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# Design and Construction Practices for the Kenyon Mill Step-Pool Nature-like Fishway, Pawcatuck River, Rhode Island

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# Design and Construction Practices Kenyon Mill Step-Pool Nature-like Fishway, Pawcatuck River, Rhode Island

James Turek<sup>1</sup>, Sean Arruda<sup>2</sup>, Nils Wiburg<sup>2</sup>, and Matt Bernier<sup>3</sup>

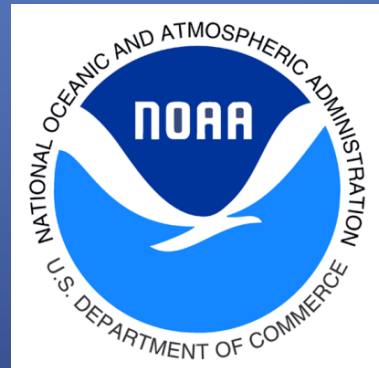
<sup>1</sup>NOAA Restoration Center, Narragansett, RI; <sup>2</sup>Fuss & O'Neill, Providence, RI;

<sup>3</sup>NOAA Restoration Center, Orono, ME

Presentation:

International Conference on Engineering and Ecohydrology  
for Fish Passage, Madison, WI

June 9, 2014



# NOAA Restoration Center – Northeast Fish Passage Projects

## Project Type

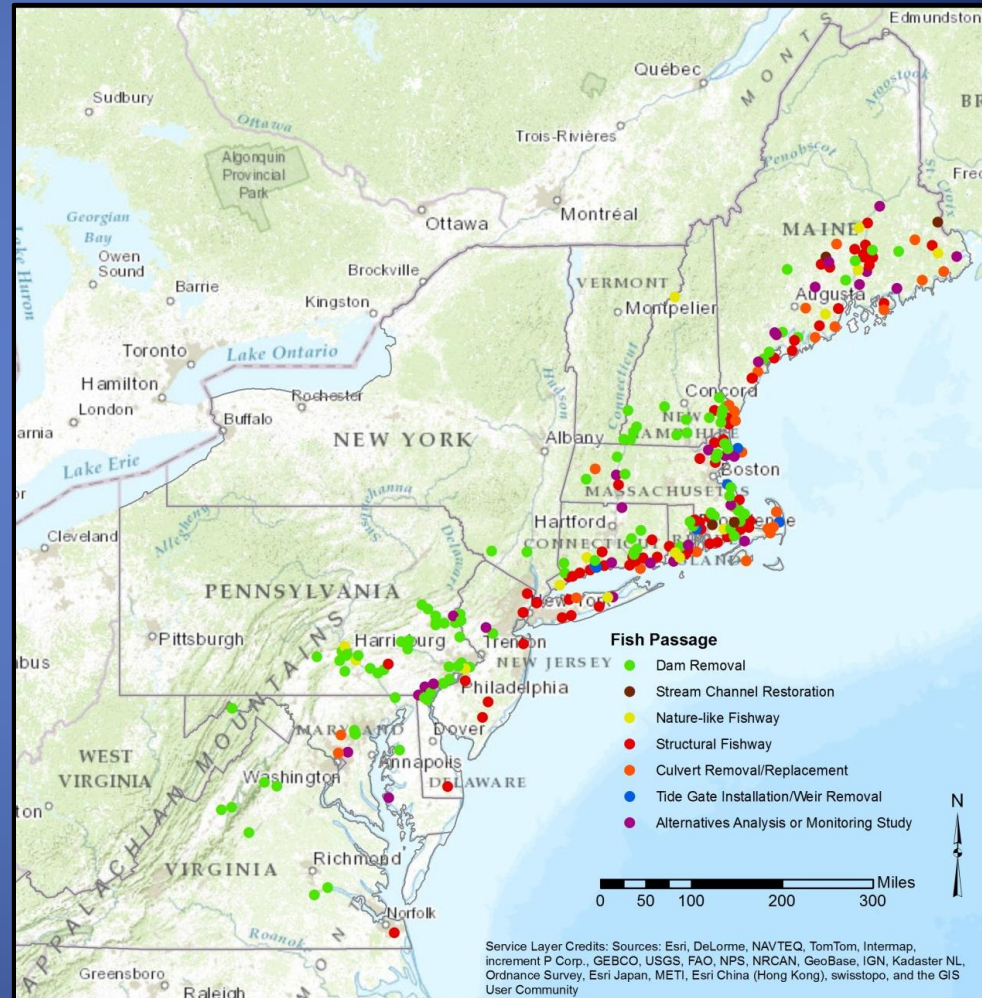
- Dam removal: **114 (41%)**
- Stream channel restoration: **5 (2%)**
- Nature-like fishway: **14 (5%)**
- Structural fishway: **78 (28%)**
- Culvert: **26 (9%)**
- Tide gate installation: **6 (2%)**
- Analysis/Studies: **34 (12%)**
- Total projects: **277**

## Habitat Opened

- River miles: **1,566**
- Pond/lake acres: **19,409**

## Funding

- NOAA: **\$71.7M**
- Partners: **\$19.4M**
- Leveraged: **\$24.2M**



# Pawcatuck River Watershed

307 mi<sup>2</sup> watershed area

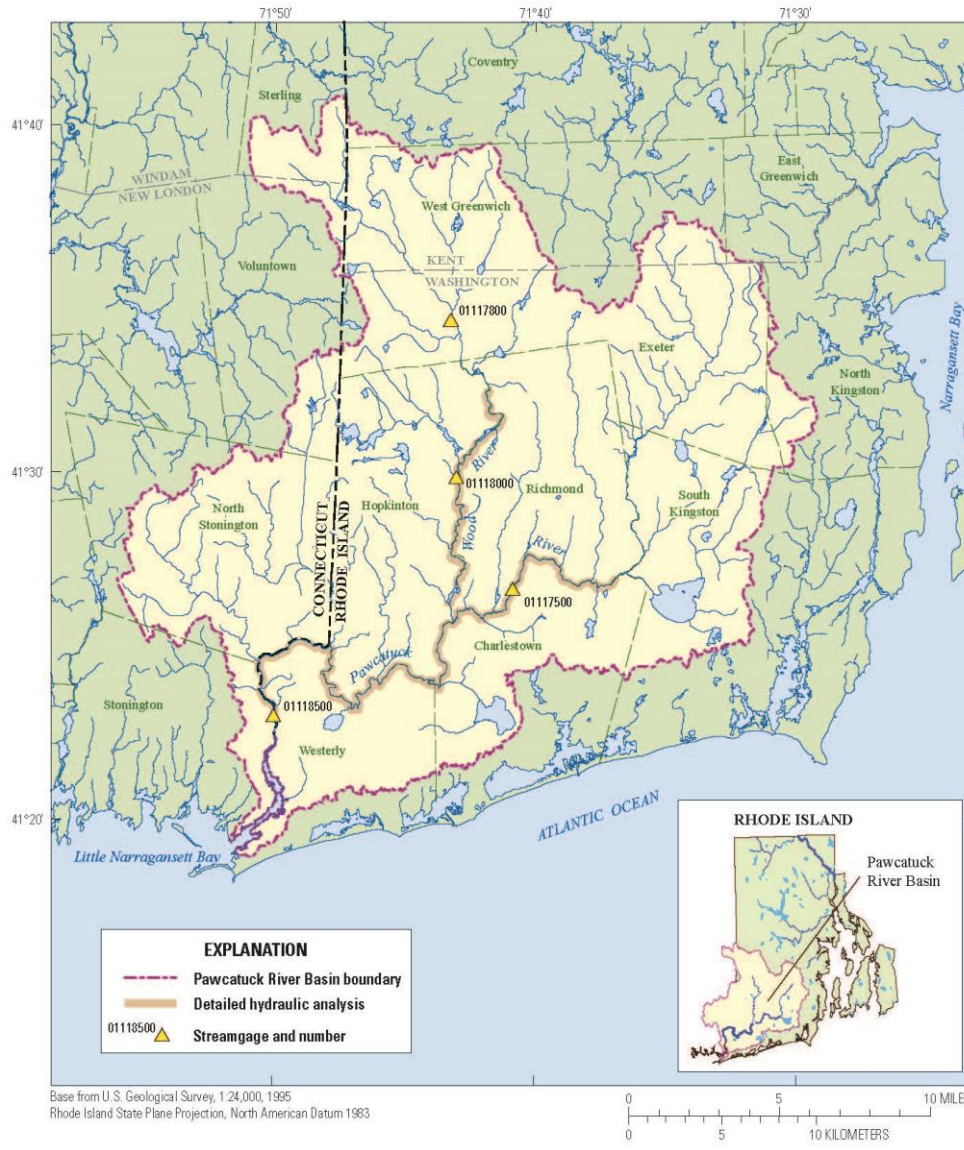
Limited development; ~3.4 percent impervious surfaces

Under review for federal Wild and Scenic River designation

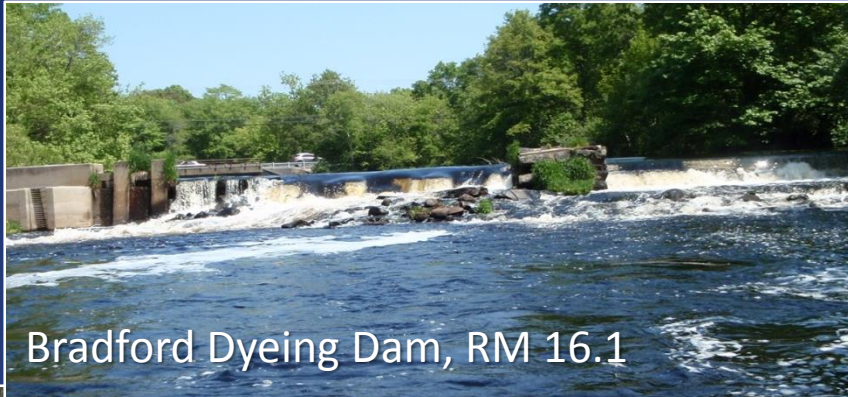
Mainstem dams as early as 1762

Fish target species: river herring, American shad, American eel

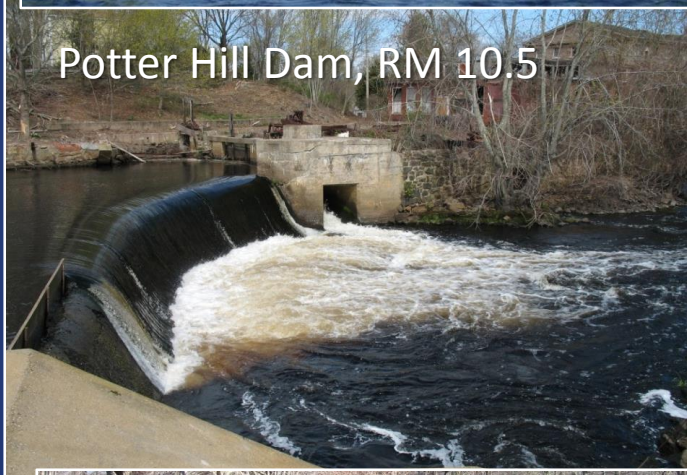
Access Restoration: **23.5** mainstem miles, **48.8** tributary miles, **1967** lake acres



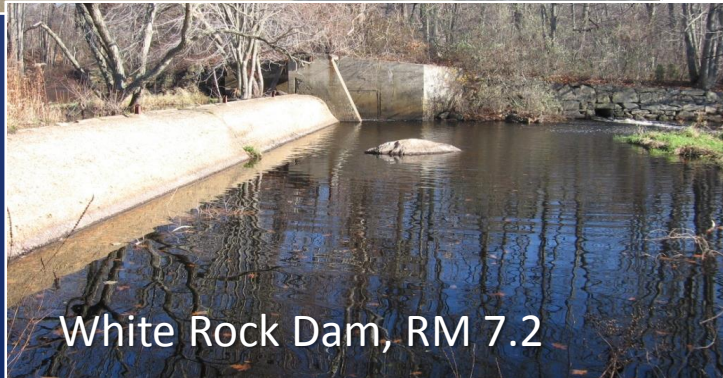
# Lower Pawcatuck River Dams



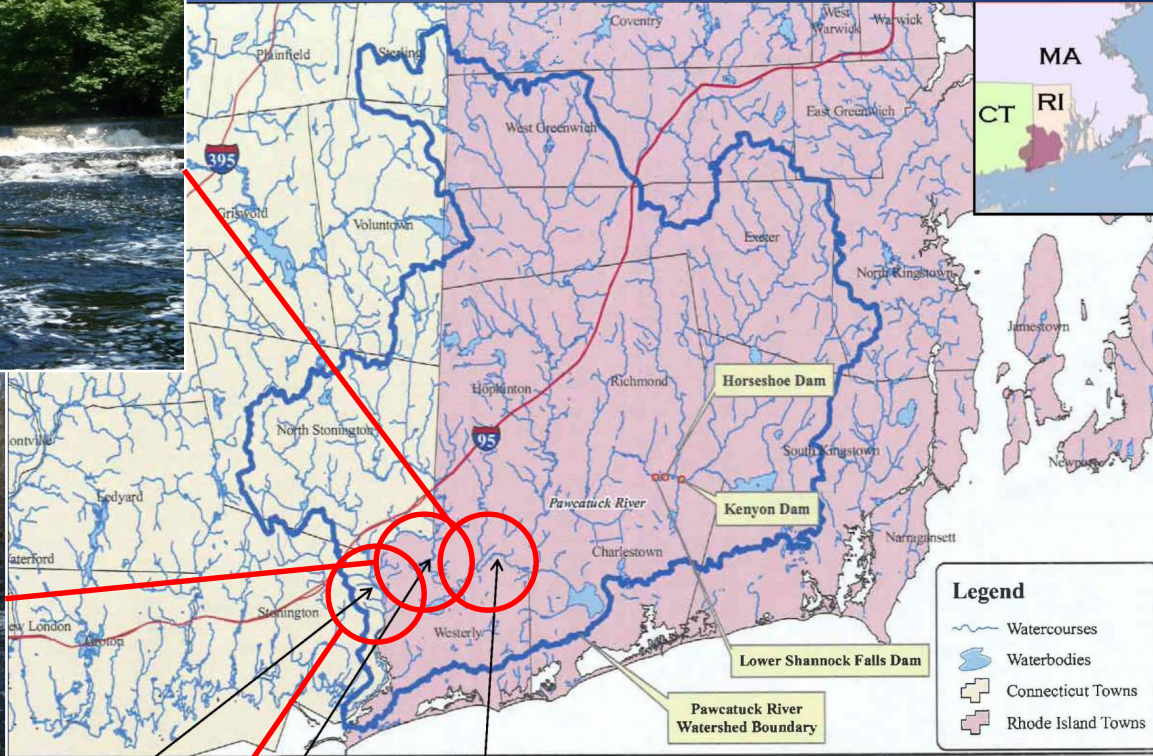
Bradford Dyeing Dam, RM 16.1



Potter Hill Dam, RM 10.5



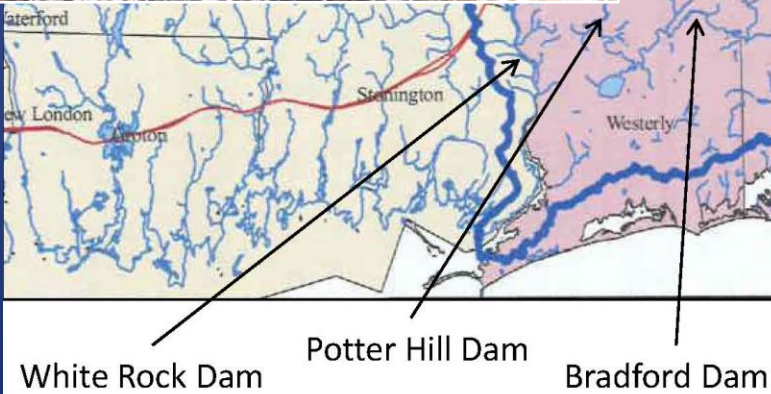
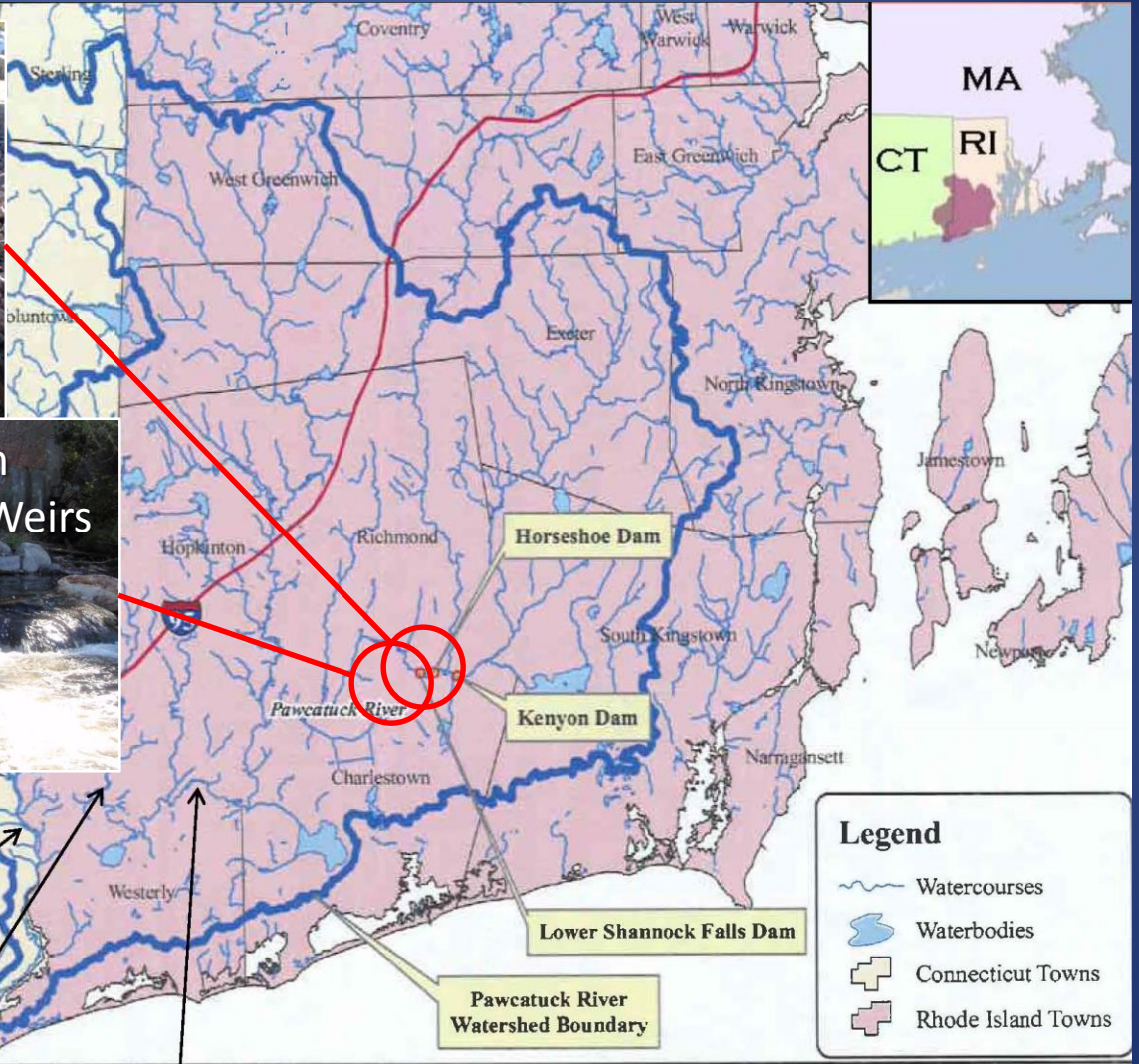
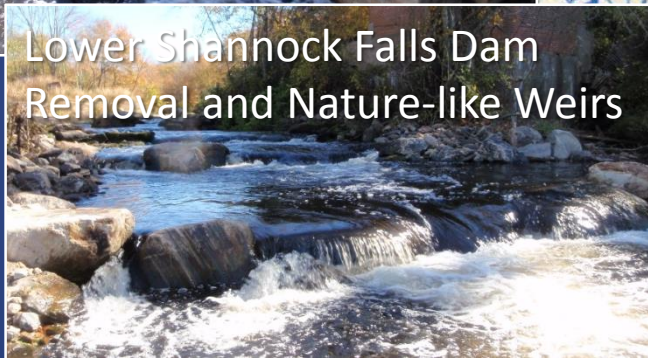
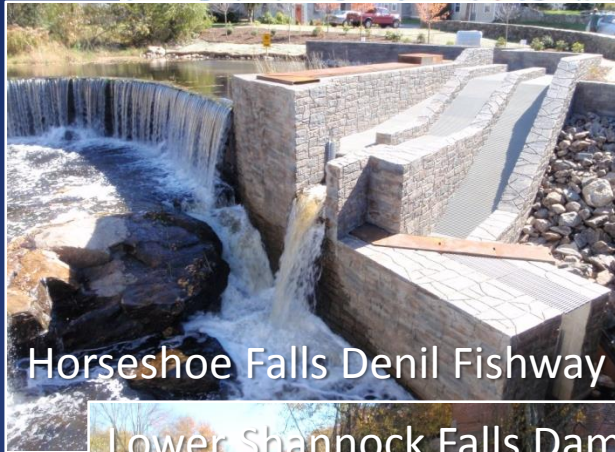
White Rock Dam, RM 7.2



White Rock Dam Potter Hill Dam Bradford Dam

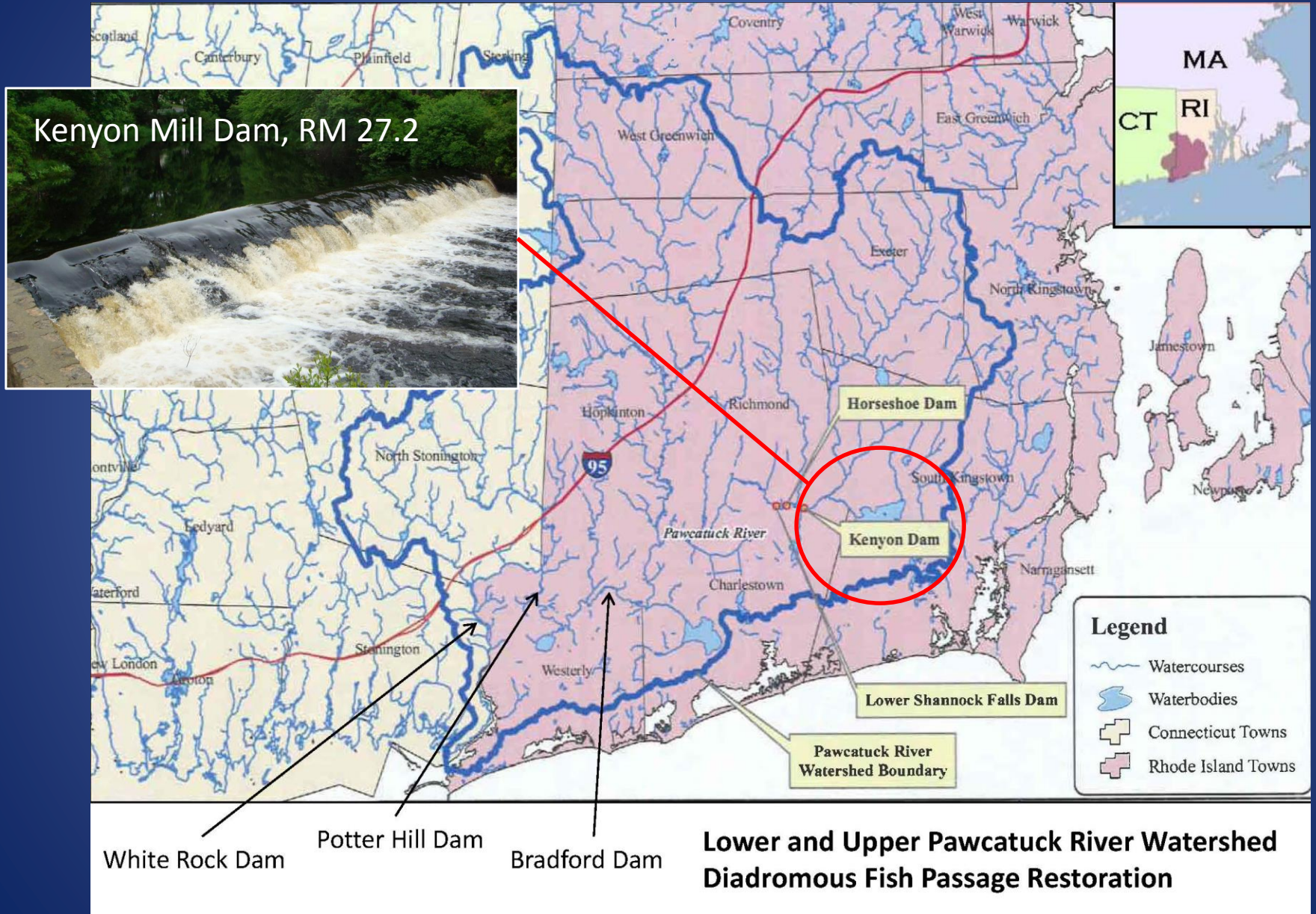
Lower and Upper Pawcatuck River Watershed Diadromous Fish Passage Restoration

# Upper Pawcatuck River Passage Restoration

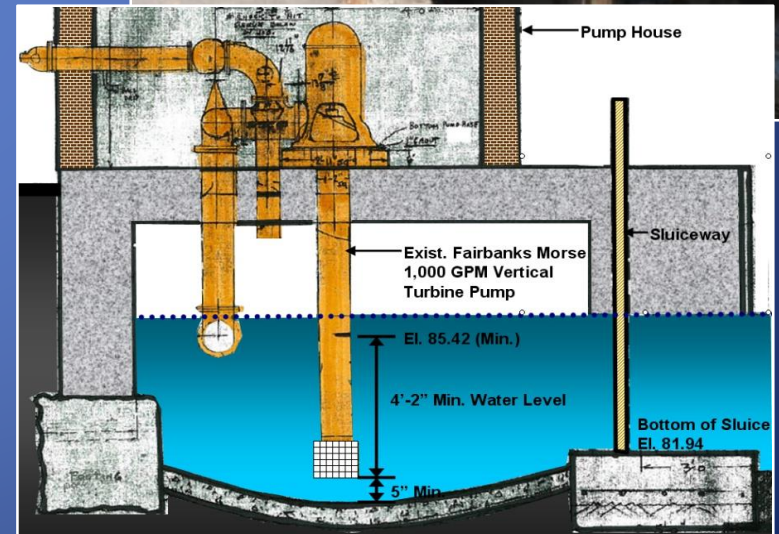
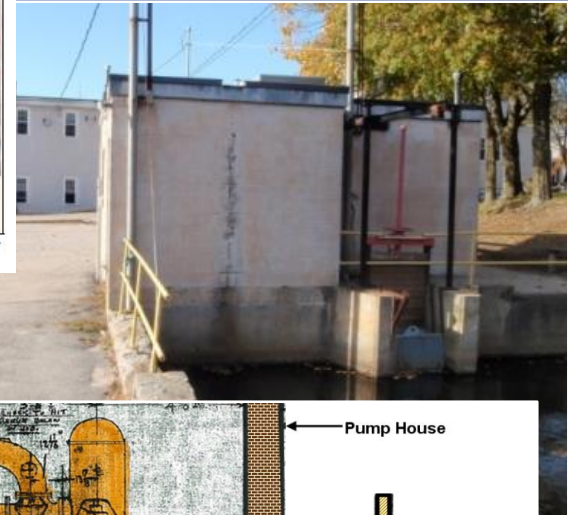
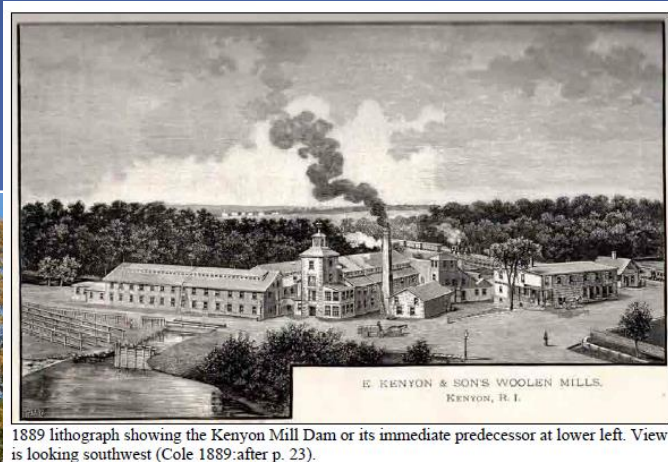


**Lower and Upper Pawcatuck River Watershed  
Diadromous Fish Passage Restoration**

# Upper Pawcatuck River Passage Restoration



# Kenyon Industries Dam, Kenyon, RI, Upper Pawcatuck River



4.5-foot high stone, timber and concrete dam (circa 1772, 1890, 1940)

Fire suppression safety needs



# Design – Target species

Alewife (*Alosa pseudoharengus*)

Blueback herring (*Alosa aestivalis*)

American shad (*Alosa sapidissima*)

American eel (*Anguilla rostrata*)

Resident fishes:

Brook trout (*Salvelinus fontinalis*),

Brown trout (*Salmo trutta*)

Fallfish (*Semotilus corporalis*)

White sucker (*Catostomus commersonii*)

Run period: March 15 – June 15

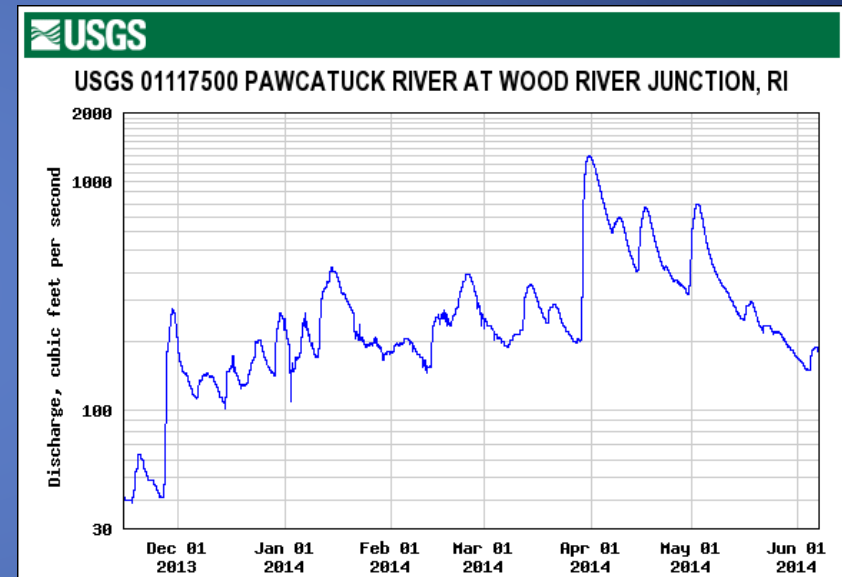


# Design – Fish Passage Flows

Passage site drainage area = 73 mi<sup>2</sup>

USGS Wood River gauge 01117500  
with drainage area = 100 mi<sup>2</sup>  
Period of record: 1940-present;  
Used flow data post-1970

USGS Kenyon gauge 01117430  
with drainage area = 72.7 mi<sup>2</sup>  
Period of record: discontinuous

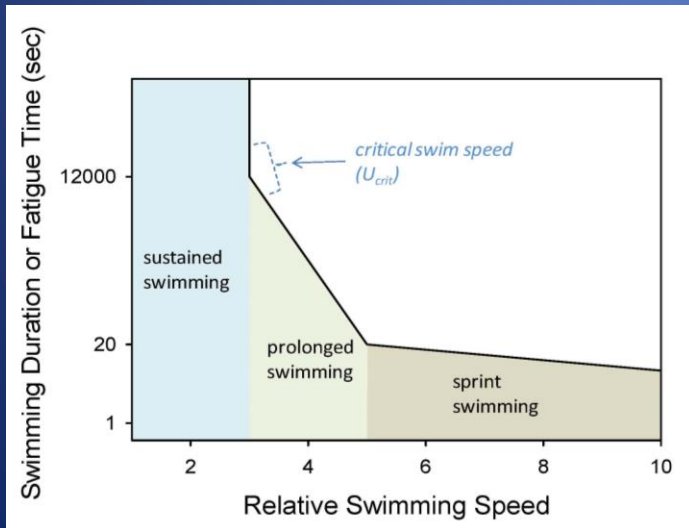


Developed rating curve for passage site hydrology

**Operational flows:** 95% exceedance: 88 cfs, normal flow (50% exceedance): 183 cfs, 5% exceedance: 461 cfs

# Design Passage Criteria

Target Species	Minimum Weir Opening Width (ft)	Minimum Weir Opening Depth (ft)	Maximum Weir Opening Velocity (ft/s)	Minimum Pool Depth (ft)
Alewife, blueback herring	2	0.75	6	2
American shad	3	1.5	7	3

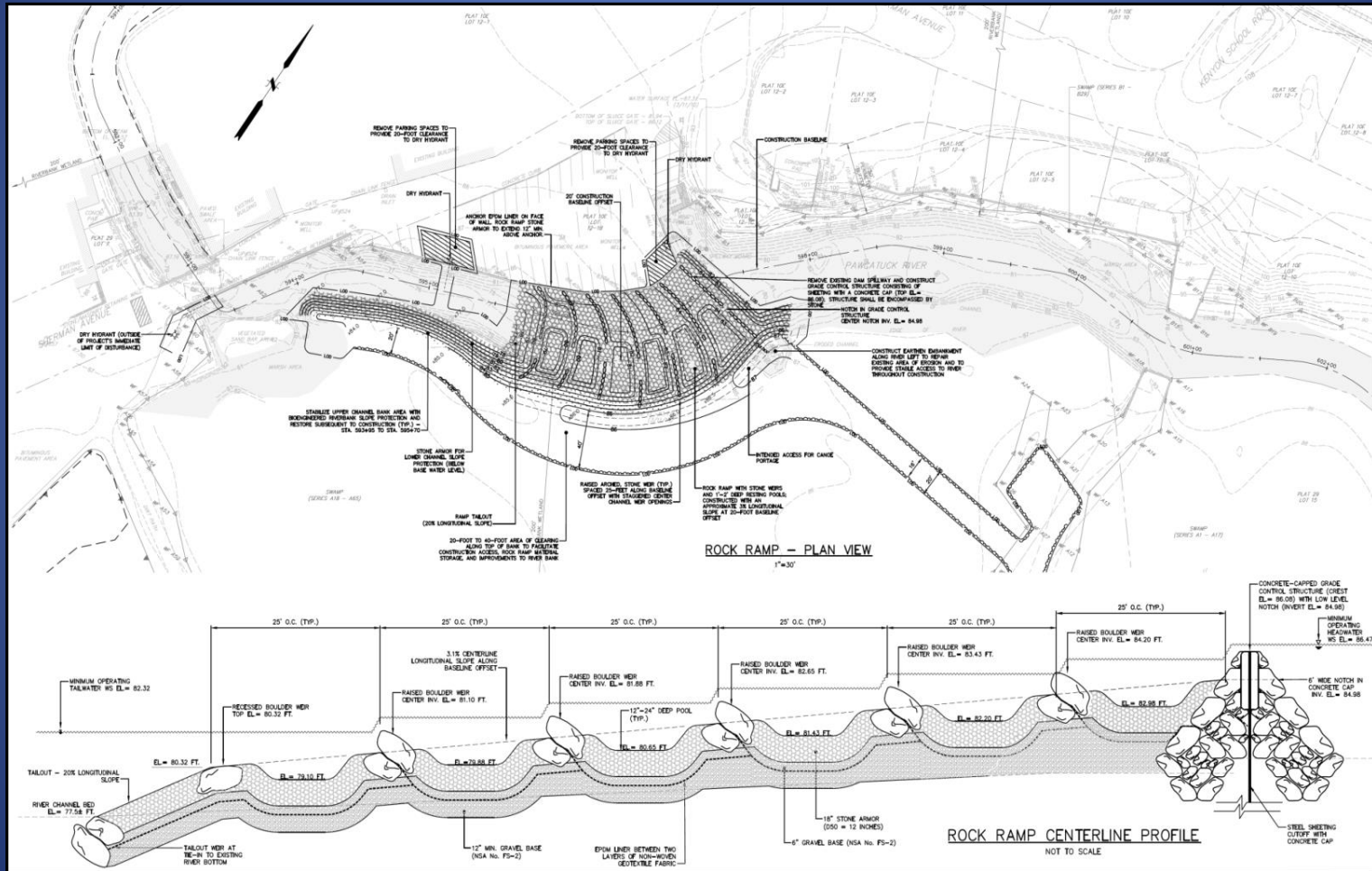


Minimum pool length: 20 ft

Swimming fatigue time is logarithmic. Swimming speed is given in relative, not absolute units. *Critical swimming speed*, or  $U_{crit}$  is physiological metric dependent on experimental test conditions.

# Design Layout

Five stone weirs with upper cutoff wall; downstream cutoff wall



Engineers: Fuss & O'Neill, KCI

# Engineering Design

Stone weirs – blocky footer and crest stones (rounded-edged), minimum of 4.0-ft length, 2.5-ft width, and 2.0-ft height, minimum weight of ~1.4 tons; embedded minimum of 1.5 ft

Weir notches – central notch in each weir; in-line notches for addressing shad passage

Upper notches along right arms of weirs on inside riverbend to provide passage during upper operational flows



# Engineering Design

Compacted channel fill

Footer stone placement

Stone bedding layer (minimum 9-inch depth) to embed two-tiered footer stones

Crest stone placed leaning on footer stones, not to exceed  $30^\circ$  to the horizontal

Non-woven geo-fabric placed between footer and crest stones to minimize water loss; covered with minimum of 1.5 ft of R-6 stone and washed fill, stone chinking



# Engineering Design

To provide low risk to Kenyon Industries for a long-term water supply, higher level of design was required

Final design included sheet-pile cutoff wall to 20± ft; very large boulders encountered during construction at depths of ~4 ft required revised plan to pour concrete wall on base of former dam

Downstream sheet-pile cutoff wall as added protection to address potential sediment scour, particularly during high flows.



# Construction Practices: Water Management



Upstream Super Sack Dam



Temporary Flow Diversion Bypass



Downstream Temporary Dam

Temporary by-pass channel along river-left bank afforded construction of the fishway in the dry; also provided opportunity to run test flows



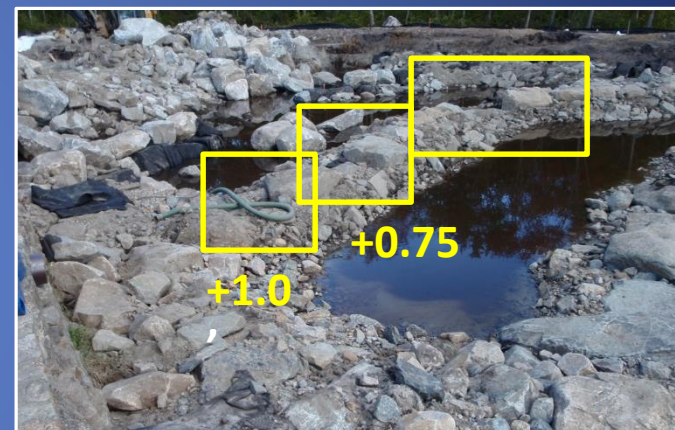
# Construction Practices



Restore grades to leftbank, install woven geo-fabric, seed with riparian plant mix, and install plantings and canoe portage access

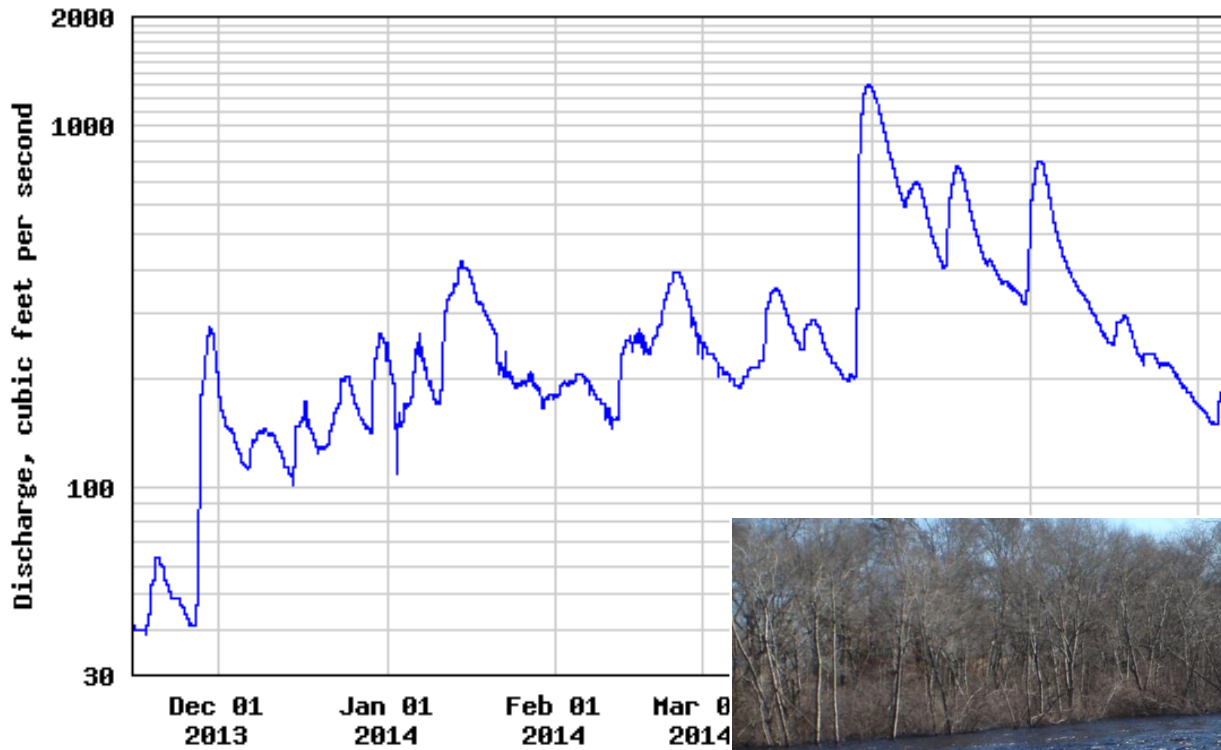
# Construction Test Flows

Test flows: protocol and calculations; November 29, 2013:  
 observations, measure V at low and normal flows, by closing or  
 reducing flow through bypass



	<b>126 cfs</b>	<b>182 cfs</b>
<b>Location of Flow Velocity Testing</b>	<b>Recorded Velocity Range (during 11/29 Flow Test #1)</b>	<b>Recorded Velocity Range (during 11/29 Flow Test #2)</b>
Low Flow Channel at Weir #1 (Dam)	4.5 fps (average)	4.9–5.3 fps
Low Flow Channel at Weir #2	4.2-5.2 fps	4.5-5.1 fps
Low Flow Channel at Weir #3	4.3-4.9 fps	4.6-5.8 fps
Low Flow Channel at Weir #4	4.3-5.5 fps	5.5-6.2 fps
Low Flow Channel at Weir #5	3.5-4.6 fps	3.4-4.4 fps

# USGS 01117500 PAWCATUCK RIVER AT WOOD RIVER JUNCTION, RI



Site conditions at 950 cfs

# Passage Diagnostic Evaluation: Post-Construction



135 cfs, 06 June 2014



	<b>8-May-14</b> <b>292 cfs</b>	<b>3-Jun-14</b> <b>100 cfs</b>
<b>Weir Drop</b>	<b>Drop (ft)</b>	<b>Drop (ft)</b>
Grade Control	0.58	0.59
Weir 1	0.86	0.88
Weir 2	0.71	0.71
Weir 3	0.79	0.74
Weir 4	0.23	0.65
Weir 5	0.03	0.28

# Project Cost

Total construction cost: \$894,000

Cost per foot rise for passage: \$223,500

