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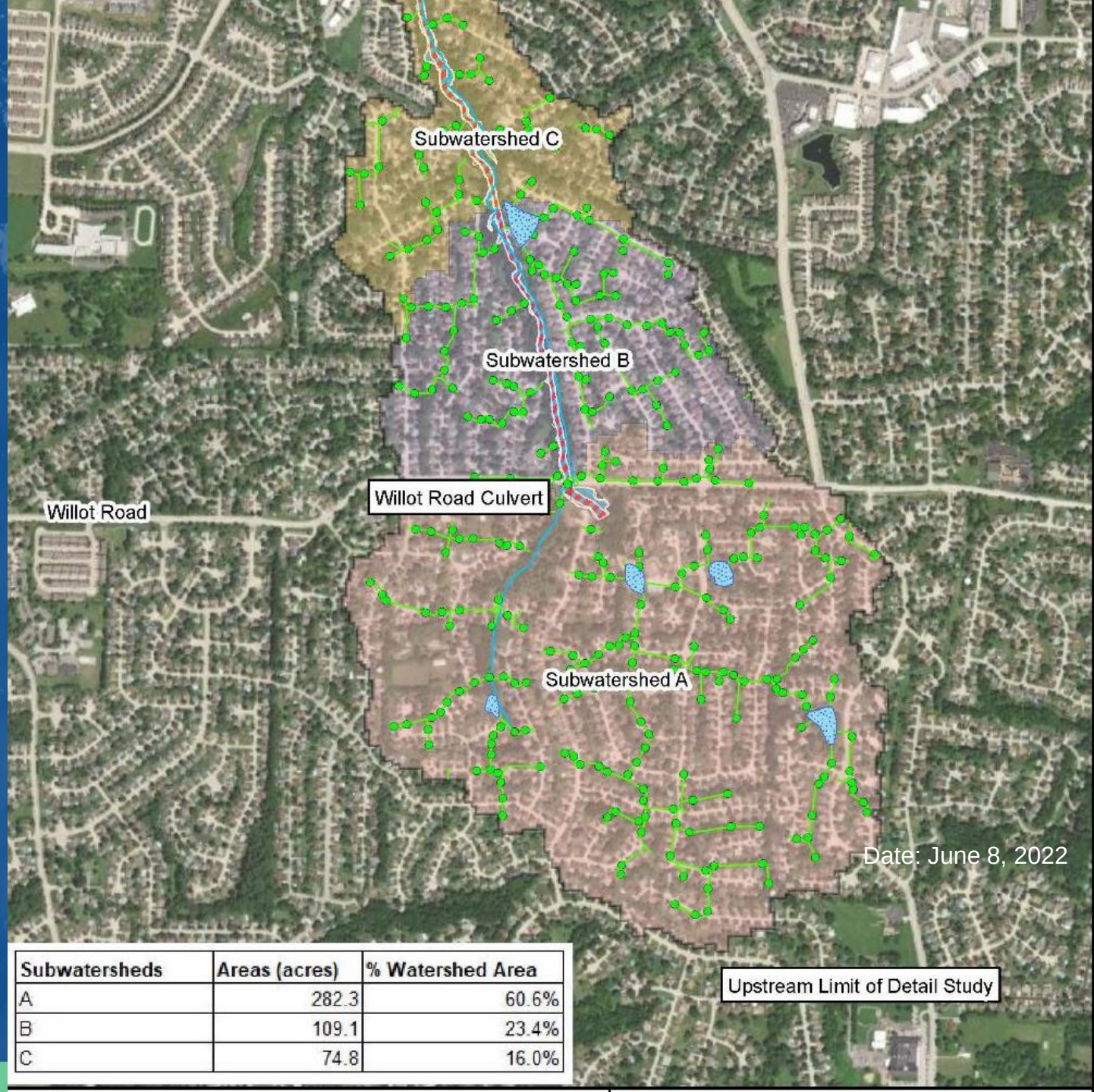
St. Peters, MO
Willott Road

Culvert & West Spencer Creek Improvements

Session 3B – IAFSM 2023

Presented by:

Matthew Bardol, PE, CFM, CPESC, D.WRE



Subwatersheds	Areas (acres)	% Watershed Area
A	282.3	60.6%
B	109.1	23.4%
C	74.8	16.0%

Topics

- Background
- Scope of Improvements
- Field Investigation
- Design Development
- Regulatory Coordination
- Design Outcomes

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Background

Existing Issues leading to Project

Background

Existing Issues:

- Roadway Crossing
  - Dual 72-inch RCP failure, excessive scour, & settlement
  - Exposed 10-inch sanitary
- Creek Corridor
  - 2,000 LF is experiencing severe incising & scouring
  - Unstable creek banks
  - Adjacent pedestrian trail & bridge at risk

How did we get here?

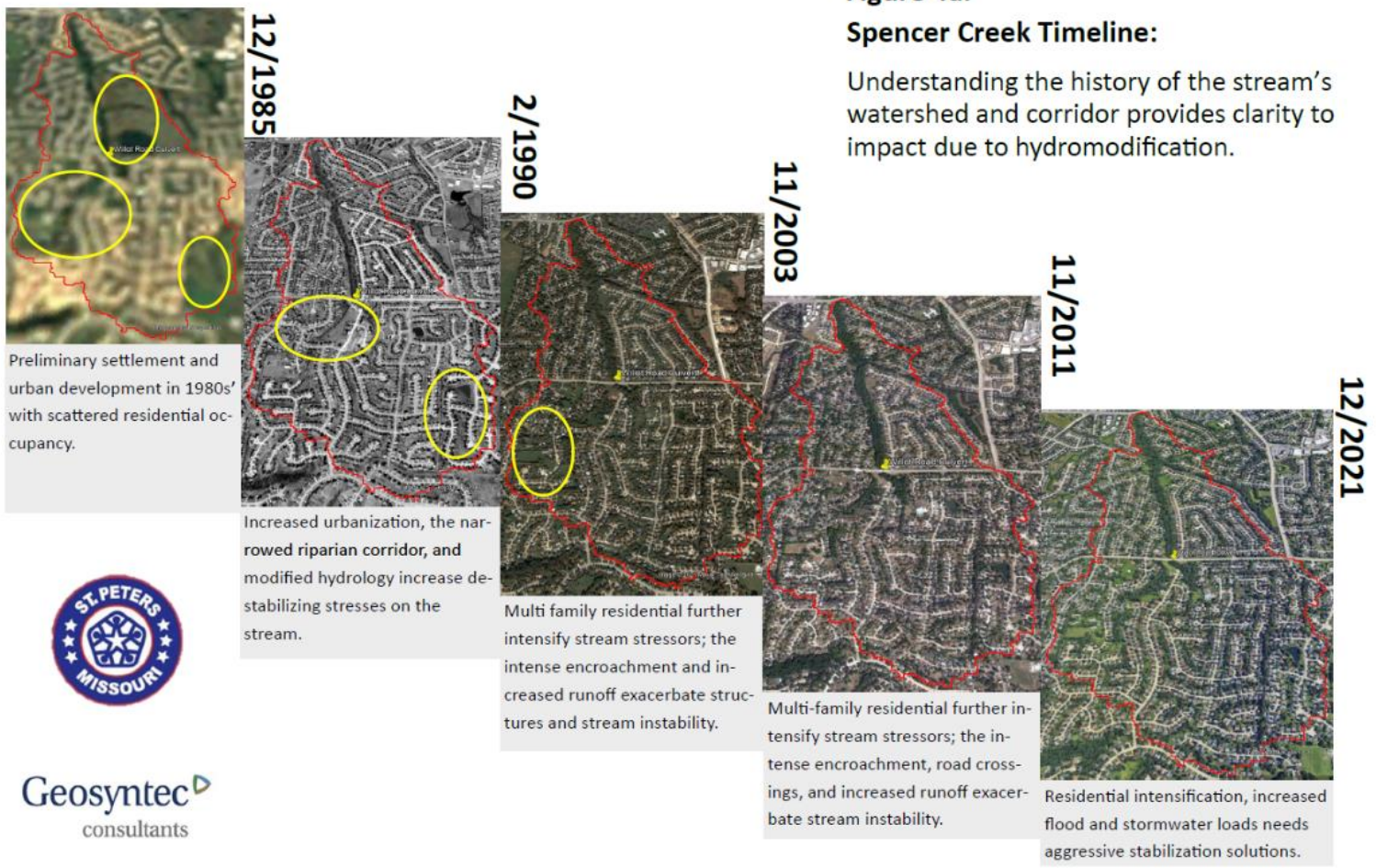

Figure 4a.

Spencer Creek Timeline:

Understanding the history of the stream's watershed and corridor provides clarity to impact due to hydromodification.

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Background

May 2011 Photograph:

- Incised creek channel
- Head-cut migrating towards roadway culverts
- Grout lining and armoring undermined by head cut

Roadway Crossing (Fall 2022)

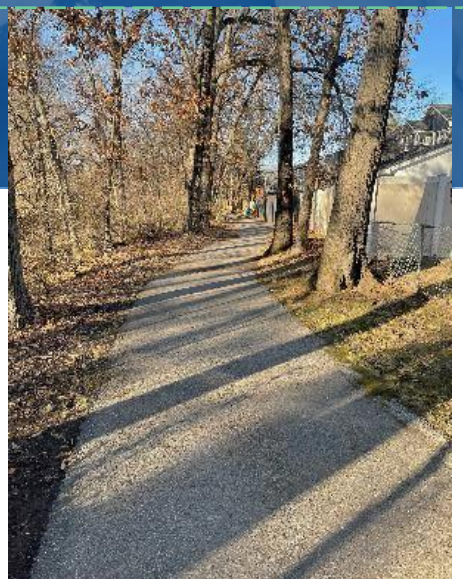
Upstream End: Deterioration of grouted channel & slope above culvert inlets. Overgrowth and debris.

Culvert pipes are settling at both ends

Downstream End: Channel Incising, bank scour, exposed sanitary sewer, & flared end settling/disconnected

Spencer Creek Corridor (Fall 2022)

Incising, Bank Scarps, Slope Destabilization & Root Exposure



Bank Scour is nearing the Pedestrian Trail & present at Bridge Abutments

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Scope of Improvements

Approach Outlined at Beginning of Project

Scope of Improvements – **Integrated Design Approach**

Scope of Improvements

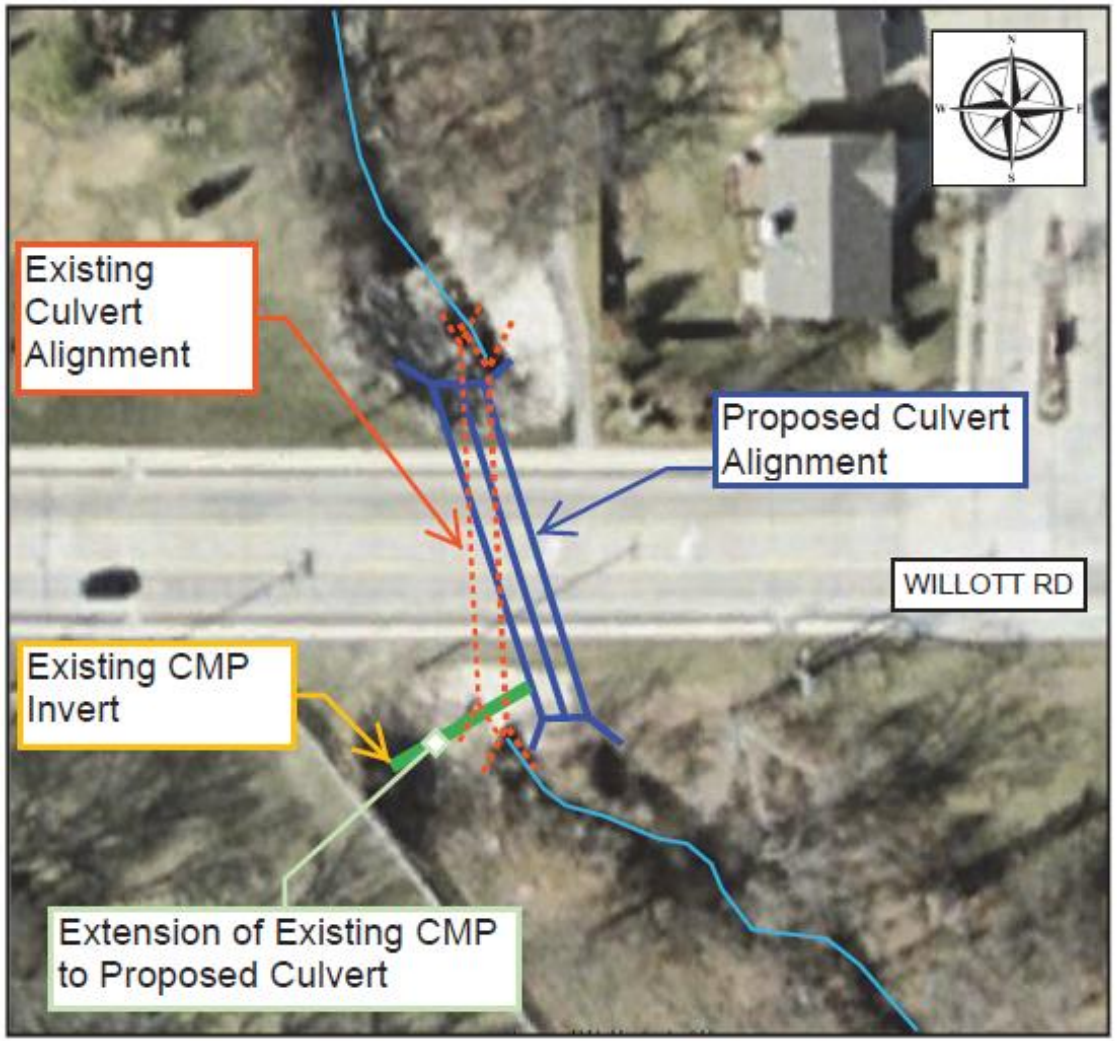

Figure 5. Conceptual Culvert Realignment

Roadway Crossing

- Realign and replace culvert vs repair
- Extend culvert over exposed sanitary sewer
- Restore creek bank, protect with formal energy dissipation at outlet
- Increase hydraulic capacity to 100-year, 24-hr event
- Design headwall and wingwall to reduce road embankment slopes

Scope of Improvements

Creek Corridor Improvements

- Restore and stabilize slopes
- Re-introduce gentle sinuosity in creek alignment
- Design grade control structures
- Reduce bed and side slopes
- Integrate hard armor with angular stone and boulder toe protection
- Bioengineering on mid & upper creek bank slopes

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Field Investigation

Site Surveying

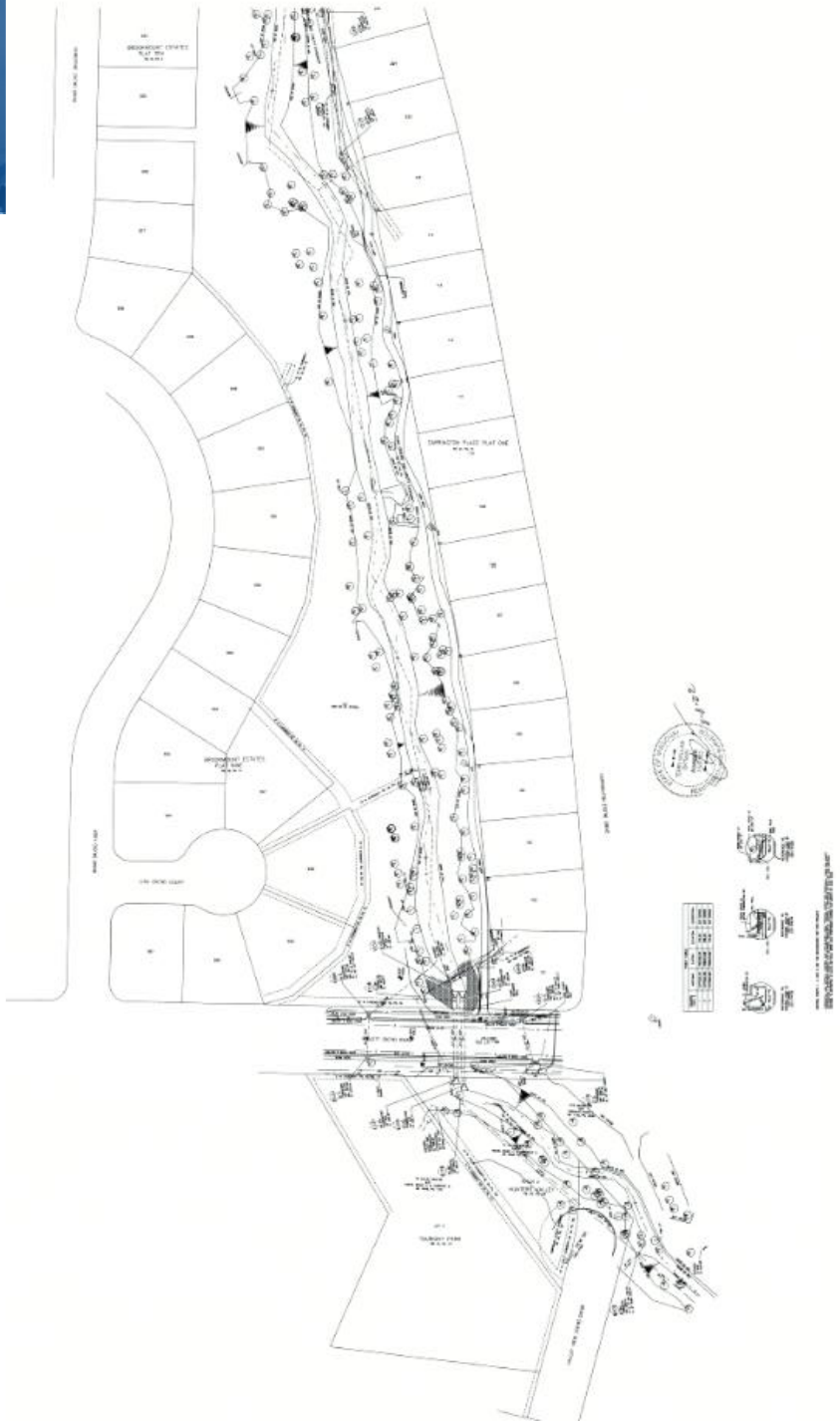
Geotechnical Investigation

Culvert Condition Assessment

Geomorphic Assessment

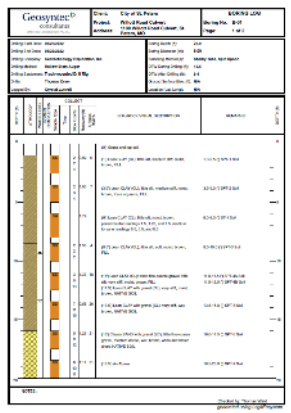
Field Investigation: Site Survey

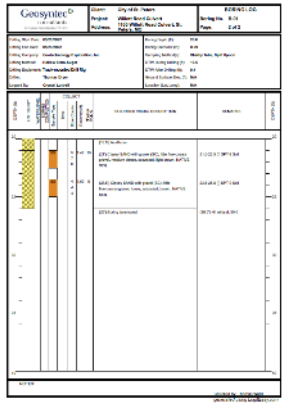
- Detailed Terrain & Topography
  - LiDAR resolution was too low
  - LiDAR impacted by tree canopy & vegetation
- Creek Corridor Survey
  - Outfall Structures
  - Channel cross-sections, centerline, bed features
  - Overbanks, rill erosion, minor drainage lines
  - Property lines and easements
  - Trees 8-inch or greater in diameter
- Detailed Roadway Crossing
  - Culverts, utilities, and slope
  - Edge of pavement, edge of armoring, roadway features
- Collaboratively worked with survey crew



Field Investigation: Geotechnical

- Multiple Borings at Crossing
- Critical to Understand Soil Properties
  - Parent material strength to support culvert & traffic loads
  - Bearing strength to support potential loads of embankment reconstruction or headwall
  - Significant factor in existing culvert settlement & failures
- Analytical Lab Results
  - Informed structural analyses
  - Used for design of headwalls, roadway, and culvert bedding





Field Investigation: Culvert Assessment

- Detailed assessment of structural conditions
  - Determination to repair or replace infrastructure
  - Provided justification for design decision
  - Develop design to mitigate failures in the future
- Issues identified included:
  - Vertical offsets, circumferential cracks exposing rebar, settlement pools, shear cracking, joint seeps and scour around the culvert pipe ends
- Issues attributed to:
  - Poor foundation support
  - Loads exceeding bedding soil strength
  - Erosion and scour

PHOTOGRAPHS

Above: Concrete grout in the invert of the pipe.

Above: Vertical Offset

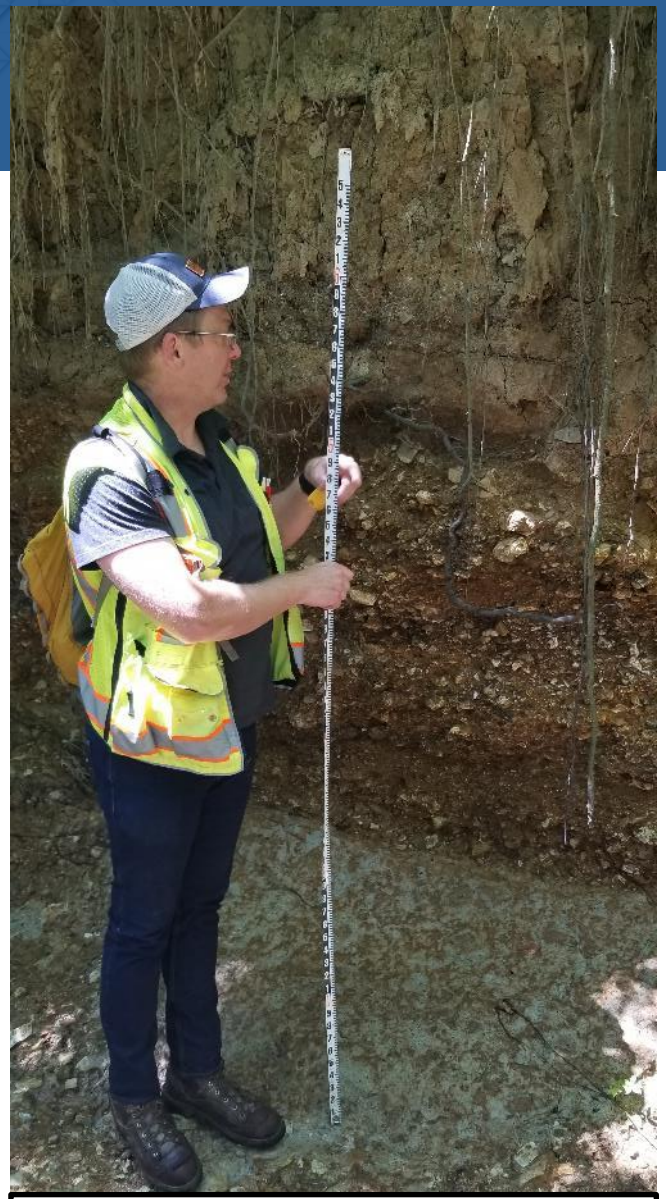
Right: Slabbing

Above: Pipe wall condition below 36 inch RCP penetration.

Above: Circumferential cracks at downstream end with exposed rebar.

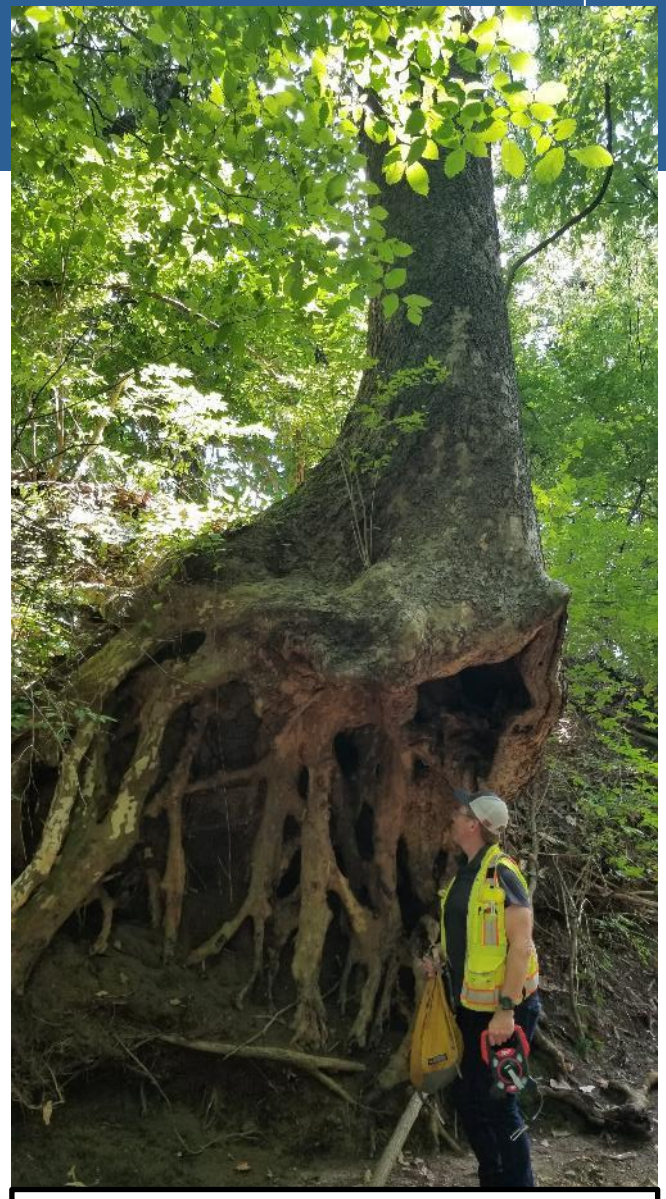
Field Investigation: Geomorphology

- Measurements
  - Pool, Riffle, Transverse Bars
  - Stable channel cross section
  - Pebble Counts
- Channel Soil Stratification
- Bedrock Outcrops
- Vegetation Species
- Aquatic Life
- Observation of varying cross-sectional geometry, bed slope, bank stability, scour, and incision channel evolution



Overbanks over 5 feet from bed rock on left bank.

Stratification observed on right bank.



Exposed root system on the right bank.

Riffle pebble count downstream of the pedestrian bridge

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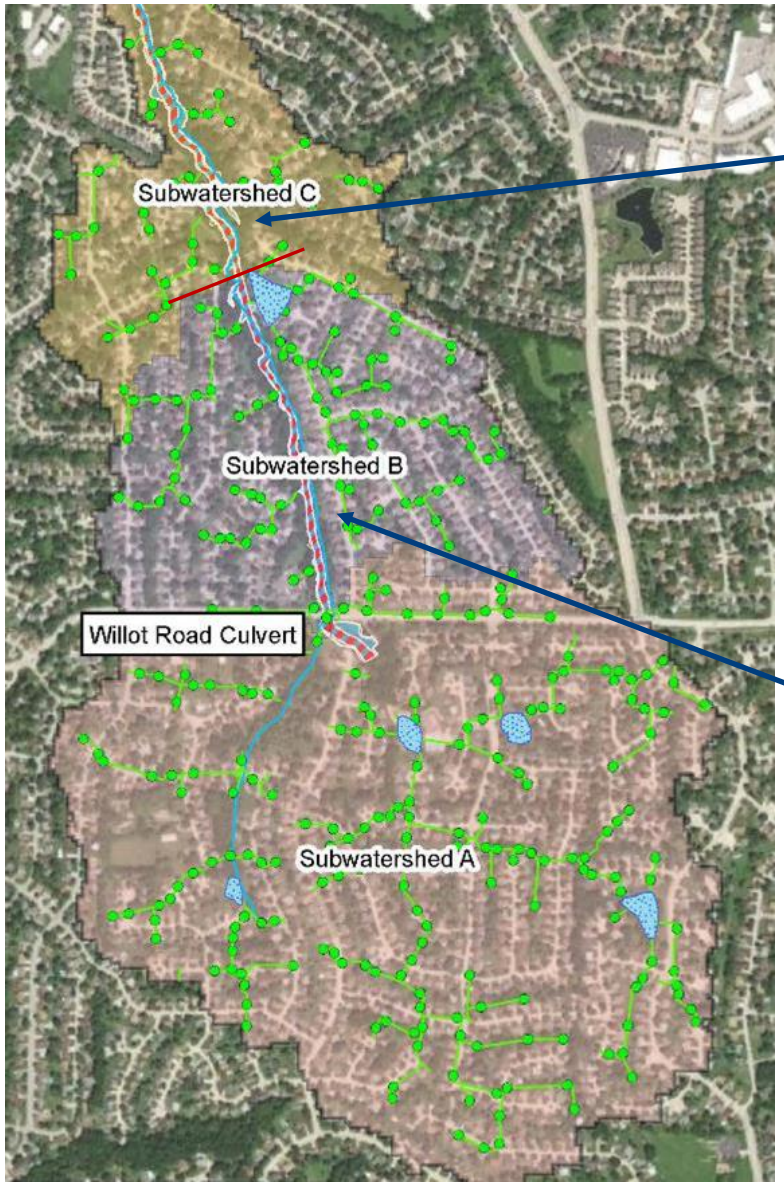
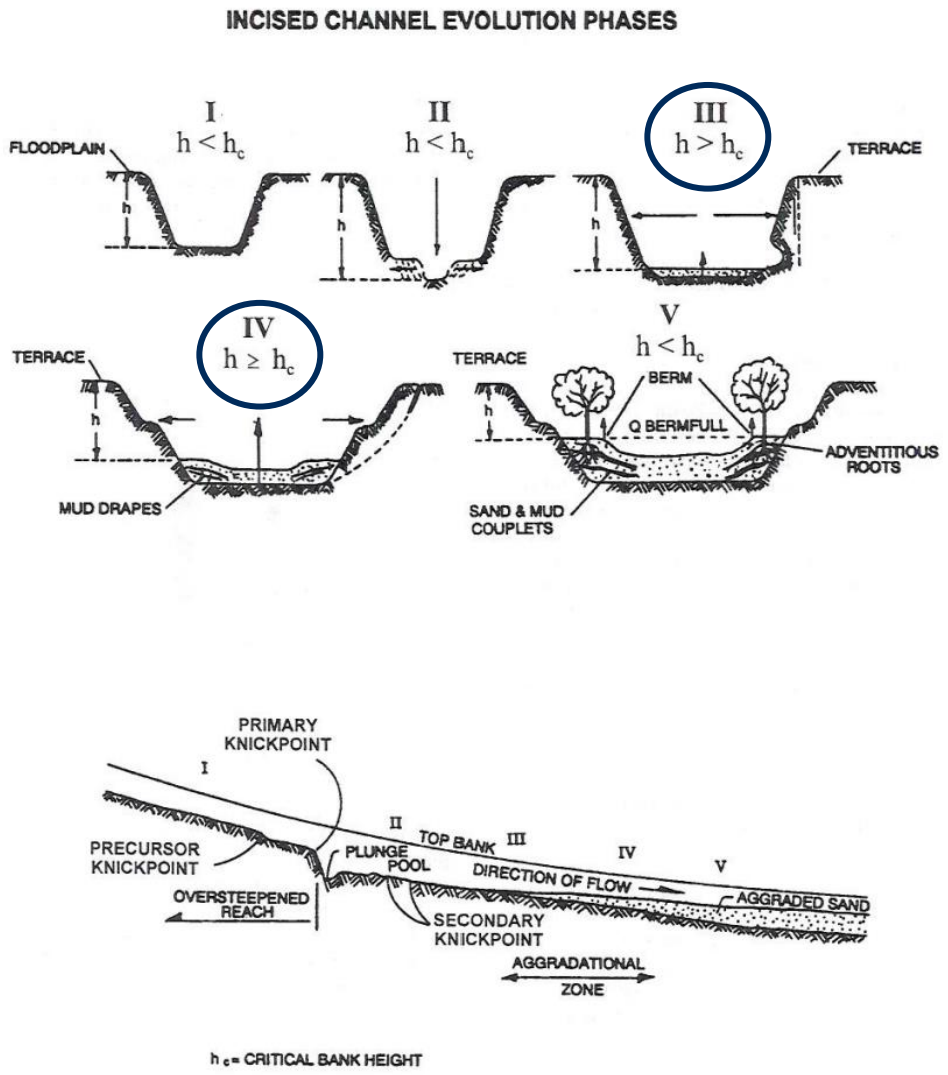
	Inches	Millimeter	Count
Gravel	0.16-0.22	4-5.7	1
	0.31-0.44	8-11.3	2
	0.44-0.63	11.3-16	4
	0.63-0.89	16-22.6	11
	0.89-1.3	22.6-32	28
	1.3-1.8	32-45	36
	1.8-2.5	45-64	17
	2.5-3.5	64-90	2
Cobble	3.5-5	90-128	1
			102

Geomorphology Assessment: Channel Evolution



Class IV downstream of pedestrian bridge

Class III upstream of pedestrian bridge



Incised Channel Evolution Sequence Schumm et al. 1984

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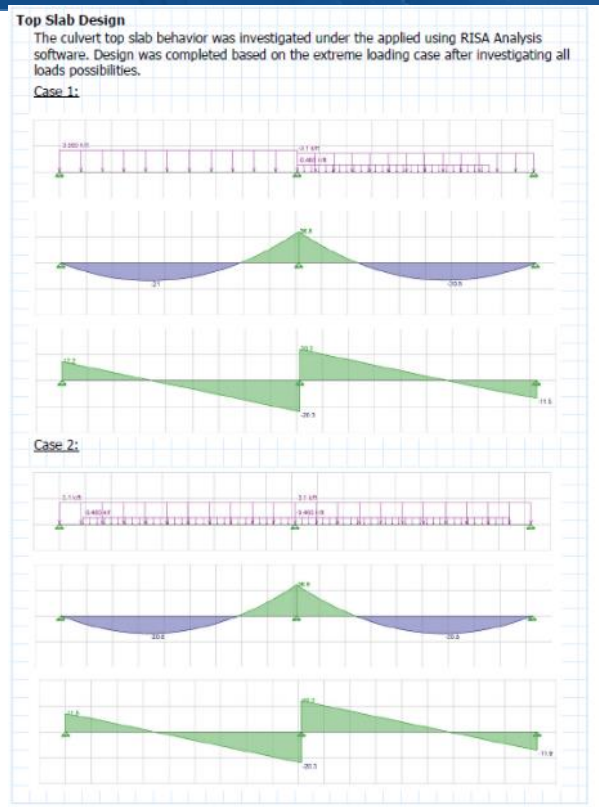
Design Development

1) Geotechnical and Structural Design
2) Hydrology and Hydraulics
3) Channel Design

Geotechnical and Structural Design

- Geo-structural stability
  - Foundation material and settlement mitigation (bearing capacity)
  - Slope stability adjacent to roadway
  - Headwall to support lateral loads
- Design of reinforced concrete culvert & headwall
- Geotechnical investigation facilitated efficient design
  - Reduce assumptions
  - Reduce potential unforeseen conditions



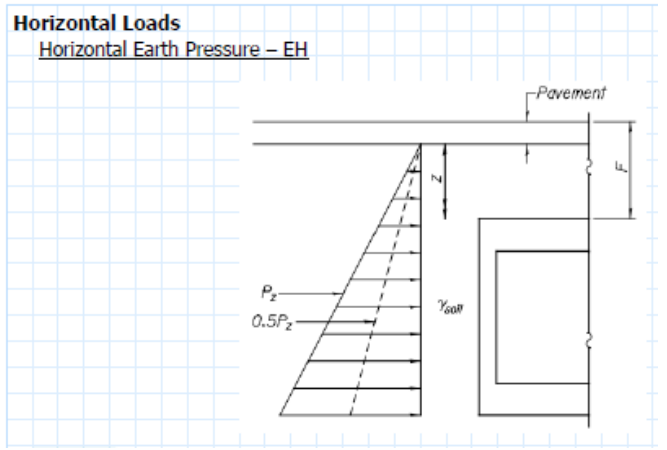


Table 2 – Lateral Earth Pressures

Soil Unit	Total Unit Weight, γ_t (pcf)	Effective Friction Angle, φ (°)	Drained Coefficient of Lateral Earth Pressure at Rest (K_0)	Drained Coefficient of Active Lateral Earth Pressure (K_a)	Drained Coefficient of Passive Lateral Earth Pressure (K_p)
Lean Clay	124	30	0.50	0.33	3.00
Clayey Sand with Gravel	134	31	0.49	0.32	3.12

Hydrologic & Hydraulic Analyses

- Design Storm Events

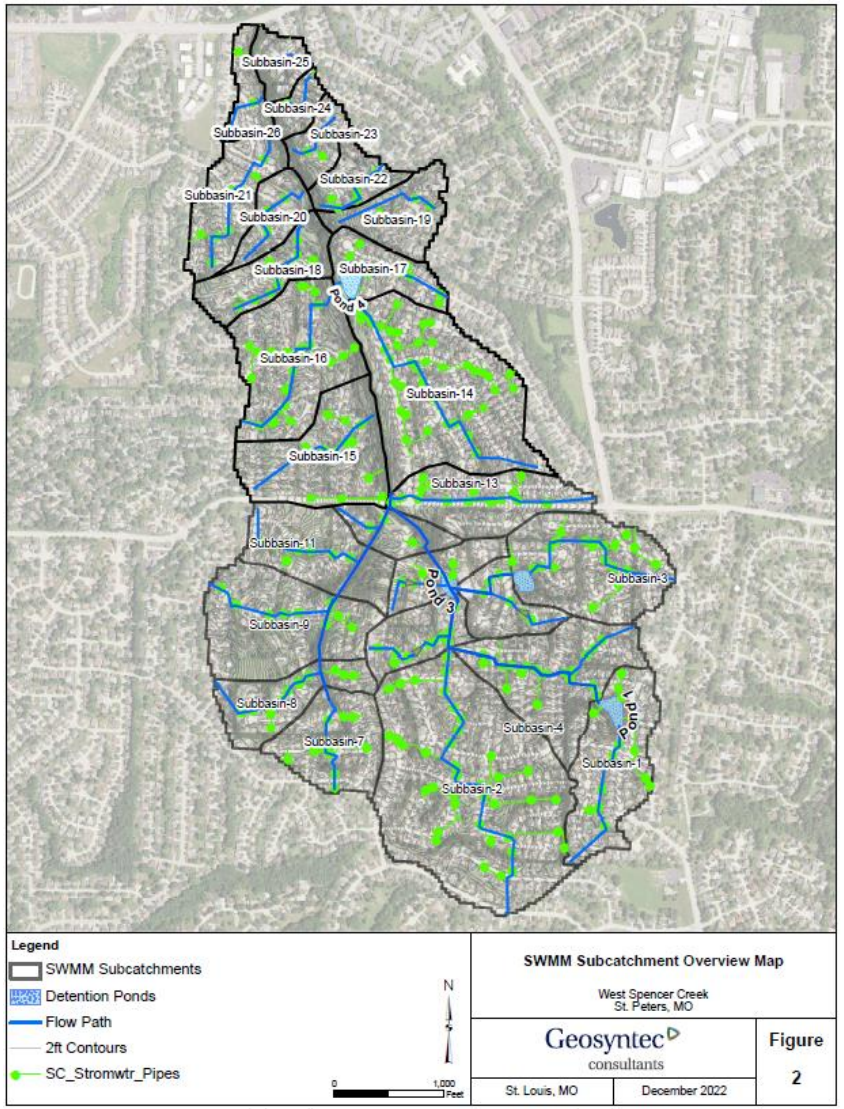
Distribution	Rainfall Event	Analysis
SCS Type-II	100-year	Peak flows for analysis of flood protection and channel design
SCS Type-II	1&2-year	Bank full flows for evaluation of natural channel forms

- FEMA Flood Events
  - 10-, 50-, 100- and 500-year

- Hydrologic and Hydraulic Modeling
  - EPA SWMM (hydrology)
  - HEC-RAS (hydraulics)

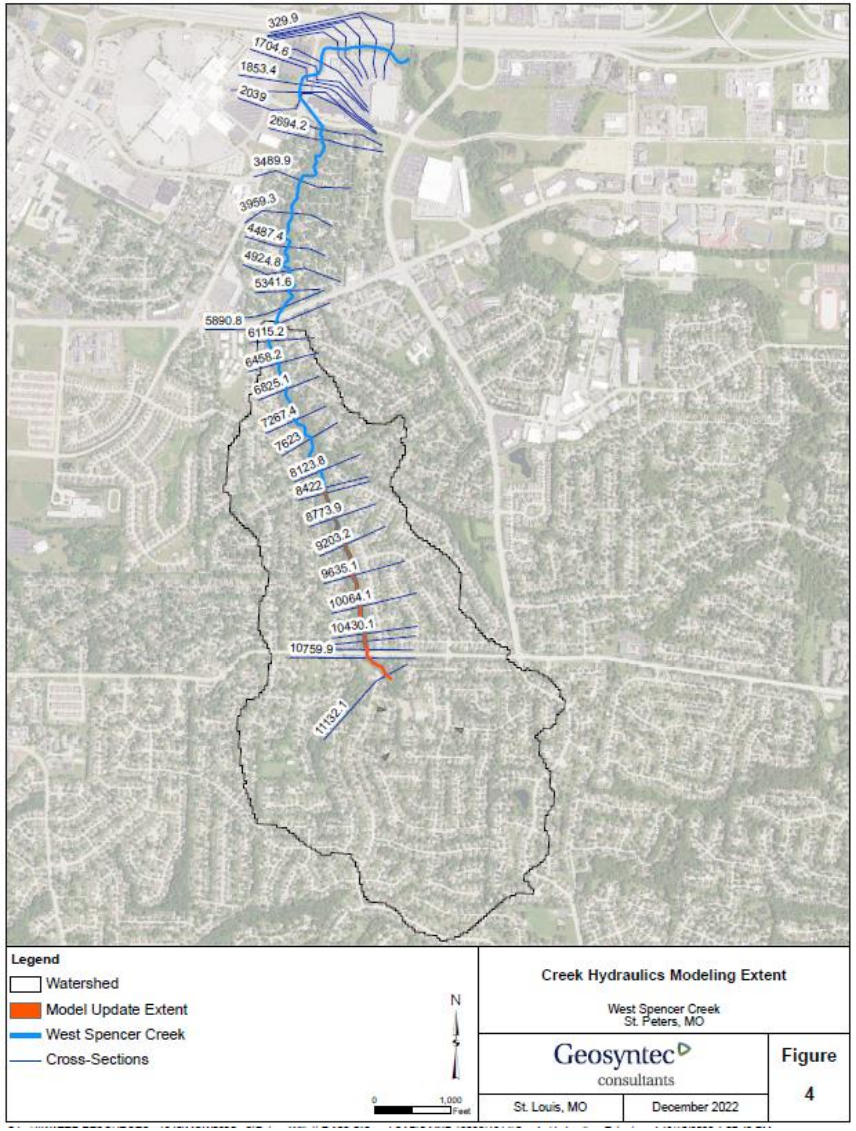
Hydrologic Assessment

- Hydrologic Model of Watershed
  - EPA-SWMM
    - Consistent with prior municipal projects
    - Flexibility in model development
  - Design Storm Runoff Hydrographs
  - Peak runoff flow comparison
    - FEMA Flood Insurance Study (FIS) 1996 & 2011
    - USGS StreamStats
  - Steady and unsteady flow simulation to evaluate culvert design and potential impacts or improvements
    - Accurately assess impacts from proposed projects on flashy creeks



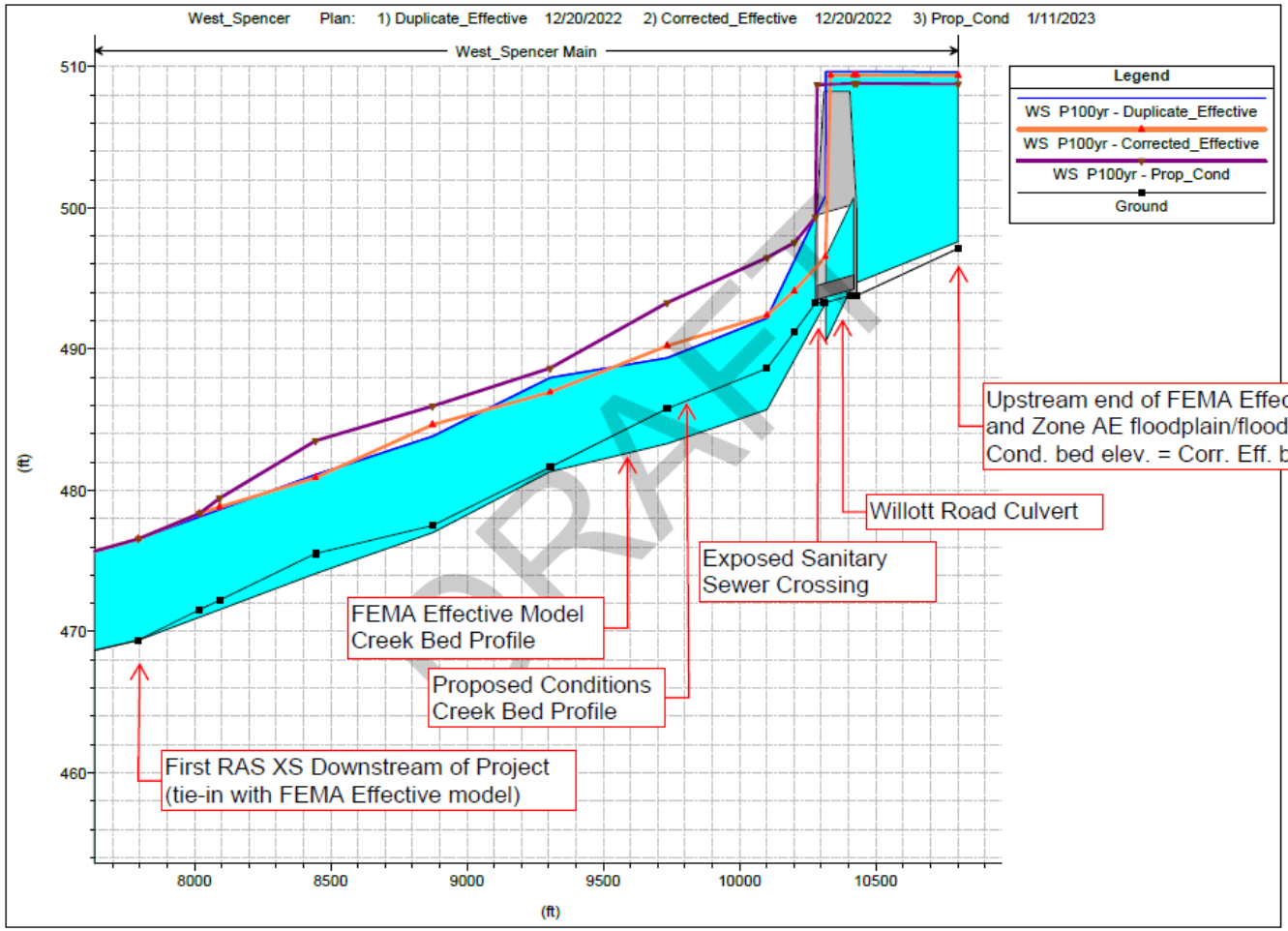
Hydraulic Analysis

- Hydraulic Model of Creek & Culvert
  - HEC-RAS: used for design & updating FEMA FIRM
  - Effective model (2010) and County FIS obtained from FEMA Library
  - Duplicate Effective simulation with latest RAS version
  - Corrected Effective created with CADD surface created with 2022 survey data
  - Proposed Conditions created using
    - CADD surface of improved/designed creek geometry
    - Updated model parameters (e.g. Manning n values)
    - New replacement culvert geometry



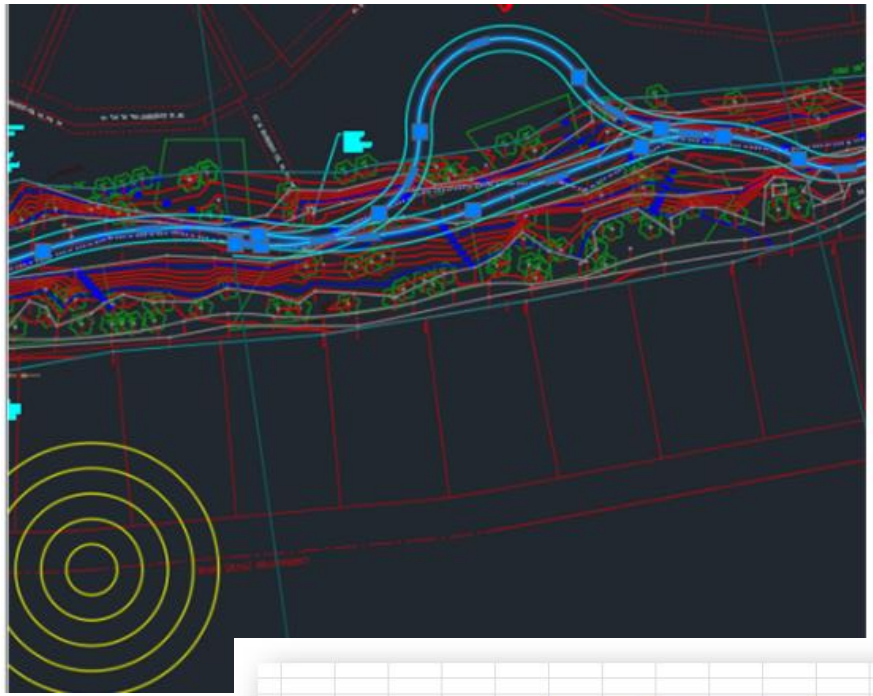
Hydraulic Analysis

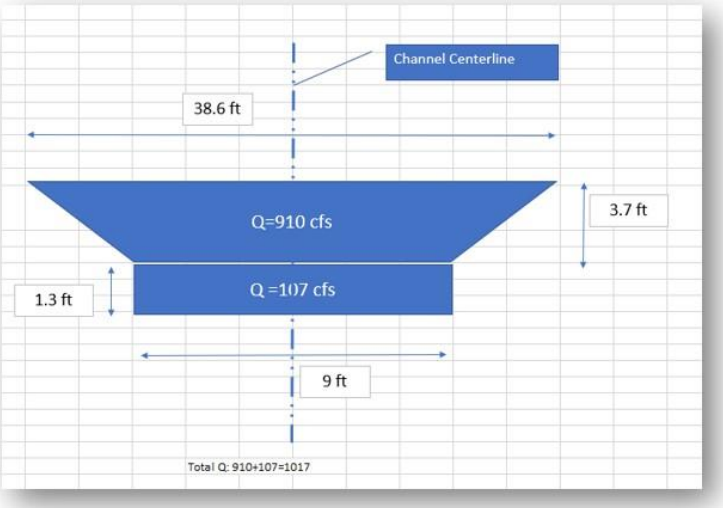
HEC-RAS 100-year Simulation Results Comparison;
1) Proposed, 2) Corrected Effective, 3) Duplicate Effective, and 4) Historical 1996 BFE



Channel Design

- Geometry and Alignment
  - USA Bieger 2015 Bankfull Statistics Report
    - Used to inform channel design given bed slope
    - Compared to downstream reference reaches
  - Channel cross section used to develop proposed channel alignment (iterative process)
    - Aimed to provide gentle meandering
    - Tie-in efficiently with existing creek banks
    - Minimize removal of critical trees
- Blended Armor Protection
  - Threshold channel design
  - Integrate hard armor with angular stone and boulder toe protection
  - Soil bioengineering on upper slopes
- Boulder Grade Control Structures





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Regulatory Coordination

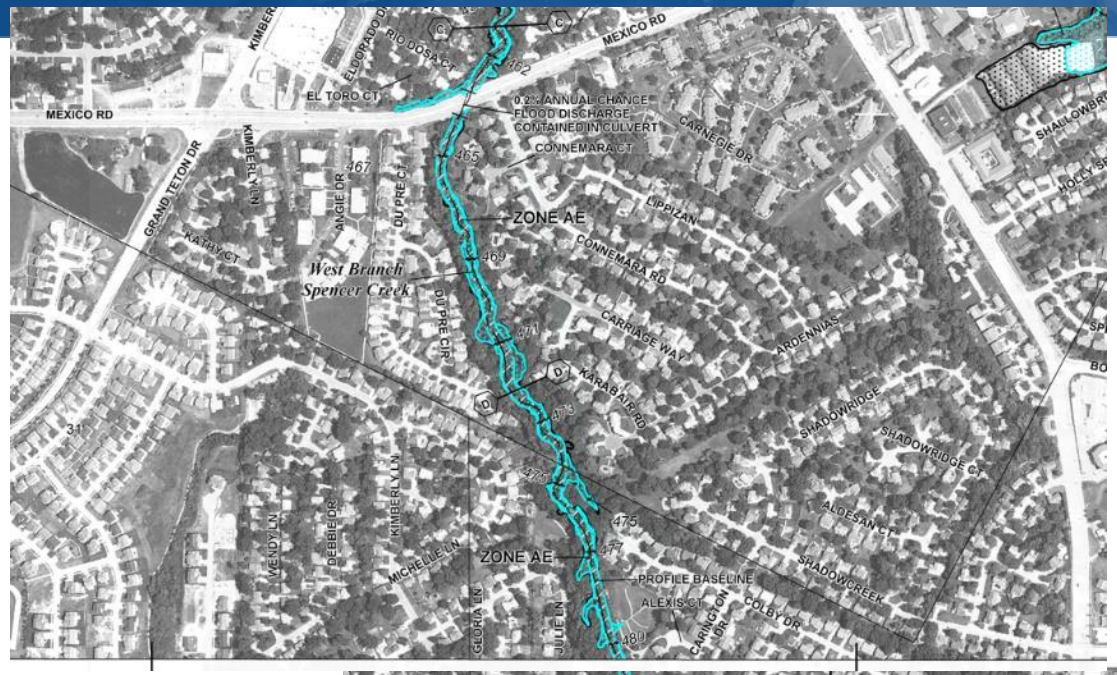
City of St. Peters, FEMA Floodplain Administrator, and USACE

Local Floodplain Administrator (FA)

- Collaboration with FA to satisfy conditions for local floodplain permits

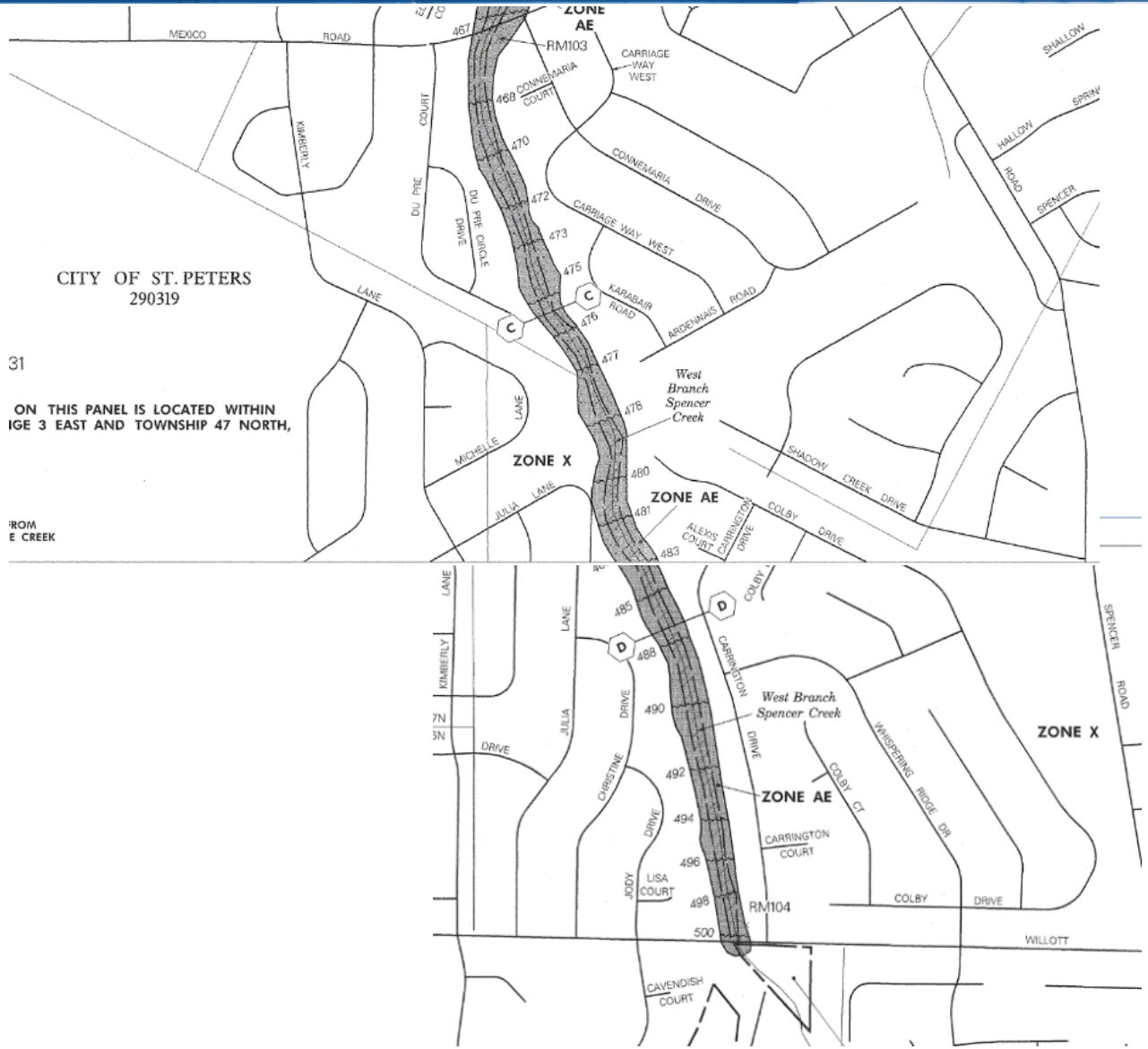
- Challenging, unnatural creek condition
  - Excessive incision resulting in unstable banks, but providing increased hydraulic conveyance
  - Design approach is to restore channel bed (i.e. fill channel bed to historic condition)

- Justification of rise in floodplain
  - Restore incised creek bed to historical condition
  - Protecting existing infrastructure (i.e. exposed sanitary sewer line)
  - Rise in BFE is fully contained within City property



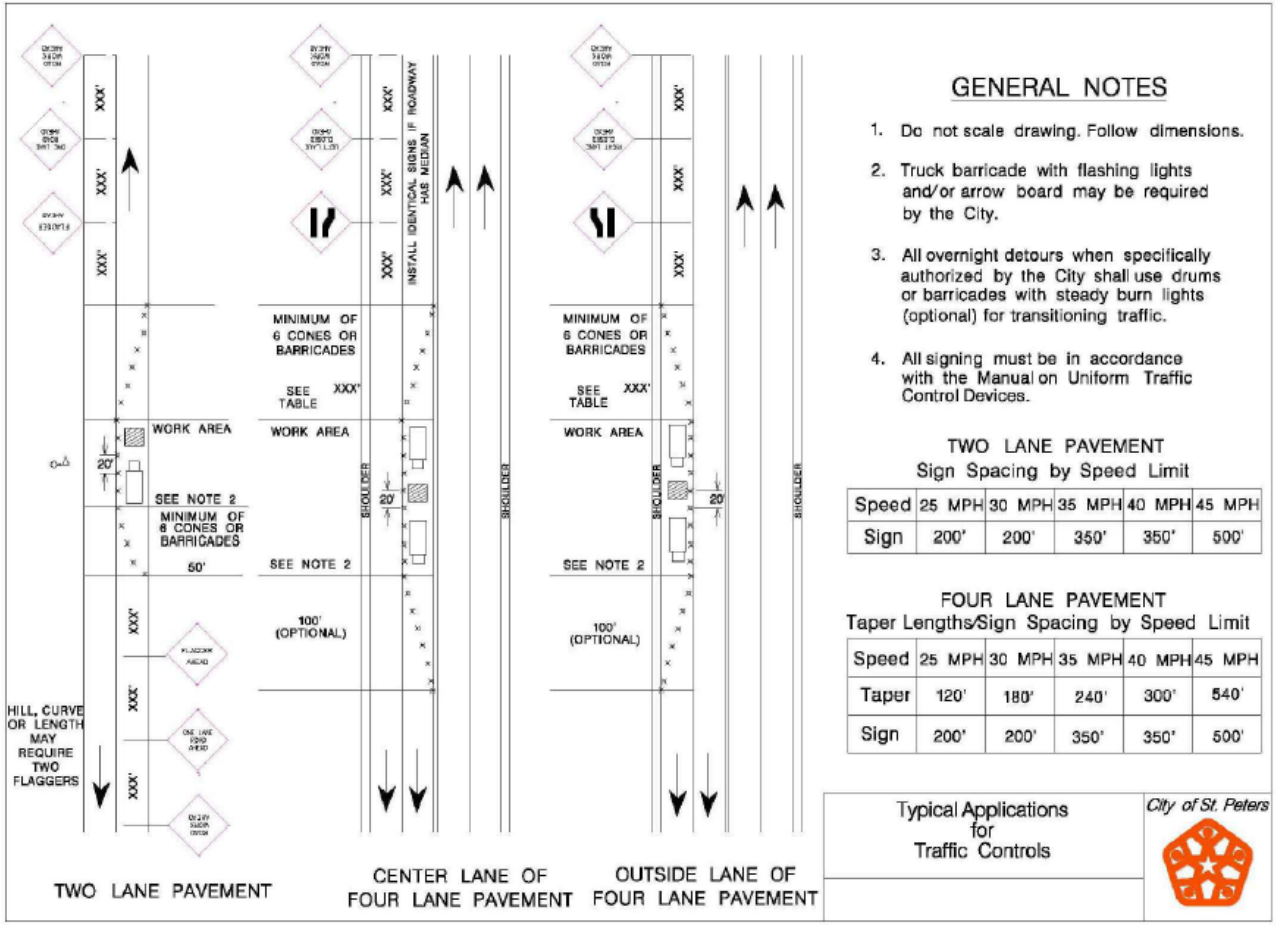
Evaluation of Rise in Base Flood Elevation

- Historic data provides evidence creek and floodplain were higher
- Compared 1996 FIS with Current 2011 FIS
  - 100-year BFE same or higher in 1996
  - Flow rate 30% lower (but higher BFE)
  - Channel bed elevation higher
  - Different flow change location
- City Photograph in 2011 shows interim condition (snapshot between 1996 to 2022 condition)



City of St. Peters – City Departments

- Traffic Department
  - Traffic control plan
  - Roadway design criteria
  - Roadway must remain open
- Horticulture Department (Public Works)
  - Tree survey and preservation
  - Vegetation maintenance in City owned parcels and within permanent drainage easements
- Parks Department
  - Pedestrian trail tie-in at Willott Road
  - Pedestrian bridge replacement



State & Federal

- USACE (St. Louis District)
  - Nationwide permit: Use of ordinary high-water mark for impacts to jurisdictional waters

- Missouri DNR & USACE
  - Culvert Design Considerations
    - Aquatic wildlife passage
    - 1-ft of creek bed material burying the bottom of the proposed culvert
  - Riparian Corridor – vegetation and tree removal offset
    - Collaboration with City’s horticulture department
    - Minimized removal of critical trees

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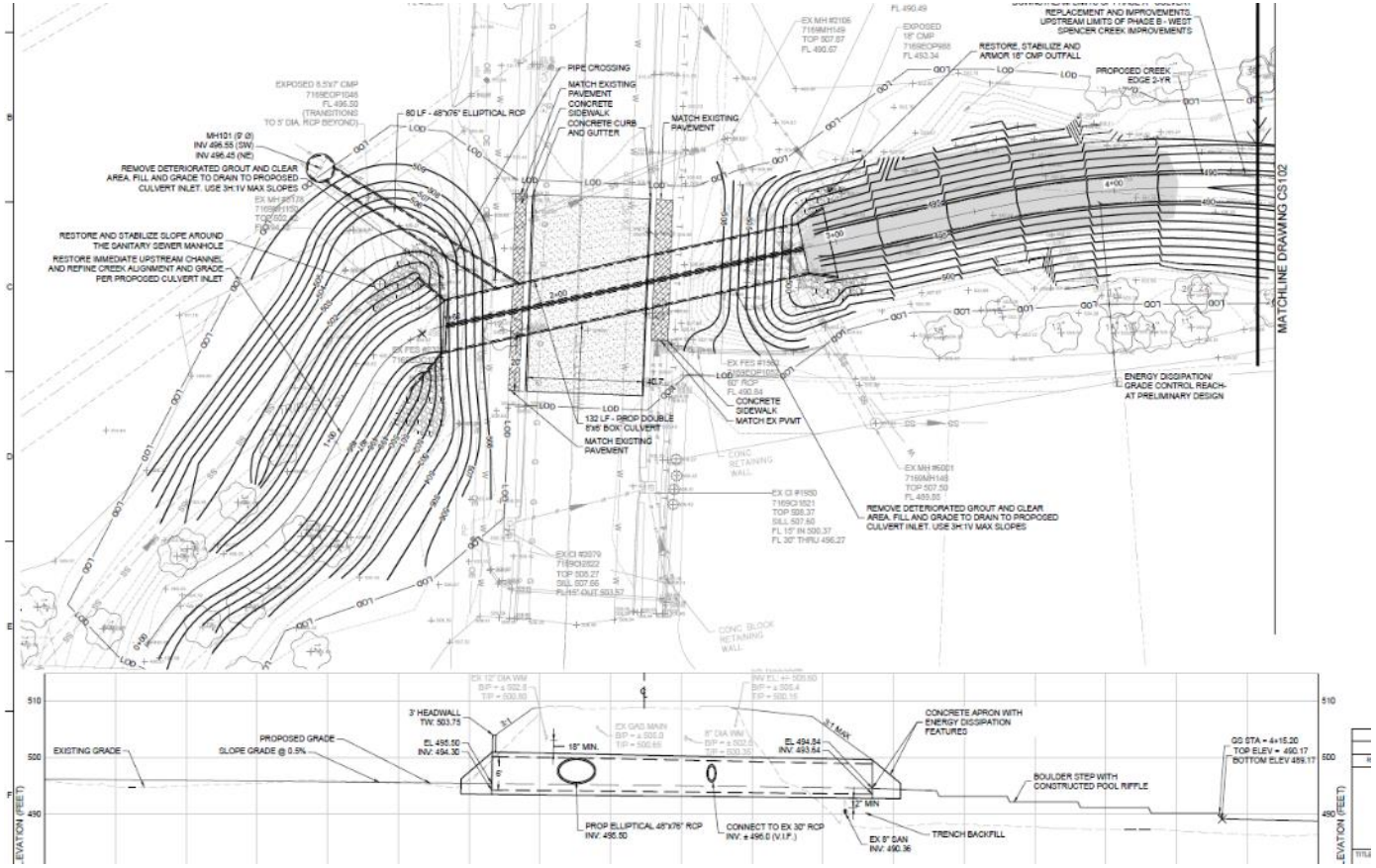
Design Outcomes

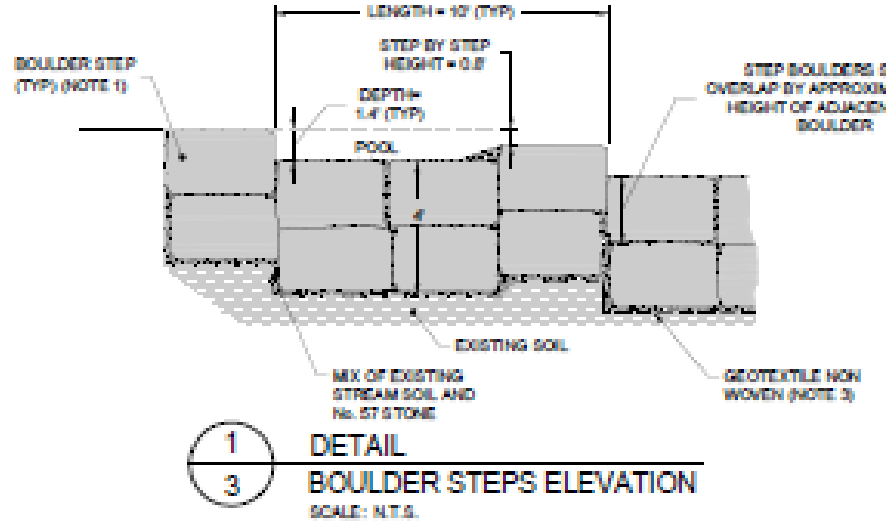
Culvert Replacement and Creek Improvements

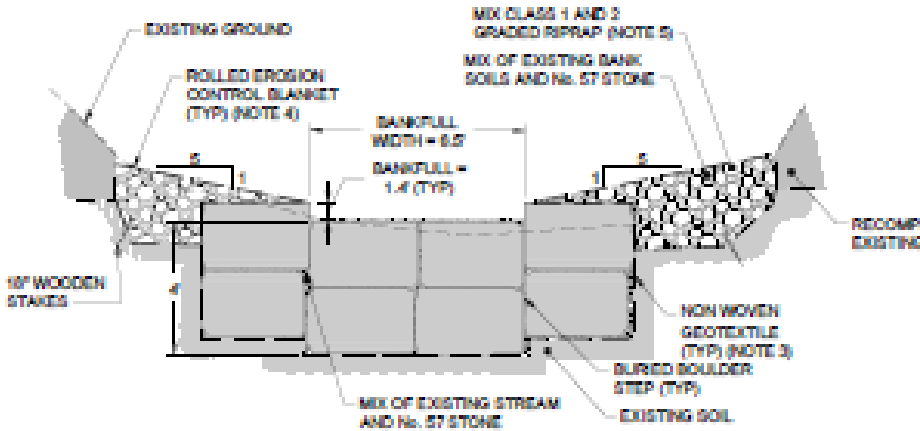
Roadway Crossing

Dual 8-ft x 6-ft RCB Culvert aligned with Creek

- Extended over existing exposed sanitary sewer
- Energy dissipation structure at discharge
- Head and wingwalls provide lower embankment slope

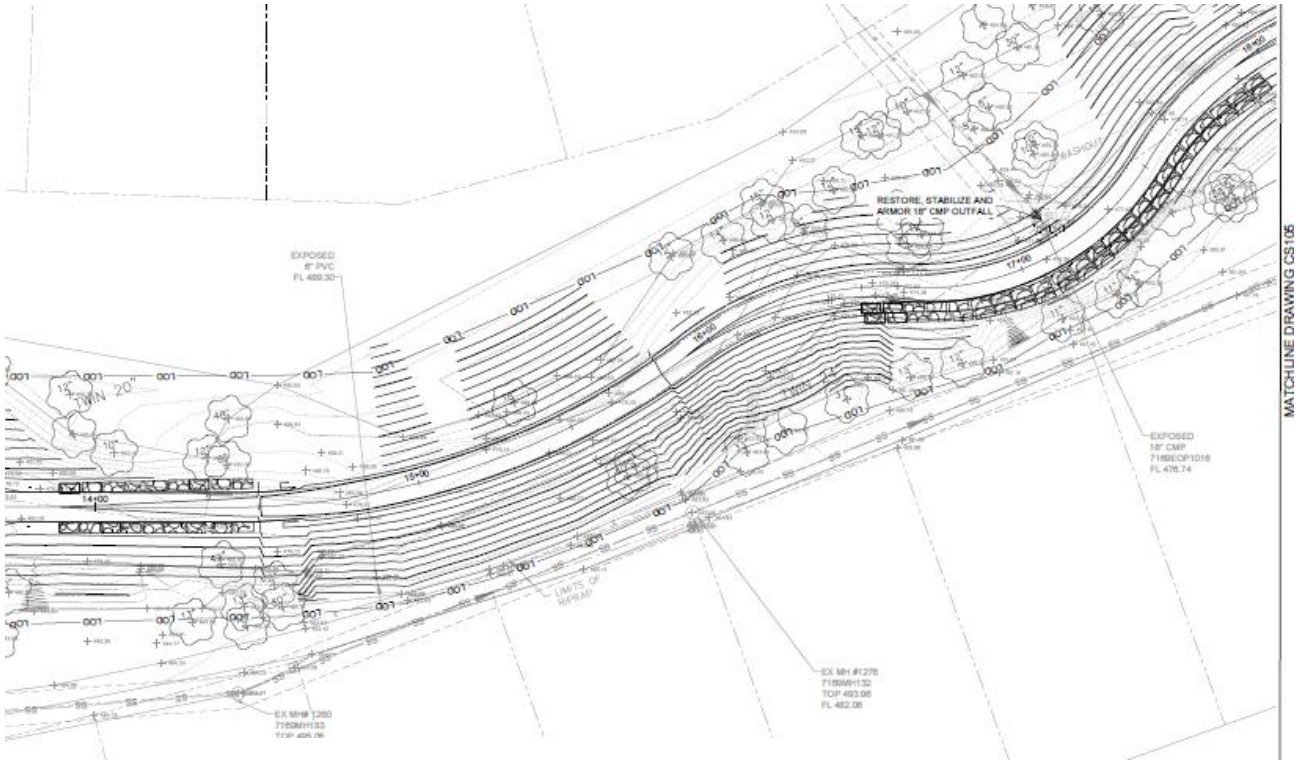


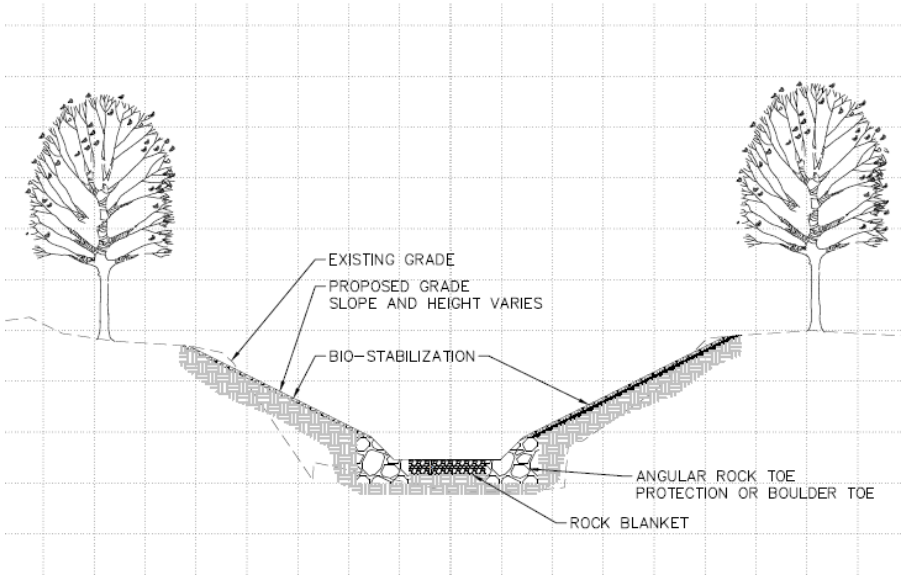


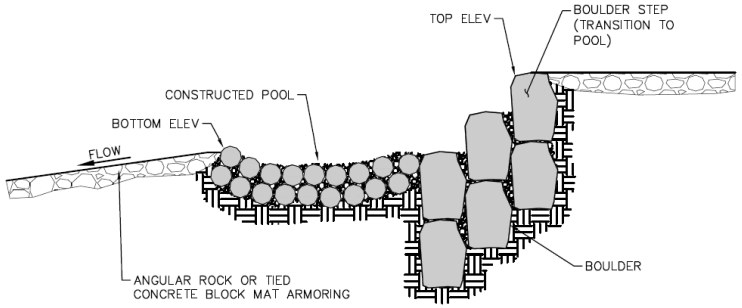


Channel Improvements

- Threshold channel design
  - Armored low-flow channel
  - Bioengineering applied on upper slopes
- Integrate hard armor with angular stone and boulder toe protection
- Reintroduced gentle-sinuosity
- Reduced bed and bank side slopes
- Grade control structures to reduce bed slope







Prior Project Examples

Calwood Channel - Pre-project inspection by David Vance

Calwood Channel - lower reach post-project

Before and after Athens Channel

THANK YOU

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