office copy 8.17.20

Nitsch Engineering

August 10, 2020

NOTICE OF INTENT

Under the *Wetlands Protection Act* (M.G.L. c. 131, §40),
the *Rivers Protection Act* (M.G.L. c. 256, Acts of 1996)
and their Regulations (310 CMR 10.00)

For:

CULVERT REPLACEMENT
LOCKS POND ROAD
Shutesbury, MA

Prepared For:

Town of Shutesbury
1 Cooleyville Road
Shutesbury, MA

Prepared by:

NITSCH ENGINEERING, INC.
2 Center Plaza, Suite 430
Boston, MA 02108

Nitsch Project #12396.1

Building better communities with you.

TABLE OF CONTENTS

SECTION 1

NOTICE OF INTENT FORMS

WPA Form 3 - Notice of Intent
NOI Wetland Fee Transmittal Form

Provided by MassDEP:

MassDEP File Number

Document Transaction Number

Shutesbury
City/Town

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

Note: Before completing this form consult your local Conservation Commission regarding any municipal bylaw or ordinance.

A. General Information

1. Project Location (**Note:** electronic filers will click on button to locate project site):

a. Street Address: Locks Pond Road	b. City/Town: Shutesbury
c. Zip Code: 01072	
Latitude and Longitude: d. Latitude: 42°30'06.6"N	e. Longitude: 72°26'12.9"W
f. Assessors Map/Plat Number: N/A	g. Parcel /Lot Number: N/A

2. Applicant:

a. First Name: Becky	b. Last Name: Torres
c. Organization: Town of Shutesbury	
d. Street Address: 1 Cooleyville Road	
e. City/Town: Shutesbury	f. State: MA
g. Zip Code: 01072	
h. Phone Number:	i. Fax Number:
j. Email Address:	

3. Property owner (required if different from applicant): ☐ Check if more than one owner

a. First Name:	b. Last Name:
c. Organization:	
d. Street Address:	
e. City/Town:	f. State:
g. Zip Code:	
h. Phone Number:	i. Fax Number:
j. Email address:	

4. Representative (if any):

a. First Name: Matthew	b. Last Name: Styckiewicz
c. Company: Nitsch Engineering	
d. Street Address: 2 Center Plaza	
e. City/Town: Boston	f. State: MA
g. Zip Code: 02108	
h. Phone Number: 508-365-1033	i. Fax Number:
j. Email address: mstyckiewicz@nitscheng.com	

5. Total WPA Fee Paid (from NOI Wetland Fee Transmittal Form):

a. Total Fee Paid:	b. State Fee Paid:	c. City/Town Fee Paid:

A. General Information (continued)

6. General Project Description:

   Culvert replacement under the bridge near the Lake Wyola Dam.

7a. Project Type Checklist: (Limited Project Types see Section A. 7b.)

1. ☐ Single Family Home
2. ☐ Residential Subdivision
3. ☐ Commercial/Industrial
4. ☐ Dock/Pier
5. ☐ Utilities
6. ☐ Coastal engineering Structure
7. ☐ Agriculture (e.g., cranberries, forestry)
8. ☒ Transportation
9. ☐ Other

7b. Is any portion of the proposed activity eligible to be treated as a limited project (including Ecological Restoration Limited Project) subject to 310 CMR 10.24 (coastal) or 310 CMR 10.53 (inland)?

1. ☐ Yes ☒ No If yes, describe which limited project applies to this project. (See 310 CMR 10.24 and 10.53 for a complete list and description of limited project types)

2. Limited Project Type

If the proposed activity is eligible to be treated as an Ecological Restoration Limited Project (310 CMR10.24(8), 310 CMR 10.53(4)), complete and attach Appendix A: Ecological Restoration Limited Project Checklist and Signed Certification.

8. Property recorded at the Registry of Deeds for:

   Franklin
   a. County
   b. Certificate # (if registered land)
   c. Book
   d. Page Number

B. Buffer Zone & Resource Area Impacts (temporary & permanent)

1. ☐ Buffer Zone Only – Check if the project is located only in the Buffer Zone of a Bordering Vegetated Wetland, Inland Bank, or Coastal Resource Area.
2. ☒ Inland Resource Areas (see 310 CMR 10.54-10.58; if not applicable, go to Section B.3, Coastal Resource Areas).

Check all that apply below. Attach narrative and any supporting documentation describing how the project will meet all performance standards for each of the resource areas altered, including standards requiring consideration of alternative project design or location.

B. Buffer Zone & Resource Area Impacts (temporary & permanent) (cont'd)

For all projects affecting other Resource Areas, please attach a narrative explaining how the resource area was delineated.

Resource Area	Size of Proposed Alteration	Proposed Replacement (if any)
a. ☒ Bank	109 1. linear feet	109 2. linear feet
b. ☒ Bordering Vegetated Wetland	25 1. square feet	 2. square feet
c. ☒ Land Under Waterbodies and Waterways	1032 1. square feet	1362 2. square feet
	 3. cubic yards dredged	

Resource Area	Size of Proposed Alteration	Proposed Replacement (if any)
d. ☐ Bordering Land Subject to Flooding	 1. square feet	 2. square feet
	 3. cubic feet of flood storage lost	 4. cubic feet replaced
e. ☐ Isolated Land Subject to Flooding	 1. square feet	
	 2. cubic feet of flood storage lost	 3. cubic feet replaced

f. ☒ Riverfront Area

Sawmill River - Inland
1. Name of Waterway (if available) - **specify coastal or inland**

2. Width of Riverfront Area (check one):

☐ 25 ft. - Designated Densely Developed Areas only

☐ 100 ft. - New agricultural projects only

☒ 200 ft. - All other projects

3. Total area of Riverfront Area on the site of the proposed project: 1362 square feet

4. Proposed alteration of the Riverfront Area:

1362	1362	0
a. total square feet	b. square feet within 100 ft.	c. square feet between 100 ft. and 200 ft.

5. Has an alternatives analysis been done and is it attached to this NOI? ☒ Yes ☐ No

6. Was the lot where the activity is proposed created prior to August 1, 1996? ☒ Yes ☐ No

3. ☐ Coastal Resource Areas: (See 310 CMR 10.25-10.35)

Note: for coastal riverfront areas, please complete **Section B.2.f.** above.

B. Buffer Zone & Resource Area Impacts (temporary & permanent) (cont'd)

Online Users: Include your document transaction number (provided on your receipt page) with all supplementary information you submit to the Department.

Check all that apply below. Attach narrative and supporting documentation describing how the project will meet all performance standards for each of the resource areas altered, including standards requiring consideration of alternative project design or location.

Resource Area	Size of Proposed Alteration	Proposed Replacement (if any)
a. ☐ Designated Port Areas	Indicate size under Land Under the Ocean, below	
b. ☐ Land Under the Ocean	1. square feet 2. cubic yards dredged	
c. ☐ Barrier Beach	Indicate size under Coastal Beaches and/or Coastal Dunes below	
d. ☐ Coastal Beaches	1. square feet	2. cubic yards beach nourishment
e. ☐ Coastal Dunes	1. square feet	2. cubic yards dune nourishment
	Size of Proposed Alteration	**Proposed Replacement (if any)**
f. ☐ Coastal Banks	1. linear feet	
g. ☐ Rocky Intertidal Shores	1. square feet	
h. ☐ Salt Marshes	1. square feet	2. sq ft restoration, rehab., creation
i. ☐ Land Under Salt Ponds	1. square feet 2. cubic yards dredged	
j. ☐ Land Containing Shellfish	1. square feet	
k. ☐ Fish Runs	Indicate size under Coastal Banks, inland Bank, Land Under the Ocean, and/or inland Land Under Waterbodies and Waterways, above 1. cubic yards dredged	
l. ☐ Land Subject to Coastal Storm Flowage	1. square feet	

4. ☐ Restoration/Enhancement
If the project is for the purpose of restoring or enhancing a wetland resource area in addition to the square footage that has been entered in Section B.2.b or B.3.h above, please enter the additional amount here.

a. square feet of BVW ____ b. square feet of Salt Marsh ____

5. ☒ Project Involves Stream Crossings

a. number of new stream crossings: 0
b. number of replacement stream crossings: 1

C. Other Applicable Standards and Requirements

☐ This is a proposal for an Ecological Restoration Limited Project. Skip Section C and complete Appendix A: Ecological Restoration Limited Project Checklists – Required Actions (310 CMR 10.11).

Streamlined Massachusetts Endangered Species Act/Wetlands Protection Act Review

1. Is any portion of the proposed project located in **Estimated Habitat of Rare Wildlife** as indicated on the most recent Estimated Habitat Map of State-Listed Rare Wetland Wildlife published by the Natural Heritage and Endangered Species Program (NHESP)? To view habitat maps, see the *Massachusetts Natural Heritage Atlas* or go to http://maps.massgis.state.ma.us/PRI_EST_HAB/viewer.htm.

   a. ☐ Yes ☒ No

   If yes, include proof of mailing or hand delivery of NOI to:

   Natural Heritage and Endangered Species Program
   Division of Fisheries and Wildlife
   1 Rabbit Hill Road
   Westborough, MA 01581

   August 2017
   b. Date of map

   If *yes*, the project is also subject to Massachusetts Endangered Species Act (MESA) review (321 CMR 10.18). To qualify for a streamlined, 30-day, MESA/Wetlands Protection Act review, please complete Section C.1.c, and include requested materials with this Notice of Intent (NOI); *OR* complete Section C.2.f, if applicable. *If MESA supplemental information is not included with the NOI, by completing Section 1 of this form, the NHESP will require a separate MESA filing which may take up to 90 days to review (unless noted exceptions in Section 2 apply, see below).*

   c. Submit Supplemental Information for Endangered Species Review*

   1. ☐ Percentage/acreage of property to be altered:

      (a) within wetland Resource Area ________ percentage/acreage

      (b) outside Resource Area ________ percentage/acreage

   2. ☐ Assessor's Map or right-of-way plan of site

2. ☐ Project plans for entire project site, including wetland resource areas and areas outside of wetlands jurisdiction, showing existing and proposed conditions, existing and proposed tree/vegetation clearing line, and clearly demarcated limits of work **

   (a) ☐ Project description (including description of impacts outside of wetland resource area & buffer zone)

   (b) ☐ Photographs representative of the site

* Some projects **not** in Estimated Habitat may be located in Priority Habitat, and require NHESP review (see http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/regulatory-review/). Priority Habitat includes habitat for state-listed plants and strictly upland species not protected by the Wetlands Protection Act.

** MESA projects may not be segmented (321 CMR 10.16). The applicant must disclose full development plans even if such plans are not required as part of the Notice of Intent process.

C. Other Applicable Standards and Requirements (cont'd)

(c) ☐ MESA filing fee (fee information available at http://www.mass.gov/dfwele/dfw/nhesp/regulatory_review/mesa/mesa_fee_schedule.htm). Make check payable to "Commonwealth of Massachusetts - NHESP" and ***mail to NHESP*** at above address

*Projects altering **10 or more acres** of land, also submit:*

(d) ☐ Vegetation cover type map of site

(e) ☐ Project plans showing Priority & Estimated Habitat boundaries

(f) OR Check One of the Following

1. ☐ Project is exempt from MESA review.
Attach applicant letter indicating which MESA exemption applies. (See 321 CMR 10.14, http://www.mass.gov/dfwele/dfw/nhesp/regulatory_review/mesa/mesa_exemptions.htm; the NOI must still be sent to NHESP if the project is within estimated habitat pursuant to 310 CMR 10.37 and 10.59.)

2. ☐ Separate MESA review ongoing. ______ a. NHESP Tracking # ______ b. Date submitted to NHESP

3. ☐ Separate MESA review completed.
Include copy of NHESP "no Take" determination or valid Conservation & Management Permit with approved plan.

3. For coastal projects only, is any portion of the proposed project located below the mean high water line or in a fish run?

a. ☒ Not applicable – project is in inland resource area only b. ☐ Yes ☐ No

If yes, include proof of mailing, hand delivery, or electronic delivery of NOI to either:

South Shore - Cohasset to Rhode Island border, and the Cape & Islands:

Division of Marine Fisheries -
Southeast Marine Fisheries Station
Attn: Environmental Reviewer
1213 Purchase Street – 3rd Floor
New Bedford, MA 02740-6694
Email: DMF.EnvReview-South@state.ma.us

North Shore - Hull to New Hampshire border:

Division of Marine Fisheries -
North Shore Office
Attn: Environmental Reviewer
30 Emerson Avenue
Gloucester, MA 01930
Email: DMF.EnvReview-North@state.ma.us

Also if yes, the project may require a Chapter 91 license. For coastal towns in the Northeast Region, please contact MassDEP's Boston Office. For coastal towns in the Southeast Region, please contact MassDEP's Southeast Regional Office.

C. Other Applicable Standards and Requirements (cont'd)

Online Users: Include your document transaction number (provided on your receipt page) with all supplementary information you submit to the Department.

4. Is any portion of the proposed project within an Area of Critical Environmental Concern (ACEC)?

   a. ☐ Yes ☒ No If yes, provide name of ACEC (see instructions to WPA Form 3 or MassDEP Website for ACEC locations). **Note:** electronic filers click on Website.

   b. ACEC

5. Is any portion of the proposed project within an area designated as an Outstanding Resource Water (ORW) as designated in the Massachusetts Surface Water Quality Standards, 314 CMR 4.00?

   a. ☐ Yes ☒ No

6. Is any portion of the site subject to a Wetlands Restriction Order under the Inland Wetlands Restriction Act (M.G.L. c. 131, § 40A) or the Coastal Wetlands Restriction Act (M.G.L. c. 130, § 105)?

   a. ☐ Yes ☒ No

7. Is this project subject to provisions of the MassDEP Stormwater Management Standards?

   a. ☐ Yes. Attach a copy of the Stormwater Report as required by the Stormwater Management Standards per 310 CMR 10.05(6)(k)-(q) and check if:

      1. ☐ Applying for Low Impact Development (LID) site design credits (as described in Stormwater Management Handbook Vol. 2, Chapter 3)

      2. ☐ A portion of the site constitutes redevelopment

      3. ☐ Proprietary BMPs are included in the Stormwater Management System.

   b. ☐ No. Check why the project is exempt:

      1. ☐ Single-family house

      2. ☐ Emergency road repair

      3. ☐ Small Residential Subdivision (less than or equal to 4 single-family houses or less than equal to 4 units in multi-family housing project) with no discharge to Critical Areas.
      or

D. Additional Information

☐ This is a proposal for an Ecological Restoration Limited Project. Skip Section D and complete Appendix A: Ecological Restoration Notice of Intent – Minimum Required Documents (310 CMR 10.12).

Applicants must include the following with this Notice of Intent (NOI). See instructions for details.

Online Users: Attach the document transaction number (provided on your receipt page) for any of the following information you submit to the Department.

1. ☒ USGS or other map of the area (along with a narrative description, if necessary) containing sufficient information for the Conservation Commission and the Department to locate the site. (Electronic filers may omit this item.)

2. ☒ Plans identifying the location of proposed activities (including activities proposed to serve as a Bordering Vegetated Wetland [BVW] replication area or other mitigating measure) relative to the boundaries of each affected resource area.

D. Additional Information (cont'd)

3. ☒ Identify the method for BVW and other resource area boundary delineations (MassDEP BVW Field Data Form(s), Determination of Applicability, Order of Resource Area Delineation, etc.), and attach documentation of the methodology.

4. ☒ List the titles and dates for all plans and other materials submitted with this NOI.

Locks Pond Road Culvert Replacement - 25% Design Plans
a. Plan Title

Nitsch Engineering
b. Prepared By

Matthew Styckiewicz
c. Signed and Stamped by

June 18, 2020
d. Final Revision Date

1" = 10'
e. Scale

f. Additional Plan or Document Title

g. Date

5. ☐ If there is more than one property owner, please attach a list of these property owners not listed on this form.

6. ☐ Attach proof of mailing for Natural Heritage and Endangered Species Program, if needed.

7. ☐ Attach proof of mailing for Massachusetts Division of Marine Fisheries, if needed.

8. ☐ Attach NOI Wetland Fee Transmittal Form

9. ☐ Attach Stormwater Report, if needed.

E. Fees

1. ☒ Fee Exempt: No filing fee shall be assessed for projects of any city, town, county, or district of the Commonwealth, federally recognized Indian tribe housing authority, municipal housing authority, or the Massachusetts Bay Transportation Authority.

Applicants must submit the following information (in addition to pages 1 and 2 of the NOI Wetland Fee Transmittal Form) to confirm fee payment:

2. Municipal Check Number

3. Check date

4. State Check Number

5. Check date

6. Payor name on check: First Name

7. Payor name on check: Last Name

F. Signatures and Submittal Requirements

I hereby certify under the penalties of perjury that the foregoing Notice of Intent and accompanying plans, documents, and supporting data are true and complete to the best of my knowledge. I understand that the Conservation Commission will place notification of this Notice in a local newspaper at the expense of the applicant in accordance with the wetlands regulations, 310 CMR 10.05(5)(a).

I further certify under penalties of perjury that all abutters were notified of this application, pursuant to the requirements of M.G.L. c. 131, § 40. Notice must be made by Certificate of Mailing or in writing by hand delivery or certified mail (return receipt requested) to all abutters within 100 feet of the property line of the project location.

Rebecca E. Jones
1. Signature of Applicant

7/9/20
2. Date

3. Signature of Property Owner (if different)

4. Date

Matthew Stechenis
5. Signature of Representative (if any)

8/4/2020
6. Date

For Conservation Commission:
Two copies of the completed Notice of Intent (Form 3), including supporting plans and documents, two copies of the NOI Wetland Fee Transmittal Form, and the city/town fee payment, to the Conservation Commission by certified mail or hand delivery.

For MassDEP:
One copy of the completed Notice of Intent (Form 3), including supporting plans and documents, one copy of the NOI Wetland Fee Transmittal Form, and a **copy** of the state fee payment to the MassDEP Regional Office (see Instructions) by certified mail or hand delivery.

Other:
If the applicant has checked the "yes" box in any part of Section C, Item 3, above, refer to that section and the Instructions for additional submittal requirements.

The original and copies must be sent simultaneously. Failure by the applicant to send copies in a timely manner may result in dismissal of the Notice of Intent.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands

NOI Wetland Fee Transmittal Form

Massachusetts Wetlands Protection Act M.G.L. c. 131, §40

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

A. Applicant Information

1. Location of Project:

Locks Pond Road — a. Street Address
Shutesbury — b. City/Town
c. Check number
d. Fee amount

2. Applicant Mailing Address:

Becky — a. First Name
Torres — b. Last Name
Town of Shutesbury — c. Organization
1 Cooleyville Road — d. Mailing Address
Shutesbury — e. City/Town
MA — f. State
01072 — g. Zip Code
h. Phone Number
i. Fax Number
j. Email Address

3. Property Owner (if different):

a. First Name
b. Last Name
c. Organization
d. Mailing Address
e. City/Town
f. State
g. Zip Code
h. Phone Number
i. Fax Number
j. Email Address

B. Fees

To calculate filing fees, refer to the category fee list and examples in the instructions for filling out WPA Form 3 (Notice of Intent).

Fee should be calculated using the following process & worksheet. ***Please see Instructions before filling out worksheet.***

Step 1/Type of Activity: Describe each type of activity that will occur in wetland resource area and buffer zone.

Step 2/Number of Activities: Identify the number of each type of activity.

Step 3/Individual Activity Fee: Identify each activity fee from the six project categories listed in the instructions.

Step 4/Subtotal Activity Fee: Multiply the number of activities (identified in Step 2) times the fee per category (identified in Step 3) to reach a subtotal fee amount. Note: If any of these activities are in a Riverfront Area in addition to another Resource Area or the Buffer Zone, the fee per activity should be multiplied by 1.5 and then added to the subtotal amount.

Step 5/Total Project Fee: Determine the total project fee by adding the subtotal amounts from Step 4.

Step 6/Fee Payments: To calculate the state share of the fee, divide the total fee in half and subtract $12.50. To calculate the city/town share of the fee, divide the total fee in half and add $12.50.

B. Fees (continued)

Step 1/Type of Activity	Step 2/Number of Activities	Step 3/Individual Activity Fee	Step 4/Subtotal Activity Fee

Step 5/Total Project Fee: ____________

Step 6/Fee Payments:

Total Project Fee: ____________ a. Total Fee from Step 5

State share of filing Fee: ____________ b. 1/2 Total Fee **less** $12.50

City/Town share of filling Fee: ____________ c. 1/2 Total Fee **plus** $12.50

C. Submittal Requirements

a.) Complete pages 1 and 2 and send with a check or money order for the state share of the fee, payable to the Commonwealth of Massachusetts.

Department of Environmental Protection
Box 4062
Boston, MA 02211

b.) **To the Conservation Commission:** Send the Notice of Intent or Abbreviated Notice of Intent; a **copy** of this form; and the city/town fee payment.

To MassDEP Regional Office (see Instructions): Send a copy of the Notice of Intent or Abbreviated Notice of Intent; a **copy** of this form; and a **copy** of the state fee payment. (E-filers of Notices of Intent may submit these electronically.)

SECTION 2

PROJECT NARRATIVE

PROJECT NARRATIVE CONTENTS

1.0 EXECUTIVE SUMMARY

On behalf of the Applicant, the Town of Shutesbury, Nitsch Engineering, Inc. is filing the enclosed Notice of Intent (NOI) with the Shutesbury Conservation Commission for the proposed culvert replacement on Locks Pond Road, which is partially located within jurisdictional wetland resource areas (subsequently referred to as the "Project"). The purpose of this NOI Application is to seek an Order of Conditions from the Shutesbury Conservation Commission approving the proposed project under the *Wetlands Protection Act* (M.G.L. c. 131, §40), the *Rivers Protection Act* (M.G.L. c. 256, Acts of 1996) and their Regulations (310 CMR 10.00), and the Shutesbury General Wetlands Protection Bylaw.

The Project site is located at Locks Pond Road, Shutesbury Massachusetts. Locks Pond Road is functionally classified by the Massachusetts Department of Transportation (MassDOT) as a rural major collector that runs for approximately 4 miles in the north-south direction and through the project area. The Project Site is located immediately downstream of the Lake Wyola dam in Shutesbury, Massachusetts. The bottom surface of the existing 10-foot diameter corrugated metal culvert is corroding and there was evidence of soil undermining in the area of the existing culvert. Additionally, the existing culvert is experiencing scour immediately downstream of the culvert. Due to the structural deterioration of the culvert and associated risk to the roadway and surrounding area, replacement is necessary. The Project is proposing the construction of a new culvert and reconstruction of Bridge No. S-15-009. The Project considered the Massachusetts Stream Crossing Standards in the design of the replacement culvert.

The site is partially located within jurisdictional wetland resource areas, including Bordering Vegetated Wetlands, Bank, Land Under Waterways, and Riverfront Area

The proposed site improvements within the Resource Area include:

- Improved culvert to maximize flow;
- Scour protection; and
- Rebuilt bridge with repaved roadway.

The Project includes several mitigation measures to offset the impacts including, scour protection, and erosion and sedimentation controls. These mitigation measures are further discussed in the narrative below.

2.0 EXISTING CONDITIONS

2.1 Existing Site Description

The 10,000 SF Project site is located on Locks Pond Road at the Lake Wyola Dam in Shutesbury, Massachusetts (Figure 1 – USGS Locus Map and Figure 2 – Aerial Locus Map). The site is bounded by residential areas to the north and southeast and open space forested areas to the west and southwest.

The existing site contains the roadway of Locks Pond Road as well as the bridge crossing the Sawmill River and the underlying cylindrical corrugated metal culvert. The bottom surface of the existing 10-foot diameter corrugated metal culvert is corroding and there was evidence of soil undermining in the area of the existing culvert. Additionally, the existing culvert is experiencing scour immediately downstream of the culvert.

2.2 Wetland Resource Areas

The Project site is directly downstream of the Lake Wyola Dam and contains the following jurisdictional wetland resource areas: Bordering Vegetated Wetland, Bank, Land Under Waterways, and Riverfront Area. Andrea Kendall conducted a site visit on July 29, 2019 to delineate these resource areas as outlined in Table 1. Detailed information on these resources is provided in the Wetland Delineation Memorandum, prepared by Andrea Kendall, provided in Section 3.

Table 1. Jurisdiction Wetland Resource Areas

Wetland Resource Area	General Location	Flag Numbers (if applicable)
Bordering Vegetated Wetland (BVW)	Along the Sawmill River	WF#104 – WF#114
Bank – Perennial Stream / River	Sawmill River Bank	WF#B6 – WF#B40
Land Under Water Bodies and Waterways (LUWW)	Land Area Beneath Sawmill River	
Riverfront Area (RFA) 200 FT	Sawmill River	
100-ft Buffer Zone (to BVW, Bank)	Adjacent to BVW and Bank	

2.3 Other Environmental Considerations

FEMA Flood Zone

Based on the FEMA Flood Insurance Rate Maps for Shutesbury (Community Panel Number 250128 0005A), the Project site is directly downstream and adjacent to the 100-year floodplain (Zone A1), but is not within the 100-year floodplain and is classified as an area of minimal flooding (Zone C). Refer to Figure 3 FEMA Map.

NHESP Priority and Estimated Habitat

Based on the 14th Edition of the Natural Heritage Atlas, effective August 1, 2017, the Project site is not located within designated Estimated Habitat of Rare Wildlife or Priority Habitat of Rare Species and does not contain any Certified Vernal Pools (Figure 4 – Natural Heritage and Endangered Species Program Map).

Certified and Potential Vernal Pools

No Certified Vernal Pools were identified in the vicinity of the Project site using MassGIS and confirmed by correspondence with NHESP (Figure 4 – Natural Heritage and Endangered Species Program Map).

3.0 PROPOSED CONDITIONS

3.1 Overview of Proposed Work

The Town is proposing the construction of a new culvert and reconstruction of Bridge No. S-15-009. Due to the structural deterioration of the culvert and associated risk to the roadway and surrounding area, replacement is necessary. The new culvert will be a concrete box culvert with a 9-foot tall by 10-foot wide opening with the bottom 2 feet of the culvert embedded in the stream. Embedding the bottom increases the roughness of the culvert, providing a more natural stream condition and reducing velocity through the culvert opening.

The Project considered the Massachusetts Stream Crossing Standards in the design of the replacement culvert. Refer to the Hydraulic Report included as an attachment for more information on the culvert design. The proposed project will result in no change in overall impervious area (Table 2).

Table 2. Existing and proposed land cover type for the Project

Land Use	Existing (sf)	Proposed (sf)	Change
Impervious Area	2362	2362	0
Pervious Area	1735	1735	0
Total	4097	4097	0

3.2 Snow Removal

Generally, snow will be moved to the edge of the road. Additionally:

- During typical snow plowing operations, snow shall be pushed to designated snow removal areas.
- Snow shall not be stockpiled in wetland resource areas or drainage system components.

4.0 RESOURCE AREA IMPACTS & PERFORMANCE STANDARD COMPLIANCE

The Project has been designed to limit disturbance in wetland resource areas to the maximum extent possible. However, due to the proximity of the Project site to the on-site wetland system, some of the proposed work will occur in the BVW, Bank, LUWW, and RFA. Table 3 provides a summary of the wetland resource areas impacted by the proposed project.

Table 3. Summary of alteration within jurisdiction wetland resource areas

Wetland Resource Area	Proposed Alteration Area (sf) (Temporary/Permanent)	New Impervious Area (sf)	Replication/ Restoration (sf)
Bordering Vegetated Wetland (BVW)	25	0	0
Bank – Perennial Stream / River	109 LF	0	109 LF
Land Under Water Bodies and Waterways (LUWW)	1092 (Permanent)	0	1362
Riverfront Area (RFA) (200 foot)	1362	0	1362
100-ft Buffer Zone (to BVW, Bank)	25	0	0

4.1 Proposed Work Within Bordering Vegetated Wetland

<u>General Performance Standards for Bordering Vegetated Wetland</u>
Under the Wetlands Protection Act, the issuing authority may issue an Order of Conditions permitting work which results in the loss of up to 5000 square feet of Bordering Vegetated Wetland when said

area is replaced in accordance with the following general conditions and any additional, specific conditions the issuing authority deems necessary to ensure that the replacement area will function in a manner similar to the area that will be lost:

1. the surface of the replacement area to be created shall be equal to that of the area that will be lost
2. the ground water and surface elevation of the replacement area shall be approximately equal to that of the lost area;
3. The overall horizontal configuration and location of the replacement area with respect to the bank shall be similar to that of the lost area;
4. the replacement area shall have an unrestricted hydraulic connection to the same water body or waterway associated with the lost area;
5. the replacement area shall be located within the same general area of the water body or reach of the waterway as the lost area;
6. at least 75% of the surface of the replacement area shall be reestablished with indigenous wetland plant species within two growing seasons, and prior to said vegetative reestablishment any exposed soil in the replacement area shall be temporarily stabilized to prevent erosion in accordance with standard U.S. Soil Conservation Service methods; and
7. the replacement area shall be provided in a manner which is consistent with all other General Performance Standards

The issuing authority may issue an Order of Conditions permitting work which results in the loss of a portion of Bordering Vegetated Wetland when;

1. said portion has a surface area less than 500 square feet;
2. said portion extends in a distinct linear configuration ("finger-like") into adjacent uplands; and
3. in the judgment of the issuing authority it is not reasonable to scale down, redesign or otherwise change the proposed work so that it could be completed without loss of said wetland.

No project may be permitted which will have any adverse effect on specified habitat sites of rare vertebrate or invertebrate species

Any proposed work shall not destroy or otherwise impair any portion of a Bordering Vegetated Wetland that is within an Area of Critical Environmental Concern.

The proposed work results in an overall improvement to the wetland system.

4.2 Proposed Work Along Bank

General Performance Standards for Bank

Under the Wetlands Protection Act, any proposed work on a Bank shall not impair the following:

1. The physical stability of the Bank;
2. The water carrying capacity of the existing channel within the Bank;
3. Ground water and surface water quality;
4. The capacity of the Bank to provide breeding habitat, escape cover and food for fisheries;
5. The capacity of the Bank to provide important wildlife functions. A project that cumulatively alters up to 10% or 50 feet of the length of the Bank found to be significant to the protection of wildlife habitat shall not be deemed to impair its capacity to provide important wildlife functions. Additional alterations beyond the above threshold may be permitted if they will have no adverse effects on wildlife habitat.

No project may be permitted which will have any adverse effect on specified habitat sites of rare vertebrate or invertebrate species.

The Project considered the Massachusetts Stream Crossing Standards in the design of the replacement culvert. The existing crossing consists of a 10' diameter pipe that allows water to flow underneath the bridge; however the culvert is in poor condition and has limited hydraulic capacity. The Project is proposing to replace this culvert with a 9' high by 10' wide precast concrete box culvert that will be embedded into the stream by two (2) feet. The hydraulic opening will be 7' by 10'. This will result in a wider span across the Bank, creation of new Bank and Land Under Water, an increased openness ratio, and improved hydraulic capacity.

The proposed work along the Bank includes the installation of rip rap scour protection immediately downstream of the culvert. The proposed work should provide no adverse effects to the stability of the Bank and should improve the water quality and carrying capacity of the existing channel. The Project will impact approximately 109 LF of Bank total. However, the proposed culvert replacement creates a new stream bed within the culvert by filling with 24 inches of stream substrate material. The replacement/restored Bank is approximately 109 feet total.

4.3 Proposed Work Within Land Under Water Bodies and Waterways

General Performance Standards for LUWW

Under the Wetlands Protection Act, any proposed work within LUWW shall not impair the following:

1. The water carrying capacity within the defined channel, which is provided by said land in conjunction with the banks;
2. Ground and surface water quality;
3. The capacity of said land to provide breeding habitat, escape cover and food for fisheries; and
4. The capacity of said land to provide important wildlife habitat functions. A project that alters up to 10% or 5,000 square feet of land in this resource area found to be significant to the protection of wildlife habitat shall not be deemed to impair its capacity to provide important wildlife functions.

No project may be permitted which will have any adverse effect on specified habitat sites of rare vertebrate or invertebrate species.

The replacement of the existing culvert and the rip rap installation will result in impacts to LUWW. The total area of impact to the LUWW is 1092 SF, which is less than the 5000 SF threshold; however, the proposed culvert replacement creates a new stream bed within the culvert by filling with 24 inches of stream substrate material. The replacement/restored LUWW is approximately 1362 square feet. This new LUWW will restore and enhance the function of the LUWW and will result in an improved connection between the BVW areas.

4.4 Proposed Work Within 100-foot Buffer Zone

The proposed site improvements within 100-foot Buffer Zone include:

- Culvert replacement;
- Rip-rap scour protection; and
- Erosion and sediment control.

5.0 RIVERFRONT AREA IMPACTS AND ALTERANTIVES ANALYSIS

There is 1,362 sf of Riverfront Area (RFA) on the Project site, located along the Sawmill River. Sawmill River is perennial and flows west from Lake Wyola. Per Section 10.58(5) of the Regulations, Previously Developed Riverfront Area (RFA) includes areas degraded prior to August 7, 1996 by absence of topsoil, which includes impervious areas. Of the 1,362 sf of existing RFA, 0% is degraded under existing conditions, either due to lack of topsoil or existing impervious area (Table 5).

Table 4. Riverfront Area Impact Summary

	0-100 ft RFA	100-200 ft RFA	Total	% of Total RFA On-site
Proposed Alteration (Total RFA within Limit of Work)	1362 sf	0 sf	1362 sf	---
Existing Degraded Area	1362 sf	0 sf	1362 sf	0%
Proposed Degraded Area	0 sf	0 sf	0 sf	0%
Net Change in Degraded Area	0 sf	0 sf	0 sf	---

The proposed project was designed to limit the increase the amount of degraded area and scour within the RFA to the maximum extent practicable, particularly within the inner 100 feet. Siting of the project entirely outside of the RFA was not practicable, as summarized in the alternatives below:

5.1 Alternative 1: No Build

Under Alternative 1, the existing site (bridge and circular culvert) would remain as they are in the existing condition. The primary issues with the existing conditions are that the culvert is degrading, disrupts water flow of the stream, and provides no scour protection. Under Alternative 1, the existing corroded culvert would remain as-is and no scour protection will be provided.

Alternative 1 is not feasible because the existing conditions are unsuitable and will continue to degrade if not reconstructed.

5.2 Alternative 2: Renovation of Existing Site

Alternative 2 would include the reconstruction of the existing site (culvert and bridge) to maximize the effectiveness of the crossing and improve the conditions of the bridge and roadway. The culvert shape would be changed to rectangular to better match the flow pattern of the stream and to prevent deterioration in the future.

Alternative 2 is feasible due to the minimal impacts on the wetland area while making key improvements to the existing deteriorating conditions.

6.0 PROPOSED MITIGATION MEASURES

The proposed project includes numerous mitigation measures to reduce the impact of the project on adjacent environmentally-sensitive areas.

6.1 Culvert Replacement

The existing 10 ft diameter corrugated metal culvert is corroding and there is evidence of soil undermining the area around the culvert. The proposed concrete culvert will create a more structurally sound riverbed and will provide greater flow for the existing stream to better prevent against flooding. Stream crossing standards were used in the design of the new culvert.

6.2 Scour Protection

The existing culvert was found to be experiencing scour immediately downstream of the culvert. It was decided that scour protection was necessary. For scour protection, Nitsch Engineering considered the riprap basin approach (Chapter 10 of HEC-14) for energy dissipation based on the critical nature of the flow at the culvert outlet. The dissipator pool for the riprap basin was calculated with a length of 33 feet, a width of 43 feet, a depth of 3.3 feet, and an overall length including the downstream apron of 50 feet. The modified riprap basin approach will provide improved scour protection while giving regard to existing site limitations and minimizing the disturbance and impact of adjacent private properties to the downstream channel.

6.3 Construction Period Erosion and Sedimentation Controls

Erosion and sedimentation controls are proposed to reduce the construction-related impact of the proposed project on adjacent wetland resource areas. Control measures will include, but are not limited to, minimizing land disturbance, providing temporary stabilization and covers, installing perimeter controls (silt fence and straw wattles/bales), and constructing temporary sediment basins. The contractor will be required to do inspections of all controls regularly to ensure that the controls are working properly. The contractor shall clean and reinstall any control that needs to be cleaned or replaced. Additionally, the contractor will clean/flush the entire stormwater management system prior to final acceptance by the owner.

The proposed project will disturb less than one acre of land, so the filing of a National Pollutant Discharge Elimination System (NPDES) Stormwater Construction General Permit is not required.

7.0 INTERESTS OF THE WETLANDS PROTECTION ACT

The Wetlands Protection Act regulates wetland resource areas in order to contribute to the following interests:

- Protection of Public and Private Water Supply
- Protection of Groundwater Supply
- Flood Control
- Storm Damage Prevention
- Prevention of Pollution
- Protection of Land Containing Shellfish
- Protection of Fisheries
- Protection of Wildlife Habitat

By improving the existing condition by improving the flow pattern of the stream and preventing future deterioration on the Project site, the proposed project will protect the interests of the Wetlands Protection Act, including protection of private/public water supply, protection of groundwater supply, providing flood control, prevention of storm damage, prevention of pollution, and protection of fish and shellfish. By minimizing work within the Resource Area, the proposed project will protect wildlife habitat.

8.0 CONCLUSION

On behalf of the Applicant, Nitsch Engineering is filing the enclosed Notice of Intent (NOI) Application with the Shutesbury Conservation Commission for the construction of the culvert replacement. The project will require some temporary alteration of Wetland Resource Areas under the Massachusetts Wetlands Protection Act (M.G.L. c. 131, §40) and its Regulations (310 CMR 10.00). The Project provides numerous mitigation measures including: increased channel flow, scour protection, and the replacement of the existing corroding culvert. This NOI report and supporting documentation provide a thorough description of the design details and regulatory compliance in accordance with the pertinent Wetland Statutes and Regulations. The Applicant seeks an Order of Conditions approving the Project as proposed.

SECTION 3
WETLAND RESOURCE AREA INFORMATION

Wetland Resource Area Delineation Report

MassDEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: ____________ Prepared by: LEC Environmental Consultants, Inc Project location: Locks Pond Road, Shutesbury, MA
Andrea Kendall, Senior Environmental Scientist LEC File #: NEI\19-100.04 DEP File #:____________

Check all that apply:

- ☐ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only
- ☑ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II
- ☐ Method other than dominance test used (attach additional information)

Section I.

Vegetation	Observation Plot Number: 1 (upland)		Transect Number: 1 (WF 110)	Date of Delineation: 7/29/19
A. Sample Layer & Plant Species (by common/scientific name)	B. Percent Cover (Midpoints used)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
Tree				
Eastern hemlock (*Tsuga canadensis*)	38.0%	50%	Yes	WPA listed*
Northern red oak (*Quercus rubra*)	38.0%	50%	Yes	No

No Shrub
No Herbaceous

* *Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus Sphagnum; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.*

Vegetation conclusion:

Number of dominant wetland indicator plants: 1 Number of dominant non-wetland indicator plants: 1

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? (yes) no
If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent

Section II. Indicators of Hydrology

Hydric Soil Interpretation

1. Soil Survey

Is there a published soil survey for this site? (yes) no
title/date: Franklin County, Massachusetts, Version 13, September 7, 2018
map number: N/A
soil type mapped: Hinckley loamy sand, 15 to 25 percent slopes
hydric soil inclusions: No

Are field observations consistent with soil survey? (yes) no
Remarks: Field observations are consistent with soil survey in color and texture.

2. Soil Description

Horizon	Depth	Matrix Color	Mottles Color
A	0-4"	5Y 5/3 fsl	
B_w	4-20"	2.5Y 4/2 fsl	
C	20-25"	2.5Y 3/2 sand	2.5Y 5/6

Remarks:

3. Other:

Conclusion: Is soil hydric? yes (no)

Other Indicators of Hydrology: (check all that apply & describe)

- ☐ Site Inundated: ____________
- ☐ Depth to free water in observation hole: ____________
- ☐ Depth to soil saturation in observation hole: ____________
- ☐ Water marks: ____________
- ☐ Drift lines: ____________
- ☐ Sediment Deposits: ____________
- ☐ Drainage patterns in BVW: ____________
- ☐ Oxidized rhizospheres: ____________
- ☐ Water-stained leaves: ____________
- ☐ Recorded Data (streams, lake, or tidal gauge; aerial photo; other): ____________
- ☐ Other: ____________

Vegetation and Hydrology Conclusion

	Yes	No
Number of wetland indicator plants ≥ # of non-wetland indicator plants	X	____
Wetland hydrology present:		
Hydric soil present	____	X
Other indicators of hydrology present	____	X
Sample location is in a BVW	____	X

Submit this form with the Request for Determination of Applicability or Notice of Intent.

MassDEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: ____________ Prepared by: LEC Environmental Consultants, Inc Project location: Locks Pond Road, Shutesbury, MA
Andrea Kendall, Senior Environmental Scientist LEC File #: NEI\19-100.04 DEP File #:____________

Check all that apply:

- ☐ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only
- ☑ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II
- ☐ Method other than dominance test used (attach additional information)

Section I.

Vegetation	Observation Plot Number: 1 (wetland)		Transect Number: 1 (WF 110)	Date of Delineation: 7/29/19
A. Sample Layer & Plant Species (by common/scientific name)	B. Percent Cover (Midpoints used)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
Ground Cover				
Sensitive fern (*Onoclea sensibilis*)	85.5%	97%	Yes	FACW*
Sedge sp. (*Carex* sp.)	3.0%	3%	No	

No Shrub
No Tree

* *Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus Sphagnum; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.*

Vegetation conclusion:

Number of dominant wetland indicator plants: 1 Number of dominant non-wetland indicator plants: 0

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? (yes) no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent

Section II. Indicators of Hydrology

Hydric Soil Interpretation

1. Soil Survey

Is there a published soil survey for this site? (yes) no
title/date: Franklin County, Massachusetts, Version 13, September 7, 2018
map number: N/A
soil type mapped: Scarboro mucky sand 0 to 2 percent slopes
hydric soil inclusions: Yes

Are field observations consistent with soil survey? (yes) no
Remarks: Field observations are consistent with soil survey in color and texture.

2. Soil Description

Horizon	Depth	Matrix Color	Mottles Color
A	0-2"	10YR 3/1 mucky fsl	
B_w1	2-5"	5Y 5/1 sand	
B_w2	5-18"	5Y 4/1 coarse sand & gravel	

Remarks: refusal at 18-inches

3. Other:

Conclusion: Is soil hydric? (yes) no

Other Indicators of Hydrology: (check all that apply & describe)

- ☑ Site Inundated: Depressional-water-stained area within wetland.
- ☑ Depth to free water in observation hole: 4-inches
- ☑ Depth to soil saturation in observation hole: 0-inches
- ☐ Water marks: ______
- ☐ Drift lines: ______
- ☐ Sediment Deposits: ______
- ☐ Drainage patterns in BVW: ______
- ☐ Oxidized rhizospheres: ______
- ☐ Water-stained leaves: ______
- ☐ Recorded Data (streams, lake, or tidal gauge; aerial photo; other): ______
- ☐ Other: ______

Vegetation and Hydrology Conclusion

	Yes	No
Number of wetland indicator plants ≥ # of non-wetland indicator plants	X	___
Wetland hydrology present:		
Hydric soil present	X	___
Other indicators of hydrology present	X	___
Sample location is in a BVW	X	___

Submit this form with the Request for Determination of Applicability or Notice of Intent.

SECTION 4

DOCUMENTATION OF ABUTTER NOTIFICATION

Abutter Notification
Affidavit of Service
Certified Abutters List

SHUTESBURY CONSERVATION COMMISSION
NOTIFICATION TO ABUTTERS

In accordance with the second paragraph of the Massachusetts Wetlands Protection Act (G.L. Ch. 131 §40), and §10.05(4)(a) of 310 CMR 10.00, and the Shutesbury Wetlands Protection Bylaw and regulations, you are hereby notified of a public hearing on the matter described below.

A. A Notice of Intent has been filed with the Shutesbury Conservation Commission seeking permission to remove, fill, dredge or alter an area subject to protection (wetland resource area and/or buffer zone) under the Massachusetts Wetlands Protection Act (General Laws Ch. 131 §40) and the Shutesbury Wetlands Protection Bylaw.

B. The name of the applicant is: Town of Shutesbury

C. The address/lot number of the land where the activity is proposed: Sawmill River Culvert at Locks Pond Road, West of Lot B-805.

D. The proposed activity is: Replacement of the culvert under Bridge No. S-15-009 and added scour protection downstream of the culvert.

E. A Public Hearing regarding this Notice of Intent will be held on: ___________________

F. **Public Participation will be via Virtual Means Only:** Governor Baker issued an Emergency Order on March 12, 2020 allowing public bodies greater flexibility in utilizing technology in the conduct of meetings under the Open Meeting Law. The Shutesbury Conservation Commission greatly values the participation of its citizens in the public meeting process, but given the current circumstances and recommendations to limit or avoid public gatherings, including Governor Baker's State of Emergency, together with the present closure of Shutesbury Town Hall, the Town has decided to implement the "remote participation" procedures allowed under Governor Baker's Emergency Order for all boards, committees, and commissions.
Remote access information will be published on the Shutesbury meeting calendar: www.shutesbury.org/node/2. Click on the agenda for the meeting you wish to attend.

G. The Notice of Intent may be examined on the Shutesbury Conservation Commission website: shutesbury.org/concom. A paper copy may be obtained, for a fee, from the Shutesbury Town Clerk: townclerk@shutesbury.org or 413.259.1204. Copies may also be obtained from the applicant or the applicant's representative.

Notice of the public hearing, including date, time, and place will be published at least five business days in advance in _________________.

For more information about this application or the Wetlands Protection Act, contact the Shutesbury Conservation Commission (concom@shutesbury.org or 413.259.3792) or the Department of Environmental Protection (DEP) Western Region Office at (413.784.1100). For information about the Shutesbury Wetlands Protection Bylaw, contact the Shutesbury Conservation Commission.

AFFIDAVIT OF SERVICE
Notice of Intent

I, *(name)*___________________________, hereby certify under the pains and penalties of perjury that on *(date)*__________________I gave notification to abutters in compliance with the Shutesbury Wetlands Protection Bylaw and regulations, in connection with the following matter:

A Notice of Intent filed under the Massachusetts Wetlands Protection Act by *(name)*______________________________with the Shutesbury Conservation Commission on *(date)*_________________for the property located at *(address)*____________________________________.

The form of the notification, and a list of the abutters to whom it was given and their addresses, are attached to this Affidavit of Service.

___________________________ ________________________
(Name) *(Date)*

TOWN OF SHUTESBURY OFFICIAL 100' ABUTTERS LIST FOR SAWMILL RIVER CULVERT AT LOCKS POND RD (WEST) OF LOT B-805

MAP	LOT	OWNER	CO-OWNER	MAILING ADDRESS	TOWN	ST	ZIP	LOCATION
B	805	TOWN OF SHUTESBURY	DAM	P O BOX 276	SHUTESBURY	MA	01072	LOCKS POND RD
B	108	LEHANE AUDREY		4 LAKE DR	SHUTESBURY	MA	01072	4 LAKE DR
B	803	DEPARTMENT OF CONSERVATION & RECREA		251 CAUSEWAY ST	BOSTON	MA	02114	LAKE WYOLA
B	818	LAKE WYOLA ASSOCIATION	C/O DONNA WEST PRESIDENT	180 LONGHILL ST	SPRINGFIELD	MA	01108	LAKE WYOLA ROADS
B	808	STOCKTON, GLENN E	STOCKTON JEANNETTE M	P O BOX 2	SHUTESBURY	MA	01072	63 LAKEVIEW RD
B	809	CUPAK THERESA		1447 EAST MOUNTAIN	WESTFIELD	MA	01085	65 LAKEVIEW RD
C	35	CUPAK THERESA J		1447 EAST MOUNTAIN	WESTFIELD	MA	01085	LAKEVIEW RD
C	41	ADAMS LISA L		56 LAKEVIEW RD	SHUTESBURY	MA	01072	56 LAKEVIEW RD
D	109	CRAWFORD MOORE LLC	MCQUEEN JEFF & KAHN AMY	156 SHUTESBURY RD	AMHERST	MA	01002	380 LOCKS POND RD
ZB	804	SHUTESBURY DAD'S PLACE, LLC	C/O K.A.Z. ASSOCIATES	46 GOLDEN HILL ST	TRUMBULL	CT	06611	387 LOCKS POND RD
ZB	806	STOCKTON, GLENN E	STOCKTON JEANNETTE M	P O BOX 2	SHUTESBURY	MA	01072	61 LAKEVIEW RD
ZD	7	DESTROMP SHELDON	O'CONNELL SUSAN	55 LAKEVIEW RD	SHUTESBURY	MA	01072	55 LAKEVIEW RD

FOR: **K ROSS**
kross@nitscheng.com
508.298.9235

FROM: **Kevin Rudden**
SHUTESBURY BOARD OF ASSESSORS
Administrative Assessor
6/15/2020

LB/KR

FIGURES

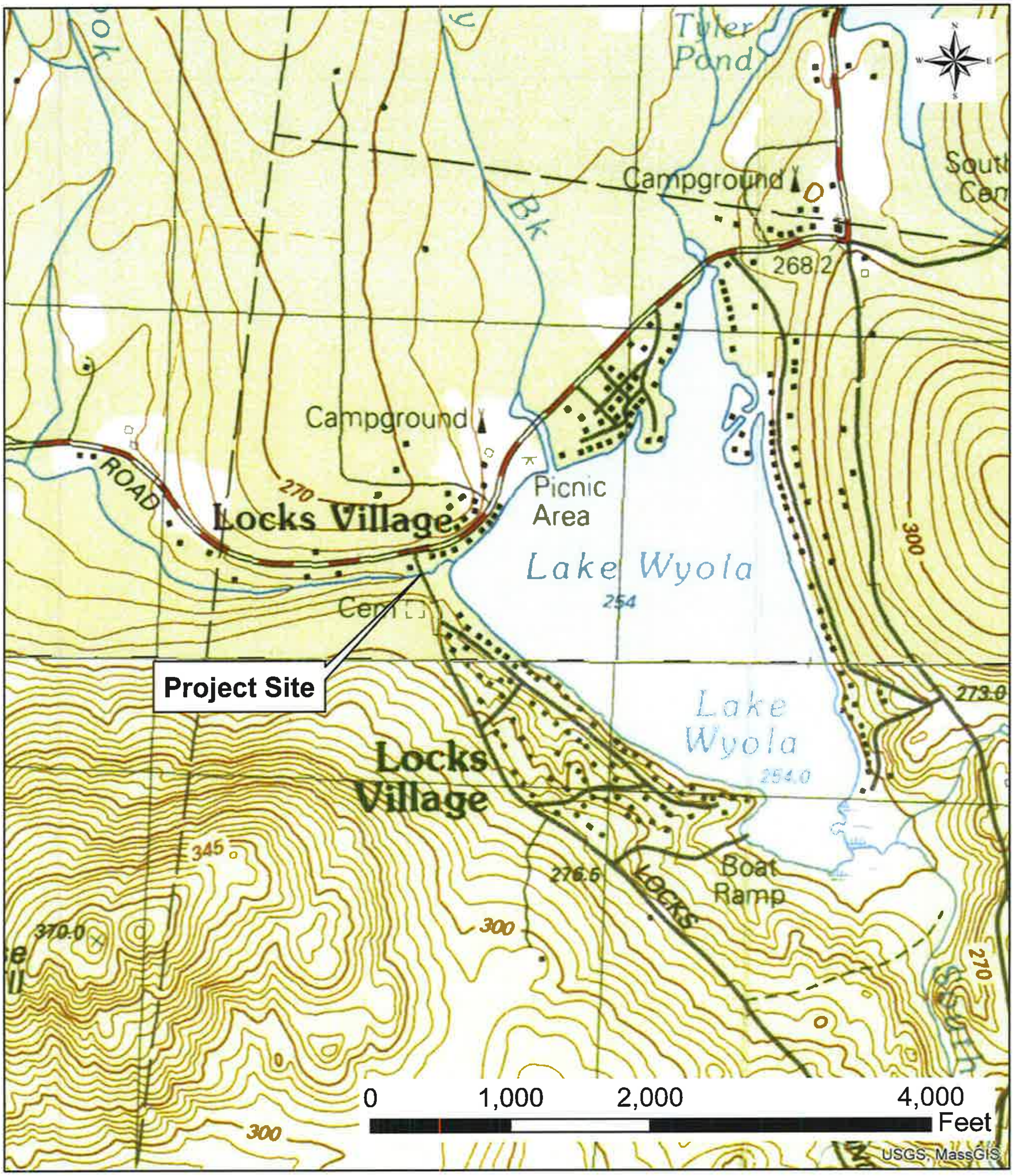


Figure 1: USGS Locus Map
Locks Pond Road Bridge and Culvert Replacement
Locks Pond Rd.,
Shutesbury, MA

Data Source: MassGIS
Nitsch Project #12396.1

Nitsch Engineering

Figure 2: Aerial Locus Map

Locks Pond Road Bridge and Culvert Replacement
Locks Pond Rd.,
Shutesbury, MA

Data Source: MassGIS
Nitsch Project #12396.1

Nitsch Engineering

Figure 3: FEMA Floodplain Map
Locks Pond Road Bridge and Culvert Replacement
Locks Pond Rd.,
Shutesbury, MA

Data Source: MassGIS
Nitsch Project #12396.1

Nitsch Engineering

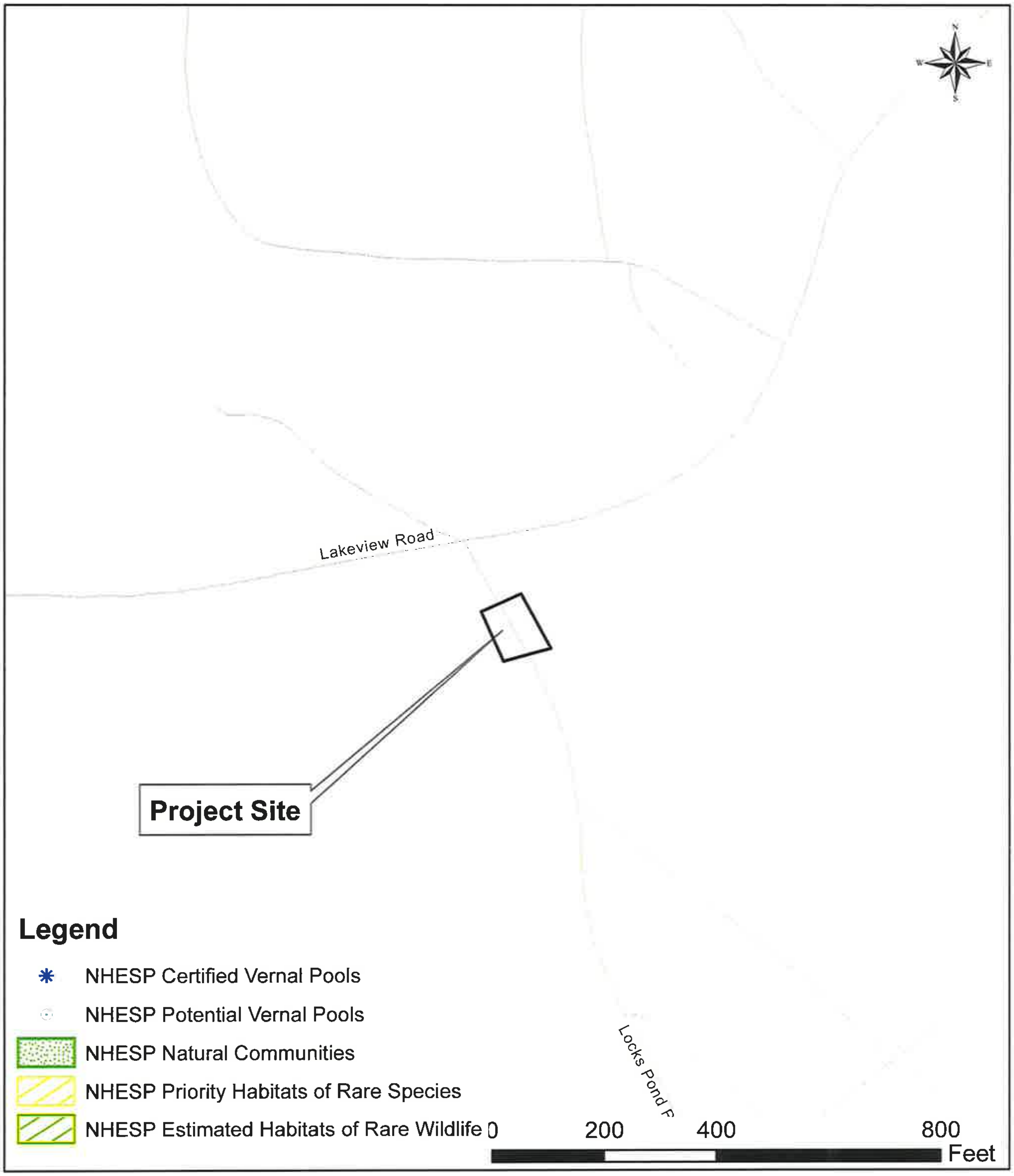
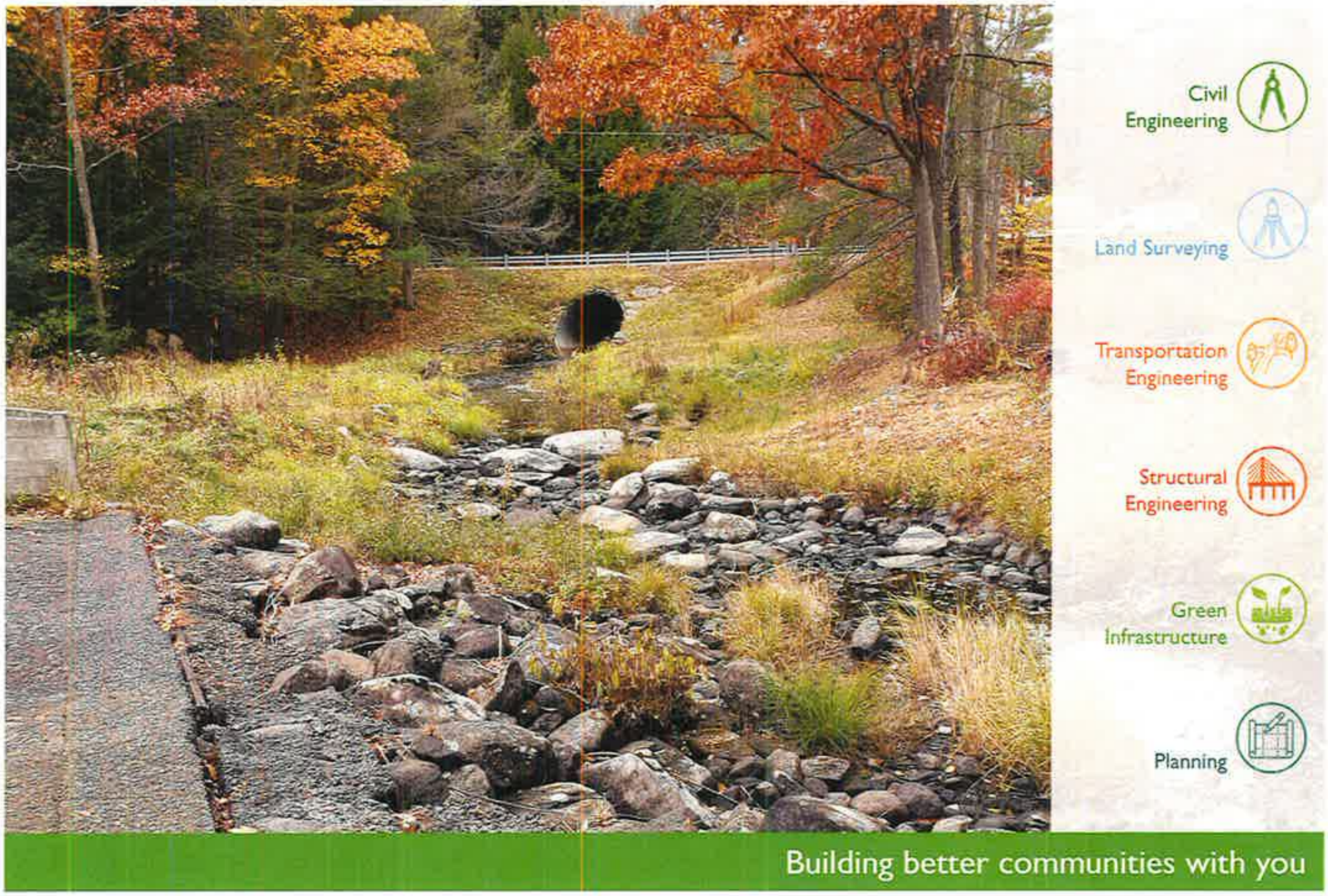


Figure 4: Natural Heritage and Endangered Species Program Map

Locks Pond Road Bridge and Culvert Replacement
Locks Pond Rd.,
Shutesbury, MA

Data Source: MassGIS
Nitsch Project #12396.1

Nitsch Engineering



Nitsch Engineering

Hydraulic Report, Locks Pond Road

The Town of Shutesbury
submitted on
December 18, 2019
Nitsch #12396.1

Table of Contents

Executive Summary

This Hydraulic Report has been prepared for the Town of Shutesbury (the Town) by Nitsch Engineering to evaluate the performance for Bridge No. S-15-009 (5PC) located along Locks Pond Road over the Sawmill River. Locks Pond Road is functionally classified by the Massachusetts Department of Transportation (MassDOT) as a rural major collector that runs for approximately 4 miles in the north-south direction and through the project area. The Project Site is located immediately downstream of the Lake Wyola dam in Shutesbury, Massachusetts. The bottom surface of the existing 10-foot diameter corrugated metal culvert is corroding and there was evidence of soil undermining in the area of the existing culvert. Additionally, the existing culvert is experiencing scour immediately downstream of the culvert. Due to the structural deterioration of the culvert and associated risk to the roadway and surrounding area, replacement is necessary.

The watershed area to the Project Site is approximately 6.84 square miles and is primarily wooded. Flow directed to the culvert within the Project Site is controlled by the Lake Wyola dam. The Town of Shutesbury manages the elevation of Lake Wyola, which fluctuates between summer and winter months. For the purposes of the hydrologic analysis, Lake Wyola was assumed to be in the "summer condition" where the lake elevation is flowing over the spillway and there is no available storage for mitigation.

The hydrologic and hydraulic analysis prepared to support the culvert replacement was prepared based on the MassDOT LRFD Bridge Manual – 2013 Edition, including the following:

- Hydraulic design of culverts crossing below rural major collectors is based on the 25-year flood return frequency event;
- Scour design is governed by the 50-year return frequency and checked for the 100-year return frequency;
- Proposed crossings may not cause any significant change in the waterway's flow regime for the design storms. This includes maintaining or reducing the peak elevation for each of the design storms – in this case, the 25-, 50-, and 100-year design storms; and
- Proposed bridges crossing or located near municipal or state-owned dams under the jurisdiction of the Massachusetts Department of Conservation and Recreation (MassDCR) Office of Dam Safety shall be designed so as to avoid or minimize any adverse impact on structural integrity of the affected flood control system.

The Massachusetts Department of Environmental Protection (MassDEP) Stream Crossing Guidelines were also reviewed with the intent of maintaining or improving the crossing's stream connectivity. The project was also designed to minimize impacts to the existing wetland resource areas, including the Bank of the existing stream channel.

The hydraulic analysis of the existing conditions determined that the 10-foot diameter existing culvert has sufficient hydraulic capacity to convey the 25-year design storm without overtopping Locks Pond Road. However, the model indicates that the roadway will overtop in larger storms, including the 50- and 100-year design storms.

The proposed conditions hydraulic analysis determined that a concrete box culvert with a 9-foot tall by 10-foot wide opening with the bottom 2 feet of the culvert embedded in the stream meets the design criteria. Embedding the bottom increases the roughness of the culvert, providing a more natural stream condition and reducing velocity through the culvert opening.

For scour protection, Nitsch Engineering considered the riprap basin approach (Chapter 10 of HEC-14) for energy dissipation based on the critical nature of the flow at the culvert outlet. The dissipator pool for the riprap basin was calculated with a length of 33 feet, a width of 43 feet, a depth of 3.3 feet, and an overall length including the downstream apron of 50 feet. Based on the magnitude of the flow discharging from the culvert during the 50-year storm event as modeled in the Hydrologic Engineering Center River Analysis System model (HEC-RAS), the riprap is proposed with a D50 of 18 inches. Given existing space constraints downstream of the culvert and the desire to utilize a scour protection measure as close to natural conditions as possible, Nitsch Engineering suggests modifying the calculated downstream scour protection design to conform to the limits of the existing channel (approximately 20 feet wide at the channel bottom). The modified riprap basin approach will provide improved scour protection while giving regard to existing site limitations and minimizing the disturbance and impact of adjacent private properties to the downstream channel.

1 Introduction

1.1 Purpose

This study has been prepared for the Town of Shutesbury (the Town) by Nitsch Engineering to evaluate the performance for the Massachusetts Department of Transportation (MassDOT) Bridge No. S-15-009 (5PC) over the Sawmill River near the Lake Wyola dam in Shutesbury, Massachusetts. The study has been prepared based on the latest American Association of State Highway Transportation Officials (AASHTO), Federal Highway Administration (FHWA), Army Corps of Engineer (ACOE), and MassDOT guidelines for bridges.

The study consists of an evaluation of hydrologic and hydraulic data for the Sawmill River where it crosses below Locks Pond Road. This includes the Lake Wyola dam and associated outfall, which are located directly upstream of the project site. The data was used to complete hydraulic and scour analysis of the opening under Locks Pond Road. The findings of the hydraulic and hydrologic research are included in this report, along with recommendations for design.

1.2 Site Description

The Project Site is a segment of roadway that lies just south of the intersection of Lakeview Road and Locks Pond Road just west of the Lake Wyola Dam in the Town of Shutesbury. The project boundary is approximately 0.9 acres and spans from the channel immediately downstream of the dam to 60 feet downstream of the Locks Pond Road culvert while bound by roadway improvements between the Lakeview Road intersection and the Morse Hill Outdoor Education Center. (Figure 1).

Figure 1: Aerial Locus (Google imagery)

1.3 Lake Wyola Dam Management

The Project Site is located within open space located directly downstream of the Lake Wyola Dam. Lake Wyola is a major recreational facility that is controlled by a dam structure with an outlet control and overflow spillway. According to the Lake Wyola Dam Phase I Inspection/Evaluation Report (Appendix 7.7), the dam is a stone wall – earth embankment structure which is 11 ½ feet high and 150 feet long with a concrete spillway section that is 78 feet long. A low-level outlet sluiceway, 3 ½ feet square, is located near the center of the stone wall – earth embankment dam. The sluiceway is controlled by a sluice gate operated from within the gatehouse located on the dam crest.

The Town of Shutesbury regulates the dam operations of Lake Wyola. This is in coordination with the Massachusetts Department of Conservation and Recreation (MassDCR) as well as the Lake Wyola Recreation Association. The operation of the dam and spillway during normal seasonal operations dictates the flow through the channel and the culvert structure. Currently, the Lake Wyola dam operates in two (2) major seasons. During the summer months, the surface elevation of the Lake is maintained to have an average of 2 inches flowing over the spillway. This flow is estimated to be approximately 8 cfs. During the winter months, Lake Wyola is drawn down through a flow control gate structure. The flow control gate structure is a manually operated gate that outlets to a 36-inch pipe at the base of the dam. The flow of the pipe when the gate is entirely open is 45 cfs. Lake Wyola is typically drawn down in the winter such that the lake height is 2 feet below the spillway. **For the purposes of the hydrologic analysis, Lake Wyola was assumed to be in the "summer condition" where the lake elevation is flowing over the spillway and there is no available storage for mitigation.**

1.4 Existing Flow Regime

Flow discharged through the Lake Wyola dam travels via two (2) stream channels before combining into a single channel that enters the existing culvert (Figure 4). The existing culvert is a 10-foot diameter corrugated metal pipe that is in deteriorating disrepair. The bottom of the culvert has corroded away, leaving a natural soil bottomed culvert with increased undermining under and around the remaining pieces of the culvert. Wingwalls on the upstream and downstream side of the culvert that support the channel and opening are made of fieldstone.

Based on previous flooding issues onsite as documented by the Town Dam Operator and the Lake Wyola Dam Phase I Inspection/Evaluation Report it appears that, in large storms, the channels between the dam and the existing culvert backs up and fills before backing up into the overall lake. According to the 2016 Dam Inspection Report, the spillway crest resides at an elevation of 835.1 feet. The height of the existing roadway is at an elevation of 835.33 feet. Historically, the roadway has not crested in a major storm event as similar to the time during the October 9, 2005 storm event where the remnants of Tropical Storm Tammy and Subtropical Depression Twenty-Two contributed to major flooding in the region (as noted in the Dam Inspection Report). See photos below depicting the current state of the onsite infrastructure.

Within the modelled natural stream reach located upstream of the culvert, there is a portion of the stream bank that is wider and has a split channel between the spillway. This is seen in the figure below (Figure 4). This condition is present in both the existing and proposed model, as this area is on private property and is not within the proposed project limit of work. The contributing area for the entire watershed is routed through Lake Wyola and outlets to these natural stream channel segments, which are located just upstream of the culvert.

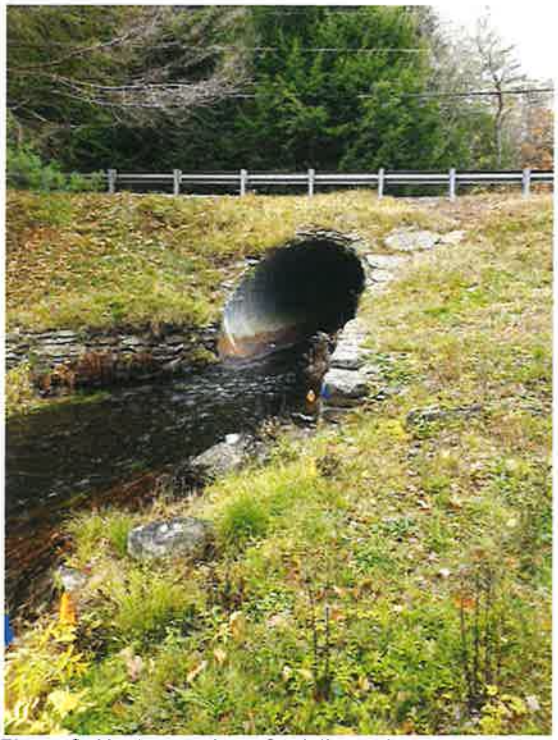


Figure 2. Upstream view of existing culvert

Figure 3. Close-up of corrosion in existing culvert

Figure 4: Split stream channel upstream of culvert.

1.5 Existing Streambed Substrate

Nitsch Engineering received a particle size analysis of the streambed characteristics prepared by Lahlaf Geotechnical Consulting and provided on November 19, 2019. The soil texture at the existing culvert inlet is poorly graded gravel with sand (ASTM classification). The streambed surroundings upstream of the culvert were observed as stabilized grass. Downstream within the channel, the embankments consisted of a fieldstone wall as well as an embankment with evidence of erosion and trees with a stabilizing root system. Photos of these soil conditions can be seen below.

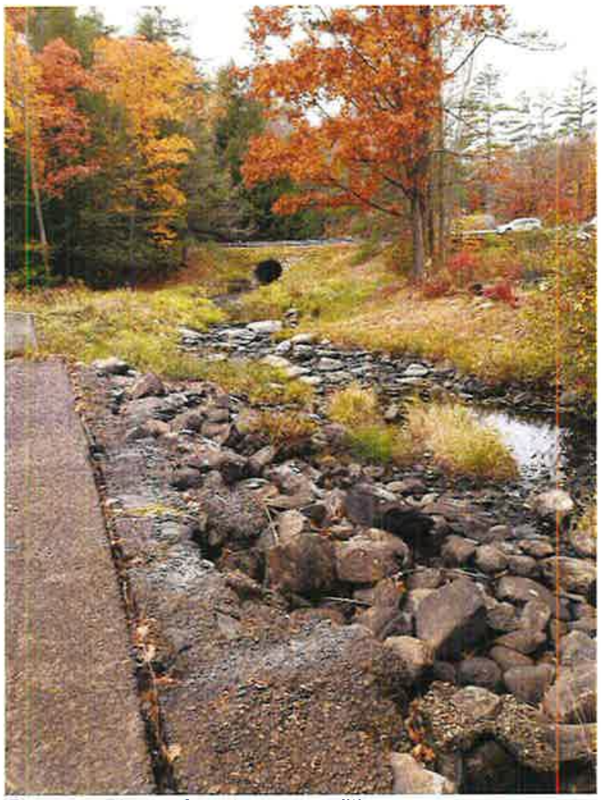


Figure 5: Photo of upstream condition

Figure 6. Photo of downstream condition

1.6 Roadways

Locks Pond Road provides an important connection through the Town of Shutesbury, as it is part of the roadway system around Lake Wyola. It is functionally classified by the Massachusetts Department of Transportation (MassDOT) as a rural major collector that runs for approximately 0.2 miles in the north-south directions through the project area. Locks Pond Road continues south until it intersects with Cooleyville Road. It also extends north and intersects with Lakeview Road terminating right outside the project limits.

1.7 Land Uses

The land use along Locks Pond Road is primarily residential and recreational. The land around Lake Wyola is primarily bordered by residential land use. Immediately upstream of the project culvert, the channel resides in open space owned by the Town of Shutesbury. This open space is surrounded by residential homes that back up to the open space and channel. Downstream, the stream is lined with residential homes on either side of wooded banks.

1.8 Environmental Considerations

1.8.1 FEMA Flood Zone

Based on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM) for the Town of Shutesbury (Community Panel Number 250128 0005A), the Project Site is directly downstream and adjacent to the 100-year floodplain (Zone A1). However, the site is not located within the 100-year floodplain and is classified as an area of minimal flooding (Zone C). The FIRM was last revised in 1980 (Appendix 5.1). There are no National Flood Insurance Program (NFIP) Regulatory Floodways identified within the project limits.

1.8.2 NHESP Priority and Estimated Habitat

Based on the 13th Edition of the Natural Heritage and Endangered Species Program (NHESP) Natural Heritage Atlas, effective October 1, 2008, the culvert is not located within designated Estimated Habitat of Rare Wildlife or Priority Habitat of Rare Species and do not contain any Certified Vernal Pools in their vicinity (Appendix 5.1).

1.8.3 Wetlands

On July 29, 2019, LEC Environmental Consultants, Inc. (LEC) conducted a site evaluation to identify and characterize existing protectable Wetland Resource Areas located immediately adjacent to and within 100 feet of where the Sawmill River crosses underneath Locks Pond Road. LEC determined that the areas surrounding the crossing is a Bordering Vegetated Wetland (BVW), and a Bank-Mean Annual High Water (MAHW), Land Under Water Bodies and Waterways (LUW), and Riverfront Area to a perennial stream. These are detailed in the Wetland Resource Areas Analysis Report provided in Appendix 5.5.

2 Hydrologic & Hydraulic Analysis

The following data resources were utilized to prepare the hydrologic and hydraulic analyses presented in this report:

- Existing Conditions Survey, prepared by Nitsch Engineering (performed in July and October 2019);
- Maine and Massachusetts 2015 QL1 AND QL2 LiDAR (to supplement surveyed topography); and
- United States Geological Survey (USGS) Streamflow Statistics (StreamStats) program.

2.1 Hydrologic Analysis

2.1.1 Methodology – USGS StreamStats

StreamStats is a mapping tool provided by United States Geological Survey (USGS) that provides spatial analytical tools to users for watershed applications, including planning and management for engineering and design. These spatial tools include watershed mapping, basin characteristics, and estimates of streamflow during storm events. The streamflow estimations by the site incorporate USGS groundcover information and other geospatial datasets aggregated by USGS data collection stations and stream gauge stations. The storm event information and runoff in each watershed area is calculated using regression equations that are used for estimating exceedance probabilities for the 50-, 25-, 10-, 2-, 1-, .05-, and 0.2- percent annual storms. More information for StreamStats calculations can be found on the USGS website at www.streamstats.usgs.gov/ss/.

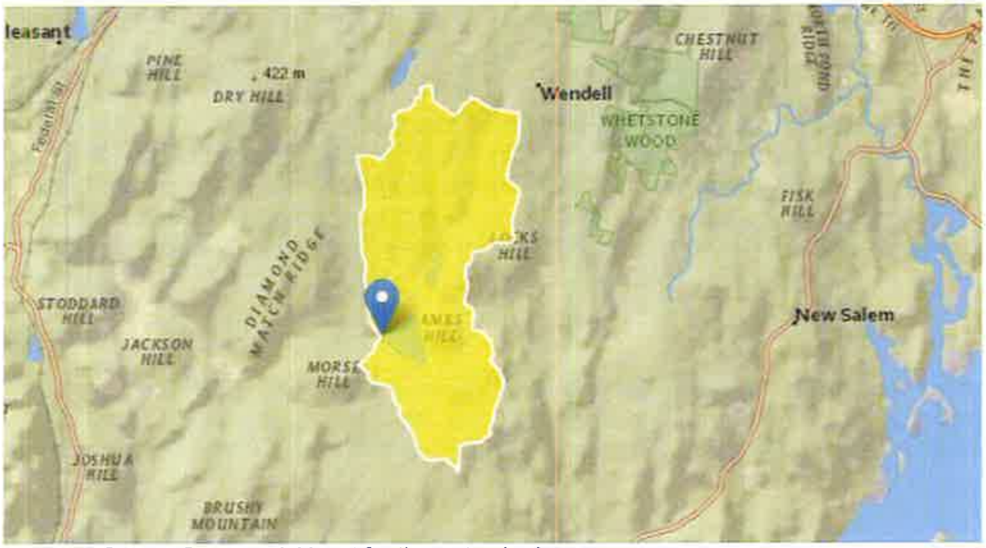


Figure 7: Stream Stats model input for the watershed

2.1.2 Hydrologic Summary

Table 1 summarizes the drainage area and peak flood flow hydrologic analysis calculated using United States Geological Survey (USGS) StreamStats. The upstream drainage watershed that drains to the Locks Pond Road drainage culvert is a total of 6.84 square miles and consists of wooded rural residential areas, including single family homes that surround Lake Wyola. Ultimately, the drainage that flows to the Locks Pond Road culvert continues downstream westward into the Town of Leverett.

Table 1: Watershed hydrologic analysis summary

Total Watershed Area (square miles)	Mean Basin Elevation (feet)	Peak Runoff Rate (cfs)		
		25-yr storm	50-yr storm	100-yr storm
6.84	922	758	930	1118

2.2 Hydraulic Analysis

2.2.1 Methodology

Nitsch Engineering referenced the following documents to develop the methodology for this hydraulic analysis:

- LRFD Bridge Manual, Part 1, Chapters 1 and 2 (MassDOT, 2013); and
- Massachusetts River and Stream Crossing Standards, (River and Stream Continuity Partnership, March 2011).

Table 2 outlines the references used by Nitsch Engineering to develop the methodology for the hydraulic analysis.

Table 2: Hydraulic Analysis Design Parameters and Methods

Parameter	Design Target / Methodology	Reference
Design Storm Frequency	*For Major Rural Collector* Hydraulic Design: 25-year storm Scour Design/Check: 50-year/100-year storm	MassDOT LFRD Bridge Manual, Part 1, Table 1.3.4-1
Peak Discharge for Design Storms	USGS StreamStats	MassDOT LFRD Bridge Manual, Part 1
Peak Elevation	Maintain or reduce existing peak elevation	MassDOT LFRD Bridge Manual, Part 1
Scour Analysis	HEC-14	MassDOT LFRD Bridge Manual, Part 1

2.2.2 HEC-RAS Model

The Hydrologic Engineering Center River Analysis System (HEC-RAS) water surface profile model, using steady flow analysis, was used to analyze the hydraulic function of the proposed culvert. The HEC-RAS software, which can simultaneously model complex hydrology, hydraulics, and water quality, can be used for designing and analyzing bridges and culverts, including roadway overtopping. For culvert modeling, the software uses the culvert hydraulics based on the Federal Highway Administration's (FHWA) standard equations from the publication Hydraulic Design of Highway Culverts, Third Edition (FHWA Publication No. FHWA-HIF-12-026), April 2012, as referenced in the Massachusetts Department of Transportation (MassDOT) Project Development and Design Guide, Chapter 8. Culverts are checked continuously during the flow routing to see if they operate under inlet control or outlet control to allow flow calculations to be adjusted accordingly.

The existing stream beds upstream and downstream of the culvert were modeled using representative cross sections of the streams from the topographic survey. The cross sections were created to represent a length of the stream that had a consistent slope and channel geometry. New cross sections were created whenever channel geometry or slope varied significantly. The cross sections were modeled in HEC-RAS as open channel flow custom sections. Observations of the stream bed material and roughness were used to estimate a Manning's roughness coefficient for each stream segment.

See Figure 8 and Figure 9 for an example of the inputs and cross section of a length of the stream in the model. The stream cross sections and locations are presented in Appendix 5.3.

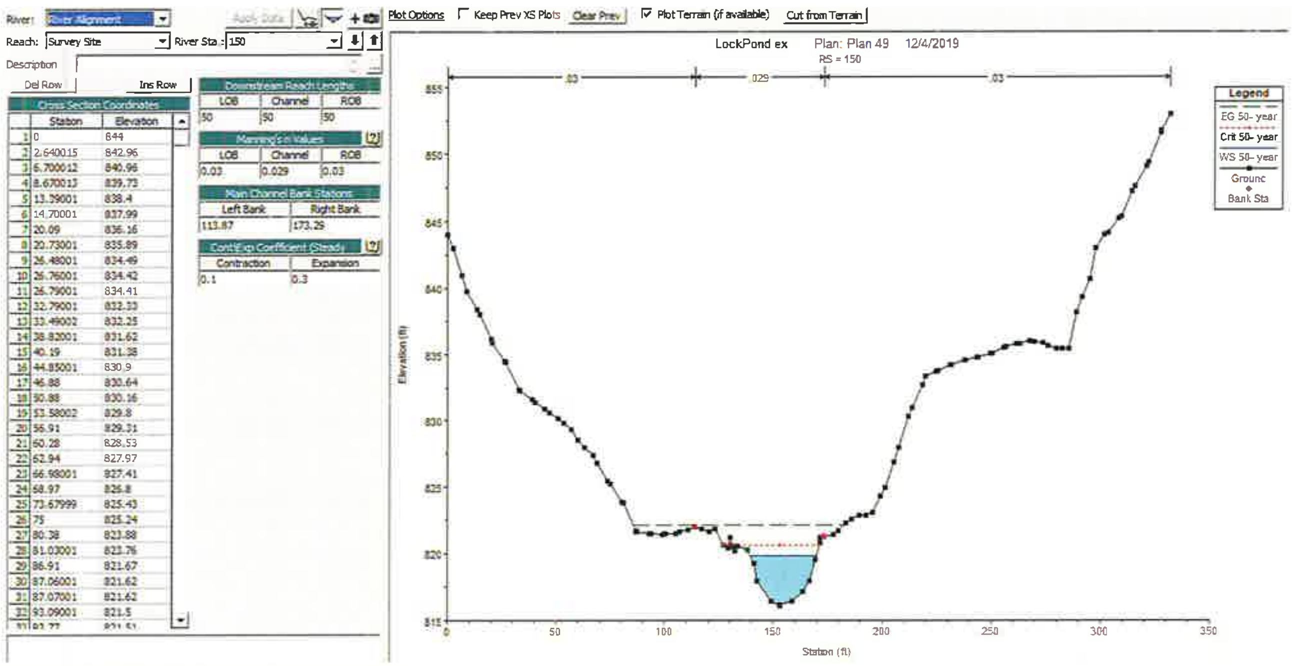


Figure 8: HEC-RAS model stream input

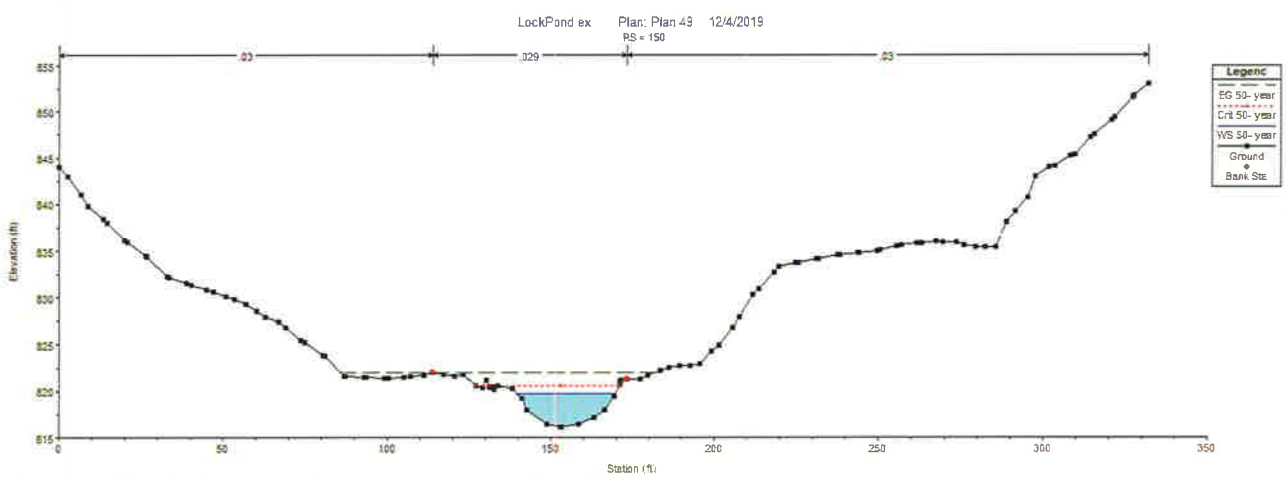


Figure 9: HEC-RAS model custom stream cross section plotted

2.2.3 Existing Conditions HEC-RAS Model

The existing culvert was analyzed using the Hydrologic Engineering Center River Analysis System model (HEC-RAS). Existing conditions information was obtained through field survey performed in July and October 2019, and a site visit performed by Nitsch Engineering on October 25, 2019. The existing culvert was modeled using the FHWA culvert methodology in HEC-RAS. Surveyed culvert information including shape, length, size, material, inverts, and slope were input into the hydraulic model. Observations of the culvert condition and roughness were used to estimate a Manning's roughness coefficient for the culvert.

Using the HEC-RAS hydraulic model, the culvert was analyzed to determine the flow depth and velocity conditions within the culvert, the flow control condition, and the elevation of the water surface at the culvert inlet (i.e. if roadway overtopping is expected to occur). The hydraulic model also included the modeling upstream to the spillway of the Lake Wyola dam (approximately 150 feet away):

This approach is conservative because:

- It routes the total runoff for the entire watershed to the starting point of the modelled stream and/or culvert reaches, rather than distributing it along the length of the modelled reach; and
- It assumes that all runoff from the upper portion of the watershed flows unrestricted to the modelled reaches in the lower portion of the watershed. It does not include the smaller road crossings and/or culverts or other ponded areas that are located within the upstream portion of the watershed.

In this culvert, the downstream hydraulic boundary condition was a free discharge (no tailwater) condition due to the downstream elevations of the existing and proposed culvert.

Table 3 summarizes the results of the analysis and includes the value of the maximum water elevation allowable as well as the velocity through the culvert for comparison. Hydraulic profiles of the existing culvert were prepared using HEC-RAS and included in Appendix 5.3.

Table 3: Summary of Existing Culvert Conditions (25-year storm)

	Culvert Size	Crossing Span (Target = 1.2)	Max. Allowable Water Peak Elevation (ft)[1]	Peak Elevation (25-year) (ft)	Openness Ratio (Target=0.82)[2]	Culvert Velocity[3] (ft/s)	Flow Control
Existing Culvert	10-ft Corrugated Metal Pipe	1	833.33	832.32	1.26	11.48	Inlet Control

1. *Determined using MassDOT guidelines. Maximum peak elevation should be 1.6 feet below the edge of the road or 2 feet below the overtopping elevation, whichever is lower*
2. *Massachusetts Stream Crossing Handbook, 2nd Edition, June 2012*

The 25-year storm peak elevations upstream of the existing culvert indicates adequate freeboard as required by the Massachusetts Department of Transportation (MassDOT) guidelines. Despite providing adequate freeboard, the existing culvert requires replacement due to the existing condition of the pipe and scour in and along the embankment.

2.2.4 Proposed Conditions HEC-RAS Model and Results

Based on the results of the existing conditions hydraulic analysis, the existing culvert meets the Massachusetts Department of Transportation (MassDOT) design criteria, however, the culvert must be replaced due to structural deterioration. Therefore, a proposed conditions hydraulic assessment was prepared to design a replacement culvert that meets the MassDOT design criteria, while also improving the safety and connectivity of the streams.

The proposed conditions hydraulic analysis demonstrates that the existing 10-foot diameter culvert can be replaced with a concrete box culvert with dimensions of 9 feet tall by 10 feet wide. The culvert will be embedded with stream substrate material to a depth of 2 feet, providing a hydraulic opening of 7 feet tall by 10 feet wide. Table 4 summarizes the proposed culvert parameters. Hydraulic profiles have been prepared using the Hydrologic Engineering Center River Analysis System model (HEC-RAS) for the culvert and are attached in Appendix 5.3.

It should be noted that an open-bottom culvert was also considered for the proposed culvert replacement. However, open-bottom culverts have increased structural footing requirements that impact the construction cost and schedule. Given the project's location on a major rural connector road, reducing community impacts and road closures are preferred. Therefore, an embedded four-sided box culvert is proposed to replace the existing culvert.

Table 4: Summary of Proposed Culvert

	Culvert Opening[3] (ft)	Manning's Coefficient	Culvert Length (ft)	Culvert Slope (ft/ft)	Inlet Elevation Condition	Outlet Elevation Condition	Flow Control
Culvert	9x 10	0.029[1]	62	0.016	Match Stream Bed	Match Stream Bed	Inlet Control

1. *Manning's Coefficient for stream channel with gravel, cobbles, and boulders*
2. *Manning's Coefficient for a rough concrete culvert*
3. *The culvert is a closed-bottom box culvert and should be embedded at least 2 feet to provide a natural stream bed and therefore actual culvert dimensions are 7 feet by 10 feet*

Table 5 compares the results of the existing and proposed conditions at the culvert, including the peak elevation and velocity through the culvert.

Table 5: Summary of Proposed Culvert Conditions (25-year storm)

	Max. Allowable Water Peak Elevation (ft)[1]	Peak Elevation (ft)	Openness Ratio (Target=0.82)[2]	Culvert Velocity[3] (ft/s)	Crossing Span (Target = 1.2)
Ex. Culvert	833.33	832.32	1.11	11.48	0.9
Pr. Culvert		831.16	1.11	11.49	0.9

1. *Determined using Mass DOT guidelines. Maximum peak elevation should be 1.6 feet below the edge of the road or 2 feet below the overtopping elevation, whichever is lower*
2. *Massachusetts Stream Crossing Handbook, 2nd Edition, June 2012*
3. *Recommended velocity range is 3 to 5 feet per second for fish movement through the culvert*
4. *The culvert is a closed-bottom box culvert and should be embedded at least 2 feet to provide a natural stream bed*

The peak elevation for the proposed culvert during a 25-year design storm is below the maximum allowable peak elevation. The proposed culvert design increases the flow capacity through the culvert, decreases the flooding frequency and minimizes the potential for downstream scour.

Note that both the existing and proposed culverts are inlet controlled, which results in storage of runoff between the Lake Wyola dam and the culvert in the 25-year storm. As demonstrated by the HEC-RAS profile included in Appendix 7.4, the proposed culvert has sufficient capacity for the 25-year storm event with the allowable 2 feet of freeboard before the roadway surface.

In larger storms (i.e. the 100-year storm), the hydraulic model indicates that the culvert is surcharged and roadway overtops. However, this does not take into the account the full capacity of the channel as the water surface elevation increases and eventually includes Lake Wyola. During large storm events that were previously recorded, the Locks Pond Road has not overtopped with a spillway crest of 22 inches. This was recorded October 9th, 2005 during the 2005 storm. Therefore, based on previous storm events and current upstream geometry, the proposed culvert, which will have similar hydraulic characteristics to the existing culvert, is not expected to overtop the roadway in storms with a flood return frequency up to 100 years.

3 Scour Analysis

3.1 Design Criteria

The Massachusetts Department of Transportation's (MassDOT) LRFD Bridge Manual references the following Federal Highway Administration's (FHA) Hydraulic Engineering Circulars (HEC) for performing scour safety assessments:

- HEC-18, "Evaluating Scour at Bridges;"
- HEC-20, "Stream Stability at Highway Structures;"
- HEC-23, "Bridge Scour and Stream Instability Countermeasures;" and
- HEC-25, "Highways in the Coastal Environment."

Locks Pond road is functionally classified by MassDOT as a rural major collector. The LRFD Bridge Manual notes a desired minimum scour design flood return frequency of 50 years with a scour check of 100 years be provided for major rural collectors.

As noted above, Nitsch Engineering recommends replacing the existing culvert with a 9-foot by 10-foot concrete box culvert as part of the Locks Pond roadway improvement project. The culvert is proposed as a closed-bottom box culvert, with 2 feet embedded to provide a natural stream bed. The culvert will match the existing inverts of the upstream and downstream ends. This will reduce the need for grading within the disturbed area.

According to the Particle Size Analysis prepared by Lahlaf Geotechnical Consulting and provided on November 19, 2019, the soil texture at the existing culvert inlet is poorly graded gravel with sand (ASTM classification). The soil texture at the culvert outlet is poorly graded sand with gravel (ASTM classification). Sand and gravel are considered cohesionless soils.

3.2 Scour Hole Geometry

Given the location of the Locks Pond Roadway project in the interior portion of the state, HEC-25 for coastal environments is not applicable. The other three (3) Hydraulic Engineering Circulars were reviewed for relevant guidance pertaining to scour at culverts. HEC-18 included a section on scour at open-bottom culverts (Section 6.9) and HEC-23 (Volume 2) included a special section on riprap protection for bottomless culverts (Design Guideline 18). However, since the culvert is proposed as a closed bottom culvert, these references are not appropriate for use.

As a result, Nitsch Engineering reviewed and referenced HEC-14, "Hydraulic Design of Energy Dissipaters for Culverts and Channels" to estimate scour at the culvert outlet and to select and design the energy dissipation approach. Using the proposed culvert parameters (Table 5) and the peak flow characteristics (Table 1), the culvert was evaluated for scour (refer to Appendix 6.6 for calculations). The scour hole geometry was calculated using the general expression for determining scour geometry in a cohesionless soil at the culvert outlet (equation 5.1 of HEC-14). Table 6 below summarizes the scour hole geometry calculated for the culvert for the 50-year and 100-year storm events.

Table 6: Summary of Scour Hole Geometry

	Storm Event (year)	Depth of Scour, Hs (ft)	Width of Scour, Ws (ft)	Length of Scour, Ls (ft)	Volume of Scour, Vs (cf)	Location of Maximum Depth of Scour, Lm (ft)
Proposed Culvert	50	7.1	41	72	26,000	29
	100	7.6	45	78	33,000	31

The scour hole geometry presented in Table 6 for the 50-year and 100-year storm events for the culvert is close in value since the peak flow rate is also close in value (930 cfs and 1118 cfs, respectively).

3.3 Energy Dissipation

Given the magnitude of the flow discharging from the culvert during the 50-year storm event as modeled in The Hydrologic Engineering Center River Analysis System model (HEC-RAS), the results presented in Table 10 indicate that protection from scour is needed at the culvert outlet. This was evidenced in the field, as the existing culvert had created a scour hole near the downstream opening with an approximate length of 36 feet, width of 25 feet, and depth of 2 feet.

Using the methodology presented in HEC-14, Nitsch Engineering calculated the critical depth, brink depth, and normal depth at the culvert outlet for the 50-year storm to determine the respective outlet Froude number for the culvert for the scour design condition. The HEC-RAS model estimates the culvert to be very close to critical flow with inlet control during the peak of the 50-year storm. This was confirmed with calculations as the brink depth and normal depth did not produce feasible Froude number values for subcritical or supercritical flow conditions, respectively. Therefore, assuming critical flow at the outlet and utilizing a Froude number of 1, Nitsch Engineering considered the riprap basin approach (Chapter 10 of HEC-14) for the culvert from the list of energy dissipators provided in Table 1.1 of HEC-14. Table 7 summarizes the basin dimensions (refer to Figures 10.1 and 10.2 of HEC-14) and riprap size designed for the outlet of the culvert. The 100-year scour check calculations demonstrate that the riprap sized for the 50-year storm event is expected to handle the 100-year storm event as well.

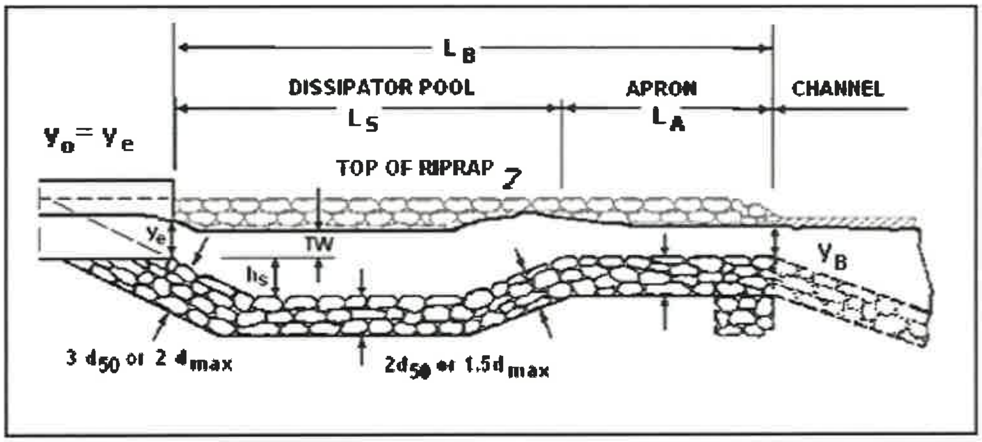


Figure 10.1. Profile of Riprap Basin

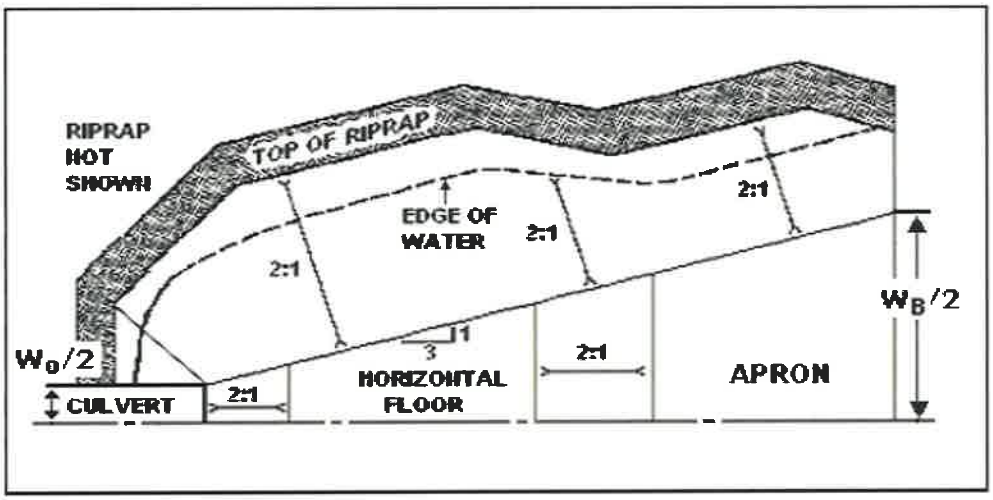


Figure 10.2. Half Plan of Riprap Basin

Figure 10 – Riprap basin details (HEC-14, Figure 10.1 and 10.2)

Table 7: Summary of Basin Dimensions and Riprap Size for Culvert (50-year storm)

Overall Basin Length, L_B (ft)	Dissipator Pool Length, L_S (ft)	Basin Width, W_B (ft)	Dissipator Pool Depth, h_s (ft)	D_{50} (in)
50	33	43	3.3	18

The riprap basin material should be consistent with the Massachusetts Department of Transportation (MassDOT) Stone for pipe ends (M2.02.3). The MassDOT specification for this material requires "sound durable rock which is angular in shape. Each stone shall have a mass of not less than 25 kilograms, not more than 44 kilograms, and at least 75% of the volume shall consist of stones that have a mass of not less than 35 kilograms each. The remainder of the stones shall be graded when placed with the larger stones; the entire mass will be compact."

Given existing space constraints downstream of the culvert and the desire to utilize a scour protection measure as close to natural conditions as possible, Nitsch Engineering suggests modifying the calculated downstream scour protection design to conform to the limits of the existing channel. The channel downstream of the culvert shows some evidence of degradation, but it is stabilized on one (1) side by a bordering retaining wall and an established root system from vegetation along the embankment on the other. A preformed scour hole currently exists at the immediate outlet of the existing culvert mimicking a smaller depression pool, as shown in the selected basin approach. Thus, given that the hydraulic performance of the proposed culvert is being designed to generally replicate that of the existing culvert, field observations suggest that armoring the existing scour hole and the banks of the channel will provide improved scour protection while giving regard to existing site limitations and minimizing the disturbance and impact of adjacent private properties to the downstream channel. Nitsch Engineering recommends the riprap basin details continue to be referenced for the proposed culvert; however, the basin width will need to be adjusted to conform to the width of the existing channel (approximately 20 feet wide at the channel bottom).

The specific details of the modified riprap basin will need to be developed once the design of the culvert has been further advanced. Based on the current calculations, there may also be a benefit to installing additional riprap protection downstream of the modified riprap basin to allow the exit flow from the basin to adjust to the natural channel condition. According to section 10.3 of HEC-14, the length of this added protection can be judged based on the difference of the exit velocity compared with the natural channel velocity. The calculated D_{50} size for this riprap protection is 6 inches. Nitsch Engineering recommends a supplemental field visit to locate and measure any larger existing stones and/or boulders downstream of the existing culvert for comparison and to obtain additional information from the existing channel that may assist in the hydraulic analysis of the proposed culvert and the design of the scour protection measures being considered.

4 Conclusions and Recommendations

Nitsch Engineering performed the hydraulic analysis of the culvert along Locks Pond Road in Shutesbury, Massachusetts as part of the larger reconstruction of the roadway and stream crossing. The culvert underneath the roadway conveys the outfall from Lake Wyola, which has a 6.84-mile drainage area. The primary goal of the analysis was to design a replacement culvert that meets the Massachusetts Department of Transportation (MassDOT) design criteria, improves stream connectivity, and minimizes impacts to wetland resource areas. The proposed culvert will improve the hydraulic function and provide safety measures against scour or large flows from storm events. The recommendations set forth in this report balance these design criteria and consider the project construction schedule and budget.

To perform the hydrologic and hydraulic analysis, the culvert and connecting streams were modeled in the Hydrologic Engineering Center River Analysis System model (HEC-RAS). The culvert appears to perform adequately given the existing conditions when looking at conveyance. However, the condition of the culvert is in disrepair and there is clear undermining and erosion due to corrosion of the bottom foot of the culvert. The results of the analysis are consistent with anecdotal evidence from the Town of Shutesbury and surrounding property owners.

Based on the results of the hydraulic analysis and guidance from MassDOT regarding both hydraulic and environmental improvements, Nitsch Engineering recommends the following:

1. **Replacement of the culvert with a 9-foot by 10-foot concrete box culvert, embedded 2 feet to provide a 7-foot by 10-foot opening.**
   Nitsch recommends this to be a box culvert. The proposed culvert will maintain the upstream inlet invert elevation which currently matches the stream bed.

2. **Installation of scour protection of on the downstream side of the culvert with a modified riprap basin design to enhance the streambed protection.**

   Nitsch Engineering recommends the use of a modified riprap basin approach for the culvert. The modified riprap basin will provide a natural approach to protecting the stream downstream from the culvert while giving regard to existing site limitations and minimizing the disturbance and impact of adjacent private properties to the stream.

Following guidance from both MassDOT and the Massachusetts Stream Crossing Standards, the proposed culvert design is anticipated to improve the hydraulic performance of the culvert, decrease flooding frequency, and minimize potential for downstream scour, thereby meeting the goals set forth with the culvert replacement.

5 Appendices

5.1 Crossing Site Catchment

5.1.1 Watershed (Streamstats) Boundaries

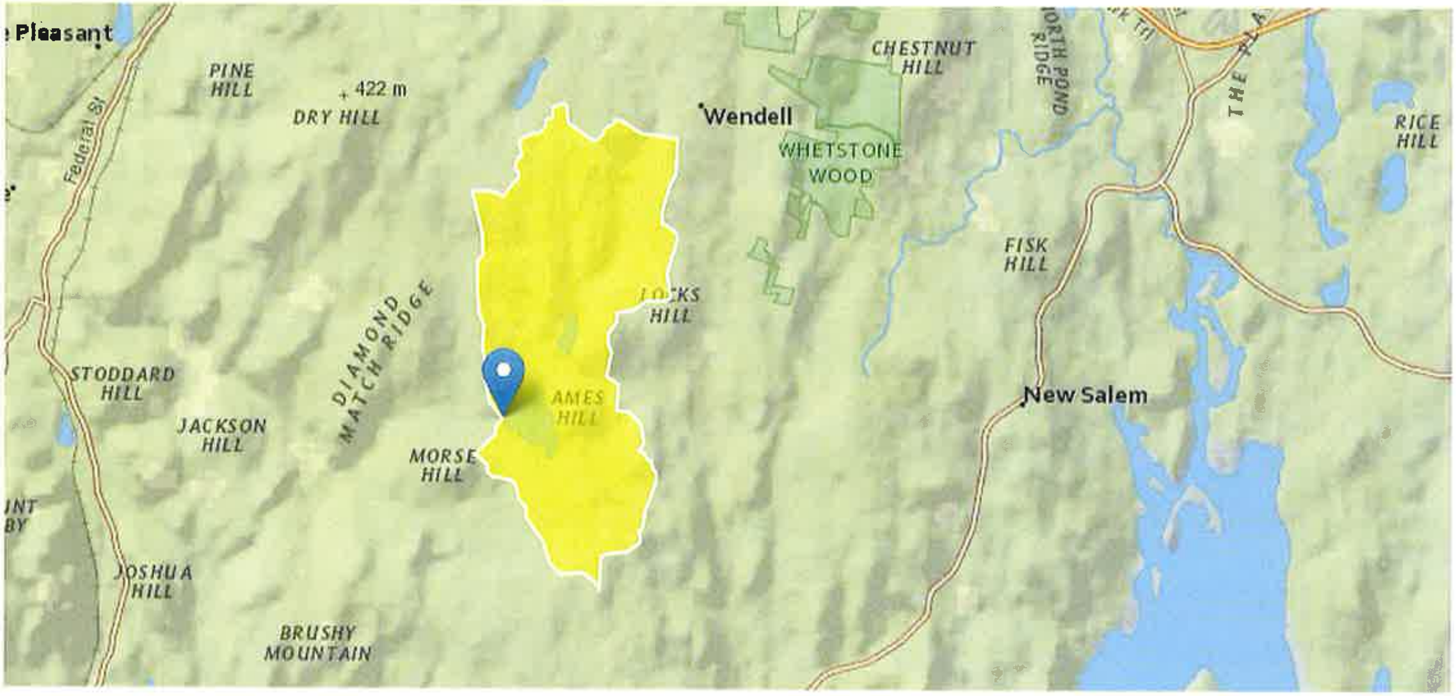
5.1.2 NRCS Hydrologic Soil Group

5.1.3 FEMA Flood Map

5.1.4 Natural Heritage and Endangered Species

StreamStats Report

Region ID: MA
Workspace ID: MA20191009192654231000
Clicked Point (Latitude, Longitude): 42.50186, -72.43662
Time: 2019-10-09 15:26:10 -0400



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	6.84	square miles
ELEV	Mean Basin Elevation	992	feet
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	8	percent
PCTSNDGRV	Percentage of land surface underlain by sand and gravel deposits	29.67	percent

Parameter Code	Parameter Description	Value	Unit
FOREST	Percentage of area covered by forest	80.01	percent
MAREGION	Region of Massachusetts 0 for Eastern 1 for Western	1	dimensionless

Peak-Flow Statistics Parameters[Peak Statewide 2016 5156]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	6.84	square miles	0.16	512
ELEV	Mean Basin Elevation	992	feet	80.6	1948
LC06STOR	Percent Storage from NLCD2006	8	percent	0	32.3

Peak-Flow Statistics Flow Report[Peak Statewide 2016 5156]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	SEp
2 Year Peak Flood	244	ft^3/s	122	486	42.3
5 Year Peak Flood	410	ft^3/s	203	830	43.4
10 Year Peak Flood	547	ft^3/s	264	1130	44.7
25 Year Peak Flood	750	ft^3/s	349	1610	47.1
50 Year Peak Flood	922	ft^3/s	415	2050	49.4
100 Year Peak Flood	1110	ft^3/s	483	2540	51.8
200 Year Peak Flood	1310	ft^3/s	554	3100	54.1
500 Year Peak Flood	1610	ft^3/s	675	3840	57.6

Peak-Flow Statistics Citations

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

Probability Statistics Parameters[Perennial Flow Probability]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	6.84	square miles	0.01	1.99
PCTSNDGRV	Percent Underlain By Sand And Gravel	29.67	percent	0	100
FOREST	Percent Forest	80.01	percent	0	100
MAREGION	Massachusetts Region	1	dimensionless	0	1

Probability Statistics Disclaimers[Perennial Flow Probability]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Probability Statistics Flow Report[Perennial Flow Probability]

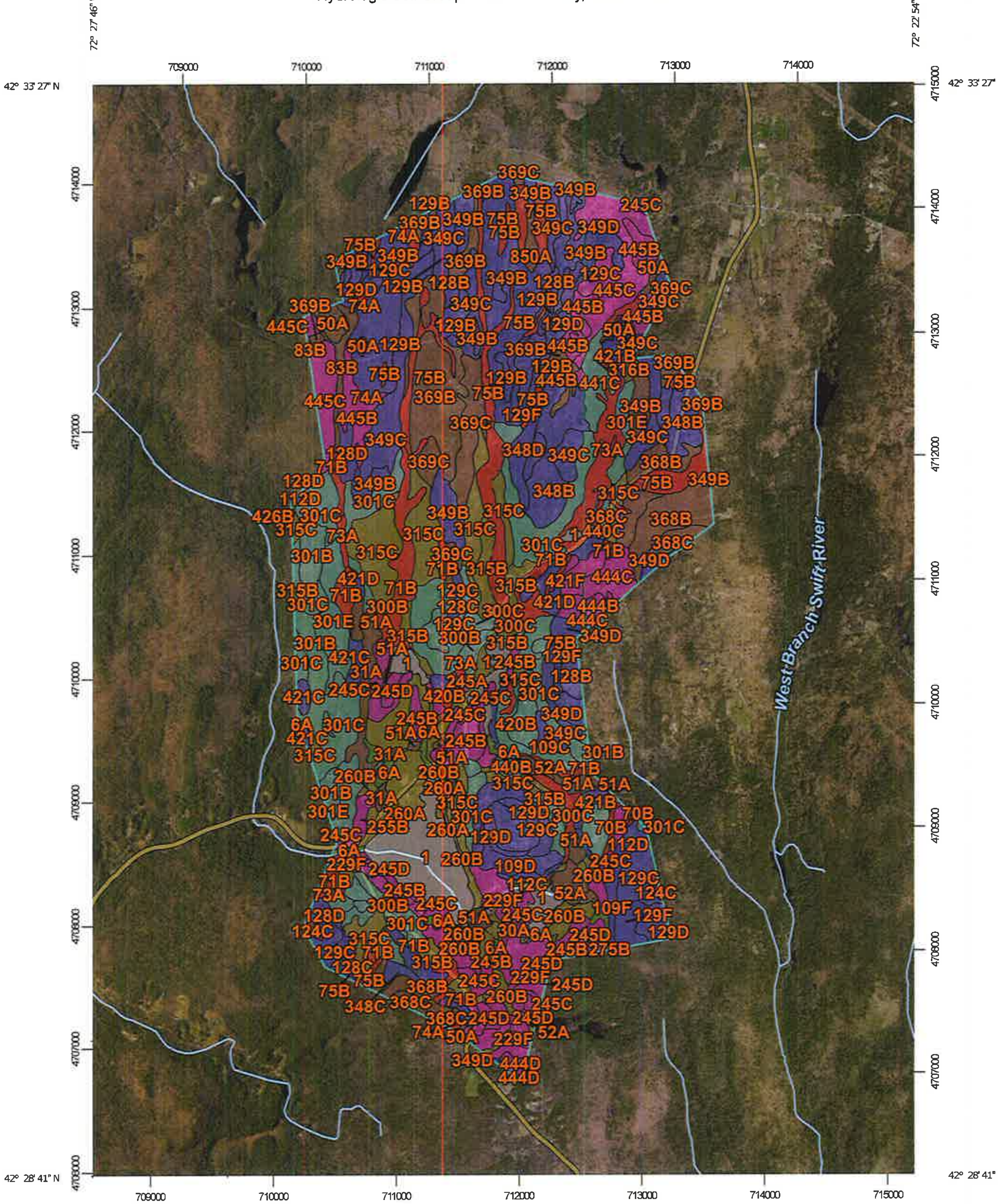
Statistic	Value	Unit
Probability Stream Flowing Perennially	0.981	dim

Probability Statistics Citations

Bent, G.C., and Steeves, P.A.,2006, A revised logistic regression equation and an automated procedure for mapping the probability of a stream flowing perennially in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2006–5031, 107 p. (http://pubs.usgs.gov/sir/2006/5031/pdfs/SIR_2006-5031rev.pdf)

Application Version: 4.3.8

Hydrologic Soil Group—Franklin County, Massachusetts



Map Scale: 1:43,100 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 500 1000 2000 3000

Feet: 0 2000 4000 8000 12000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Franklin County, Massachusetts
Survey Area Data: Version 14, Sep 12, 2019

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Apr 9, 2011—May 12, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
1	Water		188.0	4.3%
6A	Scarboro mucky sandy loam, 0 to 2 percent slopes	A/D	38.5	0.9%
30A	Raynham silt loam, 0 to 3 percent slopes	C/D	20.9	0.5%
31A	Walpole sandy loam, 0 to 3 percent slopes	B/D	43.1	1.0%
50A	Wonsqueak muck, 0 to 2 percent slopes	B/D	30.4	0.7%
51A	Swansea muck, 0 to 1 percent slopes	B/D	47.1	1.1%
52A	Freetown muck, 0 to 1 percent slopes	B/D	24.0	0.6%
70B	Ridgebury fine sandy loam, 3 to 8 percent slopes	D	23.7	0.5%
71B	Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony	D	235.6	5.4%
73A	Whitman fine sandy loam, 0 to 3 percent slopes, extremely stony	D	12.9	0.3%
74A	Peacham mucky peat, 0 to 8 percent slopes, very stony	D	5.1	0.1%
75B	Pillsbury fine sandy loam, 0 to 8 percent slopes, very stony	D	149.0	3.4%
83B	Lyme fine sandy loam, 0 to 8 percent slopes, very stony	B/D	18.8	0.4%
109C	Chatfield-Hollis complex, 8 to 15 percent slopes, rocky	B	48.6	1.1%
109D	Chatfield-Hollis complex, 15 to 25 percent slopes, rocky	B	41.6	1.0%
109F	Chatfield-Hollis complex, 25 to 60 percent slopes, rocky	B	16.2	0.4%
112C	Canton-Chatfield-Hollis complex, 8 to 15 percent slopes, rocky	B	5.6	0.1%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
112D	Canton-Chatfield-Hollis complex, 15 to 35 percent slopes, rocky	B	17.1	0.4%
124C	Woodstock-Millsite-Rock outcrop complex, 8 to 15 percent slopes	D	4.8	0.1%
128B	Millsite-Chichester complex, 3 to 8 percent slopes, rocky	B	27.4	0.6%
128C	Millsite-Chichester complex, 8 to 15 percent slopes, rocky	B	14.8	0.3%
128D	Millsite-Chichester complex, 15 to 25 percent slopes, rocky	B	32.7	0.8%
129B	Millsite-Woodstock complex, 3 to 8 percent slopes, very rocky	B	135.1	3.1%
129C	Millsite-Woodstock complex, 8 to 15 percent slopes, very rocky	B	99.3	2.3%
129D	Millsite-Woodstock complex, 15 to 25 percent slopes, very rocky	B	41.7	1.0%
129F	Millsite-Woodstock complex, 25 to 60 percent slopes, very rocky	B	56.1	1.3%
229F	Windsor and Merrimac soils, 25 to 60 percent slopes	A	36.5	0.8%
245A	Hinckley loamy sand, 0 to 3 percent slopes	A	3.6	0.1%
245B	Hinckley loamy sand, 3 to 8 percent slopes	A	67.3	1.5%
245C	Hinckley loamy sand, 8 to 15 percent slopes	A	165.0	3.8%
245D	Hinckley loamy sand, 15 to 25 percent slopes	A	49.9	1.1%
255B	Windsor loamy sand, 3 to 8 percent slopes	A	12.4	0.3%
260A	Sudbury sandy loam, 0 to 3 percent slopes	C/D	24.2	0.6%
260B	Sudbury sandy loam, 3 to 8 percent slopes	C/D	127.7	2.9%
275B	Agawam fine sandy loam, 3 to 8 percent slopes	B	0.1	0.0%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
300B	Montauk fine sandy loam, 3 to 8 percent slopes	C	37.6	0.9%
300C	Montauk fine sandy loam, 8 to 15 percent slopes	C	57.0	1.3%
301B	Montauk fine sandy loam, 0 to 8 percent slopes, very stony	C	82.7	1.9%
301C	Montauk fine sandy loam, 8 to 15 percent slopes, very stony	C	340.0	7.8%
301E	Montauk fine sandy loam, 15 to 35 percent slopes, very stony	C	98.9	2.3%
315B	Scituate fine sandy loam, 3 to 8 percent slopes	C/D	85.4	2.0%
315C	Scituate fine sandy loam, 8 to 15 percent slopes	C/D	225.1	5.2%
316B	Scituate fine sandy loam, 3 to 8 percent slopes, very stony	C/D	5.0	0.1%
348B	Henniker sandy loam, 3 to 8 percent slopes	B	113.0	2.6%
348C	Henniker sandy loam, 8 to 15 percent slopes	B	11.1	0.3%
348D	Henniker sandy loam, 15 to 25 percent slopes	B	22.4	0.5%
349B	Henniker sandy loam, 3 to 8 percent slopes, very stony	B	295.0	6.8%
349C	Henniker sandy loam, 8 to 15 percent slopes, very stony	B	168.6	3.9%
349D	Henniker sandy loam, 15 to 25 percent slopes, very stony	B	47.5	1.1%
368B	Metacomet fine sandy loam, 3 to 8 percent slopes	B/D	97.7	2.2%
368C	Metacomet fine sandy loam, 8 to 15 percent slopes	B/D	54.1	1.2%
369B	Metacomet fine sandy loam, 3 to 8 percent slopes, very stony	B/D	191.2	4.4%
369C	Metacomet fine sandy loam, 8 to 15 percent slopes, very stony	B/D	69.5	1.6%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
420B	Canton fine sandy loam, 3 to 8 percent slopes	B	15.6	0.4%
420D	Canton fine sandy loam, 15 to 25 percent slopes	A	4.0	0.1%
421B	Canton fine sandy loam, 0 to 8 percent slopes, very stony	B	12.3	0.3%
421C	Canton fine sandy loam, 8 to 15 percent slopes, very stony	B	36.6	0.8%
421D	Canton fine sandy loam, 15 to 25 percent slopes, very stony	B	17.5	0.4%
421F	Canton fine sandy loam, 25 to 45 percent slopes, very stony	A	4.0	0.1%
426B	Newfields fine sandy loam, 3 to 8 percent slopes	C/D	2.2	0.1%
440B	Gloucester sandy loam, 3 to 8 percent slopes	C	7.3	0.2%
440C	Gloucester sandy loam, 8 to 15 percent slopes	C	36.9	0.8%
441C	Gloucester sandy loam, 8 to 15 percent slopes, very stony	C	51.5	1.2%
444B	Chichester fine sandy loam, 3 to 8 percent slopes	A	14.5	0.3%
444C	Chichester fine sandy loam, 8 to 15 percent slopes	A	38.1	0.9%
444D	Chichester fine sandy loam, 15 to 25 percent slopes	A	2.0	0.0%
445B	Chichester fine sandy loam, 3 to 8 percent slopes, very stony	A	73.2	1.7%
445C	Chichester fine sandy loam, 8 to 15 percent slopes, very stony	A	156.4	3.6%
445D	Chichester fine sandy loam, 15 to 25 percent slopes, very stony	A	7.6	0.2%
445F	Chichester fine sandy loam, 25 to 45 percent slopes, very stony	A	9.0	0.2%
850A	Bucksport muck, 0 to 2 percent slopes	B/D	1.7	0.0%
Totals for Area of Interest			**4,357.0**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

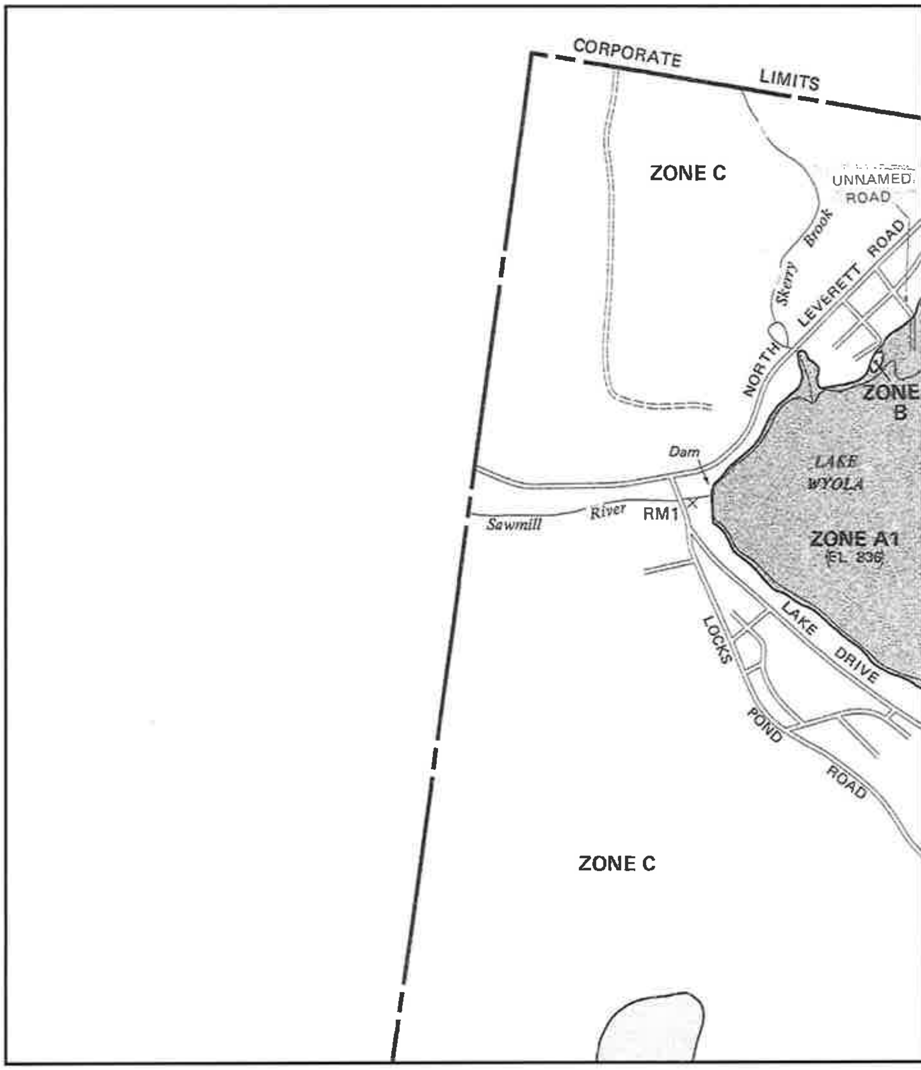
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



APPROXIMATE SCALE

1000 0 1000 FEET

KEY TO MAP

500-Year Flood Boundary
100-Year Flood Boundary
Zone Designations* With Date of Identification e.g., 12/2/74
100-Year Flood Boundary
500-Year Flood Boundary

ZONE B
ZONE B

Base Flood Elevation Line With Elevation In Feet**	513
Base Flood Elevation in Feet Where Uniform Within Zone**	(EL 987)
Elevation Reference Mark	RM7×
River Mile	• M1.5

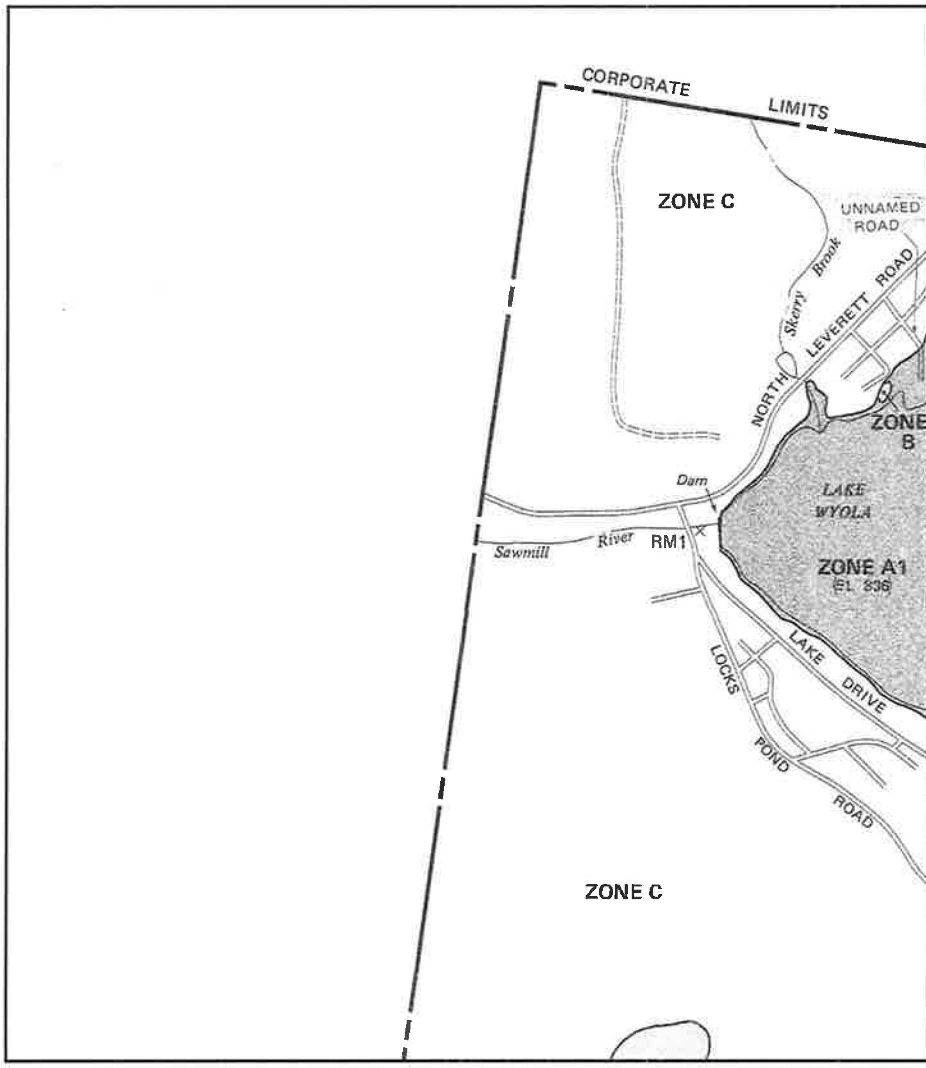
**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
A0	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



APPROXIMATE SCALE

1000 0 1000 FEET

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

TOWN OF
SHUTESBURY,
MASSACHUSETTS
FRANKLIN COUNTY

PANEL 5 OF 20
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
250128 0005 A

EFFECTIVE DATE:
JUNE 18, 1980

U.S. DEPARTMENT OF HOUSING
AND URBAN DEVELOPMENT
FEDERAL INSURANCE ADMINISTRATION

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

NHESP Priority Habitats of Rare Species

Habitat of state-listed rare species in Massachusetts.

0.2mi

MassGIS, Esri Canada, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, EPA, USDA | MassGIS, NHESP

5.2 Hydrologic Computations (from Streamstats)*

Watershed Number	Total Area (sq mi)	Mean Basin Elevation	Peak Runoff Rate (cfs)		
			25-yr storm	50-yr storm	100-yr storm
1	6.84	992	758	930	1118

*Includes 8 cfs from baseflow condition of dam operation during the summer

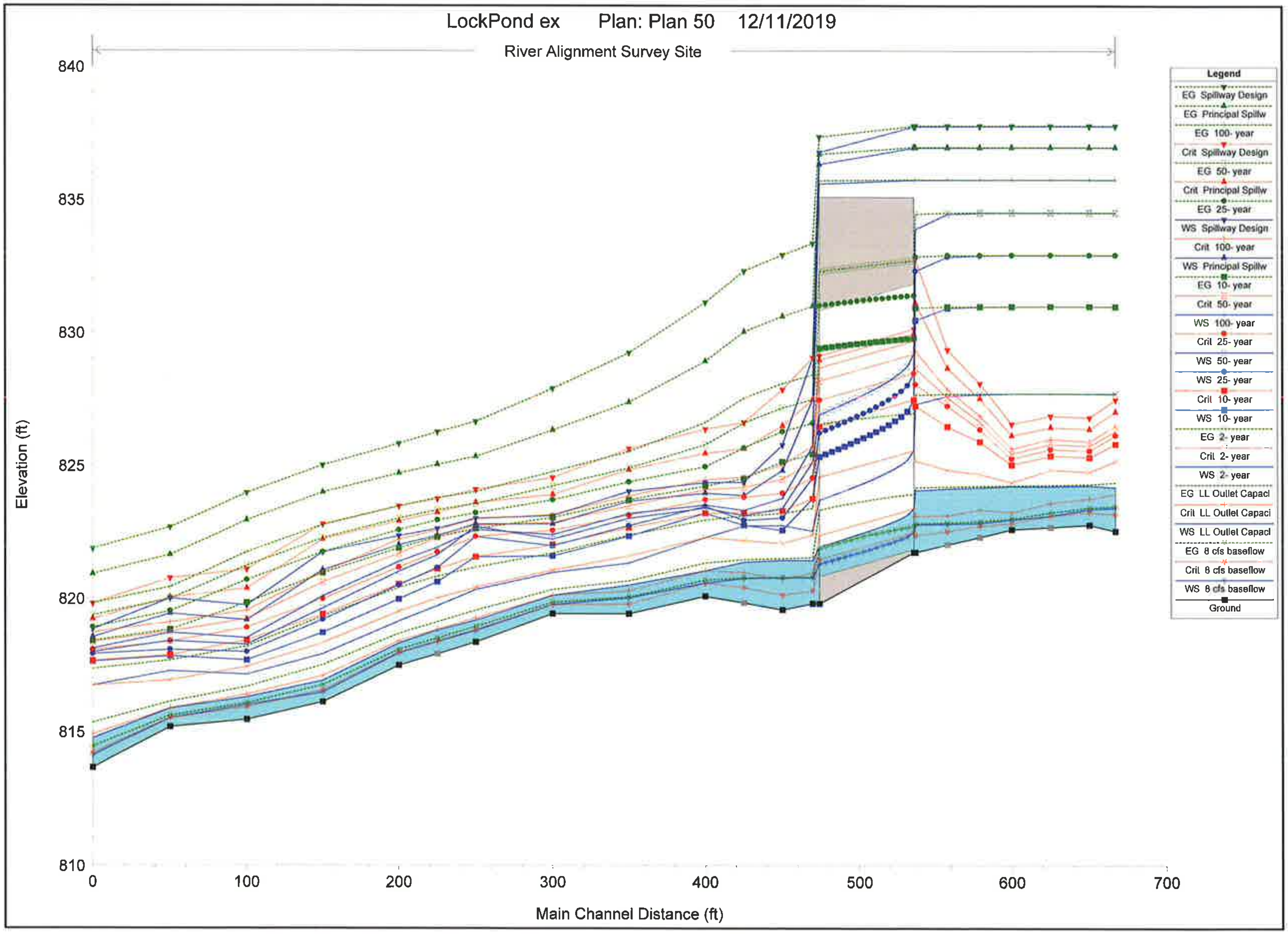
5.3 Hydraulic Computations (HEC-RAS Model Inputs and Results)

5.3.1 Existing Culvert Profile

5.3.2 Existing Culvert Table Output

5.3.3 Proposed Culvert Profile

5.3.4 Proposed Culvert Table Output



LockPond ex Plan: Plan 50 12/11/2019
River Alignment Survey Site
840
835
830
825
820
815
810
Elevation (ft)
0
100
200
300
400
500
600
700
Main Channel Distance (ft)
Legend
EG Spillway Design
EG Principal Spillw
EG 100- year
Crit Spillway Design
EG 50- year
Crit Principal Spillw
EG 25- year
WS Spillway Design
Crit 100- year
WS Principal Spillw
EG 10- year
Crit 50- year
WS 100- year
Crit 25- year
WS 50- year
WS 25- year
Crit 10- year
WS 10- year
EG 2- year
Crit 2- year
WS 2- year
EG LL Outlet Capaci
Crit LL Outlet Capaci
WS LL Outlet Capaci
EG 8 cfs baseflow
Crit 8 cfs baseflow
WS 8 cfs baseflow
Ground

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	0	LL Outlet Capaci	45.00	813.65	814.74	814.90	815.33	0.019493	6.16	7.31	10.96	1.33
Survey Site	0	Principal Spillw	1700.00	813.65	818.54	819.22	820.91	0.016506	13.30	150.92	101.23	1.49
Survey Site	0	Spillway Design	2300.00	813.65	818.84	819.80	821.87	0.019985	15.27	183.25	114.07	1.66
Survey Site	0	2- year	252.00	813.65	816.72	816.72	817.35	0.008443	6.35	40.56	36.97	0.97
Survey Site	0	10- year	555.00	813.65	817.62	817.65	818.40	0.007155	7.33	84.19	58.20	0.93
Survey Site	0	25- year	758.00	813.65	817.91	818.06	818.91	0.008266	8.40	101.47	62.66	1.02
Survey Site	0	50- year	930.00	813.65	817.98	818.35	819.36	0.011188	9.91	105.75	65.66	1.19
Survey Site	0	100- year	1118.00	813.65	818.11	818.72	819.81	0.013183	11.05	115.07	72.48	1.30
Survey Site	0	8 cfs baseflow	8.00	813.65	814.11	814.21	814.44	0.033762	4.60	1.74	6.22	1.53
Survey Site	50	LL Outlet Capaci	45.00	815.18	815.87	815.87	816.12	0.011880	4.00	11.25	23.01	1.01
Survey Site	50	Principal Spillw	1700.00	815.18	819.43	820.02	821.63	0.012038	11.90	142.87	53.66	1.29
Survey Site	50	Spillway Design	2300.00	815.18	820.00	820.75	822.67	0.012241	13.14	177.96	68.69	1.33
Survey Site	50	2- year	252.00	815.18	817.27	816.92	817.67	0.004484	5.08	49.58	33.22	0.73
Survey Site	50	10- year	555.00	815.18	817.83	817.87	818.82	0.008458	7.99	69.43	37.42	1.03
Survey Site	50	25- year	758.00	815.18	818.07	818.38	819.52	0.011233	9.66	78.46	39.18	1.20
Survey Site	50	50- year	930.00	815.18	818.40	818.75	819.98	0.011421	10.09	92.13	43.21	1.22
Survey Site	50	100- year	1118.00	815.18	818.71	819.10	820.43	0.011666	10.50	106.43	47.45	1.24
Survey Site	50	8 cfs baseflow	8.00	815.18	815.51	815.51	815.60	0.016234	2.34	3.42	19.83	0.99
Survey Site	100	LL Outlet Capaci	45.00	815.46	816.29	816.39	816.69	0.020809	5.04	8.93	19.75	1.32
Survey Site	100	Principal Spillw	1700.00	815.46	819.18	820.37	822.94	0.025788	15.55	109.36	51.11	1.87
Survey Site	100	Spillway Design	2300.00	815.46	819.74	821.09	823.97	0.024292	16.50	139.40	56.94	1.86
Survey Site	100	2- year	252.00	815.46	817.14	817.43	818.20	0.018469	8.24	30.58	29.41	1.42
Survey Site	100	10- year	555.00	815.46	817.68	818.42	819.83	0.024257	11.77	47.15	32.34	1.72
Survey Site	100	25- year	758.00	815.46	817.99	818.90	820.69	0.024881	13.18	57.50	33.75	1.78
Survey Site	100	50- year	930.00	815.46	818.27	819.22	821.23	0.026884	13.81	67.36	38.98	1.85
Survey Site	100	100- year	1118.00	815.46	818.51	819.55	821.74	0.028163	14.42	77.53	43.43	1.90
Survey Site	100	8 cfs baseflow	8.00	815.46	816.00	815.92	816.07	0.006003	2.00	3.99	13.88	0.66
Survey Site	150	LL Outlet Capaci	45.00	816.11	816.92	817.09	817.50	0.026616	6.10	7.37	14.66	1.52
Survey Site	150	Principal Spillw	1700.00	816.11	821.06	822.22	823.99	0.014989	13.71	123.99	45.21	1.46
Survey Site	150	Spillway Design	2300.00	816.11	821.74	822.79	825.01	0.015172	14.55	164.26	84.27	1.49
Survey Site	150	2- year	252.00	816.11	817.91	818.32	819.32	0.022216	9.54	26.40	23.26	1.58
Survey Site	150	10- year	555.00	816.11	818.71	819.38	820.95	0.019666	11.99	46.28	25.99	1.58
Survey Site	150	25- year	758.00	816.11	819.20	819.97	821.74	0.017495	12.79	59.29	27.46	1.53
Survey Site	150	50- year	930.00	816.11	819.62	820.60	822.27	0.015688	13.05	71.27	29.40	1.48
Survey Site	150	100- year	1118.00	816.11	820.07	820.97	822.76	0.013826	13.14	85.11	31.51	1.41
Survey Site	150	8 cfs baseflow	8.00	816.11	816.47	816.56	816.75	0.045953	4.22	1.90	9.94	1.70
Survey Site	200	LL Outlet Capaci	45.00	817.49	818.31	818.40	818.68	0.020678	4.89	9.20	21.01	1.30
Survey Site	200	Principal Spillw	1700.00	817.49	822.01	822.91	824.71	0.012998	13.46	143.28	92.66	1.39

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	200	Spillway Design	2300.00	817.49	822.35	823.47	825.83	0.015077	15.59	175.94	103.33	1.52
Survey Site	200	2- year	252.00	817.49	819.14	819.51	820.39	0.019855	8.98	28.07	24.62	1.48
Survey Site	200	10- year	555.00	817.49	819.97	820.53	821.89	0.017239	11.12	49.91	28.23	1.47
Survey Site	200	25- year	758.00	817.49	820.50	821.17	822.57	0.014367	11.56	65.73	31.54	1.39
Survey Site	200	50- year	930.00	817.49	821.01	821.69	823.01	0.011733	11.36	82.87	36.55	1.28
Survey Site	200	100- year	1118.00	817.49	821.38	822.22	823.47	0.012457	11.66	98.92	56.14	1.32
Survey Site	200	8 cfs baseflow	8.00	817.49	817.95	817.96	818.08	0.016807	2.82	2.84	12.76	1.05
Survey Site	225.00*	LL Outlet Capaci	45.00	817.92	818.81	818.84	819.12	0.014079	4.45	10.11	19.96	1.10
Survey Site	225.00*	Principal Spillw	1700.00	817.92	822.36	823.23	825.03	0.012723	13.55	147.85	97.01	1.39
Survey Site	225.00*	Spillway Design	2300.00	817.92	822.63	823.75	826.26	0.015922	16.07	174.83	101.99	1.58
Survey Site	225.00*	2- year	252.00	817.92	819.72	820.01	820.83	0.015256	8.46	29.78	23.40	1.32
Survey Site	225.00*	10- year	555.00	817.92	820.62	821.11	822.31	0.014883	10.44	53.18	29.85	1.38
Survey Site	225.00*	25- year	758.00	817.92	821.15	821.74	822.94	0.013203	10.74	70.74	36.43	1.33
Survey Site	225.00*	50- year	930.00	817.92	821.64	822.28	823.33	0.010993	10.46	90.67	52.16	1.23
Survey Site	225.00*	100- year	1118.00	817.92	821.91	822.56	823.78	0.010500	11.05	108.89	75.61	1.23
Survey Site	225.00*	8 cfs baseflow	8.00	817.92	818.38	818.39	818.51	0.017844	2.88	2.78	12.68	1.08
Survey Site	250	LL Outlet Capaci	45.00	818.36	819.18	819.26	819.55	0.020217	4.92	9.14	20.42	1.30
Survey Site	250	Principal Spillw	1700.00	818.36	822.80	823.61	825.34	0.010527	13.86	164.46	102.34	1.29
Survey Site	250	Spillway Design	2300.00	818.36	823.01	824.10	826.65	0.014543	16.91	185.18	104.44	1.53
Survey Site	250	2- year	252.00	818.36	820.32	820.40	821.17	0.009890	7.39	34.11	23.45	1.08
Survey Site	250	10- year	555.00	818.36	821.56	821.56	822.62	0.006594	8.27	68.91	38.88	0.95
Survey Site	250	25- year	758.00	818.36	822.32	822.32	823.21	0.004109	7.87	118.31	86.28	0.79
Survey Site	250	50- year	930.00	818.36	822.70	822.75	823.56	0.003616	7.98	154.76	101.36	0.75
Survey Site	250	100- year	1118.00	818.36	822.59	822.99	824.01	0.006126	10.17	143.91	100.25	0.97
Survey Site	250	8 cfs baseflow	8.00	818.36	818.79	818.82	818.94	0.020359	3.04	2.63	12.25	1.16
Survey Site	300	LL Outlet Capaci	45.00	819.43	820.11	820.11	820.33	0.012041	3.78	11.91	26.89	1.00
Survey Site	300	Principal Spillw	1700.00	819.43	822.81	823.91	826.34	0.019604	15.45	121.43	65.77	1.69
Survey Site	300	Spillway Design	2300.00	819.43	823.12	824.55	827.90	0.023340	18.17	142.12	67.87	1.88
Survey Site	300	2- year	252.00	819.43	820.98	821.07	821.70	0.010697	6.81	37.01	31.30	1.10
Survey Site	300	10- year	555.00	819.43	821.60	822.01	823.04	0.013771	9.63	57.97	37.21	1.32
Survey Site	300	25- year	758.00	819.43	821.98	822.56	823.70	0.013919	10.57	73.12	43.10	1.35
Survey Site	300	50- year	930.00	819.43	822.23	822.86	824.22	0.014498	11.38	85.24	59.24	1.40
Survey Site	300	100- year	1118.00	819.43	822.40	823.15	824.77	0.015906	12.47	95.48	61.19	1.48
Survey Site	300	8 cfs baseflow	8.00	819.43	819.77	819.77	819.86	0.016871	2.40	3.33	19.17	1.02
Survey Site	350	LL Outlet Capaci	45.00	819.43	820.51	820.28	820.66	0.003992	3.18	14.17	17.93	0.63
Survey Site	350	Principal Spillw	1700.00	819.43	823.66	824.85	827.38	0.020039	15.48	109.79	41.58	1.68
Survey Site	350	Spillway Design	2300.00	819.43	824.03	825.64	829.24	0.025215	18.31	125.59	43.88	1.91
Survey Site	350	2- year	252.00	819.43	821.33	821.59	822.38	0.012875	8.22	30.65	22.16	1.23

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

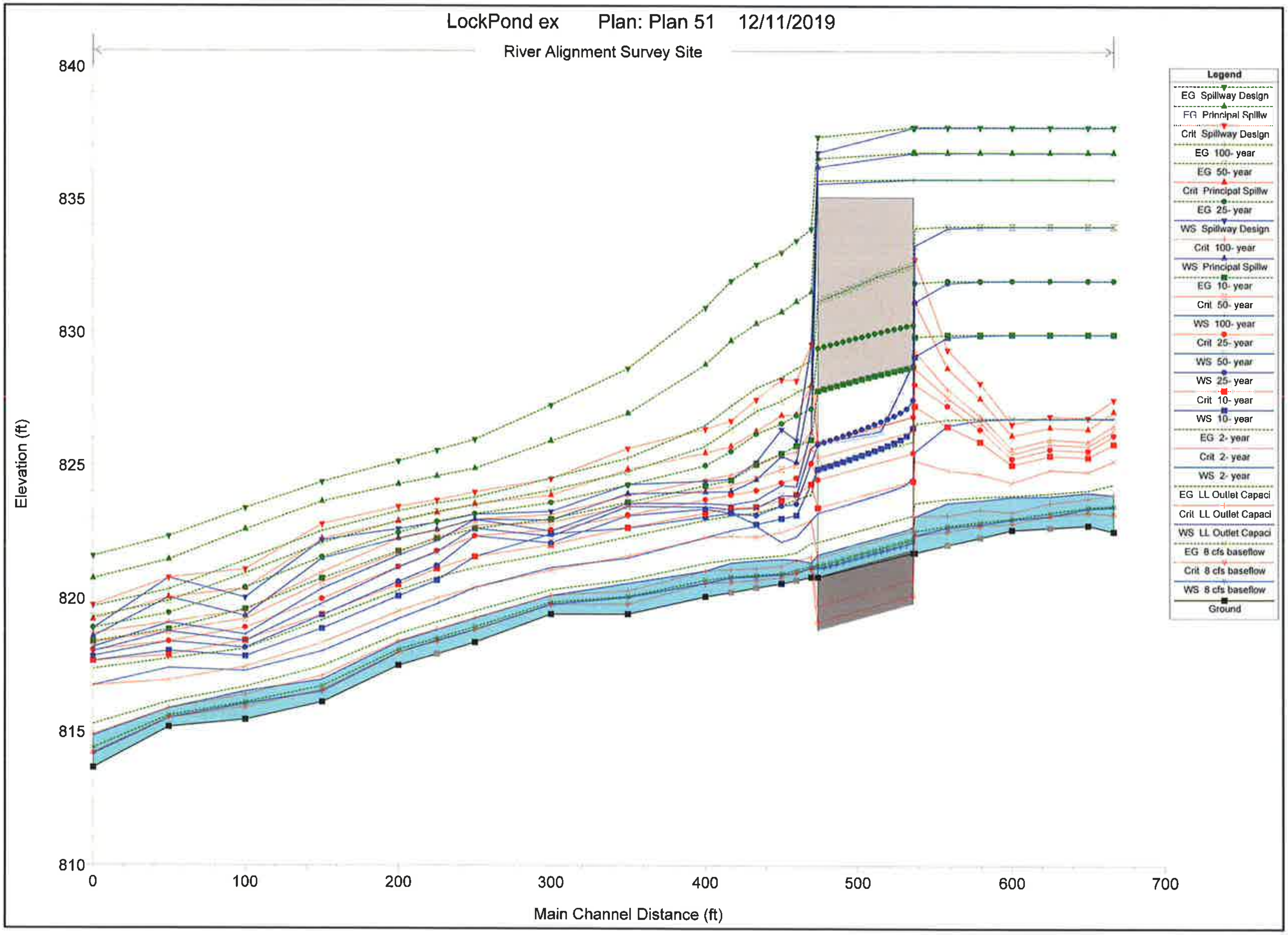
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	350	10- year	555.00	819.43	822.34	822.66	823.71	0.012761	9.38	59.15	34.47	1.26
Survey Site	350	25- year	758.00	819.43	822.75	823.14	824.38	0.012767	10.26	73.89	37.60	1.29
Survey Site	350	50- year	930.00	819.43	823.02	823.48	824.91	0.012962	11.05	84.19	38.63	1.32
Survey Site	350	100- year	1118.00	819.43	823.20	823.87	825.53	0.014723	12.26	91.16	39.17	1.42
Survey Site	350	8 cfs baseflow	8.00	819.43	820.03	819.78	820.05	0.001624	1.31	6.13	15.12	0.36
Survey Site	400	LL Outlet Capaci	45.00	820.09	821.04	821.04	821.34	0.011162	4.36	10.32	17.47	1.00
Survey Site	400	Principal Spillw	1700.00	820.09	823.97	825.47	828.93	0.027687	17.86	95.20	36.88	1.96
Survey Site	400	Spillway Design	2300.00	820.09	824.37	826.38	831.14	0.032981	20.88	110.13	38.36	2.17
Survey Site	400	2- year	252.00	820.09	822.29	822.29	822.95	0.009180	6.51	38.70	30.21	1.01
Survey Site	400	10- year	555.00	820.09	823.22	823.22	824.24	0.007869	8.10	68.52	34.04	1.01
Survey Site	400	25- year	758.00	820.09	823.47	823.72	824.97	0.010258	9.82	77.19	34.96	1.17
Survey Site	400	50- year	930.00	820.09	823.41	824.11	825.79	0.016786	12.39	75.07	34.74	1.49
Survey Site	400	100- year	1118.00	820.09	823.52	824.48	826.63	0.020723	14.13	79.12	35.17	1.66
Survey Site	400	8 cfs baseflow	8.00	820.09	820.59	820.59	820.70	0.014571	2.69	2.97	12.76	0.98
Survey Site	425.00*	LL Outlet Capaci	45.00	819.84	821.37	820.99	821.47	0.002460	2.54	17.72	21.69	0.50
Survey Site	425.00*	Principal Spillw	1700.00	819.84	823.88	825.65	830.04	0.032603	19.91	85.38	35.45	2.17
Survey Site	425.00*	Spillway Design	2300.00	819.84	824.38	826.63	832.32	0.033245	22.60	101.77	37.73	2.25
Survey Site	425.00*	2- year	252.00	819.84	822.73	822.18	823.11	0.003016	4.91	51.37	27.98	0.63
Survey Site	425.00*	10- year	555.00	819.84	822.76	823.24	824.52	0.014020	10.66	52.09	28.09	1.35
Survey Site	425.00*	25- year	758.00	819.84	822.94	823.82	825.68	0.019704	13.27	57.14	28.84	1.63
Survey Site	425.00*	50- year	930.00	819.84	823.12	824.19	826.61	0.022923	14.97	62.11	29.48	1.77
Survey Site	425.00*	100- year	1118.00	819.84	823.32	824.57	827.54	0.026796	16.49	67.82	31.46	1.92
Survey Site	425.00*	8 cfs baseflow	8.00	819.84	820.76	820.41	820.78	0.001244	1.22	6.53	14.43	0.32
Survey Site	450	LL Outlet Capaci	45.00	819.58	821.44	820.73	821.51	0.000924	2.05	21.95	21.15	0.32
Survey Site	450	Principal Spillw	1700.00	819.58	824.82	826.50	830.62	0.015401	19.31	88.05	38.27	1.62
Survey Site	450	Spillway Design	2300.00	819.58	825.78	827.86	832.93	0.014603	21.44	107.26	43.60	1.63
Survey Site	450	2- year	252.00	819.58	822.75	822.08	823.20	0.002822	5.41	46.60	25.82	0.62
Survey Site	450	10- year	555.00	819.58	822.58	823.30	825.15	0.017389	12.87	43.14	25.21	1.53
Survey Site	450	25- year	758.00	819.58	823.04	823.97	826.29	0.017251	14.46	52.42	26.84	1.57
Survey Site	450	50- year	930.00	819.58	823.40	824.49	827.18	0.016876	15.59	59.65	28.12	1.59
Survey Site	450	100- year	1118.00	819.58	823.77	825.02	828.09	0.016483	16.66	67.09	30.45	1.60
Survey Site	450	8 cfs baseflow	8.00	819.58	820.79	820.13	820.80	0.000274	0.75	10.69	15.86	0.16
Survey Site	469.57	LL Outlet Capaci	45.00	819.81	821.43	820.97	821.55	0.002051	2.76	16.30	17.88	0.47
Survey Site	469.57	Principal Spillw	1700.00	819.81	827.48	827.48	831.00	0.004889	15.04	113.03	40.46	1.00
Survey Site	469.57	Spillway Design	2300.00	819.81	829.06	829.06	833.36	0.004571	16.64	138.26	85.95	1.00
Survey Site	469.57	2- year	252.00	819.81	822.55	822.40	823.40	0.005832	7.39	34.10	22.07	0.89
Survey Site	469.57	10- year	555.00	819.81	823.76	823.76	825.44	0.006322	10.38	53.45	25.93	1.00
Survey Site	469.57	25- year	758.00	819.81	824.55	824.55	826.60	0.005836	11.48	66.01	28.52	1.00

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	469.57	50- year	930.00	819.81	825.14	825.14	827.50	0.005595	12.30	75.58	30.26	1.00
Survey Site	469.57	100- year	1118.00	819.81	825.74	825.74	828.42	0.005428	13.13	85.18	31.98	1.00
Survey Site	469.57	8 cfs baseflow	8.00	819.81	820.79	820.30	820.81	0.000698	1.11	7.19	11.82	0.25
Survey Site	535.75		Culvert									
Survey Site	536.75	LL Outlet Capaci	45.00	821.74	824.07	823.10	824.19	0.001357	2.76	16.32	9.10	0.36
Survey Site	536.75	Principal Spillw	1700.00	821.74	836.95	831.13	836.97	0.000036	1.46	1501.52	244.90	0.09
Survey Site	536.75	Spillway Design	2300.00	821.74	837.75	832.76	837.79	0.000046	1.75	1699.96	250.02	0.10
Survey Site	536.75	2- year	252.00	821.74	827.31	825.19	827.65	0.001760	4.72	53.34	23.07	0.44
Survey Site	536.75	10- year	555.00	821.74	830.46	827.24	830.94	0.001027	5.51	100.71	109.29	0.37
Survey Site	536.75	25- year	758.00	821.74	832.32	828.06	832.86	0.000848	5.89	128.59	157.33	0.35
Survey Site	536.75	50- year	930.00	821.74	833.88	828.67	834.46	0.000731	6.12	151.98	203.65	0.34
Survey Site	536.75	100- year	1118.00	821.74	835.75	829.31	835.76	0.000028	1.16	1217.83	224.52	0.07
Survey Site	536.75	8 cfs baseflow	8.00	821.74	822.79	822.38	822.82	0.001085	1.45	5.52	7.78	0.30
Survey Site	557.83*	LL Outlet Capaci	45.00	822.03	824.14	823.12	824.21	0.000826	2.16	20.87	12.52	0.29
Survey Site	557.83*	Principal Spillw	1700.00	822.03	836.96	828.67	836.98	0.000021	1.25	1781.00	248.62	0.07
Survey Site	557.83*	Spillway Design	2300.00	822.03	837.76	829.36	837.79	0.000028	1.52	1983.25	254.41	0.08
Survey Site	557.83*	2- year	252.00	822.03	827.62	824.84	827.70	0.000533	2.23	113.19	65.05	0.26
Survey Site	557.83*	10- year	555.00	822.03	830.93	826.47	830.98	0.000122	1.93	287.64	161.39	0.15
Survey Site	557.83*	25- year	758.00	822.03	832.86	827.24	832.92	0.000082	1.94	390.00	206.03	0.13
Survey Site	557.83*	50- year	930.00	822.03	834.46	827.57	834.52	0.000064	1.96	474.98	218.89	0.12
Survey Site	557.83*	100- year	1118.00	822.03	835.75	827.88	835.76	0.000014	0.97	1489.81	231.70	0.06
Survey Site	557.83*	8 cfs baseflow	8.00	822.03	822.82	822.54	822.85	0.001484	1.43	5.60	10.53	0.35
Survey Site	578.92*	LL Outlet Capaci	45.00	822.31	824.18	823.34	824.23	0.000964	1.83	24.61	23.30	0.31
Survey Site	578.92*	Principal Spillw	1700.00	822.31	836.96	827.53	836.98	0.000013	1.08	2053.90	247.58	0.06
Survey Site	578.92*	Spillway Design	2300.00	822.31	837.77	828.09	837.79	0.000018	1.33	2255.62	253.72	0.07
Survey Site	578.92*	2- year	252.00	822.31	827.69	824.69	827.71	0.000127	1.23	204.76	115.75	0.14
Survey Site	578.92*	10- year	555.00	822.31	830.97	825.91	830.99	0.000036	1.14	511.02	180.24	0.08
Survey Site	578.92*	25- year	758.00	822.31	832.90	826.37	832.92	0.000025	1.14	696.49	211.07	0.07
Survey Site	578.92*	50- year	930.00	822.31	834.51	826.65	834.53	0.000019	1.14	850.49	221.68	0.07
Survey Site	578.92*	100- year	1118.00	822.31	835.76	826.89	835.76	0.000008	0.82	1762.33	232.71	0.04
Survey Site	578.92*	8 cfs baseflow	8.00	822.31	822.84	822.74	822.91	0.005637	2.17	3.68	10.15	0.64
Survey Site	600	LL Outlet Capaci	45.00	822.60	824.23	823.25	824.25	0.000459	1.18	38.29	41.54	0.22
Survey Site	600	Principal Spillw	1700.00	822.60	836.97	826.14	836.98	0.000008	0.87	2309.15	244.31	0.04
Survey Site	600	Spillway Design	2300.00	822.60	837.77	826.57	837.79	0.000011	1.08	2508.24	249.81	0.05
Survey Site	600	2- year	252.00	822.60	827.71	824.37	827.71	0.000022	0.63	411.22	151.50	0.06
Survey Site	600	10- year	555.00	822.60	830.98	825.03	830.99	0.000010	0.67	863.56	194.26	0.05
Survey Site	600	25- year	758.00	822.60	832.92	825.27	832.92	0.000008	0.70	1130.06	208.31	0.04

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	600	50- year	930.00	822.60	834.52	825.45	834.53	0.000007	0.72	1351.39	219.84	0.04
Survey Site	600	100- year	1118.00	822.60	835.76	825.64	835.76	0.000005	0.64	2019.60	232.71	0.03
Survey Site	600	8 cfs baseflow	8.00	822.60	822.97	822.84	823.00	0.002925	1.45	5.54	17.97	0.46
Survey Site	625.00*	LL Outlet Capaci	45.00	822.68	824.23	823.60	824.27	0.000897	1.68	26.86	28.64	0.31
Survey Site	625.00*	Principal Spillw	1700.00	822.68	836.97	826.45	836.98	0.000008	0.87	2242.92	241.44	0.04
Survey Site	625.00*	Spillway Design	2300.00	822.68	837.77	826.88	837.79	0.000011	1.09	2439.79	247.14	0.05
Survey Site	625.00*	2- year	252.00	822.68	827.71	824.85	827.71	0.000029	0.63	400.25	143.87	0.07
Survey Site	625.00*	10- year	555.00	822.68	830.99	825.38	830.99	0.000010	0.62	945.33	186.09	0.04
Survey Site	625.00*	25- year	758.00	822.68	832.92	825.62	832.92	0.000007	0.63	1305.00	206.73	0.04
Survey Site	625.00*	50- year	930.00	822.68	834.52	825.81	834.53	0.000006	0.62	1606.61	223.07	0.04
Survey Site	625.00*	100- year	1118.00	822.68	835.76	826.01	835.76	0.000005	0.65	1956.45	233.04	0.03
Survey Site	625.00*	8 cfs baseflow	8.00	822.68	823.11	823.11	823.24	0.015452	2.80	2.86	11.88	1.00
Survey Site	650	LL Outlet Capaci	45.00	822.77	824.26	823.77	824.30	0.000976	1.60	28.13	34.09	0.31
Survey Site	650	Principal Spillw	1700.00	822.77	836.97	826.38	836.98	0.000008	0.86	2207.10	232.30	0.04
Survey Site	650	Spillway Design	2300.00	822.77	837.77	826.82	837.79	0.000011	1.08	2396.32	237.30	0.05
Survey Site	650	2- year	252.00	822.77	827.71	824.77	827.71	0.000029	0.62	405.32	149.80	0.07
Survey Site	650	10- year	555.00	822.77	830.99	825.32	830.99	0.000010	0.61	954.44	187.01	0.04
Survey Site	650	25- year	758.00	822.77	832.92	825.56	832.92	0.000007	0.61	1335.26	202.53	0.04
Survey Site	650	50- year	930.00	822.77	834.52	825.75	834.53	0.000005	0.61	1665.76	209.45	0.03
Survey Site	650	100- year	1118.00	822.77	835.76	825.92	835.76	0.000005	0.64	1930.84	222.22	0.03
Survey Site	650	8 cfs baseflow	8.00	822.77	823.37	823.25	823.42	0.004032	1.83	4.37	12.70	0.55
Survey Site	666.6	LL Outlet Capaci	45.00	822.54	824.19	823.92	824.37	0.005689	3.40	13.25	19.07	0.72
Survey Site	666.6	Principal Spillw	1700.00	822.54	836.97	827.03	836.98	0.000009	0.90	2095.28	234.46	0.05
Survey Site	666.6	Spillway Design	2300.00	822.54	837.77	827.48	837.79	0.000013	1.13	2287.70	241.40	0.06
Survey Site	666.6	2- year	252.00	822.54	827.71	825.18	827.72	0.000069	0.82	306.28	139.68	0.10
Survey Site	666.6	10- year	555.00	822.54	830.98	825.82	830.99	0.000015	0.69	822.99	180.53	0.05
Survey Site	666.6	25- year	758.00	822.54	832.92	826.15	832.92	0.000010	0.67	1199.18	207.12	0.04
Survey Site	666.6	50- year	930.00	822.54	834.52	826.31	834.53	0.000007	0.66	1541.46	219.07	0.04
Survey Site	666.6	100- year	1118.00	822.54	835.76	826.51	835.76	0.000006	0.68	1817.35	226.64	0.04
Survey Site	666.6	8 cfs baseflow	8.00	822.54	823.42	823.17	823.47	0.002380	1.83	4.38	8.35	0.44


LockPond ex Plan: Plan 51 12/11/2019
River Alignment Survey Site
Elevation (ft)
840
835
830
825
820
815
810
0
100
200
300
400
500
600
700
Main Channel Distance (ft)
Legend
EG Spillway Design
EG Principal Spillw
Crit Spillway Design
EG 100- year
EG 50- year
Crit Principal Spillw
EG 25- year
WS Spillway Design
Crit 100- year
WS Principal Spillw
EG 10- year
Crit 50- year
WS 100- year
Crit 25- year
WS 50- year
WS 25- year
Crit 10- year
WS 10- year
EG 2- year
Crit 2- year
WS 2- year
EG LL Outlet Capaci
Crit LL Outlet Capaci
WS LL Outlet Capaci
EG 8 cfs baseflow
Crit 8 cfs baseflow
WS 8 cfs baseflow
Ground

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	0	LL Outlet Capaci	45.00	813.65	814.86	814.90	815.28	0.016802	5.25	8.58	11.71	1.08
Survey Site	0	Principal Spillw	1700.00	813.65	818.56	819.19	820.74	0.020258	12.74	153.40	102.60	1.42
Survey Site	0	Spillway Design	2300.00	813.65	818.87	819.74	821.59	0.023911	14.46	187.13	115.00	1.56
Survey Site	0	2- year	252.00	813.65	816.73	816.73	817.34	0.011150	6.31	40.84	37.11	0.96
Survey Site	0	10- year	555.00	813.65	817.64	817.64	818.37	0.009076	7.14	85.25	58.47	0.91
Survey Site	0	25- year	758.00	813.65	817.82	818.04	818.89	0.012318	8.68	96.24	61.29	1.07
Survey Site	0	50- year	930.00	813.65	818.00	818.32	819.29	0.013908	9.57	107.44	68.87	1.15
Survey Site	0	100- year	1118.00	813.65	818.17	818.68	819.68	0.015519	10.45	119.40	75.15	1.22
Survey Site	0	8 cfs baseflow	8.00	813.65	814.17	814.21	814.39	0.025844	3.74	2.14	6.79	1.18
Survey Site	50	LL Outlet Capaci	45.00	815.18	815.87	815.87	816.12	0.015973	4.00	11.26	23.01	1.01
Survey Site	50	Principal Spillw	1700.00	815.18	820.03	820.03	821.46	0.008692	9.59	180.31	69.34	0.97
Survey Site	50	Spillway Design	2300.00	815.18	820.77	820.77	822.34	0.007862	10.16	237.67	84.72	0.94
Survey Site	50	2- year	252.00	815.18	817.38	816.92	817.73	0.004928	4.73	53.32	34.14	0.67
Survey Site	50	10- year	555.00	815.18	818.03	817.87	818.84	0.008563	7.22	76.91	38.88	0.90
Survey Site	50	25- year	758.00	815.18	818.38	818.38	819.45	0.010458	8.31	91.25	42.98	1.01
Survey Site	50	50- year	930.00	815.18	818.75	818.75	819.90	0.010398	8.59	108.25	47.87	1.01
Survey Site	50	100- year	1118.00	815.18	819.08	819.10	820.33	0.010215	8.97	124.68	50.82	1.01
Survey Site	50	8 cfs baseflow	8.00	815.18	815.51	815.51	815.60	0.021845	2.34	3.42	19.83	0.99
Survey Site	100	LL Outlet Capaci	45.00	815.46	816.51	816.39	816.68	0.008355	3.30	13.63	22.92	0.75
Survey Site	100	Principal Spillw	1700.00	815.46	819.34	820.37	822.59	0.028411	14.45	117.65	52.79	1.71
Survey Site	100	Spillway Design	2300.00	815.46	820.03	821.09	823.39	0.023606	14.69	156.52	59.56	1.60
Survey Site	100	2- year	252.00	815.46	817.28	817.43	818.10	0.017187	7.29	34.55	30.20	1.20
Survey Site	100	10- year	555.00	815.46	817.83	818.42	819.59	0.024232	10.65	52.11	33.13	1.50
Survey Site	100	25- year	758.00	815.46	818.15	818.90	820.41	0.027530	12.05	62.88	36.38	1.62
Survey Site	100	50- year	930.00	815.46	818.40	819.22	820.94	0.030662	12.78	72.78	41.74	1.71
Survey Site	100	100- year	1118.00	815.46	818.65	819.55	821.43	0.030555	13.37	83.62	44.61	1.72
Survey Site	100	8 cfs baseflow	8.00	815.46	816.05	815.92	816.09	0.005492	1.73	4.61	14.90	0.55
Survey Site	150	LL Outlet Capaci	45.00	816.11	816.95	817.09	817.46	0.029554	5.70	7.89	15.02	1.39
Survey Site	150	Principal Spillw	1700.00	816.11	821.50	822.23	823.64	0.013364	11.73	146.03	64.67	1.20
Survey Site	150	Spillway Design	2300.00	816.11	822.19	822.79	824.37	0.013266	12.07	205.81	97.59	1.21
Survey Site	150	2- year	252.00	816.11	818.02	818.32	819.19	0.022745	8.70	28.98	23.89	1.39
Survey Site	150	10- year	555.00	816.11	818.86	819.38	820.76	0.020600	11.03	50.30	26.45	1.41
Survey Site	150	25- year	758.00	816.11	819.36	819.97	821.55	0.019022	11.86	63.90	28.18	1.39
Survey Site	150	50- year	930.00	816.11	819.80	820.60	822.09	0.017188	12.12	76.72	30.25	1.34
Survey Site	150	100- year	1118.00	816.11	820.36	820.97	822.54	0.015085	11.84	94.43	34.85	1.27
Survey Site	150	8 cfs baseflow	8.00	816.11	816.50	816.56	816.71	0.039502	3.64	2.20	10.25	1.39
Survey Site	200	LL Outlet Capaci	45.00	817.49	818.37	818.40	818.66	0.019350	4.36	10.31	21.24	1.10
Survey Site	200	Principal Spillw	1700.00	817.49	822.26	822.90	824.29	0.012250	11.88	166.77	101.61	1.18

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	200	Spillway Design	2300.00	817.49	822.61	823.44	825.16	0.013972	13.61	202.36	107.55	1.28
Survey Site	200	2- year	252.00	817.49	819.24	819.51	820.30	0.020938	8.28	30.42	25.03	1.32
Survey Site	200	10- year	555.00	817.49	820.09	820.51	821.77	0.019104	10.41	53.32	28.75	1.35
Survey Site	200	25- year	758.00	817.49	820.63	821.18	822.47	0.016164	10.88	69.95	32.54	1.28
Survey Site	200	50- year	930.00	817.49	821.17	821.71	822.91	0.013874	10.61	89.01	39.80	1.20
Survey Site	200	100- year	1118.00	817.49	821.62	822.24	823.28	0.012775	10.45	112.98	64.39	1.16
Survey Site	200	8 cfs baseflow	8.00	817.49	817.96	817.96	818.07	0.019640	2.69	2.97	12.84	0.99
Survey Site	225.00*	LL Outlet Capaci	45.00	817.92	818.83	818.84	819.12	0.017145	4.31	10.43	20.02	1.05
Survey Site	225.00*	Principal Spillw	1700.00	817.92	822.58	823.21	824.59	0.012217	12.00	169.29	100.89	1.19
Survey Site	225.00*	Spillway Design	2300.00	817.92	822.86	823.70	825.57	0.015194	14.16	198.62	107.10	1.34
Survey Site	225.00*	2- year	252.00	817.92	819.79	820.01	820.79	0.017600	8.03	31.39	23.78	1.23
Survey Site	225.00*	10- year	555.00	817.92	820.68	821.11	822.26	0.018301	10.06	55.14	30.56	1.32
Survey Site	225.00*	25- year	758.00	817.92	821.23	821.77	822.89	0.015834	10.32	73.80	37.48	1.26
Survey Site	225.00*	50- year	930.00	817.92	821.74	822.29	823.26	0.012514	9.92	96.90	63.86	1.14
Survey Site	225.00*	100- year	1118.00	817.92	822.16	822.55	823.58	0.009793	9.78	128.79	90.16	1.04
Survey Site	225.00*	8 cfs baseflow	8.00	817.92	818.42	818.39	818.51	0.014936	2.44	3.27	13.35	0.87
Survey Site	250	LL Outlet Capaci	45.00	818.36	819.26	819.26	819.53	0.015959	4.17	10.79	20.64	1.02
Survey Site	250	Principal Spillw	1700.00	818.36	822.97	823.54	824.89	0.010519	12.32	181.59	104.08	1.12
Survey Site	250	Spillway Design	2300.00	818.36	823.16	824.00	825.98	0.014874	15.14	200.82	106.01	1.34
Survey Site	250	2- year	252.00	818.36	820.40	820.40	821.16	0.011291	6.99	36.03	23.73	1.00
Survey Site	250	10- year	555.00	818.36	821.57	821.57	822.61	0.008750	8.24	69.23	39.18	0.95
Survey Site	250	25- year	758.00	818.36	822.34	822.34	823.18	0.005242	7.70	119.93	87.22	0.77
Survey Site	250	50- year	930.00	818.36	822.63	822.73	823.52	0.005166	8.11	147.72	100.64	0.77
Survey Site	250	100- year	1118.00	818.36	822.97	822.97	823.80	0.004558	8.11	181.45	104.06	0.74
Survey Site	250	8 cfs baseflow	8.00	818.36	818.82	818.82	818.93	0.019344	2.67	3.00	13.05	0.98
Survey Site	300	LL Outlet Capaci	45.00	819.43	820.11	820.11	820.33	0.016202	3.78	11.91	26.89	1.00
Survey Site	300	Principal Spillw	1700.00	819.43	822.95	823.88	825.92	0.020982	14.29	131.05	66.87	1.52
Survey Site	300	Spillway Design	2300.00	819.43	823.28	824.51	827.27	0.024745	16.73	153.21	68.94	1.68
Survey Site	300	2- year	252.00	819.43	821.16	821.07	821.70	0.009356	5.90	42.73	32.41	0.91
Survey Site	300	10- year	555.00	819.43	822.43	822.02	822.99	0.004946	6.05	97.67	61.61	0.71
Survey Site	300	25- year	758.00	819.43	822.10	822.58	823.60	0.015796	9.90	78.29	45.19	1.25
Survey Site	300	50- year	930.00	819.43	822.34	822.86	824.08	0.016203	10.69	91.83	60.50	1.28
Survey Site	300	100- year	1118.00	819.43	822.54	823.15	824.53	0.016902	11.52	104.39	63.54	1.33
Survey Site	300	8 cfs baseflow	8.00	819.43	819.79	819.77	819.86	0.017613	2.18	3.67	20.15	0.90
Survey Site	350	LL Outlet Capaci	45.00	819.43	820.58	820.28	820.71	0.004175	2.92	15.41	18.29	0.56
Survey Site	350	Principal Spillw	1700.00	819.43	823.95	824.85	826.96	0.020101	13.93	122.01	43.39	1.46
Survey Site	350	Spillway Design	2300.00	819.43	824.29	825.64	828.66	0.026430	16.76	137.21	45.35	1.70
Survey Site	350	2- year	252.00	819.43	821.53	821.59	822.32	0.012271	7.17	35.16	24.12	1.05

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	350	10- year	555.00	819.43	822.65	822.66	823.62	0.010711	7.90	70.25	37.14	1.01
Survey Site	350	25- year	758.00	819.43	823.12	823.14	824.27	0.010132	8.61	88.00	38.93	1.01
Survey Site	350	50- year	930.00	819.43	823.46	823.48	824.76	0.009999	9.14	101.76	40.49	1.02
Survey Site	350	100- year	1118.00	819.43	823.59	823.87	825.29	0.012553	10.45	106.94	41.15	1.14
Survey Site	350	8 cfs baseflow	8.00	819.43	820.05	819.78	820.08	0.001811	1.23	6.52	15.32	0.33
Survey Site	400	LL Outlet Capaci	45.00	820.09	821.04	821.04	821.34	0.015019	4.36	10.32	17.47	1.00
Survey Site	400	Principal Spillw	1700.00	820.09	824.01	825.47	828.80	0.035431	17.56	96.84	37.06	1.91
Survey Site	400	Spillway Design	2300.00	820.09	824.42	826.38	830.95	0.041961	20.49	112.25	38.56	2.12
Survey Site	400	2- year	252.00	820.09	822.29	822.29	822.95	0.012353	6.51	38.70	30.21	1.01
Survey Site	400	10- year	555.00	820.09	823.08	823.22	824.25	0.013070	8.68	63.91	33.54	1.11
Survey Site	400	25- year	758.00	820.09	823.38	823.72	825.01	0.015659	10.24	74.01	34.63	1.24
Survey Site	400	50- year	930.00	820.09	823.45	824.11	825.74	0.021227	12.13	76.64	34.90	1.44
Survey Site	400	100- year	1118.00	820.09	823.59	824.48	826.52	0.025628	13.74	81.39	35.40	1.60
Survey Site	400	8 cfs baseflow	8.00	820.09	820.59	820.59	820.70	0.019607	2.69	2.97	12.76	0.98
Survey Site	416.67*	LL Outlet Capaci	45.00	820.25	821.35	821.09	821.48	0.004633	2.95	15.27	19.25	0.58
Survey Site	416.67*	Principal Spillw	1700.00	820.25	824.03	825.73	829.70	0.041301	19.11	88.97	37.11	2.08
Survey Site	416.67*	Spillway Design	2300.00	820.25	824.50	826.69	831.94	0.044765	21.89	105.08	39.13	2.21
Survey Site	416.67*	2- year	252.00	820.25	822.57	822.34	823.12	0.007874	5.98	42.14	26.76	0.84
Survey Site	416.67*	10- year	555.00	820.25	823.23	823.41	824.46	0.013817	8.92	62.20	33.34	1.14
Survey Site	416.67*	25- year	758.00	820.25	823.22	823.90	825.54	0.026038	12.22	62.00	33.31	1.57
Survey Site	416.67*	50- year	930.00	820.25	823.36	824.27	826.38	0.031023	13.95	66.69	34.05	1.73
Survey Site	416.67*	100- year	1118.00	820.25	823.53	824.66	827.25	0.034671	15.47	72.26	35.02	1.85
Survey Site	416.67*	8 cfs baseflow	8.00	820.25	820.79	820.62	820.82	0.003713	1.50	5.32	15.72	0.46
Survey Site	433.33*	LL Outlet Capaci	45.00	820.42	821.44	821.15	821.55	0.004001	2.77	16.27	20.26	0.54
Survey Site	433.33*	Principal Spillw	1700.00	820.42	824.47	826.29	830.35	0.030385	19.45	87.42	38.18	1.87
Survey Site	433.33*	Spillway Design	2300.00	820.42	825.15	827.49	832.57	0.031840	21.86	105.22	41.49	1.95
Survey Site	433.33*	2- year	252.00	820.42	822.74	822.32	823.23	0.005246	5.65	44.64	25.04	0.72
Survey Site	433.33*	10- year	555.00	820.42	822.81	823.45	825.04	0.022797	12.00	46.25	25.29	1.50
Survey Site	433.33*	25- year	758.00	820.42	823.14	824.06	826.20	0.026316	14.03	54.03	28.13	1.64
Survey Site	433.33*	50- year	930.00	820.42	823.42	824.52	827.05	0.027612	15.29	60.83	31.00	1.71
Survey Site	433.33*	100- year	1118.00	820.42	823.71	825.01	827.92	0.028512	16.47	67.89	33.35	1.76
Survey Site	433.33*	8 cfs baseflow	8.00	820.42	820.85	820.70	820.89	0.003951	1.51	5.31	16.49	0.47
Survey Site	450	LL Outlet Capaci	45.00	820.58	821.49	821.23	821.63	0.004475	3.02	14.90	21.32	0.58
Survey Site	450	Principal Spillw	1700.00	820.58	825.37	826.89	830.78	0.018244	18.67	91.05	41.79	1.54
Survey Site	450	Spillway Design	2300.00	820.58	826.37	828.25	833.03	0.017229	20.71	111.05	46.47	1.55
Survey Site	450	2- year	252.00	820.58	822.14	822.50	823.51	0.021622	9.37	26.88	23.69	1.39
Survey Site	450	10- year	555.00	820.58	823.02	823.70	825.47	0.021665	12.56	44.18	26.78	1.49
Survey Site	450	25- year	758.00	820.58	823.50	824.36	826.60	0.021101	14.12	53.69	28.45	1.52

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	450	50- year	930.00	820.58	823.88	824.88	827.45	0.020274	15.14	61.43	31.35	1.52
Survey Site	450	100- year	1118.00	820.58	824.27	825.42	828.33	0.019681	16.15	69.22	34.28	1.53
Survey Site	450	8 cfs baseflow	8.00	820.58	820.92	820.80	820.96	0.004643	1.57	5.08	17.49	0.50
Survey Site	459.79*	LL Outlet Capaci	45.00	820.70	821.47	821.43	821.74	0.011636	4.12	10.92	18.50	0.90
Survey Site	459.79*	Principal Spillw	1700.00	820.70	825.13	826.92	831.18	0.024997	19.73	86.16	35.13	1.76
Survey Site	459.79*	Spillway Design	2300.00	820.70	825.97	828.20	833.48	0.023969	21.99	104.60	38.03	1.78
Survey Site	459.79*	2- year	252.00	820.70	822.33	822.71	823.74	0.023091	9.51	26.51	22.50	1.43
Survey Site	459.79*	10- year	555.00	820.70	823.14	823.92	825.75	0.025218	12.97	42.80	25.19	1.59
Survey Site	459.79*	25- year	758.00	820.70	823.57	824.54	826.89	0.026896	14.62	51.86	29.22	1.68
Survey Site	459.79*	50- year	930.00	820.70	823.89	825.03	827.76	0.026582	15.79	58.90	30.42	1.70
Survey Site	459.79*	100- year	1118.00	820.70	824.22	825.52	828.66	0.026127	16.91	66.12	31.60	1.72
Survey Site	459.79*	8 cfs baseflow	8.00	820.70	820.98	820.98	821.08	0.020734	2.65	3.02	13.94	1.01
Survey Site	469.57	LL Outlet Capaci	45.00	820.82	821.37	821.58	822.10	0.055266	6.86	6.56	17.63	1.84
Survey Site	469.57	Principal Spillw	1700.00	820.82	828.03	828.03	831.54	0.006437	15.04	113.01	58.95	1.00
Survey Site	469.57	Spillway Design	2300.00	820.82	829.57	829.57	833.91	0.006092	16.70	137.74	97.07	1.00
Survey Site	469.57	2- year	252.00	820.82	822.95	822.95	823.93	0.009764	7.94	31.73	23.55	0.99
Survey Site	469.57	10- year	555.00	820.82	824.30	824.30	825.98	0.008343	10.39	53.41	27.50	1.00
Survey Site	469.57	25- year	758.00	820.82	825.09	825.09	827.14	0.007688	11.49	66.00	30.10	1.00
Survey Site	469.57	50- year	930.00	820.82	825.67	825.67	828.04	0.007481	12.36	75.23	31.77	1.01
Survey Site	469.57	100- year	1118.00	820.82	826.31	826.31	828.97	0.007040	13.07	85.56	33.51	1.00
Survey Site	469.57	8 cfs baseflow	8.00	820.82	821.17	821.13	821.24	0.012109	2.21	3.62	15.28	0.79
Survey Site	535.75		Culvert									
Survey Site	536.75	LL Outlet Capaci	45.00	821.74	823.10	823.10	823.59	0.014995	5.64	7.98	8.10	1.00
Survey Site	536.75	Principal Spillw	1700.00	821.74	836.76	831.13	836.78	0.000047	1.42	1454.90	242.55	0.08
Survey Site	536.75	Spillway Design	2300.00	821.74	837.71	832.76	837.74	0.000056	1.65	1689.47	249.77	0.09
Survey Site	536.75	2- year	252.00	821.74	825.52	825.19	826.57	0.009788	8.22	30.65	10.60	0.85
Survey Site	536.75	10- year	555.00	821.74	829.12	827.24	829.85	0.002919	6.90	80.46	83.25	0.53
Survey Site	536.75	25- year	758.00	821.74	831.16	828.06	831.88	0.001857	6.82	111.11	121.51	0.44
Survey Site	536.75	50- year	930.00	821.74	833.28	828.67	833.94	0.001207	6.51	142.93	199.14	0.37
Survey Site	536.75	100- year	1118.00	821.74	835.76	829.31	835.78	0.000033	1.10	1222.10	224.84	0.07
Survey Site	536.75	8 cfs baseflow	8.00	821.74	822.38	822.38	822.55	0.018926	3.27	2.44	7.34	1.00
Survey Site	557.83*	LL Outlet Capaci	45.00	822.03	823.61	823.12	823.76	0.003377	3.13	14.39	11.71	0.50
Survey Site	557.83*	Principal Spillw	1700.00	822.03	836.77	828.67	836.78	0.000026	1.21	1733.64	247.21	0.07
Survey Site	557.83*	Spillway Design	2300.00	822.03	837.72	829.36	837.74	0.000033	1.43	1972.48	254.21	0.08
Survey Site	557.83*	2- year	252.00	822.03	826.52	824.84	826.74	0.002173	3.74	67.39	30.64	0.44
Survey Site	557.83*	10- year	555.00	822.03	829.85	826.47	829.94	0.000344	2.41	230.37	131.48	0.20
Survey Site	557.83*	25- year	758.00	822.03	831.88	827.24	831.95	0.000178	2.24	338.03	184.61	0.16

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	557.83*	50- year	930.00	822.03	833.93	827.57	834.00	0.000106	2.08	447.11	214.98	0.13
Survey Site	557.83*	100- year	1118.00	822.03	835.77	827.88	835.78	0.000017	0.91	1494.13	232.05	0.05
Survey Site	557.83*	8 cfs baseflow	8.00	822.03	822.69	822.54	822.74	0.004799	1.88	4.26	10.34	0.52
Survey Site	578.92*	LL Outlet Capaci	45.00	822.31	823.70	823.34	823.84	0.003900	2.93	15.33	16.00	0.53
Survey Site	578.92*	Principal Spillw	1700.00	822.31	836.77	827.53	836.79	0.000016	1.04	2006.70	246.29	0.05
Survey Site	578.92*	Spillway Design	2300.00	822.31	837.73	828.11	837.74	0.000021	1.26	2244.79	253.59	0.06
Survey Site	578.92*	2- year	252.00	822.31	826.72	824.69	826.78	0.000688	1.93	130.28	80.30	0.26
Survey Site	578.92*	10- year	555.00	822.31	829.92	825.91	829.95	0.000096	1.40	409.81	170.34	0.11
Survey Site	578.92*	25- year	758.00	822.31	831.94	826.37	831.96	0.000052	1.30	603.87	201.97	0.09
Survey Site	578.92*	50- year	930.00	822.31	833.99	826.65	834.01	0.000031	1.20	800.64	218.82	0.07
Survey Site	578.92*	100- year	1118.00	822.31	835.77	826.89	835.78	0.000010	0.77	1766.61	233.07	0.04
Survey Site	578.92*	8 cfs baseflow	8.00	822.31	822.81	822.74	822.90	0.010334	2.41	3.32	9.92	0.73
Survey Site	600	LL Outlet Capaci	45.00	822.60	823.84	823.25	823.89	0.001522	1.80	24.94	27.69	0.34
Survey Site	600	Principal Spillw	1700.00	822.60	836.78	826.14	836.79	0.000010	0.86	2262.51	243.03	0.04
Survey Site	600	Spillway Design	2300.00	822.60	837.73	826.57	837.74	0.000014	1.05	2497.37	249.51	0.05
Survey Site	600	2- year	252.00	822.60	826.78	824.37	826.79	0.000086	0.87	288.46	127.51	0.10
Survey Site	600	10- year	555.00	822.60	829.94	825.03	829.95	0.000025	0.80	719.30	180.60	0.06
Survey Site	600	25- year	758.00	822.60	831.96	825.27	831.96	0.000016	0.79	997.59	202.54	0.05
Survey Site	600	50- year	930.00	822.60	834.00	825.45	834.01	0.000011	0.75	1279.95	216.76	0.04
Survey Site	600	100- year	1118.00	822.60	835.78	825.64	835.78	0.000006	0.63	2023.78	232.92	0.03
Survey Site	600	8 cfs baseflow	8.00	822.60	822.99	822.84	823.02	0.003301	1.37	5.86	18.12	0.42
Survey Site	625.00*	LL Outlet Capaci	45.00	822.68	823.86	823.60	823.97	0.004586	2.66	16.90	24.49	0.56
Survey Site	625.00*	Principal Spillw	1700.00	822.68	836.78	826.45	836.79	0.000011	0.87	2196.84	239.99	0.04
Survey Site	625.00*	Spillway Design	2300.00	822.68	837.73	826.88	837.74	0.000015	1.07	2429.04	246.84	0.05
Survey Site	625.00*	2- year	252.00	822.68	826.78	824.85	826.79	0.000136	0.93	270.32	135.26	0.12
Survey Site	625.00*	10- year	555.00	822.68	829.94	825.38	829.95	0.000026	0.76	757.35	174.95	0.06
Survey Site	625.00*	25- year	758.00	822.68	831.96	825.62	831.96	0.000015	0.72	1124.91	198.95	0.05
Survey Site	625.00*	50- year	930.00	822.68	834.00	825.81	834.01	0.000009	0.65	1509.32	215.90	0.04
Survey Site	625.00*	100- year	1118.00	822.68	835.78	826.01	835.78	0.000007	0.64	1960.63	233.15	0.03
Survey Site	625.00*	8 cfs baseflow	8.00	822.68	823.11	823.11	823.24	0.020793	2.80	2.86	11.88	1.00
Survey Site	650	LL Outlet Capaci	45.00	822.77	824.00	823.77	824.08	0.003954	2.29	19.65	32.03	0.52
Survey Site	650	Principal Spillw	1700.00	822.77	836.78	826.38	836.79	0.000011	0.86	2162.74	231.10	0.04
Survey Site	650	Spillway Design	2300.00	822.77	837.73	826.82	837.75	0.000015	1.06	2385.98	237.04	0.05
Survey Site	650	2- year	252.00	822.77	826.78	824.77	826.80	0.000123	0.92	274.06	130.23	0.11
Survey Site	650	10- year	555.00	822.77	829.94	825.32	829.95	0.000026	0.75	764.27	178.37	0.06
Survey Site	650	25- year	758.00	822.77	831.96	825.56	831.97	0.000014	0.70	1142.68	198.86	0.05
Survey Site	650	50- year	930.00	822.77	834.00	825.75	834.01	0.000009	0.64	1557.95	207.29	0.04
Survey Site	650	100- year	1118.00	822.77	835.78	825.92	835.78	0.000007	0.63	1934.84	222.64	0.03

HEC-RAS Plan: Plan 50 River: River Alignment Reach: Survey Site (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Survey Site	650	8 cfs baseflow	8.00	822.77	823.40	823.25	823.44	0.004137	1.68	4.77	12.89	0.49
Survey Site	666.6	LL Outlet Capaci	45.00	822.54	823.92	823.92	824.30	0.014654	4.96	9.06	11.87	1.00
Survey Site	666.6	Principal Spillw	1700.00	822.54	836.78	827.03	836.79	0.000013	0.91	2050.71	232.12	0.05
Survey Site	666.6	Spillway Design	2300.00	822.54	837.73	827.48	837.75	0.000018	1.11	2277.20	241.11	0.06
Survey Site	666.6	2- year	252.00	822.54	826.78	825.18	826.80	0.000351	1.33	189.67	113.74	0.18
Survey Site	666.6	10- year	555.00	822.54	829.94	825.82	829.95	0.000043	0.87	648.47	159.73	0.07
Survey Site	666.6	25- year	758.00	822.54	831.96	826.13	831.97	0.000021	0.78	1005.83	194.40	0.06
Survey Site	666.6	50- year	930.00	822.54	834.00	826.32	834.01	0.000011	0.70	1429.01	215.56	0.04
Survey Site	666.6	100- year	1118.00	822.54	835.78	826.51	835.78	0.000008	0.67	1821.43	226.73	0.04
Survey Site	666.6	8 cfs baseflow	8.00	822.54	823.45	823.17	823.50	0.002663	1.72	4.66	8.48	0.41

5.4 Scour and Scour Counter Measure Computations

5.4.1 Proposed Culvert – 50-Year Storm

5.4.2 Proposed Culvert – 100-Year Storm

5.4.3 USDCM Chapter 9 (condensed)

5.4.4 USDCM Chapter 8 – Open Channels, Figure 8-34

Culvert 10x7, 50-year storm

(yellow)	Values entered into spreadsheet (user input)	
(green)	Values calculated by spreadsheet	
No fill	Standard values or coefficients, or preassigned or precalculated value	
(red)	Flagged values	

Culvert Parameters

Height	D (ft)	7	
Width	B (ft)	10.000	
Length	L (ft)	62	
Upstream invert	Inv u/s (ft)	821.85	
Downstream invert	Inv d/s (ft)	820.82	
Slope	So (ft)	0.0166	
Manning's roughness coefficient	n	0.029	
Hydraulic radius	Rc (ft)	2.059	
Gravity	g (ft/s^2)	32.2	

Particle Size Analysis from Lahlaf Geotechnical Consulting (11/19/19)

	Inlet #1 (mm)	Inlet #1 (in)	Outlet #2 (mm)	Outlet #2 (in)
D84	82.0399	3.23	19.2576	0.76
D16	0.8459	0.03	0.2066	0.01
D50	28.1176	1.11	1.7114	0.07

Peak Flow Characteristics (SSA output)

Peak Flow through culvert	Q (cfs)	930	max in culvert
Peak Elevation downstream of culvert	Peak Elev d/s (ft)	825.67	821.17
Tailwater	TW (ft)	0.35	
Downstream channel depth	y (ft)	4.85	
Downstream channel velocity	v (ft)	12.36	

Evaluation of Scour at Culvert Outlet

Scour Hole Geometry, Cohesionless Soils (HEC 14, Chapter 5)

Culvert outlet above channel bed	Perched (ft)	0			
Invert height above bed ratio	Hd	0.0	(Table 5.2)		Outlet σ
Material standard deviation	σ	9.85	(Section 5.1)	(2.1 for gravel, 1.87 for sand)	9.65
Time of scour	t (min)	30	(Section 5.1.2)		

Equation coefficients		α	β	θ	Ch	Cs			
Depth of scour	hs (ft)	2.27	0.39	0.06	1.00	1.03	7.0	(Eq. 5.1)	7.1
Width of scour	Ws (ft)	6.94	0.53	0.08	1.00	1.28	40.5	(Eq. 5.1)	40.8
Length of scour	Ls (ft)	17.10	0.47	0.10	1.00	1.17	71.4	(Eq. 5.1)	71.9
Volume of scour	Vs (cf)	127.08	1.24	0.18	1.00	1.30	26153	(Eq. 5.1)	26331

Location of maximum depth of scour	Lm (ft)	28.6	(Section 5.1.6, Step 7)	28.8

Depth and Velocity Calculations

Critical depth	yc (ft)	6.47	(Fig. B.1)
Critical velocity	vc (fps)	14.38	
	Frc	1.00	

Brink Depth (mild slope) - Unsubmerged outlet (Section 3.1.3)

Dimensionless rating curve	Q/(BD$^{3/2}$)	5.0	(Fig 3.3)		
	TW/D	0.05			
	yo/D	0.71	(Fig 3.3)		
Brink depth	yo (ft)	4.97			
Outlet velocity	vo (fps)	18.71			
	Since yc<yo, the flow is subcritical and exit depth is brink depth				No
Froude number	Fro	1.48		(Fr<1, subcritical)	No

Normal Depth (steep slope) - Unsubmerged outlet (Section 3.2.2)

Uniform flow in Trap Channel Mannings Calc	$Qn/((B^{8/3}S^{1/2}))$	0.451	(Table B.1 values already factor in 1.49 conversion factor)		
	y/B	0.692	(Table B.1) interpolation calc		
Normal depth	y (ft)	6.92			
Outlet velocity	vo (fps)	13.43			
	Since yc>y, the flow is supercritical and exit depth is normal depth				No
Froude number	Fro	0.90		(Fr>1, supercritical)	No

Energy Dissipator Design, Riprap Basin (HEC 14, Chapter 10)

Equivalent brink depth	ye (ft)	6.47	Assume critical flow at outlet		
Outlet velocity	vo (fps)	14.38			
Median rock size by weight	D50 (ft)	1.50			
	TW/ye	0.054	<=0.75, No additional riprap needed d/s		
Tailwater parameter	Co	1.4	(Eq. 10.2)		
	hs/ye	0.51	(Eq. 10.1)		
Dissipator pool depth	hs (ft)	3.33			
	hs/D50	2.22	>=2, OK (Section 10.1)		
	D50/ye	0.23	>=0.1, OK (Section 10.1.5)		
Length of energy dissipating pool	Ls (ft)	33.3	>=3B (Section 10.1)		
Overall length of basin	LB (ft)	49.9	>=4B (Section 10.1)		
Width of basin	WB (ft)	43.3	(Figure 10.2)		
	$Q^2/g=A_c^3/T_c$	26860	26860 Goal seek to determine yc	(Equation 7.14)	
Critical depth at basin exit	yc (ft)	2.41			
Basin side slope	z	0.5			
Water surface width at critical flow	Tc (ft)	45.7			Existing top width of 31.77
Flow area at critical flow	Ac (sf)	107.06	(Equation 7.14)	107.06 Check	
Critical velocity at basin exit	Vc (fps)	8.69			
Riprap downstream of energy dissipator	D50 (ft)	0.49	Round to 0.5		
Riprap specific gravity	S	2.65			

Culvert 10x7, 100-year storm

(orange)	Values entered into spreadsheet (user input)
(green)	Values calculated by spreadsheet
No fill	Standard values or coefficients, or preassigned or precalculated value
(red)	Flagged values

Culvert Parameters

Height	D (ft)	7	
Width	B (ft)	10.000	
Length	L (ft)	62	
Upstream invert	Inv u/s (ft)	821.85	
Downstream invert	Inv d/s (ft)	820.82	
Slope	So (ft)	0.0166	
Manning's roughness coefficient	n	0.029	
Hydraulic radius	Rc (ft)	2.059	
Gravity	g (ft/s^2)	32.2	

Particle Size Analysis from Lahlaf Geotechnical Consulting (11/19/19)

	Inlet #1 (mm)	Inlet #1 (in)	Outlet #2 (mm)	Outlet #2 (in)
D84	82.0399	3.23	19.2576	0.76
D16	0.8459	0.03	0.2066	0.01
D50	28.1176	1.11	1.7114	0.07

Peak Flow Characteristics (SSA output)

Peak Flow through culvert	Q (cfs)	1118	max in culvert
Peak Elevation downstream of culvert	Peak Elev d/s (ft)	826.31	821.17
Tailwater	TW (ft)	0.35	
Downstream channel depth	y (ft)	5.49	
Downstream channel velocity	v (ft)	13.07	

Evaluation of Scour at Culvert Outlet

Scour Hole Geometry, Cohesionless Soils (HEC 14, Chapter 5)

Culvert outlet above channel bed	Perched (ft)	0	
Invert height above bed ratio	Hd	0.0	(Table 5.2)
Material standard deviation	σ	9.85	(Section 5.1) (2.1 for gravel, 1.87 for sand)
Time of scour	t (min)	30	(Section 5.1.2)

Equation coefficients		α	β	θ	Ch	Cs			
Depth of scour	hs (ft)	2.27	0.39	0.06	1.00	1.03	7.6	(Eq. 5.1)
Width of scour	Ws (ft)	6.94	0.53	0.08	1.00	1.28	44.6	(Eq. 5.1)
Length of scour	Ls (ft)	17.10	0.47	0.10	1.00	1.17	77.9	(Eq. 5.1)
Volume of scour	Vs (cf)	127.08	1.24	0.18	1.00	1.30	32861	(Eq. 5.1)

Location of maximum depth of scour	Lm (ft)	31.1	(Section 5.1.6, Step 7)

Depth and Velocity Calculations

Critical depth	yc (ft)	7.31	(Fig. B.1)
Critical velocity	vc (fps)	15.29	
	Frc	1.00	

Brink Depth (mild slope) - Unsubmerged outlet (Section 3.1.3)

Dimensionless rating curve	Q/($BD^{3/2}$)	6.0	(Fig 3.3)
	TW/D	0.05	
	yo/D	0.80	(Fig 3.3)
Brink depth	yo (ft)	5.60	
Outlet velocity	vo (fps)	19.96	

Since yc<yo, the flow is subcritical and exit depth is brink depth — No

Froude number	Fro	1.49	(Fr<1, subcritical)	No

Normal Depth (steep slope) - Unsubmerged outlet (Section 3.2.2)

Uniform flow in Trap Channel Mannings Calc	$Qn/((B^{8/3}S^{1/2}))$	0.542	(Table B.1 values already factor in 1.49 conversion factor)		
	y/B	0.800	(Table B.1) interpolation calc		
Normal depth	y (ft)	8.00			
Outlet velocity	vo (fps)	13.98			
	Since yc>y, the flow is supercritical and exit depth is normal depth				No
Froude number	Fro	0.87		(Fr>1, supercritical)	No

Energy Dissipator Design, Riprap Basin (HEC 14, Chapter 10)

Equivalent brink depth	ye (ft)	7.31	Assume critical flow at outlet		
Outlet velocity	vo (fps)	15.29			
Median rock size by weight	D50 (ft)	1.50			
	TW/ye	0.048	<=0.75, No additional riprap needed d/s		
Tailwater parameter	Co	1.4	(Eq. 10.2)		
	hs/ye	0.65	(Eq. 10.1)		
Dissipator pool depth	hs (ft)	4.74			
	hs/D50	3.16	>=2, OK (Section 10.1)		
	D50/ye	0.21	>=0.1, OK (Section 10.1.5)		
Length of energy dissipating pool	Ls (ft)	47.4	>=3B (Section 10.1)		
Overall length of basin	LB (ft)	71.1	>=4B (Section 10.1)		
Width of basin	WB (ft)	57.4	(Figure 10.2)		
	$Q^2/g=A_c^3/T_c$	38818	38818 Goal seek to determine yc	(Equation 7.14)	
Critical depth at basin exit	yc (ft)	2.26			
Basin side slope	z	0.5			
Water surface width at critical flow	Tc (ft)	59.7			Existing top width of 31.77
Flow area at critical flow	Ac (sf)	132.31	(Equation 7.14)	132.31 Check	
Critical velocity at basin exit	Vc (fps)	8.45			
Riprap downstream of energy dissipator	D50 (ft)	0.47	Round to 0.5		
Riprap specific gravity	S	2.65			

Chapter 9
Hydraulic Structures

Contents

Tables

Figures

Appendix A

1.0 Structures in Streams

Hydraulic structures are used to guide and control water flow in streams. Structures described in this chapter consist of grade control structures and outfall structures for various applications and conditions.

Photograph 9-1. This grouted boulder drop structure exemplifies the opportunity available for creating an attractive urban hydraulic setting for a riparian corridor.

The discussion of grade control structures in this chapter addresses the hydraulic design and grouted boulder, sculpted concrete, and vertical drop structures, whereas the *Open Channels* chapter discusses the placement of grade control structures in the stream and the *Stream Access and Recreational Channels* chapter covers safety considerations relevant to all urban streams and specialized design of boatable hydraulic structures.

The outfalls section provides design guidance for various types of pipe end treatment and rock protection to dissipate hydraulic energy at outfalls of storm drains and culverts. Related design information is covered in the *Streets, Inlets, and Storm Drains* and *Culverts and Bridges* Chapters.

Considered environmental, ecological, and public safety objectives in the design of each structure. The proper application of hydraulic structures can reduce initial and future maintenance costs by managing the character of the flow to best meet all project needs.

The shape, size, and features of hydraulic structures vary widely for different projects, depending upon the design discharge and functional needs of the structure. Hydraulic design procedures discussed herein govern design of all structures. For the design of unique structures that may not fit the guidance provided, hydraulic physical modeling or computational fluid dynamics (CFD) modeling may be beneficial.

Guidance for Using this Chapter

- Determine if the project can be designed using the simplified method (Section 2.2) or if a detailed design is required (Section 2.3).
- Perform soils and seepage analyses as necessary for the design of the foundation and seepage control system (Section 2.4). Additional analysis of forces acting on a structure may be necessary and should be evaluated on a case-by-case basis (Section 2.5).
- Use criteria specific to the type of drop structure to determine the final flow characteristics, dimensions, material requirements, and construction methods. Refer to Section 2.6 for Grouted Stepped Boulder (GSB) drop structures or to Section 2.7 for Sculpted Concrete (SC) drops.
- Refer to the *Trails and Recreations Channels* chapter for design of boatable structures and other criteria required for public safety.

2.0 Grade Control Structures

2.1 Overview

Photograph 9-2. Grouted stepped boulder drop structures such as this one in Denver's Bible Park can be safe, aesthetically pleasing, and provide improved aquatic habitat besides performing their primary hydraulic function of energy dissipation.

As discussed in the *Open Channels* Chapter, urbanization increases the rate, frequency and volume of runoff in natural streams and, over time, this change in hydrology may cause streambed degradation, otherwise known as down cutting or head cutting. Stabilization improvements to the stream are necessary prior to or concurrent with development in the watershed. Stream stabilization is the third step of the *Four Step Process to Stormwater Management* (see Chapter 1 of Volume 3 of this manual).

"Drop structures" are broadly defined. Drop structures provide protection for high velocity hydraulic conditions that allow a drop in channel grade over a relatively short distance. They provide controlled and stable locations for a hydraulic jump to occur, allowing for a more stable channel downstream where flow returns to subcritical. This chapter provided specific design guidance for the following basic categories of drop structures:

- Grouted stepped boulder (GSB) drop structures
- Sculpted concrete (SC drop structures
- Vertical drop structures

The design of the drop structure crest and the provision for the low flow channel directly affect the ultimate configuration of the upstream reach. A higher unit flow will pass through the low flow area than will pass through other portions of the stream cross section. Consider the situation in design to avoid destabilization of the drop structure and the stream. It is also important to consider the major flood, the path of which frequently extends around structure abutments.

Design grade control structures for fully developed future basin conditions, in accordance with zoning maps, master plans, and other relevant documents. The effects of future hydrology and potential down cutting will negatively impact the channel.

There are two fundamental systems of a drop structure that require design consideration: the hydraulic surface-drop system and the foundation and seepage control system. The surface drop system is based on project objectives, stream stability, approach hydraulics, downstream tailwater conditions, height of the drop, public safety, aesthetics, and maintenance considerations. The material components for the foundation and seepage control system are a function of soil and groundwater conditions. One factor that influences both systems is the potential extent of future downstream channel degradation. Such degradation could cause the drop structure to fail.

See the *Stream Access and Recreational Channels* chapter for special design issues associated with drop structures in boatable channels.

Drops in series require full energy dissipation and return to normal depth between structures or require specialized design beyond the scope of this manual.

Evaluate drop structures during and after construction. Secondary erosion tendencies will necessitate additional bank and bottom protection. It is advisable to establish construction contracts and budgets with this in mind.

The sections that follow provide guidance on drop structure design using either a simplified design method or a more detailed hydraulic design method. The designer must evaluate each method and determine which is appropriate for the specific project.

Key Considerations during Planning and Early Design of a Drop Structure

- Identify the appropriate range of drop height based on the stable channel slope (as provided in the master plan or based on guidance provided in the *Open Channels* chapter). Limit the net drop height to five feet or less to avoid excessive kinetic energy and avoid the appearance of a massive structure. Vertical drops should not exceed 3 feet at any location to minimize the risk of injury from falling. With a 12-inch stilling basin, this limits the net drop height to two feet.
- Design with public safety in mind. Structures located in streams where boating, including tubing, is anticipated require additional considerations. See the *Stream Access and Recreational Channels* chapter.
- Begin the process of obtaining necessary environmental permits, such as a Section 404 permit, early in the project.
- Evaluate fish passage requirements when applicable. This may also be a requirement of environmental permits.

2.2 Simplified Design Procedures for Drop Structures

2.2.1 Introduction

The simplified design procedure can be used for grade control structures meeting design criteria provided in Table 9-1 and where all of the following criteria are met:

- Maximum unit discharge for the design event (typically the 100-year) over any portion of the drop structure is 35 cfs/ft or less,
- Net drop height (upstream channel invert less downstream channel invert exclusive of stilling basin depth) is 5 feet or less,
- Drop structure is constructed of GSB or SC,
- Drop structure is located within a tangent section and at least twice the distance of the width of the drop at the crest both upstream and downstream from a point of curvature,
- Drop structure is located in a reach that has been evaluated per the design requirements of the *Open Channel* chapter.

The simplified design procedures provided herein do not consider channel curvature, effects of other hydraulic structures, or unstable beds. If any of these conditions exist or the criteria above are not met, a detailed analysis is required per Section 2.3. Even if the criteria are met and the simplified design procedures are applied, checking the actual hydraulics of the structure using the detailed comprehensive hydraulic analysis may yield useful design insight.

There is a basic arrangement of upstream channel geometry, crest shape, basin length, and downstream channel configuration that will result in optimal energy dissipation. The following sections present simplified relationships that provide basic configuration and drop sizing parameters that may be used when the above criteria are met.

2.2.2 Geometry

Table 9-1 below summarizes the specific design and geometric parameters applicable to drop structures designed using the simplified design procedures. Additional discussion is provided in the sections following for some of the specific parameters summarized in the table. Graphical depiction of the geometric parameters listed in Table 9-1 can be found in Figure 9-11 through 9-14 for GSB drop structures and Figures 9-16 through 9-21 for SC drop structures.

Table 9-1. Design criteria for drop structures using simplified design procedures

Design Parameter	Requirement to Use Simplified Design Procedures	
	GSB Drop Structure	SC Drop Structure
Maximum Net Drop Height (H_d)	5 feet[1]	
Maximum Unit Discharge over any Portion of Drop Width	35 cfs per foot of drop width (see Section 2.2.3)	
Maximum Longitudinal Slope (Steepest Face Slope)	4(H):1(V) (see Section 2.2.4 for additional discussion)	
Minimum Stilling Basin Depression (D_b)	1 foot (see Section 2.2.6 for additional discussion and requirements for non-cohesive soils)	2 feet (see Section 2.2.6 for additional discussion and requirements for non-cohesive soils)
Minimum Length of Approach Riprap (L_a):	8 feet	
Minimum Stilling Basin Length (L_b):	Determine using Figure 9-1 (see Section 2.2.4)	
Minimum Stilling Basin Width (B)	same as crest width	
Minimum Cutoff Wall Depth	6 feet (for cohesive soils only, see Section 2.2.6 for additional discussion)	
Minimum Length of Riprap Downstream of Stilling Basin	10 feet	
Minimum D_{50} for Approach and Downstream Riprap	12 inches	
Minimum Boulder Size for Drop Structure	Per Figure 9-1	N/A

[1]This is considered a large drop structure and is only appropriate where site specifics do not accommodate installation of smaller drop structures. Urban Drainage and Flood Control District (UDFCD) recommends the height of the drop structure not exceed 3 feet.

2.2.3 Unit Discharge

The unit discharge is an important design parameter for evaluating the hydraulic performance of a drop structure. In order to use the simplified design procedures, the design event maximum unit discharge over any portion of the drop structure width is 35 cfs/ft. This value is derived from recommended values for velocity and depth listed in the *Open Channels* chapter. Typically, this maximum unit discharge will occur in the low-flow channel, but in rare circumstances may be in the overbanks. Determine the design unit discharge at the crest of the drop structure and at a channel cross section 20 to 50 feet upstream of the crest. Depending on the depth of the low-flow channel at these two locations, the unit discharge could differ at the sections. Normally, the maximum unit discharge of the cross sections and exercise judgement regarding the appropriate unit discharge used for the drop structure design. Further discussion on the hydraulic evaluation of a channel cross section is in Section 2.3.6.

2.2.4 Longitudinal Slope of the Drop Structure Face

The longitudinal slope of the structure face should be no steeper than 4(H):1(V), while even flatter slopes will improve safety. Flatter longitudinal face slopes (i.e., flatter than 8(H):1(V), help to mitigate overly retentive hydraulics at higher tailwater depths that can cause submerged hydraulic jump formation and create reverse rollers with "keeper" waves which are a frequent cause of drowning deaths in rivers. Where possible roughen the face of the drop by developing a series of slopes rather than a smooth surface. Individual steps and differences in vertical elevation should be no greater than 3 feet in any location to limit consequence associated with slip and fall during dry conditions. The *Stream Access and Recreational Channels* chapter provides additional longitudinal slope considerations for water-based recreation and in-channel safety as well as other avoidance techniques for overly-retentive drop structures.

Overly Retentive Hydraulics

Drop faces should have a longitudinal slope no steeper than 4(H):1(V). The formation of overly retentive hydraulics is a major drowning safety concern when constructing drop structures. Longitudinal slope, roughness and drop structure shape all impact the potential for dangerous conditions. See the *Stream Access and Recreational Channels* chapter for additional criteria.

2.2.5 Stilling Basin

Typically, drop structures include a hydraulic jump dissipater basin. The stilling basin should be depressed in order to start the jump near the toe of the drop face, per the requirements in Table 9-1. A sill should be located at the basin end to create a transition to the downstream invert elevation. The profiles for GSB (Figure 9-12) and SC (Figure 9-17) drop structures include options for both non-draining and draining stilling basins. Where it is undesirable to have standing water, provide an opening in the end sill.

When using the simplified design, the length of the stilling basin (L_b) can be determined using Figure 9-1. Figure 9-1 provides the required stilling basin length for both GSB and SC drop structures up to a unit discharge of 35 cfs/ft. If the proposed drop structure does not fit within the requirements of the simplified design, complete a detailed hydraulic analysis as described in Section 2.3.

In non-cohesive soil channels and channels where future degradation is expected, especially where there is no drop structure immediately downstream, it is generally recommended that the stilling basin be eliminated and the sloping face extended five feet below the downstream future channel invert elevation (after accounting for future streambed degradation). A scour hole will form naturally downstream of a structure in non-cohesive soils and construction of a hard basin is an unnecessary cost. Additionally, a hard basin would be at risk for undermining. See Figure 9-12 for the profile of the GSB and Figure 9-17 for that of an SC in this configuration. In some cases, the structure may have a net drop height of zero immediately after construction, but is designed with a long-term net height of 3 to 5 feet to accommodate future lowering of the channel invert.

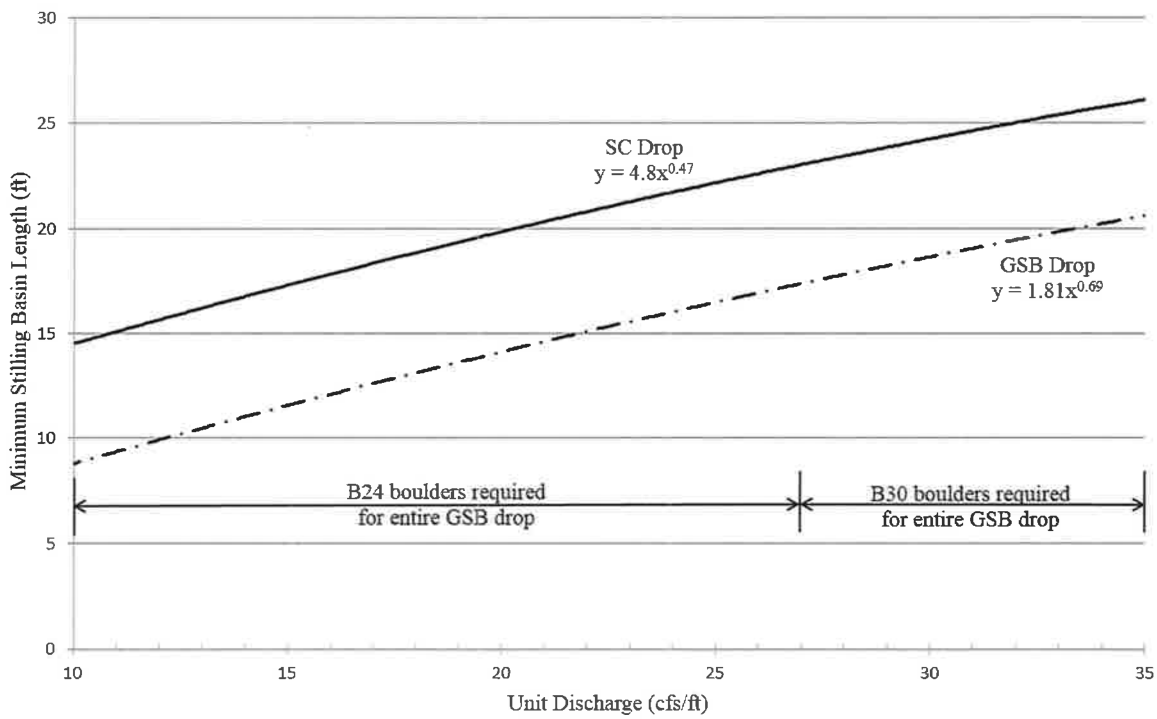


Figure 9-1. Stilling basin length based on unit discharge (for simplified design procedure)

2.2.6 Seepage Analysis and Cutoff Wall Design

The simplified drop structure design only applies to drops with cutoffs located in cohesive soils. Therefore, it is necessary to determine surface and subsurface soil conditions in the vicinity of a proposed drop structure prior to being able to use the simplified approach for cutoff design. For a drop structure constructed in cohesive soils meeting all requirements of a simplified design, the cutoff wall must be a minimum of six feet deep for concrete and ten feet deep for sheet pile.

If a proposed drop structure meets the requirements of the simplified approach, but is located in non-cohesive soils, guidance on determining the required cutoff wall depth is described in Section 2.4.

Photograph 9-4. View of the sheet pile cutoff wall and steel reinforcement for a sculpted concrete drop structure prior to the concrete placement. Note the steel reinforcement has been spot welded to the sheet pile.

The vertical seepage cutoff wall should be located upstream of the crest and can be constructed of either concrete or sheet pile. One of the most important details for grade control structures involves the interface between the seepage cutoff wall and the remainder of the structure. Regardless, of the material used for the cutoff wall, the structure should completely bury the interface between the wall and structure. This eliminates the unattractive view of the cutoff wall within the drop structure and provides a more effective seal at the interface. To ensure a good seal, specify that the contractor must fully clean the surface of the cutoff wall prior to the construction of the interface. Figures 9-7 through 9-9 provide multiple options (for both GSB and SC drop structures) for connecting the verticle cutoff wall to the drop structure. Additionally, the cutoff wall should extend beyond the low-flow channel and five to ten feet into the bank on each side of the structure as shown in Figure 9-27.

Take special care when designing cutoff walls for drops in series. This typically requires a deeper wall or a wall at each crest.

2.2.7 Low-flow Channel

The crest of the drop structure is frequently shaped similarly to, although sometimes slightly shallower than, the upstream low-flow channel. It is also typical that the shape transition along the face of the structure in an effort to disperse the flow and dissipate energy over the width of the drop structure. This geometry is recommended unless the stream is boatable. The low-flow channel can then be re-established beyond the end sill of the drop structure. In some circumstances protection in the low-flow channel may need to extend further downstream than protection in the main channel. This should be evaluated on a case-by-case basis. When the stream is boatable, it is typically preferred that flows remain concentrated through the drop.

2.3 Detailed Drop Structure Hydraulic Analysis

2.3.1 Introduction

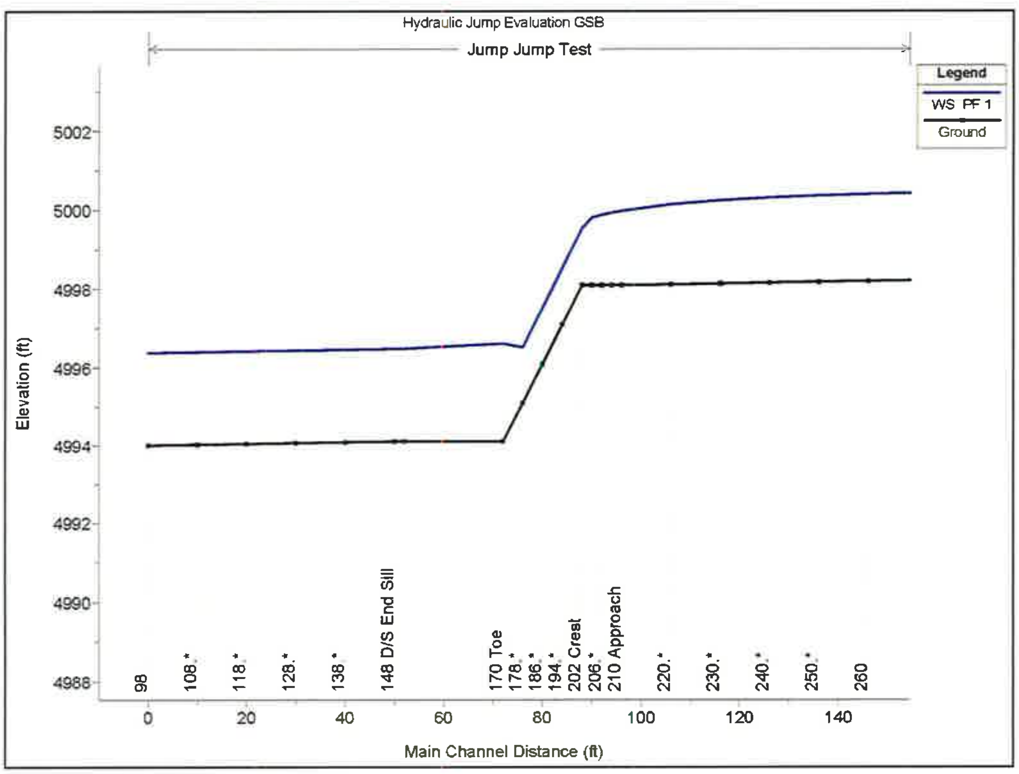
When the parameters of a proposed drop structure do not fit within the criteria of a simplified design (see Section 2.2), or when a designer desires a more thorough analysis of drop structure hydraulics, a detailed hydraulic analysis is conducted. The guidelines presented in this section assume that the designer is using HEC-RAS to assist with the detailed computations necessary for drop structure analysis. It is important to be familiar with the HEC_RAS variables selected for the computations and the effect these variables have on the results of the analysis. The analysis guidelines discussed in this section are intended to assist the engineer in addressing critical hydraulic design factors.

2.3.2 Cross Section Placement

Appropriate placement of cross sections is important when completing a hydraulic analysis of a drop structure using HEC_RAS. Place cross-sections at the following locations:

- Upstream of Drop (50 feet +/-) where channel is at normal depth
- Drop Approach (5 feet +/- upstream of drop crest)
- Drop Crest
- Toe of Drop
- Upstream and at Drop End Sill
- Downstream of Drop (50 feet +/-) where channel has recovered to normal depth

In addition to the locations above, use the "cross section interpolation" option in HEC_RAS. At a minimum, add interpolated cross sections (denoted with * in Figure 9-2) along the drop face. Interpolated cross sections upstream of the drop crest and downstream of the end sill may also be beneficial. Figure 9-2 provides a sample channel profile from HEC_RAS with cross section locations for reference.



*Denotes Interpolated Cross Section

Figure 9-2. Sample HEC_RAS profile with cross section locations for hydraulic analysis

2.3.3 Mannings's Roughness Coefficient for Drop Structures

Depending on the type of materials and the relative depth, select the appropriate roughness parameters for the HEC-RAS model. Table 9-2 provides roughness parameter recommendations and references for both sculpted concrete and grouted boulder drop structure.

Table 9-2. Approximate Manning's roughness at design discharge for stepped drop structure

Stepped sculpted concrete where step heights equal 25% of drop	0.025[1]
Grouted Boulders	See Figure 9-3

[1] This assumes an approach channel depth of at least 5 feet. Values would be higher at lesser flow depths.

The equations typically used for riprap and provided in the *Open Channels* chapter do not apply to boulders and grouted boulders because of their near uniform size and because the voids may be completely or partially filled with grout. Therefore, the Manning's roughness values for grouted boulders are based on (Chow 1959; Oliver 1967; Anderson et. Al 1973; Henderson 1966; Barnes 1967; Smith and Murray 1975; Stevens et. Al. 1976; Bathurst, Li and Simons 1979; and Stevens 1984). The roughness coefficient varies with the depth of flow relative to the size of the boulders and the depth of grout used to lock them in place.

The following equations may be used to find the recommended Manning's n as a function of flow depth over height of the boulders, y/D, as represented by the curves in Figure 9-3:

When the upper one-half (plus or minus 1inch) of the rock height is ungrouted, the equation for n is:

$$n_{24"-42"(1/2)} = \frac{0.097\left(y/D\right)^{0.16}}{\ln\left(2.55y/D\right)}$$ Equation 9-1

When the upper one-third (plus or minus 1 inch) of the rock height is ungrouted, the equation for n is:

$$n_{24"-42"(2/3)} = \frac{0.086\left(y/D\right)^{0.16}}{\ln\left(2.55y/D\right)}$$ Equation 9-2

Where:

y = depth of flow above top of rock (feet)

D = diameter of the boulder (feet)

The upper limit for Equation 9-1 is $n \le 0.104$ and for Equation 9-2 is $n \le 0.092$. Determine the value for "y" by reviewing the HEC_RAS cross sections and determining an appropriate representation of the average flow depth over the structure. If the value for y/D is < 1, use 1.

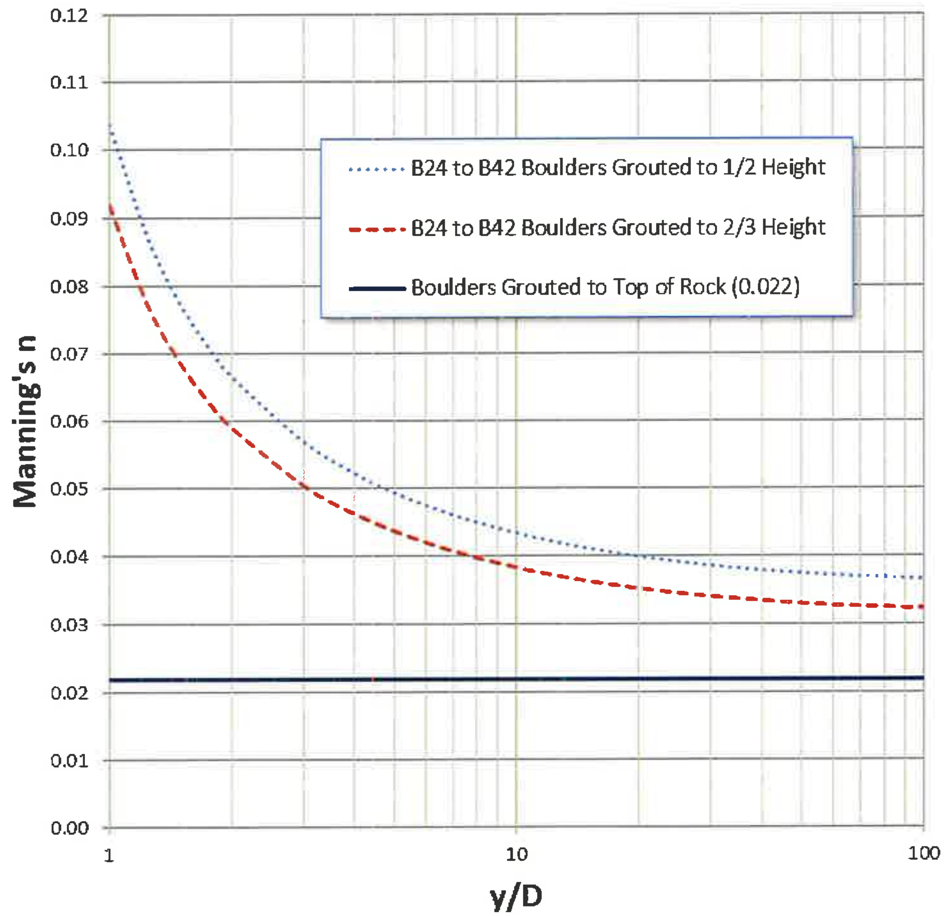


Figure 9-3. Recommended Manning's n for flow over B24 to B42 grouted boulders

Using a stepped grouted rock placement and grouting only the lower ½ of the rock on the drop face creates a significantly higher Manning's n roughness coefficient and, as a result, greater flow depth and lower velocity, reducing the boulder size needed to have a stable structure. Refer to Section 2.6.3 for discussion on boulder sizing for GSB drop structures.

2.3.4 Hydraulic Jump Formation

Once the location and geometry of the drop structure cross sections have been determined, evaluate the HEC-RAS model for the design flow under both subcritical and supercritical flow conditions. To minimize the stilling basin length, use a downstream tailwater depth great enough to force a hydraulic jump to start near the toe of the drop face. This requires that the specific force of the downstream tailwater be greater than the specific force of the supercritical flow at the toe of the drop. The tailwater is modeled by a subcritical water surface (M1 backwater or M2 drawdown curve) profile analysis that starts from a downstream control point and works upstream to the drop structure basin. Model the depth and specific force at the toe of the drop by a supercritical water surface (S2 drawdown curve) profile analysis starting at the crest of the drop and running down the drop face.

Using the output from the subcritical and supercritical HEC-RAS hydraulic models, calculations should be completed to verify that the specific force associated with the downstream tailwater is greater than the specific force of the supercritical flow at the toe of the drop, not only for the design discharge, but for flows corresponding to more frequent events. Specific force can be calculated using equation 9-3 (Chow 1959):

$$F = \frac{Q^2}{gA} + \bar{z}A \qquad \text{Equation 9-3}$$

Where:

F = specific force

Q = flow at cross section

g = acceleration of gravity

$\bar{z}$ = distance from the water surface elevation to the centroid of the flow area (A)

A = area of flow

The required tailwater depth is determined using Equation 9-4 (Chow 1959). This equation applies to rectangular channel sections and should be applied to a rectangular portion of flow within a drop structure. For irregular (non-rectangular) channel shapes, the designer should apply Equation 9-4 using the unit discharge within a rectangular segment of the drop crest. Assuming the low-flow channel is incorporated into the drop crest and this portion of the crest has the largest unit discharge, the rectangular portion would extend over the bottom width of the low-flow channel. See Section 2.3.6 for additional discussion on evaluating the conditions in both the low-flow channel and the overbanks.

$$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1+8F_1^2} - 1\right) \qquad \text{Equation 9-4}$$

Where:

y_2 = required depth of tailwater (also called the sequent depth, in feet)

y_1 = depth of water at drop toe, feet (taken from cross section at drop toe, supercritical HEC-RAS model)

F_1 = Froude Number = $V_1/(gy_1)^{1/2}$ (based on depth and velocity at drop toe)

Calculate the required tailwater depth (y_2) using Equation 9-4. Compare the results of this calculation to the modeled tailwater depth determined in the subcritical HEC-RAS model at the upstream side of the end sill (channel depth plus Db). The modeled tailwater depth must be greater than or equal to the calculated required headwater depth for a hydraulic jump to start near the toe of the drop. If the modeled tailwater depth is less than required, the drop structure geometry must be re-evaluated. One option is to increase the depth of the stilling basin, thereby increasing the effective tailwater depth and specific force, and another is to widen the crest of the drop or reduce the depth of the low-flow channel to produce a smaller unit discharge.

2.3.5 Hydraulic Jump Length

After the hydraulic jump has been analyzed using the guidelines provided in Section 2.3.4, the jump length must be calculated. This will aid the designer in determining the appropriate stilling basin length and the need for additional rock lining downstream of the end sill. The following values are required to determine the hydraulic jump length:

y_2 = required depth of tailwater (feet)

F_1 = Froude Number = $V_1/(gy_1)^{1/2}$ (based on depth and velocity at drop toe)

Use the above values to determine the length of the hydraulic jump (L) in Figure 9-4. Note that this figure is for horizontal channels, which is appropriate for most applications in the UDFCD region. Curves for sloping channels (from 5 to 25%) are in Chow, 1959.

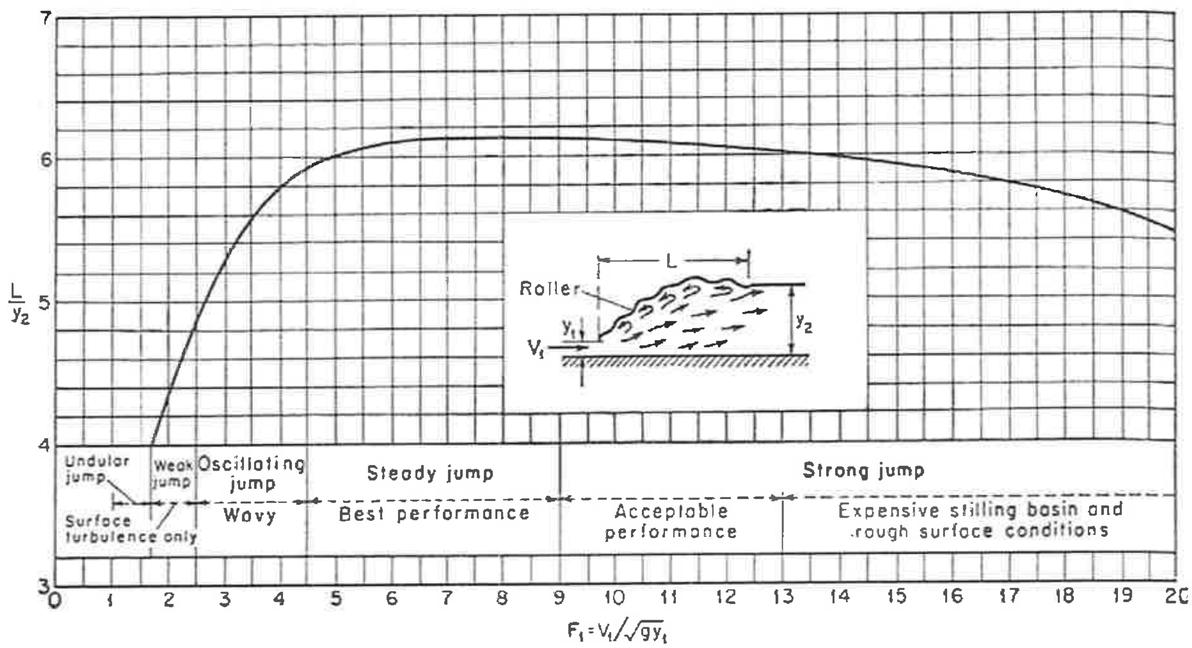


Figure 9-4. Length in terms of sequent depth of jumps in horizontal channels
(Source: US Bureau of Reclamation, 1955)

UDFCD recommends a hard-lined stilling basin (sculpted concrete, grouted boulders, or concrete grout) that is at least 60% of the hydraulic jump length (L). Extend riprap downstream of the sill and provide protection for at least the balance of the full hydraulic jump length (see Figure 9-5). Determine riprap size using the equations provided in the *Open Channels* chapter for channel lining.

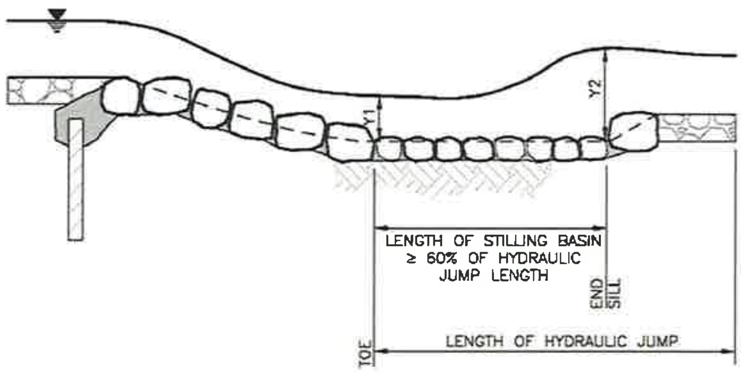


Figure 9-5. Stilling basin profile

2.3.6 Evaluation of Low-flow Channel versus Overbanks

Review the HEC-RAS model to evaluate the hydraulic conditions in both the low-flow channel and the overbanks at the crest and 20 to 50 feet upstream of the crest and determine the maximum representative unit discharge (See Section 2.2.3). Check the shear velocity in the overbanks of low-flow drops to determine if protection in this area is appropriate.

Use the "worst case" hydraulic scenario to design the entire drop structure. In most conditions, the low-flow channel will see the greater unit discharge and velocity and therefore represent the "worst case." HEC-RAS provides output tables to assess the conditions in both the low-flow and overbanks (see Figure 9-6).

Certain site conditions may warrant a separate evaluation for the low-flow channel and overbanks. In some cases, the designer may elect to extend the stilling basin longer in the low-flow channel area than the overbanks; however, in such cases the transition in basin length should be gradual rather than abrupt.

Plan: extrasec Jump Jump Test RS: 202 Profile: PF 1

E.G. Elev (ft)	5001.06	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.65	Wt. n-Val.	0.05	0.05	0.05
W.S. Elev (ft)	5000.41	Reach Len. (ft)	4	4	4
Crit W.S. (ft)	5000.41	Flow Area (sq ft)	69.05	23.09	69.05
E.G. Slope (ft/ft)	0.027778	Area (sq ft)	69.05	23.09	69.05
Q Total (cfs)	1000	Flow (cfs)	400.13	199.74	400.13
Top Width (ft)	118.47	Top Width (ft)	54.23	10	54.23
Vel Total (ft/s)	6.2	Avg. Vel. (ft/s)	5.8	8.65	5.8
Max Chl Dpth (ft)	2.31	Hydr. Depth (ft)	1.27	2.31	1.27
Conv. Total (cfs)	6000	Conv. (cfs)	2400.8	1198.4	2400.8
Length Wtd. (ft)	4	Wetted Per. (ft)	54.56	10	54.56
Min Ch El (ft)	4998.1	Shear (lb/sq ft)	2.19	4	2.19
Alpha	1.09	Stream Power (lb/ft s)	12.72	34.64	12.72
Frctn Loss (ft)	0.1	Cum Volume (acre-ft)	0.03	0.46	0.03
C & E Loss (ft)	0	Cum SA (acres)	0.03	0.2	0.03

Figure 9-6. Sample HEC-RAS output for cross section located at drop crest

2.3.7 Evaluate Additional Return Period Flow Rates

Evaluate the design flow and then assess additional return-period flow rates, as appropriate. For all flows, the actual downstream tailwater should be greater than the tailwater required to force a hydraulic jump to start near the toe of the drop structure face. When this condition is met for a range of events a stilling basin length of 60% of the hydraulic jump length should be adequate.

2.3.8 Rock Sizing for Drop Approach and Downstream of End Sill

Calculate the appropriate rock size for the drop approach and downstream of the end sill. The hydraulic conditions at the approach include the acceleration effects of the upstream drawdown as the water approaches the drop crest. Turbulence generated from the hydraulic jump will impact the area downstream of the end sill. Determine riprap size using the equations provided in the *Open Channels* chapter for channel lining. Because normal depth conditions do not exist upstream and downstream of the drop structure, refer to the HEC-RAS output and use the energy grade line slope (rather than channel slope) to determine the appropriate riprap size.

Riprap at the approach and downstream of the end sill should be a minimum D_{50} of 12-inches, or larger as determined using the channel lining equation in the *Open Channels* chapter. Use either void-filled or soil-filled riprap in these areas.

2.4 Seepage Control

2.4.1 Introduction

Subgrade erosion caused by seepage and structure failures caused by high seepage pressures or inadequate mass are two failure modes of critical concern.

Seepage analyses can range from hand-drawn flow nets to computerized groundwater flow modeling. Use advanced geotechnical field and laboratory testing techniques confirm permeability values where complicated seepage problems are anticipated. Several flow net analysis programs are currently available that are suitable for this purpose. Full description of flow net analysis is beyond the scope of the Urban Storm Drainage Criteria Manual (USDCM). Referred to Cedergren 1967; USBR 1987; and Taylor 1967 for more information and instruction in the use of flow net analysis techniques. See Section 2.4.3 for Lane's Weighted Creep method, a simplified approach.

2.4.2 Weep Drains

Install weep drains in all grade control structures greater than 5 feet in net height or as recommended by the geotechnical engineer. Weep drains assist in reducing the uplift pressure on a structure by providing a location for groundwater to escape safely through a filter. For concept, see Figure 9-10. Weep drains should be placed outside of the low-flow path of the structure and spaced to provide adequate relief of subsurface pressures.

2.4.3 Lane's Weighted Creep Method

As a minimum level of analysis and as a first order of estimation, Lane's Weighted Creep (Lane's) Method can be used to identify probable seepage problems, evaluate the need for control measures, and estimate rough uplift forces. It is not as definitive as the flow net analyses mentioned above. Lane's method was proposed by E.W. Lane in 1935. This method was removed from the 1987 revision of *Design of Small Dams* (USBR 1987), possibly indicating greater use of flow net and computer modeling

APPENDIX B

Inspection Checklist

DAM SAFETY INSPECTION CHECKLIST INSTRUCTION PAGE

The checklist includes sections applicable to a variety of dam structure types. Complete those pages pertaining to each structure and omit pages that are not relevant. Checklist should be signed by the inspecting engineer and a clean, neat copy included in the final inspection report.

E1: DESIGN METHODOLOGY
1. Unknown Design – no design records available
3. Some standard design features
5. State of the art design – design records available

E2: LEVEL OF MAINTENANCE
1. No evidence of maintenance, no O&M manual
2. Very little maintenance, no O&M manual
3. Some level of maintenance and standard procedures
4. Adequate level of maintenance and standard procedures
5. 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

E4: EMBANKMENT SEEPAGE
1. Severe piping and/or seepage with no monitoring
2. Evidence of monitored piping and seepage
3. No piping but uncontrolled seepage
4. Controlled seepage
5. No seepage or piping

E5: EMBANKMENT CONDITION
1. Severe erosion and/or large trees
2. Significant erosion or significant woody vegetation along lower
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
1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns
2. Cracks with misalignment inclusive of transverse cracks with no misalignment
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
2. Outlet with insufficient drawdown capacity
3. Inoperable gate with potentially sufficient capacity
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 - 20% of the SDF
2. 21- 40% of the SDF
3. 41- 60% of the SDF
4. 61- 80% of the SDF
5. 81- 100% of the SDF

E10: OVERALL PHYSICAL CONDITION OF THE 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 for 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

See Appendix D for a complete listing of dam orientation and terminology definitions.

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.

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.

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

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

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

Appurtenant Works – Shall mean structures, either in dams or separate therefrom. including but not be limited to, spillways; reservoirs and their rims; low level outlet works; and water conduits including tunnels, pipelines, or penstocks, either through the dams or their abutments.

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

DAM SAFETY INSPECTION CHECKLIST

NAME OF DAM:	Lake Wyola	STATE ID #:	2-6-272-2
REGISTERED:	☑ YES ☐ NO	NID ID #:	MA00510
STATE SIZE CLASSIFICATION:	Large	STATE HAZARD CLASSIFICATION:	High
		CHANGE IN HAZARD CLASSIFICATION REQUESTED?:	No

DAM LOCATION INFORMATION

CITY/TOWN:	Shutesbury	COUNTY:	Franklin
DAM LOCATION: (street address if known)	Locks Pond Road	ALTERNATE DAM NAME:	
USGS QUAD.:	Orange	LAT.: 42.5019	LONG.: -72.43621
DRAINAGE BASIN:	Connecticut	RIVER:	Sawmill River
IMPOUNDMENT NAME(S):	Lake Wyola		

GENERAL DAM INFORMATION

TYPE OF DAM:	Stone masonry - earth mill	OVERALL LENGTH (FT):	230
PURPOSE OF DAM:	Recreation	NORMAL POOL STORAGE (ACRE-FT):	815
YEAR BUILT:	1883	MAXIMUM POOL STORAGE (ACRE-FT):	1069
STRUCTURAL HEIGHT (FT):	12	EL. NORMAL POOL (FT):	835.1
HYDRAULIC HEIGHT (FT):	10	EL. MAXIMUM POOL (FT):	837.1

FOR INTERNAL MADCR USE ONLY

FOLLOW-UP INSPECTION REQUIRED: ☐ YES ☐ NO CONDITIONAL LETTER: ☐ YES ☐ NO

NAME OF DAM: Lake Wyola | STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016 | NID ID #: MA00510

INSPECTION SUMMARY

DATE OF INSPECTION: November 22, 2016

DATE OF PREVIOUS INSPECTION: November 18, 2014

TEMPERATURE/WEATHER: 35/sunny

ARMY CORPS PHASE I: ☑ YES ☐ NO If YES, date March 1979

CONSULTANT: Root Engineering

PREVIOUS DCR PHASE I: ☑ YES ☐ NO If YES, date August 2010

BENCHMARK/DATUM: NGVD

OVERALL PHYSICAL CONDITION OF DAM: SATISFACTORY

DATE OF LAST REHABILITATION: 2008 - 2009

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

EL. POOL DURING INSP.:

EL. TAILWATER DURING INSP.: 827.6

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Howard Kinder	Caretaker	Town of Shutesbury
Walter Tibbetts	Emergency Management Dir	Town of Shutesbury
Morris Root	Principal Engineer	Root Engineering

EVALUATION INFORMATION

	Click on box to select E-code
E1) TYPE OF DESIGN	5
E2) LEVEL OF MAINTENANCE	4
E3) EMERGENCY ACTION PLAN	5
E4) EMBANKMENT SEEPAGE	4
E5) EMBANKMENT CONDITION	5
E6) CONCRETE CONDITION	5
E7) LOW-LEVEL OUTLET CAPACITY	4

	Click on box to select E-code
E8) LOW-LEVEL OUTLET CONDITION	4
E9) SPILLWAY DESIGN FLOOD CAPACITY	5
E10) OVERALL PHYSICAL CONDITION	4
E11) ESTIMATED REPAIR COST	$45,000
ROADWAY OVER CREST	NO
BRIDGE NEAR DAM	NO

NAME OF INSPECTING ENGINEER: Morris J. Root

SIGNATURE: Morris J. Root

NAME OF DAM:	Lake Wyola	STATE ID #:	2-6-272-2
INSPECTION DATE:	November 22, 2016	NID ID #:	MA00510

OWNER:	ORGANIZATION	Town of Shutesbury	CARETAKER: ORGANIZATION	Town of Shutesbury
	NAME/TITLE		NAME/TITLE	Howard Kinder, Caretaker
	STREET	P. O. Box 276	STREET	
	TOWN, STATE, ZIP	Shutesbury, MA 01072	TOWN, STATE, ZIP	
	PHONE	413-259-1214	PHONE	413-367-9515
	EMERGENCY PH. #	413-259-1211	EMERGENCY PH. #	413-259-1211
	FAX	413-259-1107	FAX	
	EMAIL	townclerk@shutesbury.org	EMAIL	
	OWNER TYPE	Municipality or Political subdivision		

PRIMARY SPILLWAY TYPE: concrete, broad crested weir

SPILLWAY LENGTH (FT)	78	SPILLWAY CAPACITY (CFS)	1,700
AUXILIARY SPILLWAY TYPE	concrete, broad crested weir	AUX. SPILLWAY CAPACITY (CFS)	600
NUMBER OF OUTLETS	one	OUTLET(S) CAPACITY (CFS)	45
TYPE OF OUTLETS	36" PVC liner in stone box culvert	TOTAL DISCHARGE CAPACITY (CFS)	2,345
DRAINAGE AREA (SQ MI)	6.8	SPILLWAY DESIGN FLOOD (PERIOD/CFS)	1/2 PMF/ 2300 cfs

HAS DAM BEEN BREACHED OR OVERTOPPED ☑ YES ☐ NO IF YES, PROVIDE DATE(S) March 1936 and/or September 1938

FISH LADDER (LIST TYPE IF PRESENT)

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: Lake Wyola

STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016

NID ID #: MA00510

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	concrete and stone			
	2. SURFACE CRACKING	no			
	3. SINKHOLES, ANIMAL BURROWS	no			
	4. VERTICAL ALIGNMENT (DEPRESSIONS	none			
	5. HORIZONTAL ALIGNMENT	none			
	6. RUTS AND/OR PUDDLES	none			
	7. VEGETATION (PRESENCE/CONDITION)	good			
	8. ABUTMENT CONTACT				

ADDITIONAL COMMENTS:

NAME OF DAM: Lake Wyola | STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016 | NID ID #: MA00510

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	none observed			
	2. SLOPE PROTECTION TYPE AND COND.	concrete cutoff extends 2' below NWL, riprap face			
	3. SINKHOLE/ANIMAL BURROWS	none observed			
	4. EMB.-ABUTMENT CONTACT	good			
	5. EROSION	none observed			
	6. UNUSUAL MOVEMENT	none observed			
	7. VEGETATION (PRESENCE/CONDITION)	none observed			

ADDITIONAL COMMENTS:

NAME OF DAM: Lake Wyola

STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016

NID ID #: MA00510

INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	No			
	2. OBSERVATION WELLS	No			
	3. STAFF GAGE AND RECORDER	Manual recording daily by caretaker			
	4. WEIRS	Downstream seep monitor			X
	5. INCLINOMETERS	No			
	6. SURVEY MONUMENTS	No			
	7. DRAINS	No			
	8. FREQUENCY OF READINGS	Daily			
	9. LOCATION OF READINGS	Caretaker's log book maintained in gate house			

ADDITIONAL COMMENTS: 1. Corrective action is needed to make the seepage monitor functional.

NAME OF DAM: Lake Wyola STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016 NID ID #: MA00510

DOWNSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS			NO ACTION	MONITOR	REPAIR
D/S WALLS	1. WALL TYPE	dry laid stone masonry					
	2. WALL ALIGNMENT	good, original slight horizontal curve and vertical batter					
	3. WALL CONDITION	Satisfactory, loose stones reset December 2008					
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: 1	max: 11	avg: 8			
	5. SEEPAGE OR LEAKAGE	seepage is seen at toe. Total is estimated to be less than 2 gallons per minute					
	6. ABUTMENT CONTACT	Good					
	7. EROSION/SINKHOLES BEHIND WALL	None					
	8. ANIMAL BURROWS	None					
	9. UNUSUAL MOVEMENT	None					
	10. WET AREAS AT TOE OF WALL	Seepage near left abutment and abandoned sluiceway feeds downstream wetland.					

ADDITIONAL COMMENTS:

NAME OF DAM: Lake Wyola STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016 NID ID #: MA00510

DOWNSTREAM AREA

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S AREA	1. ABUTMENT LEAKAGE	at normal to high water on left; none on right			
	2. FOUNDATION SEEPAGE	at NWL; ceases with drawdown			
	3. SLIDE, SLOUGH, SCARP	none observed			
	4. WEIRS	in concrete handhole for seepage			
	5. DRAINAGE SYSTEM	none observed			
	6. INSTRUMENTATION	not in downstream area			
	7. VEGETATION	controlled near dam; small wetland on left between dam and Locks Pond rd			
	8. ACCESSIBILITY	drives from Locks Pond Road			
	9. DOWNSTREAM HAZARD DESCRIPTION	Major town highways and several residences close to the Sawmill River			
	10. DATE OF LAST EAP UPDATE	42536			

ADDITIONAL COMMENTS:

NAME OF DAM: Lake Wyola

STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016

NID ID #: MA00510

MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS
MISC.	1. RESERVOIR DEPTH (AVG)	20 feet; Lake Wyola is a Great Pond with depths up to 30 feet without the dam
	2. RESERVOIR SHORELINE	good condition
	3. RESERVOIR SLOPES	moderate to flat
	4. ACCESS ROADS	good condition
	5. SECURITY DEVICES	gate house is locked
	6. VANDALISM OR TRESPASS	☑ YES ☐ NO WHAT: dam is open to public
	7. AVAILABILITY OF PLANS	☑ YES ☐ NO DATE: 2008
	8. AVAILABILITY OF DESIGN CALCS	☑ YES ☐ NO DATE: 2008
	9. AVAILABILITY OF EAP/LAST UPDATE	☑ YES ☐ NO DATE: June 15, 2016
	10. AVAILABILITY OF O&M MANUAL	☑ YES ☐ NO DATE: February, 2017
	11. CARETAKER/OWNER AVAILABLE	☑ YES ☐ NO DATE: November 22, 2016
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES ☑ NO PURPOSE:

ADDITIONAL COMMENTS: Signage has been posted to ask public to stay off the dam. The Town has chosen not to install fencing.

NAME OF DAM: Lake Wyola | STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016 | NID ID #: MA00510

PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	uncontrolled concrete open channel			
	WEIR TYPE	7' wide broad crested weir			
	SPILLWAY CONDITION	good,			
	TRAINING WALLS	good,			
	SPILLWAY CONTROLS AND CONDITION	uncontrolled			
	UNUSUAL MOVEMENT	no			
	APPROACH AREA	pond - no derbis			
	DISCHARGE AREA	stream below spillway - nonobstructive			
	DEBRIS	minor brush growth over riprap below right overflow spillway			
	WATER LEVEL AT TIME OF INSPECTION	18" below crest of spillway - November 2016			

ADDITIONAL COMMENTS: At the time of inspection, August 2016, with water spilling over the spillway, it is noted that there is water infiltrating in two ways.

1. The construction joint between the steps in the spillway; i.e., upper control level to next lower, is open and allows infiltration.
2. The mortar sealing the upper control level concrete to the existing stones has broken in a few locations. Infiltation occurs in these
3. A small (8" by 12") piece of concrete has broken off the front face of the dam adjacent to the right spillway training wall.

NAME OF DAM: Lake Wyola — STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016 — NID ID #: MA00510

AUXILIARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	concrete and mortared stone - uncontrolled			
	WEIR TYPE	12 - 20' wide broad crested weit			
	SPILLWAY CONDITION	good			
	TRAINING WALLS	none - overflow on dam crest, SDF does not overtop ends.			
	SPILLWAY CONTROLS AND CONDITION	uncontrolled			
	UNUSUAL MOVEMENT	none			
	APPROACH AREA	Lake Wyola			
	DISCHARGE AREA	heavy riprap erosion protection at dam toe; good condition			
	DEBRIS	none			
	WATER LEVEL AT TIME OF INSPECTION	833.6			

ADDITIONAL COMMENTS:

NAME OF DAM: Lake Wyola

STATE ID #: 2-6-272-2

INSPECTION DATE: November 22, 2016

NID ID #: MA00510

OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE	36" PVC sleeve in stone box culvert			
	INTAKE STRUCTURE	36" PVC sleeve in stone box culvert			
	TRASHRACK	galvanized steel, cleaned by divers 2X a year			
	PRIMARY CLOSURE	slide gate			
	SECONDARY CLOSURE	none			
	CONDUIT	36" PVC sleeve in stone box culvert			
	OUTLET STRUCTURE/HEADWALL	stone headwalls upstream and downstream			
	EROSION ALONG TOE OF DAM	None, stone cobbled channel			
	SEEPAGE/LEAKAGE	Seepage around PVC liner when gate is in use.			X
	DEBRIS/BLOCKAGE	No			
	UNUSUAL MOVEMENT	no			
	DOWNSTREAM AREA	Cobble channel with stone riffle			
	MISCELLANEOUS				

ADDITIONAL COMMENTS: 1. The upstream bulkhead for the PVC liner outlet conduit has apparently failed. This allows water to infiltrate behind the liner.

APPENDIX C
Previous Reports and References

PREVIOUS REPORTS AND REFERENCES

The following is a list of reports that were located during the file review, or were referenced in previous reports.

1. Lake Wyola Dam Phase I Inspection Report, U. S. Army Corps of Engineers, March 1979.
2. Lake Wyola Dam Phase I Inspection, MA DEM, 1998.
3. Letter reports on file with Franklin County Engineer for 1925 - 1968
4. Plan titled Locks Pond Reservoir dam dated November 1883.

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

1. United States Department of the Interior, Bureau of Reclamation, Design of Small Dams, 1987.
2. King & Brater, Handbook of Hydraulics, 1963.
3. U. S. Army Corps of Engineers, recommended guidelines for safety inspections of dams, November 1976.
4. Federal Energy Regulatory Commission, Engineering Guidelines for the Evaluation of Hydropower Projects, 1991.
5. Kent Healy, ASCE Monograph – Safety of Small Dams, "Evaluation and Repair of Stonewall-earth Dams," 1979.

Memo to file

From Morris Root 5/6/05

Subject: Archival Retrieval of Data for Lake Wyola Dam (also known as Locks Pond Reservoir Dam)

The following information is as recorded in the Franklin County Plan Book, Book 3, Page 139. There is a sketch of the structure and a written specification of the structure as "viewed by the County Commissioners" on November 17, 1883. The "()" reference indicate points called out on the sketch.

The specification is as follows:
"1. General Dimensions – Dam is about 200 feet long, 12 feet high, 35 feet wide on the bottom, and 20 feet on top.

2. Main Wall (g) – It has an average thickness on bottom of 10 feet and on top of 7 feet. It is laid on hard pan. The top stones are broad flat ones with cemented joints.

3. Second Wall (h) – Right to and inside of main wall is a solid cement wall of split stones 16 inch thick laid on hard pan or on puddling of cement and cobble stones, where hard pan could not be reached.

4. Sand Filling (I) – In front of second wall is a sand filling 12 feet wide on top and 25 feet on bottom, covered with a riprapping of cobble stones.

5. Outlet (m) – This is 3+3 foot walled with split stones, the width of the outlet, which are laid in cement. The stone over and above the outlet to (o) are also laid in cement. Wing walls protect the embankment on either side, and a broad flat stone is placed in front of the outlet to prevent undermining.

6. Second outlet (e) – At this point, but reaching only through the main wall, is another outlet with opening next. The cement wall covered with a flat stone – left thus to meet a possible future need for a second outlet.

7. Sand below Rollway – This is nearly on a level with the rollway and is well protected, with rocks, brush, and growing trees. (The main wall at this point is therefore but 5 feet wide, on bottom, and 4 feet on top, with a cement wall in front 1 foot thick.)"

Memo to file

From Morris Root 5/6/05

RE: Supplemental archival information from Franklin County Records for Locks Pond Reservoir Dam

The writer met with James Toth, Franklin County Engineer, and reviewed dam inspections that were available and on file for the years between 1925 and 1968. Many of the reports prepared by James Tighe, F. Deane Avery, or Avery's successor were perfunctory and sparse observations that the dam was in good repair and safe to operate.

Notable exceptions are:

1. Correspondence from Avery to William Callahan, Public Works Department Commission dated November 18, 1938. The text being,

"As you requested after the meeting in Greenfield last night I am writing to explain the situation at Locks Pond otherwise known as Lake Wyola.

This is a natural pond with a stone and earth dam which raises the water level about 6 feet to provide additional flow in dry times for the benefit of several mill owners below.

It is located in Shutesbury at the head of Sawmill River which flows through Montague and in flood time is a menace to roads and private property.

Mr. Leon Billings is the largest stockholder in the Locks Pond Reservoir Co. and he controls the operation. The spillway was damaged in the recent flood and some repairs are necessary to make it effective for any sort of flood control. I believe larger gates are needed.

The Reservoir Co. claim they are not in a financial condition to enable them to do this and probably they should not be expected to spend their money for the benefit of the public.

In my opinion $5000. would be adequate to make any necessary repairs and put in flood gates which if properly handled would materially aid in controlling the Sawmill River."

2. From 1939 inspection;

"This is a heavy stone masonry structure with earth fill on the upstream side. It has a large flat stone top and stone paved spillway. Some of the stones of the spillway on the downstream slope have become removed, probably last spring, these should be replaced because in continued high water with ice going out it is probable that more would be carried away and eventually weaken the dam at the spillway. I recommend that this be repaired…"

There is a black and white photo attached showing an upstream flat stone wall with downstream - two sizable tree stumps and cobbles arranged as would be expected in viewing a wash out.

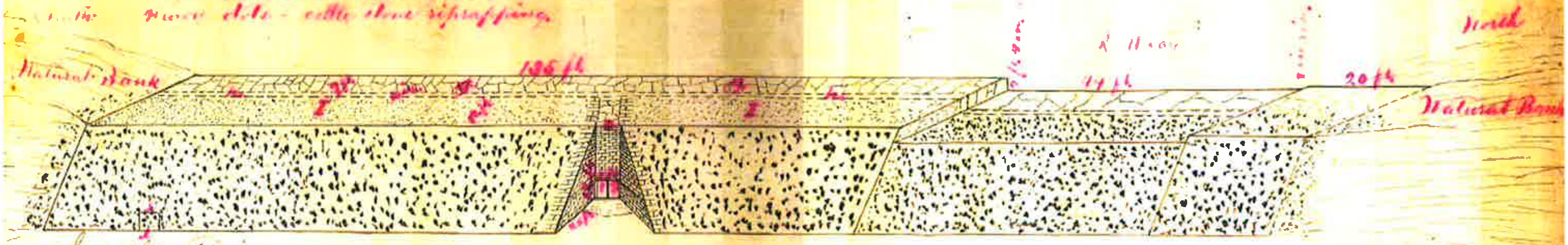
3. Another Avery letter, date is unclear, but interpreted as, August 30, 1938:

"As requested, I met Mr. Leon Billings at Locks Pond Dam on August 25, regarding proposed repairs to the dam. What he proposes to do is practically what I recommended in my 1936 report. He will put in stones at the toe of the spillway and probably reinforce them with cement mortar and steel rods. In addition he plans to put a thin cement wall across the spillway on the upstream side. Also I asked to the dam north of the spillway raised a little because the 1936 flood went over at that point."

4. Miscellaneous reports from 1953 through 1956 regarding a leak at the sluiceway, small not increasing – no comment about repair – mentions south of sluiceway in one report.

5. Mentions in 1949 – 1951, there is a method needed to keep public from throwing stones into outlet gate.

Locks Pond Reservoir Dam



Specification

1. General dimensions — The dam is about 2[illegible] ft long 12 ft high, 3[illegible] ft [illegible] on bottom and 2[illegible] ft on top.

2. Main Wall (a) — [illegible] on bottom [illegible] on top [illegible] It is [illegible] on hard pan. The top stones [illegible] with cemented joints.

3. Second Wall (b) — Next to and inside of main wall is a [illegible] cemented wall of split stones, [illegible] in thick laid on hard pan, or on [illegible] where hard pan could not be reached, and cobble stones, where hard pan could not be reached.

4. Sand Filling (c) — In front of second wall is a sand filling [illegible] 25 ft on bottom covered with a riprapping of cobble stones.

5. Outlet (m) — There is 3 + 3 ft walled with split stones, the width of the outlet which are laid in cement. The stone over, and above the outlet [illegible] laid in cement. Wing walls protect the embankment on either side, and a broad flat stone is placed in front of the outlet to prevent under mining.

6. Second Outlet (d) — At this point, but reaching only through the main wall is another outlet, with the opening next. The cement wall covered with a flat stone — left there to meet a possible [illegible] for a second outlet.

7. Land below Rollway — This is nearly on a level with the rollway and is well protected with rocks brush and growing trees. The main wall at this point is therefore but [illegible] ft wide on bottom, and 4 ft on top, with a cement wall [illegible] 1 foot thick.

[illegible] by Commissioners
[illegible] 17, 18[illegible]

Approved { [illegible] Burton
Edwell F. Mayo
Carlos [illegible]

The accompanying diagram figures and description are correct.

[illegible] Com.
G. N. Watson
A. L. Moore — Director and member of Building Com.

[illegible] and [illegible] Superintendent
Director L. A. Rugg

"

Clerk and [illegible] [illegible]

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APPENDIX D

Definitions

COMMON DAM SAFETY DEFINITIONS

For a comprehensive list of dam engineering terminology and definitions refer to 302 CMR10.00 Dam Safety, or other reference published by FERC, Dept. of the Interior Bureau of Reclamation, or FEMA. Please note should discrepancies between definitions exits, those definitions included within 302 CMR 10.00 govern for dams located within the Commonwealth of Massachusetts.

Orientation

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

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

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

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

Dam Components

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

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

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

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

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

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

Size Classification

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

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

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

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

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

Hazard Classification

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

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

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

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

General

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

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

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

Acre-foot – Shall mean a unit of volumetric measure that would cover one acreto a depth of one foot. It is equal to 43,560 cubic feet. On million U.S. gallons = 3.068 acre feet
Height of Dam – Shall mean the vertical distance from the lowest portion of the natural ground, including any stream channel, along the downstream toe of the dam to the crest of the dam.

Spillway Design Flood (SDF) – Shall mean the flood used in the design of a dam and its appurtenant works particularly for sizing the spillway and outlet works, and for determining maximum temporary storage and height of dam requirements.

Condition Rating

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

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

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

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

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