit Brook to the Headworks Dam (MA02326) and down the Asnebumskit Canal to Kendall Reservoir.

1.2.5 Description of the Dam and Appurtenances

As shown in Figure 4, Pine Hill Reservoir Dam is an approximately 840-foot long, 70-foot high dam consisting of a concrete gravity dam with earthen embankments at each end, an overflow spillway section, and a gated outlet structure.

The concrete gravity dam is cyclopean masonry construction founded on bedrock with internal seepage collection system and seepage/inspection gallery. The concrete crest of the masonry dam section is generally flat, and 15 feet wide over the spillway, but widens to 25 feet at the abutment. There is an iron pipe railing along both sides of the crest and a small concrete building which is the access to the gate chamber. The dam is a maximum of 70 feet high, with the crest at El. 920. The upstream face of the dam is vertical. The downstream face is curved, about 0.75:1 horizontal to vertical.

Earthen embankments extends left (300 feet) and right (170 feet) of the concrete section of the dam. A concrete masonry core wall is located within each earth embankment section. The earth sections are about 25 feet wide at the crest. The upstream face is protected with riprap, and slopes are 2:1 (horizontal to vertical). The crest and downstream face of each embankment is covered with grass. The downstream

[1] As indicated within the MADCR Office of Dam Safety database.

face also slopes at 2:1, although there is a narrow berm at elevation 890.0 on the slope of the north embankment. The earth sections tie into natural ground at each abutment. Bedrock outcrops at the south (right) abutment. Apparently, rock was quarried from this area to provide the masonry blocks for the main dam. The dam was founded on bedrock.

The spillway is located near the center of the gravity dam section. It is a concrete ogee weir divided into three arched bays by two concrete pillars. Each bay is 25 feet long, and 8.5 feet high at the centerline. The crest of the weir is at El. 910.0. The approach to the spillway is the vertical upstream face of the dam. The steep, downstream face is bounded by concrete training walls 2 feet high and 4 feet wide. Concrete baffle blocks at the toe of the spillway serve as energy dissipators. The spillway discharges into a semi-circular concrete stilling pool with the bottom at El. 847.0. The side walls of the pool are a continuation of the spillway training walls, but are 10 to 12 feet high. The pool is 83 feet wide at the base of the spillway, and extends 76 feet downstream. The downstream end of the spillway descends in two broad steps to El. 851.0. Downstream of the steps is the stream channel which narrows from 70 to 50 feet. The channel is naturally paved with stone, with some vegetation growing in it.

There is an inspection gallery inside the base of the concrete dam. The gallery is accessible through both a manhole at the top of the dam, and one at the toe of the dam at the left side of the stilling pool. The gallery, which is also used as a drainage conduit, is 335 feet long, and 6.5 feet high. For about 1/2 its length, the floor is fairly level at El. 855.0 but it slopes up to El 878.0 near the right abutment of the dam. Vertical drainage wells both 6-inch by 12-inch, and 12-inch diameter, collect seepage through the dam and conduct it directly to the gallery. Inside the gallery, the seepage flows in a shallow drain, and eventually into an 8-inch cast iron outlet pipe. The pipe discharges downstream of the dam, in the streambed.

The outlet works for the dam are located in the gate chamber on the upstream face. The chamber is situated over a well with the invert at El. 850.0. The three intakes to the well are 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 pool. A valve in the gatehouse regulates flow from the outlet to the stilling pool, and then into the channel.

A low-level outlet with invert at 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 Quinapoxet Reservoir (MA 00929) to Pine Hill Reservoir by a 24-inch diameter main that connects with the 30-inch outlet pipe at the lower gatehouse. At the present time, the main is instead used to conduct water by gravity flow from Pine Hill to Kendall Reservoir.

1.2.6 Operations and Maintenance

No formal Operation and Maintenance (O&M) Manual exists for the structure. The City performs the operations and maintenance for the dam, including measuring and recording daily water levels. The gates in the upstream gatehouse are reported to be operated regularly and the gates in the lower gatehouse are reported to not be operated.

1.2.7 DCR Size Classification

Pine Hill Reservoir Dam has a maximum height of approximately 70 feet and a reported 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, Pine Hill Reservoir Dam is a **Large** size structure.

1.2.8 DCR Hazard Classification

Pine Hill Reservoir Dam is located immediately upstream of a wooded and undeveloped area. Discharges from the dam pass along Askebumskit Brook into Eagle Lake, located 1.2 miles downstream. From Eagle Lake, flows pass beneath Causeway street 1.4 miles downstream and then Route 122A 1.7 miles downstream. It appears that a failure at, maximum pool will impact Eagle Lake and any surrounding properties and Route 122A (secondary highway), and potentially impact Wachusett Regional High School and additional structures further downstream. 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, Pine Hill Reservoir Dam is classified as a **Class I (High)** hazard potential structure.

The hazard potential classification is consistent with the hazard potential classification identified in the Office of Dam Safety database.

1.3 Engineering Data

1.3.1 Drainage Area

The drainage area for Pine Hill Reservoir Dam is approximately 6.74 square miles[1] and is comprised of extensive wooded areas around the perimeter of the impoundment and some residential development and farmlands along the extents of the drainage area. The drainage area includes approximately 51.7% forests, 9.6% lakes and ponds, 7.7% wetlands, 15.5% developed (urban) areas, 4.4% impervious area, and has an average land slope of 4.2% (250k DEM). The drainage area is shown on Figure 1: Locus Plan. Based upon a review of information available within the MADCR Office of Dam Safety database, the following jurisdictional and non-jurisdictional control structures are located within the drainage area.

Table 1-1 Control Structures in Drainage Area

Dam Name	NID #	Hazard
Streeter Pond Dam	MA00678	Low
Asnebumskit Pond Dam	MA00679	Low
Kaupilla Pond Dam	MA01963	Non-Jurisdictional
Cournoyer's Dam	MA01965	Non-Jurisdictional
Small Pond Dam	MA01962	Non-Jurisdictional

[1] As determined through USGS Stream Stats.

1.3.2 Reservoir

Table 1-2 Reservoir Properties[1]

	Elevation (ft)	Length (ft)	Width (ft)	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

No records of discharges at the dam site were made available during the preparation of this report.

1.3.4 General Elevations (feet)

Elevations are based upon information presented in previous reports as well as relative elevation survey completed by Pare personnel during the inspection referencing the centerline of the first step of the end weir with an elevation of 852.0 (NAVD88).

A.	Dam Crest	920.0 ±
		Min Recorded (918.65) / Max Recorded (919.84)
B.	Spillway Design Flood Pool	918.0 / ½ PMF
C.	Normal Pool	910.0 ±
D.	Upstream Water at Time of Inspection	908.9 ±
E.	Downstream Water at Time of Inspection	
	1. Stilling basin	852.0 ±
	2. Downstream channel	850.3 ±
F.	Downstream Channel	850.0 ±

1.3.5 Primary Spillway

A.	Type	Concrete Ogee Weir
B.	Widths	Three 25 foot bays
C.	Crest Elevation	910.0 ±
D.	Bottom of Plunge Pool	847.0 ±
E.	Top of End Weir	852.0 ±

1.3.6 Low Level Outlet

A.	Type	Gate Valve-Controlled CI water mains
	1. Three Sluice Gates	
	a. Size	30-inch diameter
	b. Invert In[2]	
	i. Top	897.6 ±
	ii. Middle	882.6 ±
	iii. Bottom	867.6 ±

[1] As indicated within the September 2015 Phase I Inspection/Evaluation Report by CDM Smith.
[2] Based upon inferred elevations from low quality design plans

c. Invert Out	Unknown
2. Lower Gate	
a. Size	24-inch by 26-inch
b. Invert In	850.0 ±
c. Invert Out	Unknown

1.3.7 Design and Construction Records

Based on information provided within the 1978 ACOE inspection report, construction of the dam began in 1916 and was completed in 1924. Limited plans from the original construction were available for review. The concrete section of the dam is reported to be on sound bedrock. Based on previous reports and records, spalling of the concrete on the dam and spillway has been a recurring issue since 1934 with the first mention of a surface repair in a 1960 report, stating a gunite surface was installed.

In 1962, subsequent repair work on the concrete section was undertaken. The specific nature of the work was not reported. Between 1981 and 1982, spalled concrete on the upstream and downstream dam faces and training walls were sandblasted and repaired with shotcrete. Reinforcing mesh was placed before the shotcrete was applied. The spillway slab was sandblasted and re-covered with steel fiber. This repair has since systemically failed, and large pieces of the concrete have broken free and fallen down the face, and many are in the process of coming loose and becoming dead fall risks.

1.3.8 Operating Records

No operating records were available or indicated to be maintained during the inspection and preparation of this report.

1.4 Summary Data Table

Table 1-3 Summary Data Table

Required Phase I Report Data	Data Provided by 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 (acres)	336
Normal Impoundment Volume (acre-feet)	9398
Max Impoundment Volume ((top of dam) acre-feet)	13023
SDF Impoundment Volume (acre-feet)	12,254
Spillway Type	Uncontrolled overflow ogee weir
Spillway Length (feet)	75
Freeboard at Normal Pool (feet)	10
Principal Spillway Capacity (cfs)	7515
Auxiliary Spillway Capacity (cfs)	N/A
Low-Level Outlet Capacity (cfs)	Unknown
Spillway Design Flood (flow rate - cfs)	1/2 PMF / 5,550
Winter Drawdown (feet below normal pool)	Unknown
Drawdown Impoundment Vol. (acre-feet)	Unknown
Latitude	42.32100
Longitude	-71.90500
City/Town	Holden
County Name	Worcester
Public Road on Crest	None
Public Bridge over Spillway	None
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	508-929-1300
Owner Emergency Phone	0
Owner Type	Municipality or Political subdivision
Caretaker Name	Water Operations - Reservoirs
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	6/15/2022
Consultant Firm Name	Pare Corporation
Inspecting Engineer	Clarence C. Hutto, III, P.E.
Engineer Phone Number	508.543.1755

SECTION 2

2.0 INSPECTION

2.1 Visual Inspection

The Pine Hill Reservoir Dam was inspected on June 15, 2022. At the time of the inspection, temperatures were near 65ºF with mostly clear skies. Photographs to document conditions were taken during the inspection and are included in Appendix A. In addition to inspection photographs, detailed imagery of the above water faces of the dam not accessible by foot were collected via drone; drone imagery is included in Appendix A (on CD). The level of the impoundment was approximately 1.1 feet below normal pool elevation. Underwater areas were not evaluated during this inspection. A copy of the inspection checklist is included in Appendix B.

For reference purposes, a baseline was established along the crest of the dam during the inspection with 0+00 near the right abutment and 8+40 near the right abutment. Subtract approximately 1+75 to the inspection baseline to correlate to baselines shown on available drawings. Observations were made in relation to their location along the baseline as appropriate and as noted herein.

2.1.1 General Findings

Pine Hill Reservoir Dam was found to be in **Fair** condition. The specific concerns are identified in the sections below.

2.1.2 Dam

The following was noted along the embankment portion of the dam during the inspection.

Upstream Side

- Between the right abutment and STA 0+90, the upstream slope was vegetated with areas of bedrock outcrops. The outcrops continued upstream of the riprap to STA 1+40.
- Between STA 0+90 and the upstream concrete wall, the slope consisted of a riprap protected slope. The following was noted in this area.
  - The riprap consisted of stones 4 inches to 5 feet in diameter.
  - At the bend in the riprap, the stones were loose and a void was probed up to 16-inches behind the riprap.
  - Near STA 0+80, an erosion path up to 2 feet wide was present from the shoulder of the crest to the top of the riprap.
  - An area of displaced stones and an erosion path was present near STA 0+90 at bend in the riprap.
  - A 6 inch wide by 7 inch deep erosion channel was present near STA 0+90 on the upstream shoulder, leading to the top of the riprap. The intersection of the vegetated slope and the riprap was depressed and was able to be probed to 18-inches deep. Eroded soil from this area was observed on the surface of the riprap within this area.
  - Exposed embankment soils were present beneath the stones.
  - Voids up to 35 inches wide were typical throughout. No chinking stones were observed.
  - The upstream shoulder appeared to be retained by the top of the riprap slope.

  - Vegetation was developing between the stones throughout.
  - An apparent cracked stone was observed near STA 1+80. A 5-inch gap was present between the two pieces.
- Within the center section of the dam, the upstream slope consisted of a concrete wall. The following was observed.
  - Cracks were spaces about 4 feet apart throughout the concrete cap.
  - A gap between the cap and the upstream wall was observed throughout. The cap was up to 0.25 inches wide.
  - Throughout the upstream face, efflorescent staining, spalling, and map cracking were observed throughout
    - Spalling was present at the waterline where the riprap meets the upstream face to the right of the spillway. The delamination measured 3 inches deep, 4 feet wide by 2 feet tall. No rebar was observed.
  - The alignment of the upstream face appeared satisfactory.
  - Record photographs of the upstream face were collected by drone; detailed historic imagery for comparison of previous conditions to those observed during the inspection was not available.
- Between STA 5+50 and the left abutment, the slope consisted of a riprap protected slope. The following was noted in this area.
  - Minor brush and small trees are developing within the upstream riprap
    - Small tree growth is concentrated at the far-left end of the slope
    - Dense brush and vine growth is present near embankment contact with the left side of the concrete portion of the dam
  - Minor erosion is present at the base of the contact between the left side of the concrete portion of the dam and the earthen embankment
  - Contact between the riprap of the upstream slope and the embankment crest appeared good, with no notable settlement or voids
- Floating debris (logs, etc.) is accumulating at the upstream waterline adjacent to the left abutment

Crest

- The following was noted on the crest between the right abutment and STA 1+75.
  - The surface of the crest consists of gravel and asphalt. The asphalt was significantly deteriorated due to vehicles.
  - The shoulders consisted of maintained grass
  - The alignment of the crest appeared good.
  - Tire ruts were noted on the surface.
  - The right abutment contact appeared good with no signs of movement.
- The following was noted on the concrete section of the crest.
  - The surface of the crest was observed to have multiple cracks and deterioration. The surface had vegetation developing within the cracks.
  - The railings were observed to be in good condition. A missing post to the railing was observed at the right end of the concrete crest near STA 1+75.
  - The manhole entrance to the seepage gallery was observed near STA 2+05.
  - Between the right end of the concrete crest and the upper gatehouse, the crest appeared to be more deteriorated than the left side due to vehicular access.

  - On the downstream edge of the crest, between STA 3+25 to STA 3+40, a longitudinal crack with spalling and delamination was observed. The crack was measured up to 2 inches wide. Pieces of concrete has fallen off the edge of the crest.
- The following was observed between STA 5+50 and the left abutment:
  - The crest appeared to have a well-maintained grass cover.
  - No unusual alignment or settlement noted
  - A 3 to 4 inch diameter burrow (turtle nest) was observed at the upstream side of the dam crest near Sta. 7+15
  - The left abutment contact appeared good with no signs of movement.

Downstream Side

- The following was noted on the grassed section downstream slope to the right of the spillway.
  - The surface of the slope consisted of a well-maintained grass cover.
  - Rutting was observed throughout from mowing equipment.
  - The right abutment contact appeared good with no signs of movement.
  - Multiple burrows were present near STA 0+60, up to 1-foot in diameter.
  - Remnants of a concrete structure were present in the downstream area near STA 1+15, approximately 50 feet downstream.
  - An observation well was present at the toe near STA 1+40. The well was locked and not read during the inspection.
  - An animal burrow was present near STA 1+45, measured to be 21 inches deep and 6 inches in diameter.
  - On the shoulder near STA 1+65, a 9-inch diameter and 2 inch deep hole was noted.
  - Near STA 2+15, near mid-slope, a 3-inch diameter by 10-inch-deep animal burrow/hole was present.
  - An observation well was present adjacent to the gatehouse. The well was locked and not read during the inspection. The area around the well to the right of the gatehouse appeared to have ponded iron oxide-stained water. Vegetation blocked full view of the area.
- The following was noted on the downstream wall to the right of the spillway.
  - The concrete facing was in poor condition, with delamination, map cracking, and efflorescent staining throughout. Pieces of the facing have delaminated and are observed at the toe of the wall. The missing areas of concrete appeared to be 6 to 12 inches deep.
  - Two areas of seepage were noted:
    - Approximately 60 feet from the right of the spillway, a 15 foot wide area of seepage was noted approximately 10 feet up from the toe. Trace flow, iron oxide staining, and efflorescence was noted. Vegetation was observed growing from the top of the seepage area.
    - To the right of the training wall, seepage was noted 10 feet up from the toe with trace flow. Vegetation was developing on the wall in this area.
  - An area of exposed rebar was noted to the left of seepage area approximately 60 feet to the right of the spillway, 15 to 20 feet up from toe
  - A 2 to 3 inch diameter tree was noted near the toe of the wall 25 feet to the right of the spillway.
- The following was noted on the downstream wall to the left of the spillway.

  - Two areas of flowing seepage were identified at the base of the left downstream concrete portion of the dam and the left downstream embankment
    - One location is at Sta. 5+15 and is flowing approximately 2 to 3 gallons per minute (gpm). The area of the embankment in this area is highly saturated
    - The other location is at Sta. 4+65 and is flowing approximately 0.5 gpm. This area of seepage is near the base of a climbing rose bush.
    - Seepage appeared clear at both locations, but sediment deposition was observed in the area
  - Minor erosion is present at the base of the contact between the left side of the concrete portion of the dam and the earthen embankment
  - Minor unwanted plant growth is present along the contact of the concrete portion of the dam and the downstream embankment slope
- The following was noted on the grassed section of the downstream slope to the right of the spillway.
  - Slope appeared to be steeper than 3:1 and may be closer to 2:1.
  - Minor areas of sparse vegetative cover were present at multiple locations.
  - An apparent earth slump was present around STA. 5+65.
    - The slump was located approximately ¼ of the way up the slope from the dam toe.
    - An area approximately 10-ft in diameter was displaced, with a small mound downhill from a depression of roughly equal size.
    - No leaking or seepage was observed in this area.
    - It is unknown if the slump is still in motion.
  - Two observations wells are located near STA 5+65 at the toe and halfway up the slope.

2.1.3 Appurtenant Structures

Spillway

- At the intersection of the training walls and the spillway slab, cracking with spalling was noted.
- On the spillway bridge supports, cracks and spalls were observed, with iron oxide staining and efflorescence
- Two rows of baffles were present at the toe of the spillway. Exposed rebar was present on multiple baffle blocks in the top row.
- No flow was observed over the spillway.
- No signs of leakage or seepage were noted.
- Various longitudinal cracks were present on the spillway slab.
- More flow was noted over the left end of the end sill than the right end.
- The following was noted on the right training wall.
  - Spalling with exposed rebar was present on the downstream end
  - The downstream face of the wall was cracked with missing pieces. The cracks appeared to be misaligned.
- The soil was eroded around end of right training wall.
- The second step of the end sill was cracked and settled. Various areas of flow were noted between the cracks and beneath the second step of the end still. Multiples sections of cracking and flow were present.

- Wetness with no observed flow was noted in various areas up to 10 feet above the water in the stilling basin.

Low Level Outlet

- The following was noted at the upper gatehouse.
  - The gates appeared to be closed at time of inspection. It was reported by the City that the gates are operated regularly. Based on the underwater inspection in 2017 by CDM Smith, the bottom intake has apparent migration of soil.
  - Cracking was noted on the top upstream left side of the upstream gatehouse.
- The following was noted at the lower gatehouse.
  - The floor appeared to be delaminating and was saturated and bulging.
  - It was reported that the gates are not operated. The operability is unknown.

Seepage Gallery

- The seepage gallery was visually inspected, and a general conditional assessment was performed by Pare Corporation, and Mr. Eric Brown of the City of Worcester Department of Public Works. It is a confined space, and the Confined Space Entry and Safety Team was provided by T. Ford Construction, Mr. Fred Wallace and Mr. Sebastian Burke-Cobble. The following was noted during the inspection:
  - Upon arrival, the gallery access manhole was noted as full, and water was seeping through the perforated manhole top, indicating that the gallery was filled.
  - The seepage gallery was pumped clear of all water by the City of Worcester DPW, using two pumps. The gallery was then kept clear of water accumulation by the City, using a 2" DIA sump pump, set up at the gallery drainage trench low point at the gallery entrance manhole, located at the left toe of the dam, adjacent to the spillway pool, opposite of the gatehouse. The sump pump capacity kept the drainage water from collecting or re-filling the gallery, and allowed for safe occupancy of the seepage gallery. The original drain line out of the gallery has become clogged, most likely by calcification material, which is prevalent throughout the gallery drainage system.
  - The seepage gallery is approximately 360 LF long and is a collection system for internal drainage wells within the concrete dam. While the available dam drawings indicate that there are 9 drainage wells, a total of 18 drainage wells were located within the gallery.
  - All of the drainage wells were free draining water, and observations of each well indicated that they were open, but with extensive layering of calcification along the walls.
  - The drainage trench along the gallery floor drained effectively to the low point located at the gallery access manhole.
  - Along the lower section of the gallery, a minor, apparently long term leak was noted, which has since been sealed up by the calcification, with 6 to 8 inch long stalactites running along the length. The leak was no longer active. The leak was located approximately 210 from the right end of the seepage gallery.
  - There is an access ladder located on the upper end of the gallery, which appears to be serviceable as an emergency egress, however, there does appear to be some localized damage to some of the existing rungs.
    - The anchorages of the ladder appeared to be sound at the time of the inspection.
    - The ladder exits the dam on the crest, adjacent to the left abutment, through a manhole, which is kept locked by the City DPW.

- Overall, the seepage gallery appeared to be serviceable, and all drainage features appeared to be operable, however, free drainage of the seepage gallery has been blocked for many years, resulting in continued deposit of material on the gallery walls and floors.
- While the drainage features are still operating, the free drainage of the gallery is not, which results in the gallery being filled with water until it is pumped out by the City. The original drain was blocked, probably by calcification, which is prevalent throughout the floors trenches and walls below the standing water levels in the gallery.
- Using both a 4" DIA and a 2" DIA sump pump, the gallery is pumped out in approximately 2-3 hours, and a 2" DIA submersible sump pump, with an approximate capacity of 100 gal/min, is enough to keep the draining water from re-filling the gallery.

Downstream Channel

- The downstream channel consisted of a natural channel. The channel was unrestricted and appeared free of debris.

2.1.4 Downstream Area

The area downstream of the dam is generally wooded and undeveloped. Flows from the dam discharge into a natural channel and head downstream to the Kendall Diversion Dam (MA02326). Flows from the Kendall Diversion Dam flow into Kendall Reservoir (MA00622) and then towards Eagle Lake Dam (MA00979). Residential homes and businesses are present around the impoundment of Eagle Lake.

2.1.5 Reservoir Area

The impoundment is located within the Town of Holden, MA with no residential or commercial businesses around the shoreline. The perimeter of the reservoir is heavily wooded. The trees and brush are cleared within 50 feet of the shoreline about every other year.

The geometry of the impoundment is irregular. The upstream side of the embankment is not open to the full fetch of the impoundment due to the irregular shape of the impoundment.

2.2 Caretaker Interview

Mr. Eric Brown and Matthew Dufrense, Jr Civil Engineer, of the City of Worcester Department of Public Works and Parks were present during the inspection. Information provided by the Mr. Brown and Mr. Dufrense have been incorporated within sections of this report.

2.3 Operation and Maintenance Procedures

2.3.1 Operational Procedures

A formal Operations and Maintenance (O&M) Manual is not known to exist for this structure. The gates within the upper gatehouse are operated regularly. The gates in the lower gatehouse are not operated.

2.3.2 Maintenance of Dam

The City reported that maintenance of the dam is performed annually. The embankments are mowed two to three times per year.

2.4 Emergency Warning System

An Emergency Action Plan was prepared by CDM Smith dated June 2007. As of the 2015, an update was reportedly in progress; however, the updated EAP was not available at the time of this inspection.

2.5 Awareness of Potential Dam related Safety Hazards at, near, and on Dams

The following section identifies a list of potential dam related safety hazards which may be present in the vicinity of a dam. As part of the field inspection, the site was reviewed for the presence of these potential hazards. This list may be incomplete, and it is the responsibility of the Dam Owner to ensure compliance with Local, State, and Federal Laws, inclusive of OSHA, ADA, MADPH, and other applicable safety regulators. It is the intent of this section to inform the Dam Owner of potential safety risks that may be present.

It should be noted that the scope of the safety assessment is limited to observations noted during the inspection. Pare recommends that the Owner consider completing a comprehensive site safety assessment by trained risk reduction and hazard assessment specialists.

Table 2-1 Potential Related Safety Hazards At, Near, and On Dams

Hazard Category Checked	Hazard Present?		Comments
	Yes	No	
Fall Hazard	X		Potential fall hazard from the gate house entrance to the gatehouse floor.
Submerged Inlet	X		Submerged LLO inlets at upper gatehouse
Boater Safety		X	None observed. Boats not allowed in impoundment.
Roll Dam		X	Not Applicable
Sudden Releases		X	None observed
Confined Space	X		Access to the seepage gallery and gatehouse chambers.
Ergonomic Safety		X	None observed
Others	X		Potential for concrete facing on downstream end to detach off the wall.

Dam Safety Regulations 302 CMR Section 10.13: Liability (1), states "The owner shall be responsible and liable for damage to property of others or injury to persons, including but not limited to, loss of life resulting from the operation, failure of or mis-operation of a dam." Implementation of any recommendations may require local, state, or federal permits as well as securing property rights if subject areas are not owned by the dam owner. Securing such permits and/or land rights is the sole responsibility of the dam owner.

2.6 Hydraulic/Hydrologic Data

Based upon the size (**Large)** and hazard potential (**High** (Class III)) of this structure, the spillway design flood (SDF) for the dam is the ½ PMF-year storm event.

Based upon the available Hydraulic and Hydrologic (H&H) computations completed as part of the 2017 Rehabilitations Alternatives and Preliminary Costs by CDM Smith, the SDF outflow associated with the ½ PMF-year spillway design flood is approximately 5,550 cfs. The cumulative 72-hour rainfall associated with the SDF is 18.85-inches, which 16.83 inches runs off as excess. As reported within the same computations, with the level of the impoundment at the crest of the dam (El. 920), the weir at the spillway can accommodate approximately 7,515 cfs, which is more than the required discharge capacity. During the SDF event, the dam will have approximately 1.4 feet of freeboard to a peak elevation of approximately 918.6 feet.

Table 2-2 H&H Data Summary During the 100-yr Event

	Top Elevation (feet)	Peak Elevation (feet)	Freeboard (feet)	Peak Inflow (cfs)	SDF Outflow (cfs)	Spillway Capacity (cfs)
Pine Hill Reservoir Dam	920.0	918.6	1.4	14,470	5,550	7,515

2.7 Structural and Seepage Stability

Formal stability and seepage evaluations were completed as part of the 2017 Rehabilitations Alternatives and Preliminary Costs by CDM Smith were reviewed during the preparation of this report. No records of the original design computations were available for review.

2.7.1 Embankment Structural Stability

Based upon a visual assessment of the dam, no current signs of immediate instability were observed. In general, the slopes at the dam appear stable. However, rodent activity, erosion, sloughing, or other indications of potential movement which warrant monitoring were noted, as indicated in the sections above.

Table 2-3 Results of Embankment Slope Stability Analyses for the Existing Condition

Design Loading Condition	Slope	Required Factor of Safety	Calculated Factor of Safety	
			Left	Right
Steady Seepage at Normal Pool	Downstream	**1.5**	1.51	1.64
	Upstream		1.69	1.77
Steady Seepage at Surcharge Pool	Downstream	**1.4**	1.41	1.44
Sudden Drawdown – Maximum Pool to El. 850.0	Upstream	**1.1**	1.55	1.48
Sudden Drawdown – Normal Pool to El 850.0	Upstream	**1.2**	1.53	1.48
Psuedo-Static Seismic at Normal Pool	Downstream	**> 1.0**	1.25	1.25
	Upstream		1.17	1.11

Bold values indicate calculated factors of safety lower than the recommended minimum factors of safety.

Based on these results, the embankment slopes of the dam met the minimum required factors of safety for all conditions. CDM Smith also analyzed the concrete section of the embankment, as summarized below. The concrete section is delaminating. Analyses were done in both single and multiple wedge. The single wedge analyses was completed without cohesion and the multiple wedge analyses was completed with cohesion.

Table 2-4 Results of Concrete Embankment Stability Analyses for the Existing Condition

Design Loading Condition	% Cracked	Allowable % Cracked	$FS_{sliding}$		Required $FS_{sliding}$
			Without Cohesion (single wedge)	With Cohesion (multiple wedge)	
Normal Pool	0.0	0	**2.05**	3.37	3
Normal Pool + Ice	0.0	25	**2.01**	3.31	2
Design Flood	5.6	25	**1.62**	2.75	2
Seismic	19.6	99	1.38	2.32	1

Bold values indicate calculated factors of safety lower than the recommended minimum factors of safety.

Based on the results of the stability analyses, the dam does not meet the required factors of safety when done without cohesion, but meets the factors of safety with cohesion.

2.7.2 Structural Stability of Non-Embankment Structures

Based upon a visual assessment of the dam, no current signs of immediate instability of non-embankment structures were observed. The concrete section of the dam is deteriorating and the shotcrete facing is delaminating. As part of the 2017 Rehabilitations Alternatives and Preliminary Costs by CDM Smith, the concrete spillway and embankment section was analyzed at multiples cases, as summarized below.

Table 2-5 Results of Spillway Stability Analyses for the Existing Condition

Design Loading Condition	% Cracked	Allowable % Cracked	$FS_{sliding}$		Required $FS_{sliding}$
			Without Cohesion (single wedge)	With Cohesion (multiple wedge)	
Normal Pool	0.0	0	**1.77**	3.07	3
Normal Pool + Ice	0.0	25	**1.73**	3.01	2
Design Flood	13.1	25	**1.37**	2.32	2
Seismic	18.1	99	1.26	2.24	1

Based on the results of the stability analyses, the spillway does not meet the required factors of safety when done without cohesion, but meets the factors of safety with cohesion.

2.7.3 Seepage Stability

Based upon a visual assessment of the dam, seepage was noted on the downstream face of the concrete section of the dam. The seepage was trace flow and vegetation was noted growing from the seepage areas. Seepage was previously noted to the right of the lower gatehouse, but was not observed during this inspection.

SECTION 3

3.0 ASSESSMENTS AND RECOMMENDATIONS

3.1 Assessments

In general, the overall condition of Pine Hill Reservoir Dam is **Fair**, similar to that previously reported, with the following deficiencies identified:

Table 3-1 Deficiency Summary

Deficiency Number	*Description*
1.	Voids, erosion, developing vegetation, and areas of settlement within the upstream slope riprap.
2.	Spalling, exposed reinforcing bar, cracks, and efflorescence on the upstream face of the dam, spillway slab, training walls, and baffle blocks.
3.	Systemic failure of the previous concrete facing repair on the downstream face of the dam resulting in spalling, delamination, seepage, and fallen pieces of the facing repair.
4.	Animal burrows and tire rutting along crest and downstream slope
5.	Seepage through the downstream face of the dam
6.	Misaligned cracks and flow through cracks on the end sill.
7.	Unknown operability of the lower gates.
8.	Ponded water to the right and saturation of the floor of the lower gatehouse
9.	Calcification, blocked outlet, evidence of previous leaks, and damage to the ladder rungs within the access manhole on the crest of the seepage gallery.
10.	No formal Operations & Maintenance Manual.
11.	Other areas of additional maintenance and dam safety concerns, as reported herein.

The following tables provides a summary of the previously reported deficiencies and the current condition.

Table 3-2 Previously Reported Deficiencies & Current Status Summary

Previously Noted Deficiency/ Recommendation	*Resolution or Current Condition*
Update emergency action plan	EAP reportedly under update during 2015 inspection / Similar recommendation
Prepare formalized Operations and Maintenance Manual	No apparent change / Similar recommendation
Perform seepage and stability analysis	Seepage and stability analysis performed during 2017 Rehabilitation Alternatives and Preliminary Costs Analysis
Perform an updated H&H analysis	H&H analysis performed during 2017 Rehabilitation Alternatives and Preliminary Costs Analysis
Perform underwater inspection of the upstream face of the dam	Underwater inspection performed during 2017 Rehabilitation Alternatives and Preliminary Costs Analysis
Repair downstream face	No apparent change / Similar recommendation
Repair concrete spalling and cracking on upstream and downstream face, and spillway slab and training walls	Concrete deterioration has continued to progress / Similar recommendation
Control seepage through dam's concrete surfaces. Re-grout areas of spalled and damaged concrete	No apparent change / Similar recommendation
Construct new drainage outlet for the seepage gallery and maintain an open outlet.	No apparent change / Similar recommendation

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 measures, the applicability of environmental permits needs to be determined for activities that may occur within resource areas under the jurisdiction of local conservation commissions, MADEP, or other regulatory agencies.

3.2 Studies and Analyses

It is recommended that the owner of the dam arrange for the following investigations to be performed by a qualified registered professional engineer experienced with embankment dams and hydrology, maintenance, and monitoring activities.

1. **Operations and Maintenance Manual**: Develop an O&M for this structure. O&M should include procedures for maintaining the level of the impoundment, including adjusting the level of the impoundment seasonally to provide additional freeboard during the wetter months. Additionally, the manual should include periodic inspection schedules and operational and maintenance procedures required to ensure satisfactory operation and minimize deterioration of the facility.

2. **Update Emergency Action Plan:** Confirm update of the EAP. If no update was completed after the 2015 Phase I Inspection Report, review and update the emergency action plan.

3. **LLO Inspection:** Complete an inspection of the lower LLO structure to assess the condition of the concrete, outlet pipes, gates, and all components.

4. **Seepage Gallery Outlet Inspection**: Complete an ROV inspection of the outlet to the seepage gallery.

3.3 Yearly & Recurrent Maintenance Recommendations

The following recommendations should be performed on a regular schedule and allotted for within yearly operational budgets for the structure:

1. Perform regular monitoring and inspection of the dam and appurtenant structures, inclusive of checking for the following:
   a. Areas of suspected soil movement (e.g.: erosion, holes, depression, bulge, slides, slough)
   b. Areas of seepage through the downstream face of the wall.
   c. Areas of ponded water to the right of the gatehouse and within the gatehouse.
   d. Check operation of the gates.
   e. Complete formal Phase I Inspections of the dam; as the dam is currently considered a high hazard potential structure, formal inspection is required every 2 years.

2. Complete regular maintenance activities at the site; inclusive of the following:
   a. Routine removal of accumulated debris (fallen branches, logs, leaves, etc.) from the approach of the spillway and at the outlet pipe.
   b. Control vegetation at the dam and downstream area including hand clearing of woody vegetation within the upstream slope and downstream area.
   c. Address issue identified during the regular monitoring and inspection activities.
3. Review and update EAP annually.

3.4 Minor Repair Recommendations

The minor repairs presented below should be implemented to maintain the integrity of the structure. If deferred these maintenance items could develop into larger deficiencies that are more costly to address.

1. ***Restrict access to the downstream face immediately due to the hazard of falling delaminated pieces of the concrete facing. Measures to restrict access are recommended to be implemented promptly.***

2. Install chinking stone within the upstream slope riprap.

3. Develop concrete repair program to address the areas of concrete spalling, delamination, cracks, efflorescent staining, and exposed rebar. *It is understood that in 2017 CDM Smith prepared a Rehabilitation Alternatives and Preliminary costs presentation outlining addressing the areas of concrete deterioration. At the time of the development of the report, the status of the design is unknown.*

4. Trap and remove burrowing animals, fill animal burrow holes.

5. Improve conditions within the seepage gallery:
    a. Pending the results of the ROV inspection of the outlet pipe, either re-install the pipe or clean the outlet pipe. The free drainage of the seepage gallery needs to be restored, possibly by core drilling into the lower end of the drainage trench at the access manhole, from the inside of the wall of the drainage pool.
    b. Removal of calcium deposits from the ceiling, drainage outlets, drainage trench, and gallery walkaways.
    c. Removal of timber that is lodged in last drainage outlet.
    d. Removal of accumulated mud and debris from walls and floors.

3.5 Remedial Modification Recommendations

The following remedial measures are recommended to meet current dam safety regulations and improve the integrity and safe operation of the dam.

1. Pending results of the underwater and pipe inspection of the low-level outlet components, remedial measures may be required to address operability and identified areas of deficiency. Approach may include replacement of the gate components and repairing the floor of the lower gatehouse.

2. Address areas of seepage through the concrete section of the dam. *It is understood that in 2017 CDM Smith prepared a Rehabilitation Alternatives and Preliminary costs presentation outlining addressing the areas of seepage at the dam. At the time of the development of the report, the status of the design is unknown.*

3.6 Alternatives

The following alternatives are presented based upon a conceptual review of the concerns. Additional studies and or considerations may indicate that some or all of the options presented below are not suitable for the conditions specific to this dam and dam site.

All Recommendations: Alternative to implementing any of the repairs noted above, breaching of the dam is a viable alternative for addressing safety and stability concerns at the dam. However, given the function of the dam as part of the City's water supply system, this alternative is unlikely to be feasible.

3.7 Opinion of Probable Costs

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

Studies and Analyses

1. O&M Manual		$	5,000	-	$	10,000
2. EAP Update		$	3,000	-	$	5,000
3. LLO Inspection		$	10,000	-	$	20,000
4. Seepage Gallery Outlet Inspection		$	8,000	-	$	15,000
	Subtotal	**$**	**26,000**	**-**	**$**	**50,000**

Yearly Recommendations

1. Inspection and Monitoring		$	4,000	-	$	6,000
2. Regular Maintenance		$	4,000	-	$	6,000
3. Review and Update EAP		$	1,000	-	$	2,000
	Subtotal	**$**	**9,000**	**-**	**$**	**14,000**

Minor Repairs Recommendations

1. Restrict Downstream Access		$	0	-	$	500
2. Upstream Riprap Chinking		$	10,000	-	$	25,000
3. Concrete Repair Program[1]		$	1,500,000	-	$	4,000,000
4. Address Animal Burrows		$	3,000	-	$	8,000
5. Seepage Gallery Repairs		$	50,000	-	$	100,000
	Subtotal	**$**	**1,563,000**	**-**	**$**	**4,133,500**
	Engineering & Design	$	100,000	-	$	250,000
	Permitting	$	25,000	-	$	75,000
	30% Contingency	$	469,000	-	$	1,240,000
	Subtotal	**$**	**2,157,000**	**-**	**$**	**5,698,500**

Remedial Modifications

1. To address LLO deficiencies		*Additional Information Needed*				
2. Seepage Repairs[1]		$	2,500,000	-	$	10,000,000
	Subtotal	**$**	**2,500,000**	**-**	**$**	**10,000,000**

[1] As noted within the 2017 Repair Alternatives and Preliminary Costs Report

RECOMMENDATIONS TOTAL $ 4,692,000 - $ 15,762,500
(Exclusive of Remedial Modifications)

When comparing costs, the total cost including design, engineering, permitting, construction, and long-term maintenance should be considered.

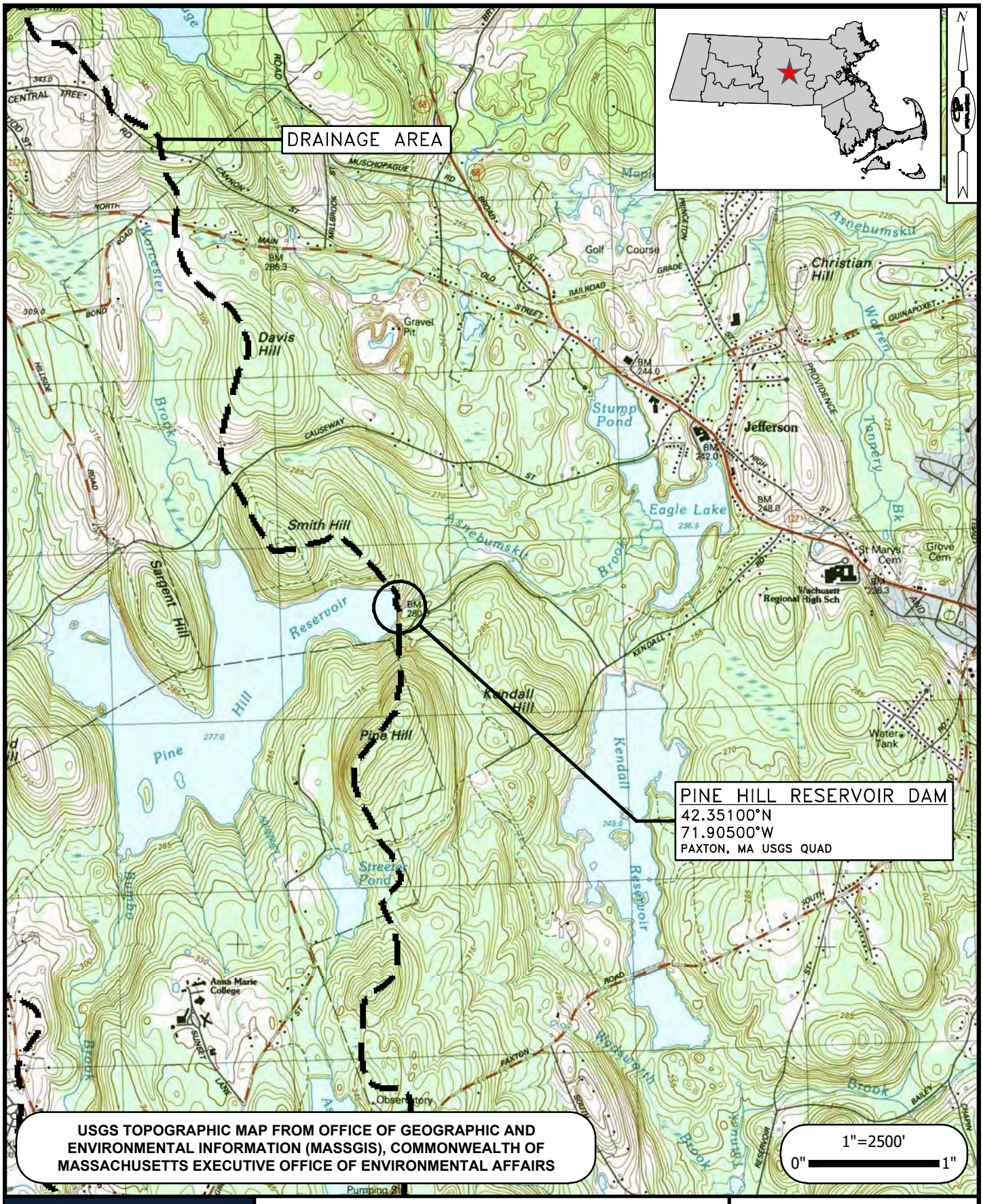
While most of these activities can be undertaken as maintenance activities under 302 CMR 10 Dam Safety and will only require that the Office of Dam Safety be notified of the activities, the applicability of other environmental permits (ie., NOI, PGP, Water Quality Certificate, etc.) needs to be determined prior to undertaking maintenance activities that may occur within resource areas under the jurisdiction of MADEP, the local conservation commission or other regulatory agency.

3.8 Site Safety Considerations

Based upon the site safety screening completed as part of the inspection, Pare recommends that the owner complete the recommended site safety assessments (See Section 3.2). The following presents a list of potential site safety improvements that should be considered. It should be noted that a detailed site safety assessment may find that some of these measures are not required and may identify additional hazards that are not identified herein.

- Post signage at the entrance to confined spaces; develop and implement confined space entry protocols.

FIGURES
Pine Hill Reservoir Dam
Holden, MA



PARE CORPORATION

PINE HILL RESERVOIR DAM

MA00623 / 3-14-134-6

HOLDEN, MASSACHUSETTS

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS

LOCUS PLAN

JUNE 2022

FIGURE 1

PARE CORPORATION

PINE HILL RESERVOIR DAM

MA00623 / 3-14-134-6

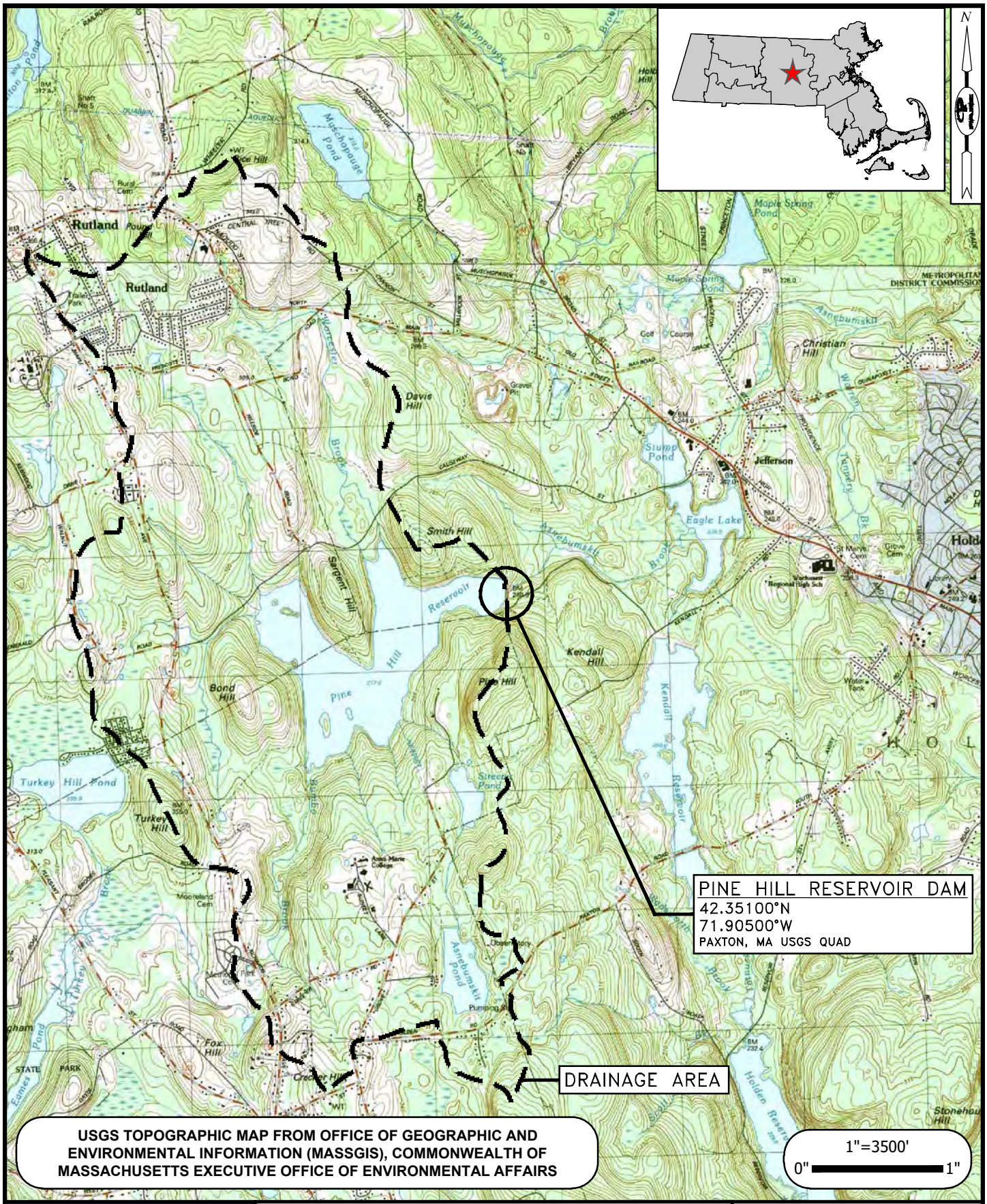
HOLDEN, MASSACHUSETTS

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS

AERIAL PLAN

JUNE 2022

FIGURE 2



USGS TOPOGRAPHIC MAP FROM OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS

PARE CORPORATION

PINE HILL RESERVOIR DAM

MA00623 / 3-14-134-6

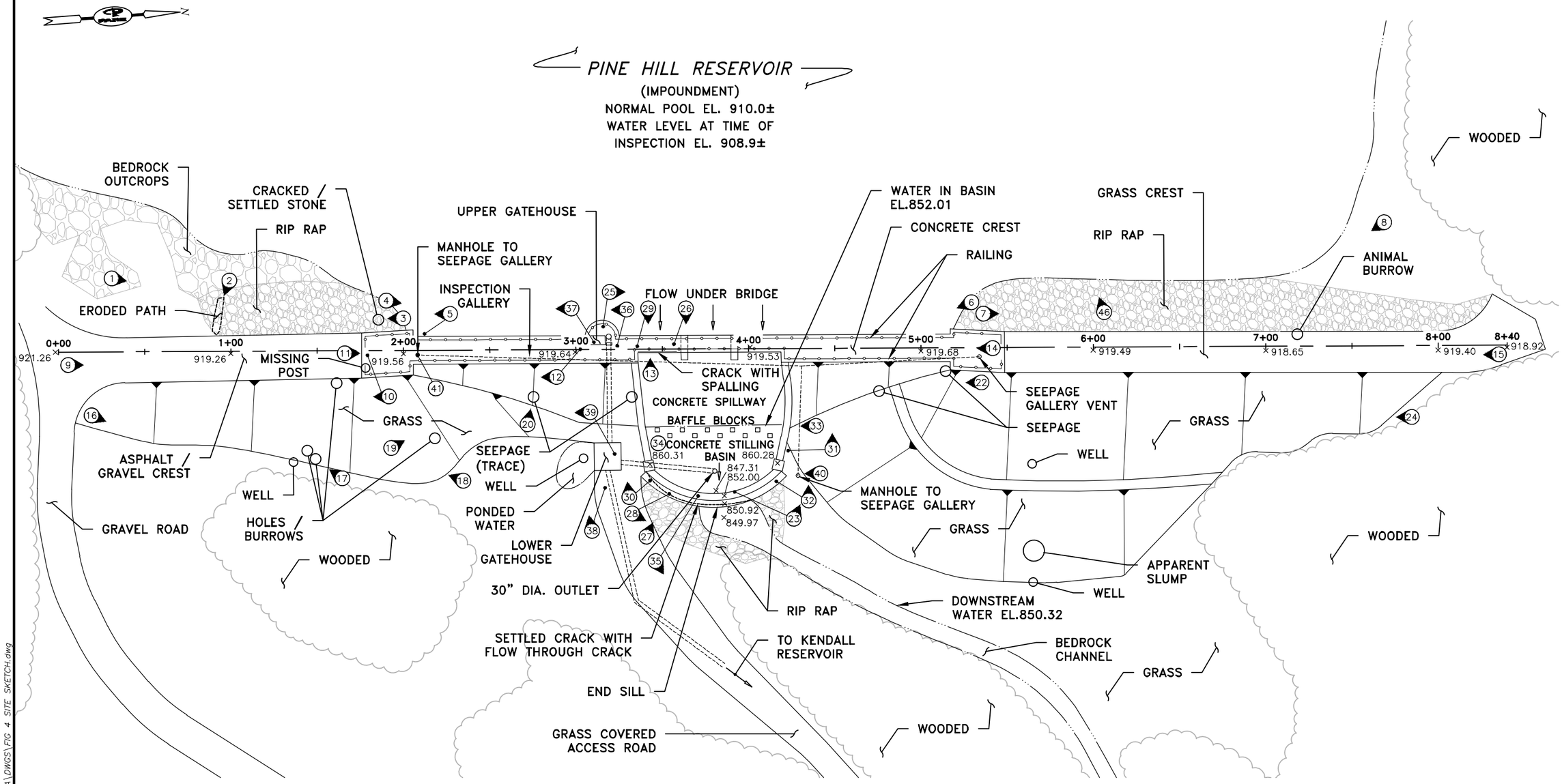
HOLDEN, MASSACHUSETTS

CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS

DRAINAGE AREA MAP

JUNE 2022

FIGURE 3



SITE SKETCH

SCALE: 1"=60'±

NOTES AND LEGEND

1. PLAN DEVELOPED FROM NOTES TAKEN DURING INSPECTION, AVAILABLE AERIAL IMAGERY FROM MASSGIS, AND THE 2015 PHASE I INSPECTION. THIS INFORMATION IS PROVIDED FOR REFERENCE PURPOSES ONLY.
2. ELEVATIONS REFERENCE THE CENTERLINE OF THE FIRST STEP OF THE END WEIR EL. 852.0.

◀# DENOTES APPROXIMATE LOCATION AND DIRECTION OF PHOTOGRAPH.

×123.45 INDICATES SPOT ELEVATIONS AS IDENTIFIED BY PARE PERSONNEL DURING THE INSPECTION.

1+00 BASELINE AND STATIONING

PARE
PARE CORPORATION
ENGINEERS - SCIENTISTS - PLANNERS
10 LINCOLN ROAD, SUITE 210
FOXBORO, MA 02035
508-543-1755

SCALE ADJUSTMENT GUIDE
0" 1"
BAR IS ONE INCH ON ORIGINAL DRAWING.

PINE HILL RESERVOIR DAM
MA00623 / 3-14-134-6
HOLDEN, MASSACHUSETTS
CITY OF WORCESTER DEPARTMENT OF PUBLIC WORKS AND PARKS

REVISIONS:

PROJECT NO.:	22001.00
DATE:	JUNE 2022
SCALE:	AS NOTED
DESIGNED BY:	HMS
CHECKED BY:	CCH
DRAWN BY:	LMC
APPROVED BY:	ARO

SITE SKETCH

FIGURE NO.: 4

Y:\JOBS\22 Jobs\22001.00 Worcester-PineHillResvDamPhaseI-MA\DWGS\FIG 4 SITE SKETCH.dwg

APPENDIX A
Photographs
Pine Hill Reservoir Dam
Holden, MA

- *Inspection Photographs*
- *Drone Imagery (on Flash Drive)*

Photo No. 1.: Upstream slope from near the right abutment looking left.

Photo No. 2.: Area of erosion and soil movement at the bend of the upstream riprap near STA 0+90.

Photo No. 3.: Upstream slope from STA 2+00 looking right.

Photo No. 4.: Upstream face from STA 2+00 looking left.

Photo No. 5.: Spalled and cracked concrete on the upstream face near STA 2+00.

Photo No. 6.: Upstream face from near STA 5+50 looking right. Note cracking and efflorescent staining throughout.

Photo No. 7.: Upstream slope from near STA 5+50 looking left.

Photo No. 8.: Upstream slope from the left abutment looking right

Photo No. 9.: Crest from the right abutment looking left.

Photo No. 10.: Crest from STA 1+75 looking right. Note deterioration of the asphalt.

Photo No. 11.: Crest from STA 1+75 looking left. Note deterioration and cracking of the concrete.

Photo No. 12.: Crest from the upper gatehouse looking right.

Photo No. 13.: Crack on the downstream edge of the crest. Note missing concrete and exposed steel mesh.

Photo No. 14.: Crest from STA 5+50 looking right. Note cracking and developing vegetation within cracks.

Photo No. 15.: Crest from the left abutment looking right.

Photo No. 16.: Downstream slope from the right abutment looking left.

Photo No. 17.: Typical animal burrow observed on the downstream slope.

Photo No. 18.: Downstream slope from STA 2+25 looking right.

Photo No. 19.: Downstream face from the right end looking left. Note delamination, spalls, and vegetation developing on the wall.

Photo No. 20.: Seepage area approximately 60 feet from the right side of the spillway. Note vegetation developing immediately above the seepage and iron oxide staining.

Photo No. 21.: Downstream face of the dam from the downstream area to the left of the dam looking right and upstream.

Photo No. 22.: Seepage where the downstream face meets the embankment slope near STA 5+15.

Photo No. 23.: Overview of the downstream face and slope left of the spillway from the center of the end sill looking left.

Photo No. 24.: Downstream slope from the left abutment looking right.

Photo No. 25.: Approach to the spillway from the right end looking left.

Photo No. 26.: Spillway from the crest looking down.

Photo No. 27.: Overview of the downstream face of the spillway.

Photo No. 28.: End sill of the spillway with settled cracks and water penetrating the cracks.

Photo No. 29.: Right training wall and spillway. Note delamination and cracking of concrete at the intersection of the two.

Photo No. 30.: End of the right training wall with exposed rebar and delamination.

Photo No. 31.: Left training wall of the spillway. Note developing vegetation and cracking.

Photo No. 32.: Downstream end of the left training wall. Note cracking and potential misalignment.

Photo No. 33.: Stilling basin of the spillway from the left end looking right.

Photo No. 34.: Baffle block with exposed rebar in the top row of the baffle blocks.

Photo No. 35.: Downstream channel of the spillway.

Photo No. 36.: Upper gatehouse exterior and plaque on the dam.

Photo No. 37.: Interior of the upper gatehouse.

Photo No. 38.: Exterior of the lower gatehouse.

Photo No. 39.: Lower gatehouse controls.

Photo No. 40.: Manhole to the seepage gallery in the downstream area to the left of the spillway. Note the seepage gallery is filled with water and leaking from the manhole.

Photo No. 41.: Interior of the access to the gatehouse from the manhole on the crest near STA 2+05.

Photo No. 42.: Bottom of the access ladder from the manhole on the crest near STA 2+05.

Photo No. 43.: Typical view of seepage gallery looking to the left.

Photo No. 44.: Seepage gallery drain with iron oxide staining, flow, and calcification.

Photo No. 45.: Seepage gallery from the left end looking right.

Photo No. 46.: Impoundment upstream of the dam.

APPENDIX B
Inspection Checklist
Pine Hill Reservoir Dam
Holden, MA

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.: 42.32100 LONG.: -71.90500

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): 60.0

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: June 15, 2022 | NID ID #: MA00623

INSPECTION SUMMARY

DATE OF INSPECTION: June 15, 2022 | DATE OF PREVIOUS INSPECTION: September 24, 2015

TEMPERATURE/WEATHER: 65° F, Mostly Clear | ARMY CORPS PHASE I: ☑ YES ☐ NO | If YES, date October 1978

CONSULTANT: Pare Corporation | PREVIOUS DCR PHASE I: ☑ YES ☐ NO | If YES, date September 24, 2015

BENCHMARK/DATUM: Center of Top Step of End Sill, El. 852.0 (NGVD29)

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

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

EL. POOL DURING INSP.: 908.9 ± | EL. TAILWATER DURING INSP.: 850.3 ±

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Clarence C. Hutto, III, P.E.	Senior Project Engineer	Pare Corporation
Andrew Cummings, P.G.	Engineer II	Pare Corporation
Heather M. Shanks	Project Engineer	Pare Corporation
Eric Brown		City of Worcester DPW
Fred Wallace		T. Ford Company
Sebastien Burke-Cobble		T. Ford Company
Dan Galante		T. Ford Company

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	$4.9M - $15.8M
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: Clarence C. Hutto, III, P.E. | SIGNATURE:

NAME OF DAM:	Pine Hill Reservoir Dam	STATE ID #:	3-14-134-6
INSPECTION DATE:	June 15, 2022	NID ID #:	MA00623

OWNER:		CARETAKER:	
ORGANIZATION	City of Worcester DPW&P	ORGANIZATION	City of Worcester DPW&P
NAME/TITLE		NAME/TITLE	Water Operations - Reservoirs
STREET	20 East Worcester Street	STREET	55 Moy Ranch Road
TOWN, STATE, ZIP	Worcester, MA 01604	TOWN, STATE, ZIP	Holden, MA 01520
PHONE	508-929-1300	PHONE	508-829-4811
EMERGENCY PH. #		EMERGENCY PH. #	508-829-4811
FAX	508-799-1448	FAX	
EMAIL	dpw@worcesterma.gov	EMAIL	DufresneM@worcesterma.gov
OWNER TYPE	Municipality or Political subdivision		

PRIMARY SPILLWAY TYPE	Uncontrolled overflow ogee weir		
SPILLWAY LENGTH (FT)	75	SPILLWAY CAPACITY (CFS)	7,515
AUXILIARY SPILLWAY TYPE	N/A	AUX. SPILLWAY CAPACITY (CFS)	N/A
NUMBER OF OUTLETS	1	OUTLET(S) CAPACITY (CFS)	Unknown
TYPE OF OUTLETS	30-inch diameter cast iron pipe	TOTAL DISCHARGE CAPACITY (CFS)	7,515
DRAINAGE AREA (SQ MI)	6.7	SPILLWAY DESIGN FLOOD (PERIOD/CFS)	1/2 PMF / 5,550

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

FISH LADDER (LIST TYPE IF PRESENT) None

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: June 15, 2022 NID ID #: MA00623

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	To the right of the concrete section, gravel and asphalt with grassed. To the left of the concrete section, well-maintained grass cover.		X	
	2. SURFACE CRACKING	Asphalt was significantly deteriorated due to vehicular access		X	
	3. SINKHOLES, ANIMAL BURROWS	3 to 4 inch diameter burrow (turtle nest) at the upstream side near Sta. 7+15		X	X
	4. VERTICAL ALIGNMENT (DEPRESSIONS	Appeared good		X	
	5. HORIZONTAL ALIGNMENT	Appeared good		X	
	6. RUTS AND/OR PUDDLES	Tire ruts noted throughout surface due to mowing equipment and vehicular access		X	
	7. GRASS COVER CONDITION	Maintained grass to the left of the spillway. Gravel in center with maintained shoulders to the right of the spillway		X	
	8. WOODY VEGETATION (TREES/BRUSH)	None observed.		X	
	9. ABUTMENT CONTACT	Appeared good		X	

ADDITIONAL COMMENTS:

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

INSPECTION DATE: June 15, 2022 NID ID #: MA00623

EMBANKMENT (D/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S SLOPE	1. WET AREAS (NO FLOW)	To the right of the gatehouse appeared to have ponded iron oxide-stained water. Vegetation blocked full view of the area.		X	
	2. SEEPAGE	None observed.		X	
	3. SLIDE, SLOUGH, SCARP	Apparent earth slump was present around STA. 5+65, located approximately ¼ of the way up the slope from the toe. An area 10-ft in diameter was displaced, with a small mound downhill from a depression of roughly equal size.		X	X
	4. EMB.-ABUTMENT CONTACT	Appeared good		X	
	5. SINKHOLE/ANIMAL BURROWS	Multiple burrows were present near STA 0+60, up to 1-foot in diameter. Animal burrow near STA 1+45, 21 inches deep and 6 inches in diameter. On the shoulder near STA 1+65, 9-inch diameter and 2 inch deep hole. Near STA 2+15, near mid-slope, a 3-inch diameter by 10-inch-deep animal burrow/hole.		X	X
	6. EROSION	None observed.		X	
	7. UNUSUAL MOVEMENT	See slide, slough, scarp		X	X
	8. GRASS COVER CONDITION	Well-maintained grass cover, with minor areas of sparse vegetative cover.		X	
	9. WOODY VEGETATION (TREES/BRUSH)	None observed.		X	

ADDITIONAL COMMENTS: 1. Rutting was observed throughout from mowing equipment.

2. Slope appeared to be steeper than 3:1 and may be closer to 2:1.

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

INSPECTION DATE: June 15, 2022 NID ID #: MA00623

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	None observed.		X	
	2. SLOPE PROTECTION TYPE AND COND.	Riprap protect slope s 4 inches to 5 feet in diameter. At bend in the riprap, stones loose. Voids up to 35-inches wide and 16-inches deep present throughout. Exposed embankment soils present behind stones.		X	X
	3. SINKHOLE/ANIMAL BURROWS	None observed		X	
	4. EMB.-ABUTMENT CONTACT	Appeared good		X	
	5. EROSION	STA 0+90, 6 inch wide by 7 inch deep on the upstream shoulder, leading to the top of the riprap. Near STA 0+90, intersection of vegetated slope and the top of riprap depressed and probed to 18-inches deep. Eroded soil was observed on the surface of the riprap within this area. Minor erosion is present at the base of the contact between the left side of the concrete portion of the dam and the earthen embankment		X	
	6. UNUSUAL MOVEMENT	An apparent cracked stone was observed near STA 1+80. A 5-inch gap was present between the two pieces, potential movement.		X	
	7. GRASS COVER CONDITION	Not Applicable		X	
	8. WOODY VEGETATION (TREES/BRUSH)	Vegetation was developing between the stones consisting of minor brush and small trees.		X	

ADDITIONAL COMMENTS:

1. The upstream shoulder appeared to be retained by the top of the riprap slope.
2. Between the right abutment and STA 0+90, the upstream slope was vegetated with areas of bedrock outcrops. The outcrops continued upstream of the riprap to STA 1+40.
3. Floating debris (logs, etc.) is accumulating at the upstream waterline adjacent to the left abutment

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

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INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None observed	X		
	2. OBSERVATION WELLS	At the toe near STA 1+40, to the right of the lower gatehouse and at the toe and halfway up the sloe near STA 5+50. All wells were locked and not read.		X	
	3. STAFF GAGE AND RECORDER	None observed	X		
	4. WEIRS	None observed	X		
	5. INCLINOMETERS	None observed	X		
	6. SURVEY MONUMENTS	None observed	X		
	7. DRAINS	Seepage gallery present within the concrete section of the dam. The seepage gallery has extensive calcification, but free draining within the drains, previously identified leaks, broken access ladder rungs to upper manhole, and a blocked outlet so the gallery fills with water and outlets from manhole on downstream end.		X	X
	8. FREQUENCY OF READINGS	Not applicable	X		
	9. LOCATION OF READINGS	Not applicable	X		

ADDITIONAL COMMENTS:

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

INSPECTION DATE: June 15, 2022 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	See instrumentation - drains.		X	
	6. INSTRUMENTATION	See instrumentation		X	
	7. VEGETATION WITHIN 15 FT	Trees approximately 15 to 20 feet from the downstream toe.		X	
	8. ACCESSIBILITY	Accessible from unpaved road on the right abutment.		X	
	9. DOWNSTREAM HAZARD DESCRIPTION	Kendall Diversion Dam (MA02326), Kendall Reservoir Dam (MA00622), Eagle Lake Dam (MA00979), Kendall Road, residences around Eagle Lake		X	
	10. Date of last EAP Update	June 2007			X

ADDITIONAL COMMENTS: 1. Remnants of a concrete structure were present in the downstream area near STA 1+00, approximately 50 feet downstream.

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MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS
MISC.	1. RESERVOIR DEPTH (AVG)	Unknown
	2. RESERVOIR SHORELINE	Wooded
	3. RESERVOIR SLOPES	Moderate to steep
	4. ACCESS ROADS	Yes, road leading to right abutment
	5. SECURITY DEVICES	Gate at the end of Kendall Rd
	6. WATER PUBLIC HAZARDS & PROTECTION	Submerged LLO inlets
	7. LAND-SIDE PUBLIC HAZARDS & PROTECTION	Fall hazard for gatehouse wells, Confined space for seepage gallery and gatehouse wells, Unstable concrete facing prone to falling to the toe of the wall.
	7. VANDALISM OR TRESPASS	☐ YES ☑ NO WHAT:
	8. AVAILABILITY OF PLANS	☑ YES ☐ NO DATE: Phase I report October 1978
	9. AVAILABILITY OF DESIGN CALCS	☐ YES ☑ NO DATE:
	10. AVAILABILITY OF EAP/LAST UPDATE	☑ YES ☐ NO DATE: June 2007
	11. AVAILABILITY OF O&M MANUAL	☐ YES ☑ NO DATE:
	12. CARETAKER/OWNER AVAILABLE	☑ YES ☐ NO DATE: During inspection
	13. CONFINED SPACE ENTRY REQUIRED	☑ YES ☐ NO PURPOSE: Seepage gallery and Gatehouse Wells

ADDITIONAL COMMENTS:

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

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PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Concrete	X		
	WEIR TYPE	Uncontrolled ogee weir	X		
	SPILLWAY CONDITION	Generally okay. Various longitudinal cracks on the spillway slab.		X	
	TRAINING WALLS	At intersection of training walls and spillway slab, cracking with spalling. Right training wall: Spalling with exposed rebar on the downstream end. The end of the wall was cracked with missing pieces, cracks were misaligned.		X	X
	SPILLWAY CONTROLS AND CONDITION	Not applicable	X		
	UNUSUAL MOVEMENT	The second step of the end sill wat settled due to flow beneath concrete.		X	X
	APPROACH AREA	Appeared clear.		X	
	DISCHARGE AREA	Exposed rebar present on multiple baffle blocks in the top row. More flow was noted over the left end of the end sill. The second step of the end sill was cracked and settled. Various areas of flow were noted between the cracks and beneath the second step of the end still.		X	X
	DEBRIS	None observed.		X	

ADDITIONAL COMMENTS: 1. On the spillway bridge supports, cracks and spalls were observed, with iron oxide staining and efflorescence

2. No flow was observed over the spillway.

3. No signs of leakage or seepage were noted.

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AUXILIARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	NOT APPLICABLE TO THIS DAM			
	WEIR TYPE				
	SPILLWAY CONDITION				
	TRAINING WALLS				
	SPILLWAY CONTROLS AND CONDITION				
	UNUSUAL MOVEMENT				
	APPROACH AREA				
	DISCHARGE AREA				
	DEBRIS				

ADDITIONAL COMMENTS:

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

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OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE	five sluice gates	X		
	INTAKE STRUCTURE	Gatehouse in upstream face of dam		X	
	TRASHRACK	Underwater at time of inspection.	X		
	PRIMARY CLOSURE	Sluice gates. Three gates of unknown size and a LLO 24-inch by 26-inch sluice gate.		X	
	SECONDARY CLOSURE	Gates within downstream gatehouse. Operability of gates unknown and reportedly not		X	X
	CONDUIT	30-inch cast iron pipe from the upper gatehouse to the lower gatehouse, to an outlet within the stilling basin. Condition unknown.		X	X
	OUTLET STRUCTURE/HEADWALL	Lower gatehouse floor cracked, saturated, and bulging.		X	X
	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	The three intakes discharge within stilling basin. Outlet for LLO not visible.		X	
	MISCELLANEOUS				

ADDITIONAL COMMENTS:

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

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CONCRETE/MASONRY DAMS (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	TYPE	Concrete	X		
	SURFACE CONDITIONS	Multiple cracks and deterioration. Vegetation developing within the cracks. Crest more deteriorated on right side than left side due to vehicular access. On the downstream edge of the crest, between STA 3+25 to STA 3+40, longitudinal crack with spalling observed, measured up to 2 inches wide, with missing sections.		X	X
	CONDITIONS OF JOINTS	Vegetation developing within joints.		X	X
	UNUSUAL MOVEMENT	None observed		X	
	HORIZONTAL ALIGNMENT	Appeared good.		X	
	VERTICAL ALIGNMENT	Appeared good.		X	

ADDITIONAL COMMENTS: 1. A missing post to the railing was observed at the right end of the concrete crest near STA 1+75.
2. The manhole entrance to the seepage gallery was observed near STA 1+85.

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CONCRETE/MASONRY DAMS (DOWNSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S FACE	TYPE	Concrete	X		
	SURFACE CONDITIONS	Concrete facing in poor condition, with delamination, map cracking, and efflorescent staining throughout. Pieces of the facing are observed at the toe of the wall. The missing areas of concrete appeared to be 6 to 12 inches deep. An area of exposed rebar noted to the left of seepage area near STA 2+75, 15 to 20 feet up from toe.		X	X
	CONDITIONS OF JOINTS	Appeared okay		X	
	UNUSUAL MOVEMENT	None observed.		X	
	ABUTMENT CONTACT	Appeared okay		X	
	LEAKAGE	Near STA 2+75, 15 foot wide area of seepage approximately 10 feet up from the toe with trace flow, iron oxide staining, efflorescence and developing vegetation. Immediately right of the training wall, seepage 10 feet up from the toe with trace flow and developing vegetation. Two areas of flowing seepage at the base of the left downstream concrete portion of the dam and the left downstream embankment: Sta. 5+15 2 to 3 gpm and Sta. 4+65 and is flowing approximately 0.5 gpm. Seepage appeared clear at both locations, but sediment deposition was observed in the area.		X	X

ADDITIONAL COMMENTS:
1. A 2 to 3 inch diameter tree was noted near the toe of the wall 25 feet to the right of the spillway.
2. Minor erosion is present at the base of the contact between the left side of the concrete portion of the dam and the earthen embankment
3. Minor unwanted plant growth is present along the contact of the concrete portion of the dam and the downstream embankment slope.

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

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CONCRETE/MASONRY DAMS (UPSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S FACE	TYPE	Concrete	X		
	SURFACE CONDITIONS	Fair condition. Cracks spaced about 4 feet apart throughout the cap. Efflorescent staining, spalling, and map cracking throughout. Spalling, measured 3 inches deep, 4 feet wide by 2 feet tall, at the waterline where riprap meets the upstream face to the right of the spillway.		X	X
	CONDITIONS OF JOINTS	A gap, up to 0.25 inches wide between the cap and the upstream wall.		X	X
	UNUSUAL MOVEMENT	None observed		X	
	ABUTMENT CONTACTS	Appeared good		X	

ADDITIONAL COMMENTS:

APPENDIX C
Previous Reports and References
Pine Hill Reservoir Dam
Holden, MA

PREVIOUS REPORTS AND REFERENCES

During the development of the report Pare also reviewed available information included within the following databases or were referenced in previous reports:

1. "Rehabilitation Alternatives and Preliminary Costs", prepared by CDM Smith, January 2017.
2. "Pine Hill Reservoir Dam Phase I Inspection/Evaluation Report", prepared by CDM Smith, date of inspection: September 24, 2015.
3. "Pine Hill Reservoir Dam Phase I Inspection/Evaluation Report", prepared by CDM Smith, date of inspection: April 11, 2012.
4. "Pine Hill Reservoir Dam Phase I Inspection/Evaluation Report", prepared by CDM Smith, date of inspection: October 9, 2007.
5. "Pine Hill Reservoir Dam Emergency Action Plan" prepared by CDM Smith, June 2007.
6. "DCR Dam Inspection Summary Report", prepared by Fuss & O'Neill, October 2005.
7. "Department of Environmental Management, Office of Dam Safety, municipally Owned Dam, Inspection/Evaluation Report", prepared by pare Engineering Corporation, date of inspection: March 27, 1998.
8. "Notice of Inspection to Worcester Department of Public Works", prepared by the Department of Environmental Management, March 1992
9. "Department of Environmental Management, Office of Dam Safety, municipally Owned Dam, Inspection/Evaluation Report", prepared by Pare Engineering Corporation, date of inspection: June 1993.
10. "Inspection Summary and Recommendations", prepared by Department of Environmental Management, date of inspection: March 4, 1992.
11. "Dam Inspection Checklist", prepared by Office of Dam Safety, dated November 20, 1991
12. "Alternative for Repair for Pine Hill Reservoir Dam", prepared by Coffin & Richardson, June 1989.
13. "Department of Environmental Management, Office of Dam Safety, Municipally Owned Dam, Inspection/Evaluation Report", prepared by CVP, date of inspection July 27, 1987.
14. "Design Drawings for Repair of Pine Hill Reservoir Dam", prepared by Coffin & Richardson Consulting Engineers, dated July 1980.
15. "Phase I Inspection Report, National Dam Inspection Program", prepared by Department of Army Core of Engineers, dated October 1978

The following references were utilized during the preparation of this report and the development of the recommendations presented herein:

1. "Design of Small Dams", United States Department of the Interior Bureau of Reclamation, 1987.
2. "ER 110-2-106 - Recommended Guidelines for Safety Inspection of Dams", Department of the Army, September 26, 1979.
3. "Guidelines for Reporting the Performance of Dams" National Performance of Dams Program, August 1994.
4. 302 CMR: Department of Conservation and Recreation Section 10.00 Dam Safety.

APPENDIX D
Common Dam Safety Definitions
Pine Hill Reservoir Dam
Holden, MA

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 therefrom, including but not be limited to, spillways; reservoirs and their rims; LLO 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. One 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, operational 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.

APPENDIX E
Visual Dam Inspection Limitations
Pine Hill Reservoir Dam
Holden, MA

VISUAL DAM INSPECTION LIMITATIONS

Visual Inspection

1. 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.

2. 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.

3. 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.

4. It is critical to note that the condition of the dam is evolutionary in nature and depends on numerous and constantly changing internal and external conditions. 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.

Use of Report

1. The applicability of other environmental permits (ie., NOI, PGP, Water Quality Certificate, etc.) needs to be determined prior to undertaking maintenance activities that may occur within resource areas under the jurisdiction of MADEP, the local conservation commission or other regulatory agency.

2. This report has been prepared for the exclusive use of the City of Worcester for specific application to the Pine Hill Reservoir Dam in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made.

3. This report has been prepared for this project by Pare. This report is for preliminary evaluation purposes only and is not necessarily sufficient to support design or repairs or recommendations or to prepare an accurate bid.