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Case Studies II: Design and Construction of a Riffle Grade Control for Fish Passage

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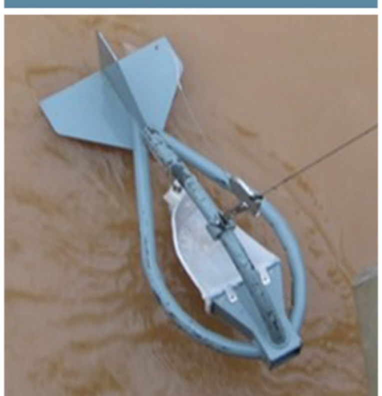

June
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Outline

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- Background on Mitigation Project
- Design History
  - Assessment
  - Concepts & Agency Feedback
- Final Design
  - Design Constraints
  - Overview
- Construction

Whitemarsh Run 2008

Background: I-95 Express Toll Lanes

- I-95 Express Toll Lanes℠
- 8-mile segment of I-95 = Section 100
  - 12,199 linear feet of streams impacted
  - 2.89 acres of wetlands impacted
  - Mitigation achieved at King Avenue Mitigation Site and Whitemarsh Run Mitigation Site

Mitigation Site Location

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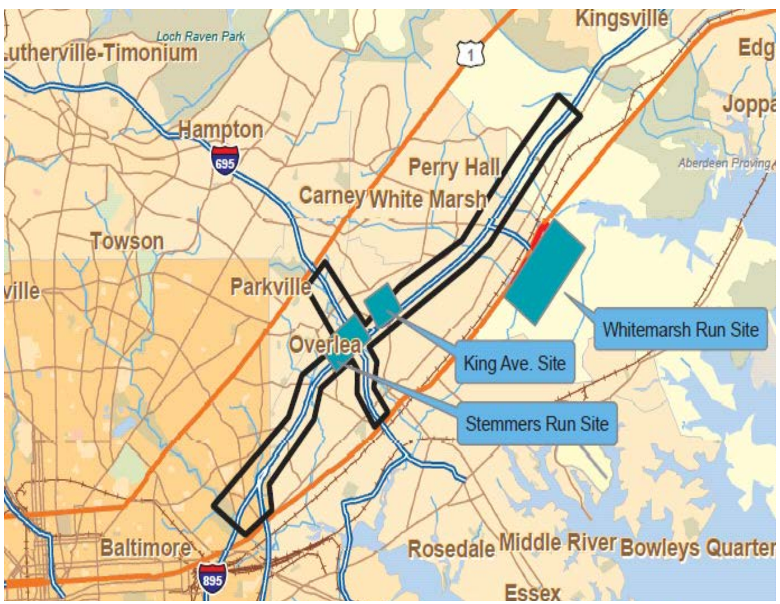
- Whitemarsh Run
  - Coastal plain sand and gravel-bedded stream located in Baltimore County, Maryland



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Watershed and Site Assessments

Whitemarsh Run Watershed

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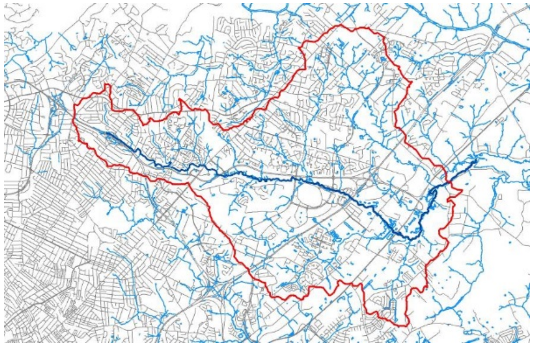
- Urbanized 13.5-mi^2 watershed
- History of gravel mining
- Upstream restoration projects have had varying success
- Straughan measured large bedload supply to downstream reaches

Risk Factors



White Marsh Run Site

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- Whitemarsh Run Mitigation Site
  - 184 acres containing streams, forest, and wetlands
  - Degraded streams, wetlands, and habitat
  - History of gravel mining
  - MD 43 and BGE ROW

Site Assessment

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Geomorphic and Hydrology Assessment

- Stream gage installations
- Discharge and bedload measurements during storm events
- Sediment transport modeling
- Baseflow analysis

Hydrology Measurements

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Summary of Discharges Used in HEC-RAS Modeling							
Whitemarsh Run	**Drainage Area**	**Low Flows (cfs)**				**High Flows (cfs)**	
		50%	**90%**	**1-year**	**2- year**	**10- year**	**100- year**
Downstream of U.S. Route 40	10.88	6.7	14.2	1,154	1,694	2,841	4,030
	12.97	4.3	16.9	1,220	1,767	3,453	7,502

Bankfull & Effective Discharge Summary	
	U.S. Route 40
Bankfull	1,024 cfs
Effective	555 cfs

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Sediment Transport Model

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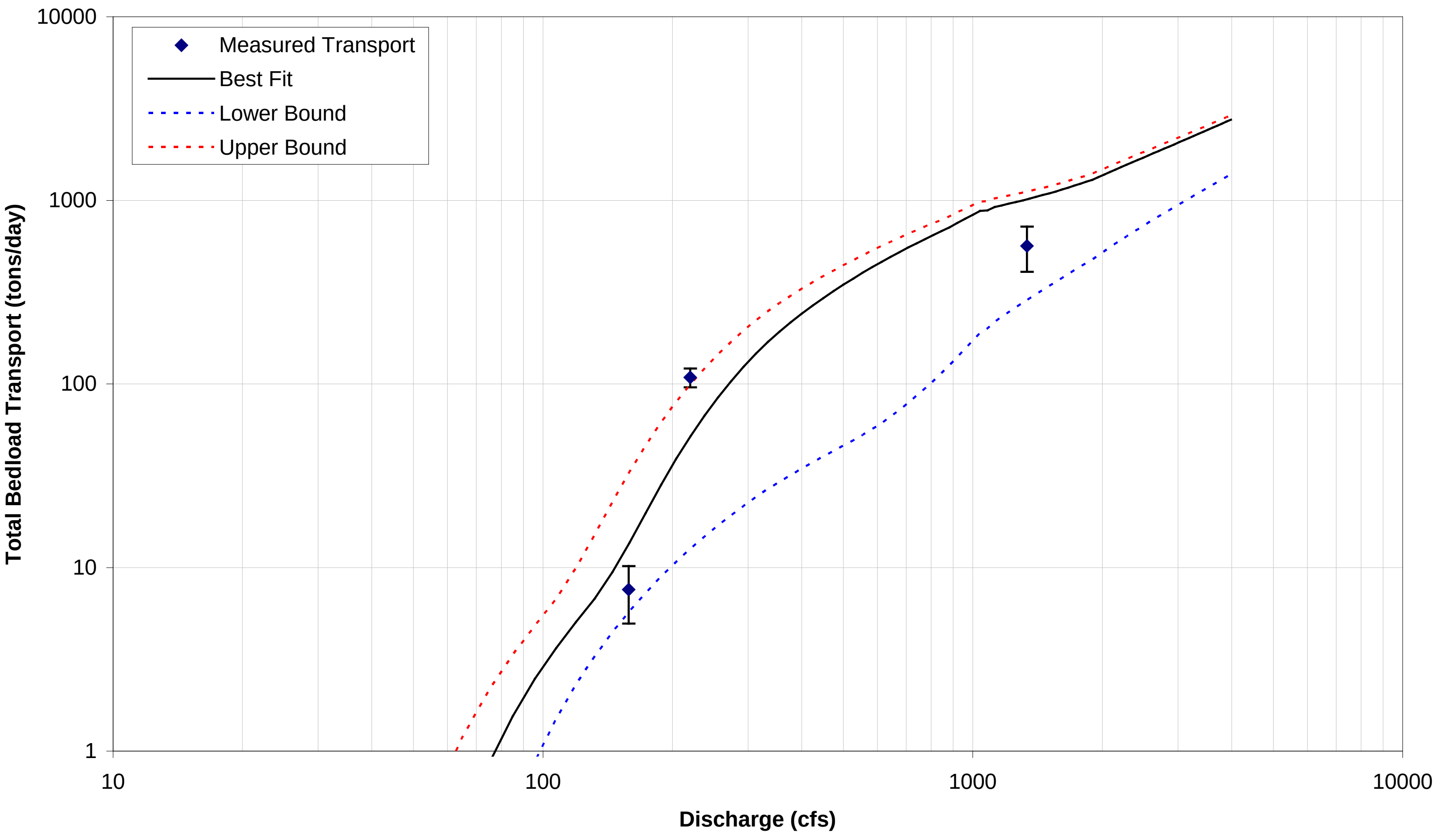
Wilcock (2001) Calibrated Two-Fractional Bedload Transport Model Results:
Total Transport at Ebenezer Road



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Sediment Supply

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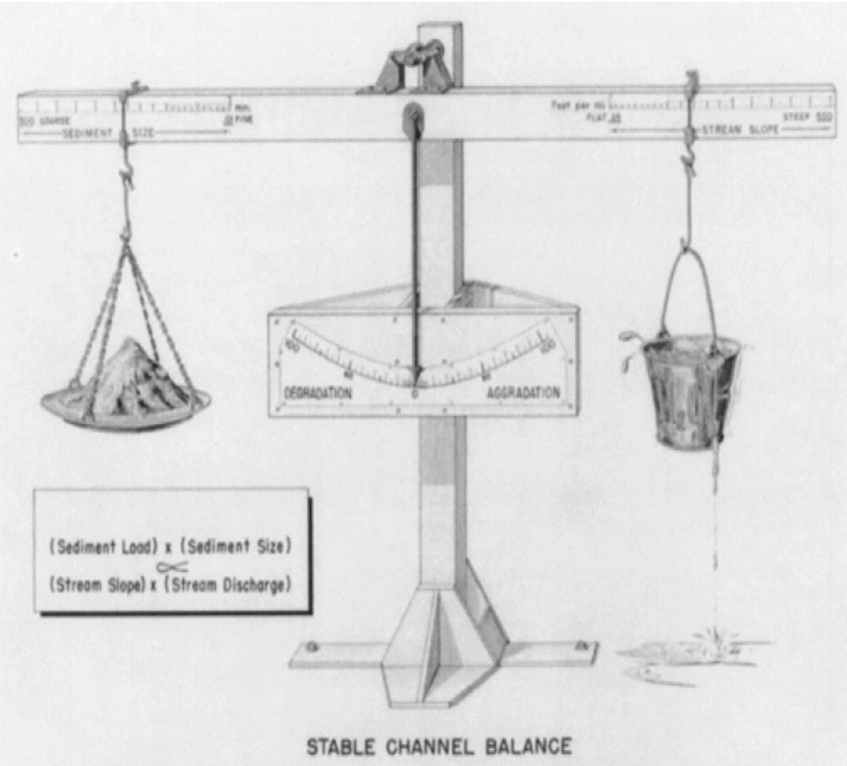
- Primarily sand and gravel
- Annual bedload yield
  - MD Route 7: 5,300 tons
  - MD Route 43: 17,400 tons
  - Ebenezer Road: 8,900 tons
- Localized sources and sinks
- General aggradation

Lane/Borland stable channel stability relation (Borland, 1960)



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Design Process and Agency Negotiations

Whitemarsh Run: Initial Goals

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- Initial mitigation goals
  - Replace the functions and values of impacted wetlands and streams
  - Preserve, enhance, and create wetlands and forest
  - Restore Whitemarsh Run
    - geomorphically stable dimension, pattern, and profile
    - transports sediment and water without aggradation or degradation

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Whitemarsh Run Design Process

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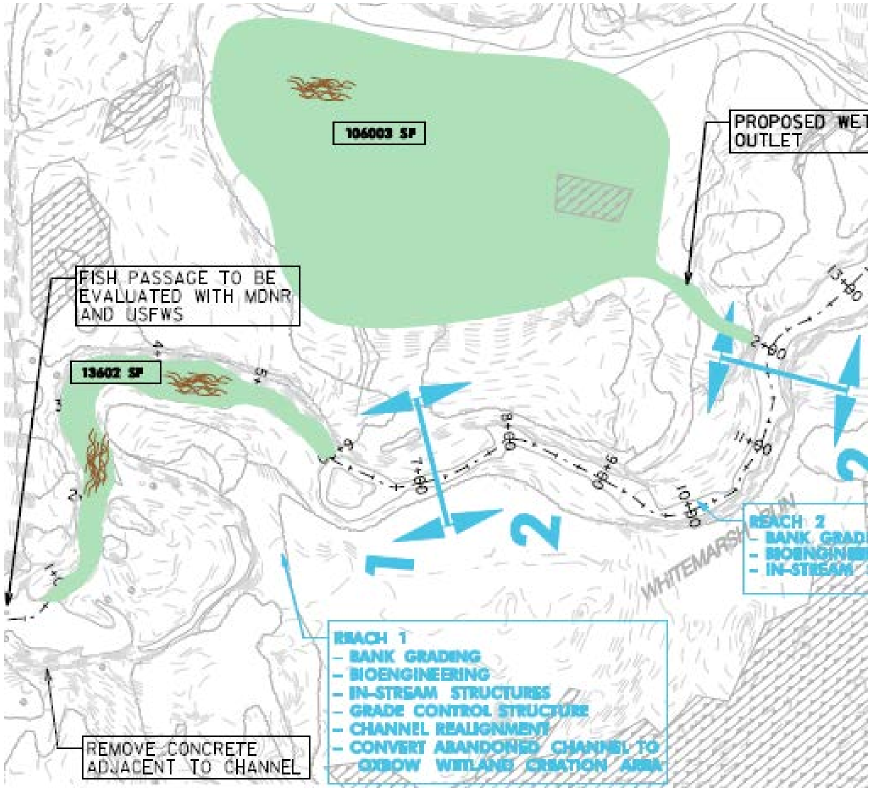
- Initial concept design
  - Natural channel design
- Limitations
  - Agencies wary due to failures
  - Costly
  - No credit for oxbow wetlands



Whitemarsh Run Design Process

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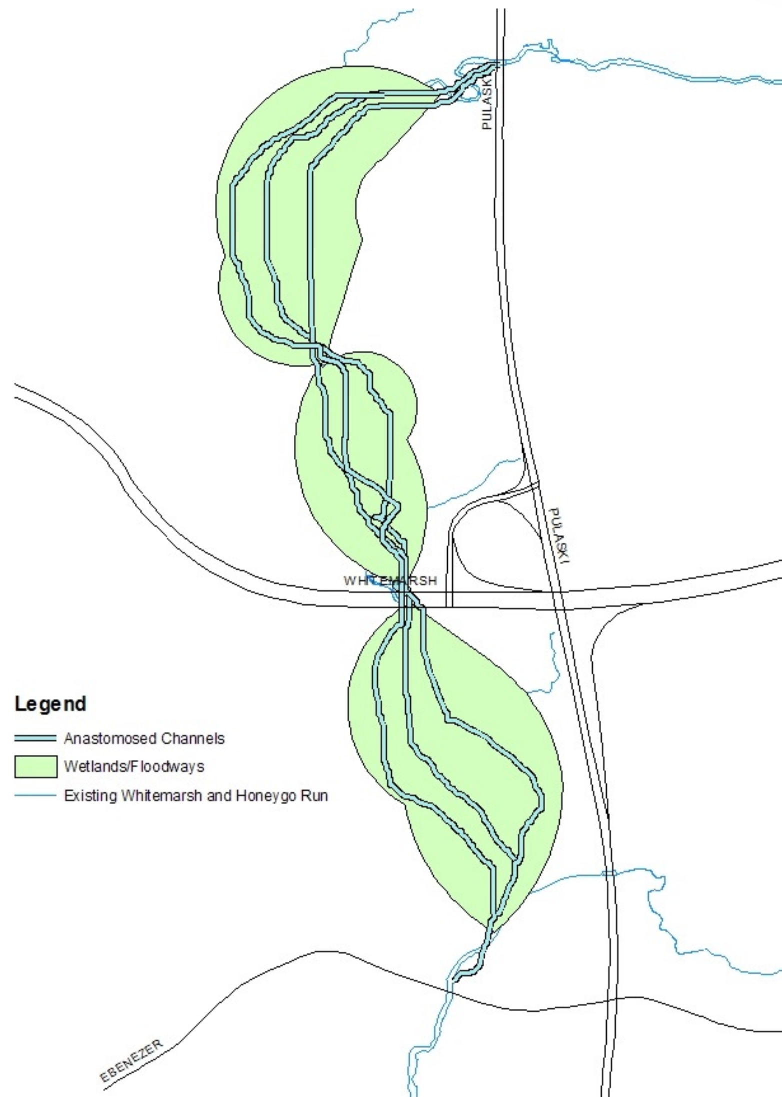
- Other concept stream designs
  - Shallow braided stream through wetlands
    - Suspended sediment and nitrogen removal
  - Limitations
    - Fish passage may be limited
    - Gravel aggregation expected
    - Historical images and topo maps suggest stream is naturally single-threaded



Whitemarsh Run Design Process

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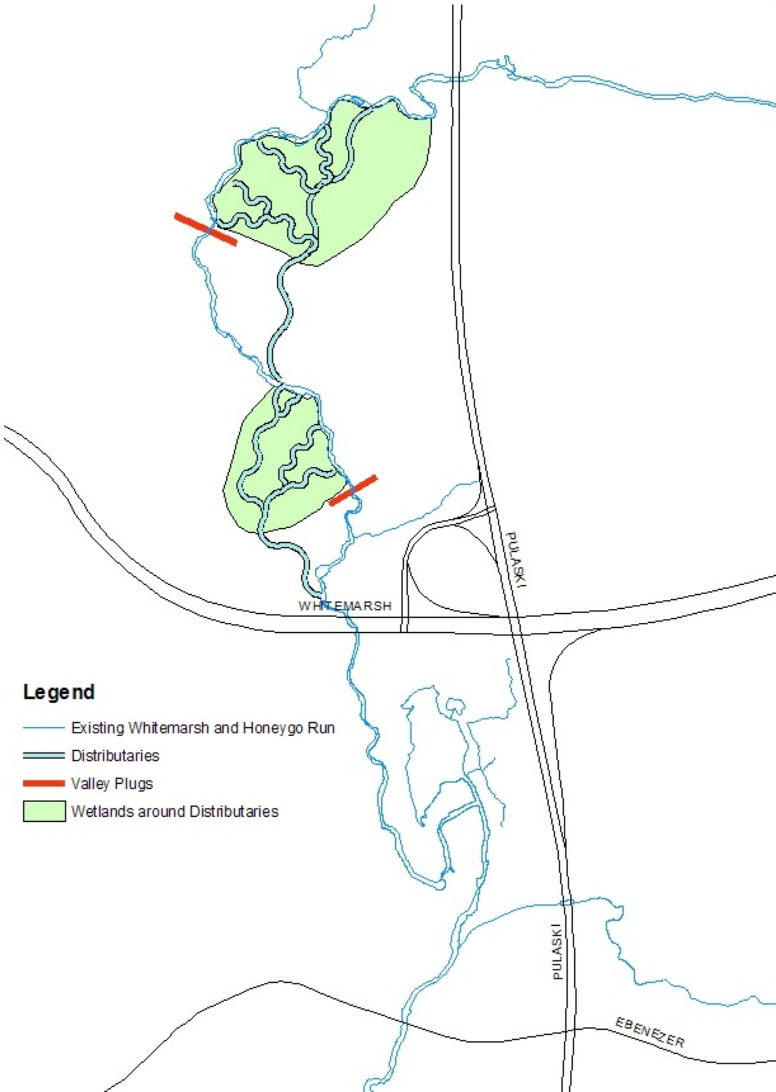
- Other concept stream designs
  - Valley plugs to form distributary channels
    - Store 37K tons of sediment
  - Limitations
    - Fish passage a concern
    - Future stability uncertain



Whitemarsh Run Design Process

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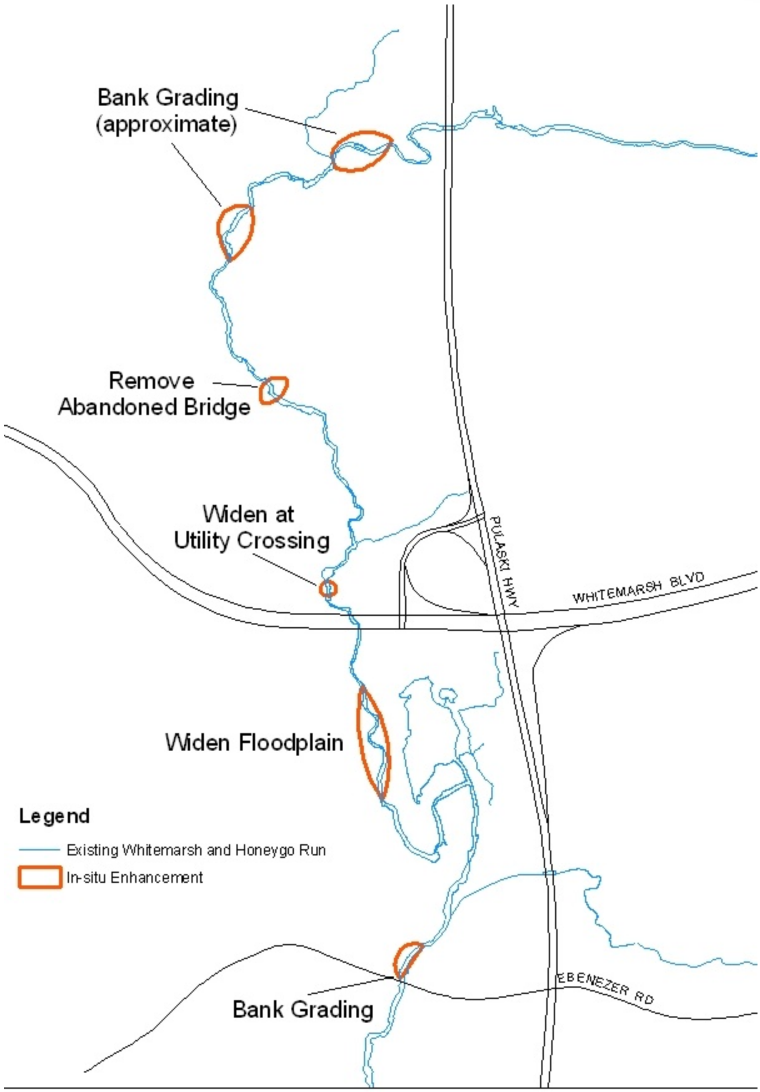
- Other concept stream designs
  - In-situ enhancement
    - Limited bank grading
  - Limitations
    - Fish ladder required
    - No sediment storage
    - Improvements at BGE right-of-ways not possible



Whitemarsh Run Design Process

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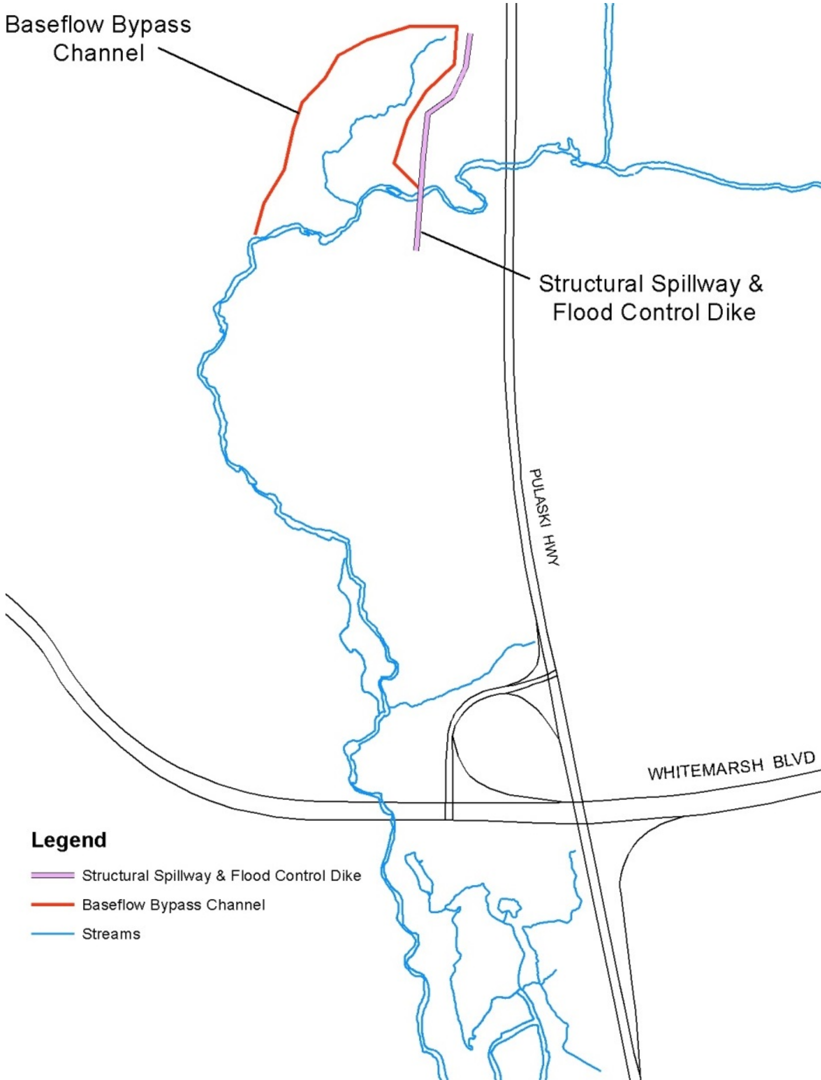
- Other concept stream designs
  - Bypass channel
    - Bypass solely for fish passage at baseflow
    - Primary channel below structural spillway for bedload transport and high discharge conveyance
    - Bypass channel may aggrade and require maintenance



Whitemarsh Run Design Process

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- Revised Goals
  - Primary Objectives
    - wetland creation, enhancement, preservation, and restoration selected locations
    - Protect existing infrastructure
    - Stabilize stream banks at selected locations
    - *Improve fish passage for selected anadromous species at the Route 40 culvert*
      - MDE and NOAA/NMFS recommended a rock riffle grade control structure

Riffle Grade Control Design Process

Whitemarsh Run: Design Constraints

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Conflicting Goals

- Fish Passage
  - Minimum Spring baseflow depth = 9 in
  - Maximum Spring baseflow velocity = 3 ft/s
- Structural stability during the 10- and 100-year discharges
- Competence and capacity to transport existing bedloads
- Maintain existing 100-yr floodplain elevation
- Avoid diesel fuel soil contamination area and utility right-of-ways
- Ensure surficial flow

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Whitemarsh Run Riffle Grade Control

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- Riffle grade controls installed successfully at other Maryland coastal plain streams
  - Previous designs did not consider fish passage, but post-construction monitoring showed positive results for stability and fish passage
  - White Marsh Run presented challenges because of lower baseflow and higher storm discharges

Fish Passage: Baseflow Constraints

- **Goal:** Spring baseflow at least 9 inches deep and less than 3 ft/s
  - 4.2-foot vertical barrier at Whitemarsh Run
  - Alaskan fish ladder was not successful
- Target fish: alewife, blueback herring, and white perch

Structural Stability

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- **Goal:** Immobile D30 stone size at the highest expected shear stresses (10-year and 100-year)
- Stability Checks:
  1. Mussetter relationship (1989) used to develop Manning's 'N' at baseflow conditions
  2. Rosgen's Rock Size Relationship (Rosgen, 2007) for refugia boulders
  3. Riprap Sizing Methods from USACE EM 1110-2-1601 for D30
  4. Wilcock and Crowe (2003) sediment transport function
  5. Modified Andrews critical shear stress
- Grouted sections where needed

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Sediment Transport Capacity

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- **Goal:** Threshold Channel
- Utilized iSURF (Wilcock and Crowe, 2003) transport relation to determine the required cross-sectional width, depth, and slope required to transport the sediment supply input through a channel section.
- Steeper channel will be more "efficient" in transporting sediment.

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Maintain 100-year Floodplain at Rt. 40

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- **Goal:** Maintain 100-year Floodplain at Rt. 40

- White Marsh Run floods Rt. 40 at ~25 year storm
- Design adds significant fill material near Rt. 40
- Oxbow wetland

Whitemarsh Run Riffle Grade Control

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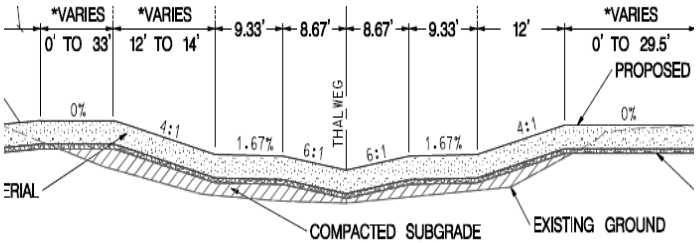
- Iterative design process
  - Stone size and gradation determine roughness at baseflow
    - Which determines baseflow depth and velocity
  - Slope and cross-sectional parameters drive:
    - Baseflow depth and velocity and
    - Required stone sizes for structural stability at 10- and 100-year storms, which must be available stone sizes
  - Bedload competence and capacity determined with models including iSURF
  - Final depths, velocities, and floodplain elevations modeled with HEC-RAS
  - HEC-RAS sheer stress values assisted with stone sizing



Whitemarsh Run Riffle Grade Control

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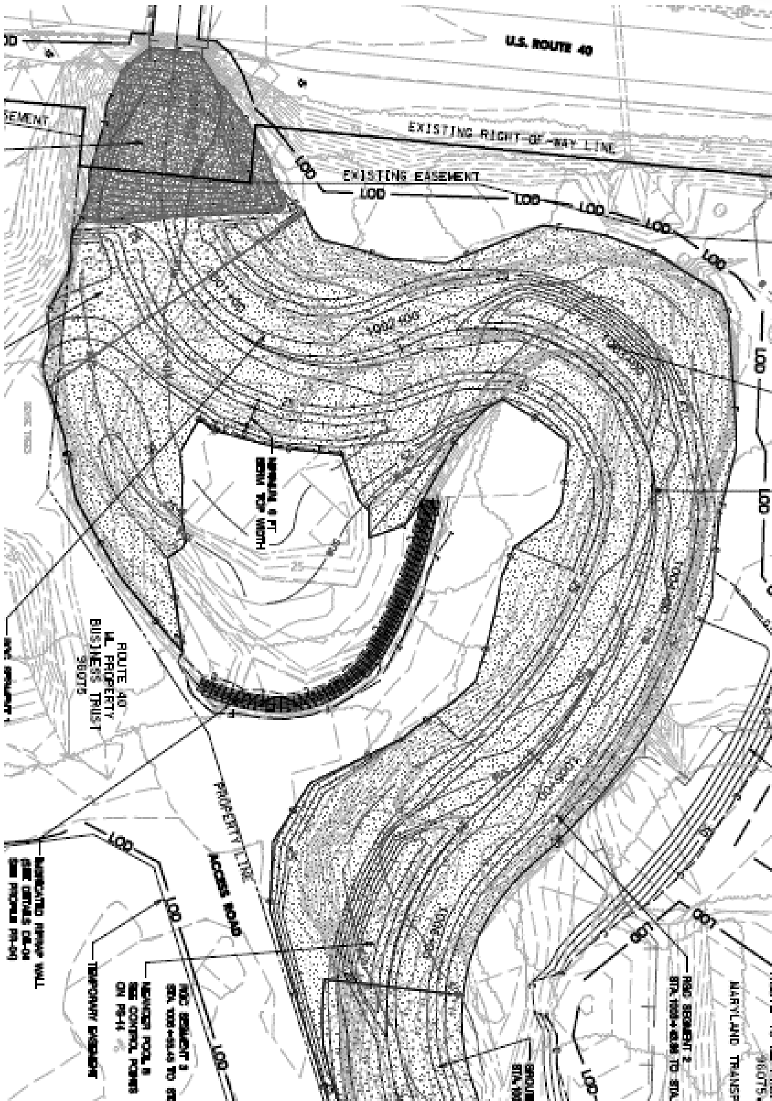
- Riffle Grade Control
  - Plunge pool downstream of U.S. 40 and downstream of RGC
  - Loosely follows the existing stream alignment to maximize length (1,407 ft)
  - Slope = 0.0092 (0.92 %), 3X existing stream slope
  - Contains refugia boulders to provide fish resting areas



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Construction: Riffle Grade Control

Riffle Grade Control Fish Passage

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Stream channel/RGC construction (December 2014)

Riffle Grade Control Fish Passage

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Pump-around established for stream work; note grouted riprap section (lighter area immediately left of pump). (December 2014)

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Riffle Grade Control Fish Passage

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Grading a section of stream prior to placing riprap (December 2014)

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Riffle Grade Control Fish Passage

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Stream channel/RGC construction (January 2015)

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Riffle Grade Control Fish Passage

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Riffle Grade Control Fish Passage

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Bank Stabilization

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Bank Stabilization

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Imbricated riprap, bank grading and stabilization at an area downstream of the RGC. (January 2015)

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Bank Stabilization

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Red line plans were needed due to stream movement from topo (2008) to construction (2014).

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Vernal Pool Construction

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Vernal pool after construction; note use of root wads from trees cleared on site. (December 2014)

PARSONS BRINCKERHOFF

Vernal Pools Post Construction

Signs of life in the vernal pools (April 2015)

Vernal Pool Survey 2016

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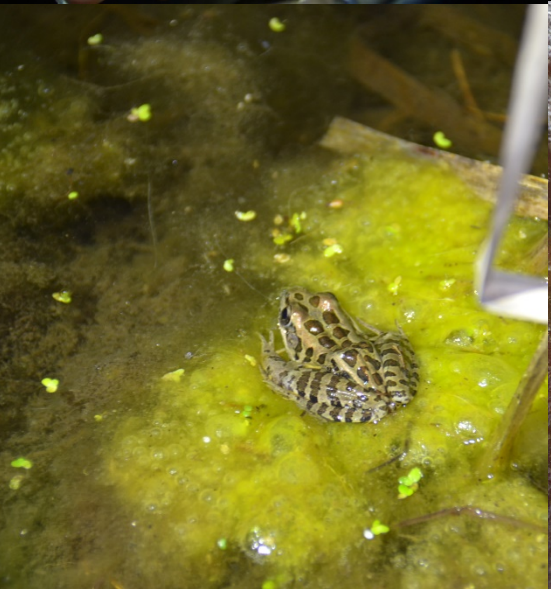

Wetland Creation

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Treatment of Invasive Species

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Initial Results are Positive

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- The Riffle Grade Control held up after a 10-year storm shortly after construction
  - Isolated damage to new trees
- Anecdotal evidence of fish passage in the spring and fall (gizzard shad)

Discussion

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- Regulatory agencies drive priorities
  - Fish passage requirement
  - Resistance to unproven concepts
  - Lengthy negotiations for out of kind mitigation
- Uncertainty drives costs
  - Initial studies, peer reviews, independent experts
  - Iterative designs and multiple models
- Large rock provides stability but drives costs
  - More natural solutions can reduce costs

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