When Does a Process Become a Hazard?

Managing a Complex System of River Crossings

Amber Garrett, P.Eng.
Geohazard Engineer - Hydrotechnical

ENBRIDGE

Agenda

- Hydrotechnical Threats
  - Hazards
  - Damage mechanisms
- Geohazard Management Process Flow
- Site Identification
- Site Assessment and Classification
  - Response levels
  - Phase 1, 2, and 3 assessments
- Integrity Plans and Monitoring
  - Frequency
  - Event-based triggers
- Mitigation
  - Risk informed decision making
  - Mitigation design objectives

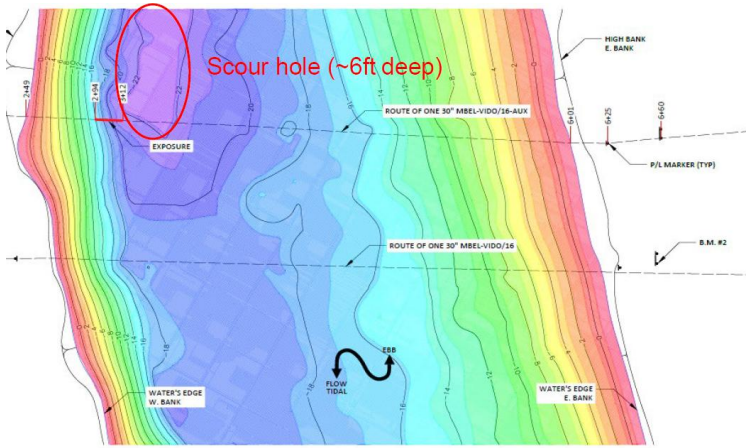
Hydrotechnical Threats – Pipelines 101

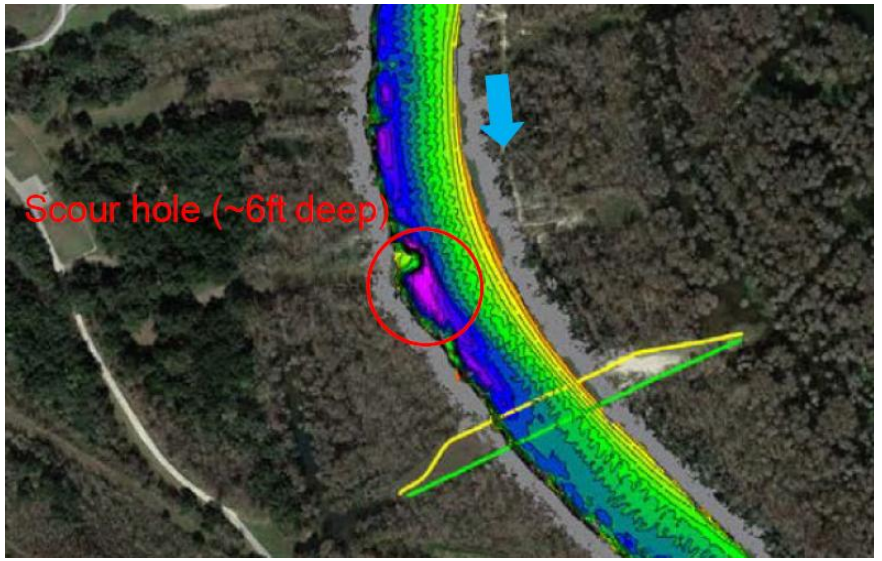
Hazards = Natural Processes

- Event Based
  - Scour
  - Avulsion
  - Storm surge (already spanning)
- Duration Based
  - Erosion/Migration
  - Degradation
  - Coastal retreat/Land loss

Damage Mechanisms = Pipe Loading

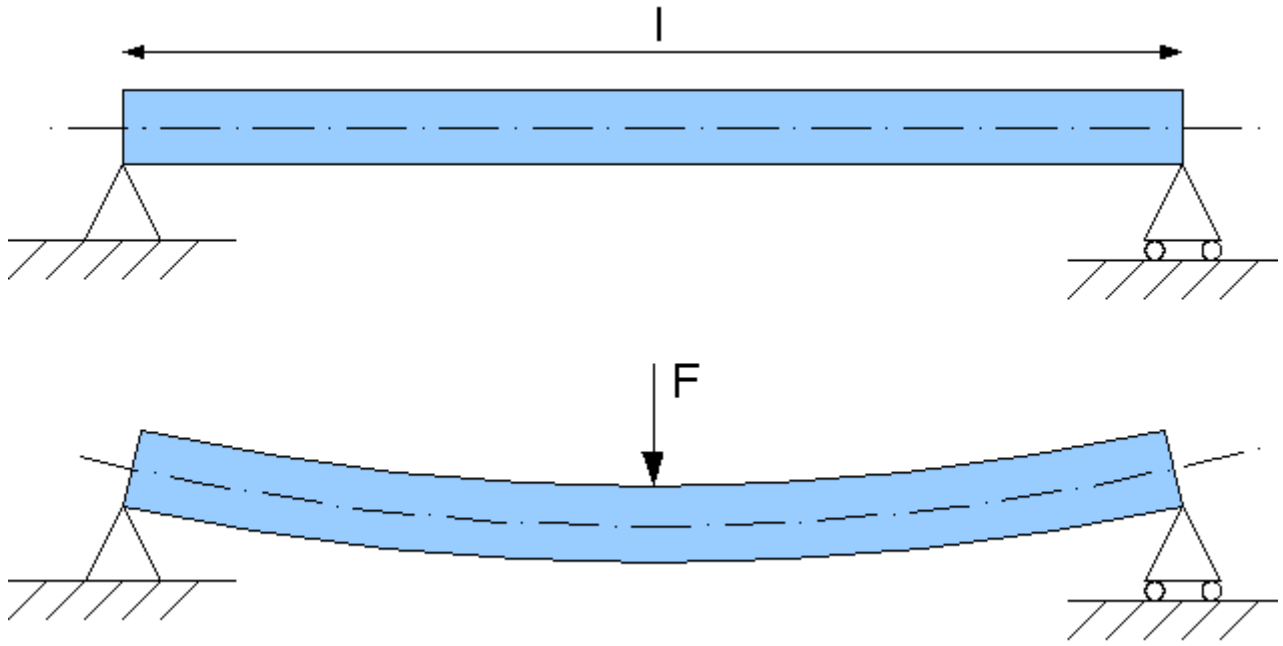
- Hydrodynamic Loading (Drag)
  - With or without added debris
- Vortex-Induced Vibration (VIV)
- Debris Impact
- Span in Air
- Out of Program: Third Party Damage





Damage Mechanisms – Bending Stress

- Phenomenon:
  - Pipe is spanning
  - Water causes drag force on pipe
  - Added debris can act as a sail (drag)
  - Stress limits per Z662 in Canada
  - Assess like simply supported beam



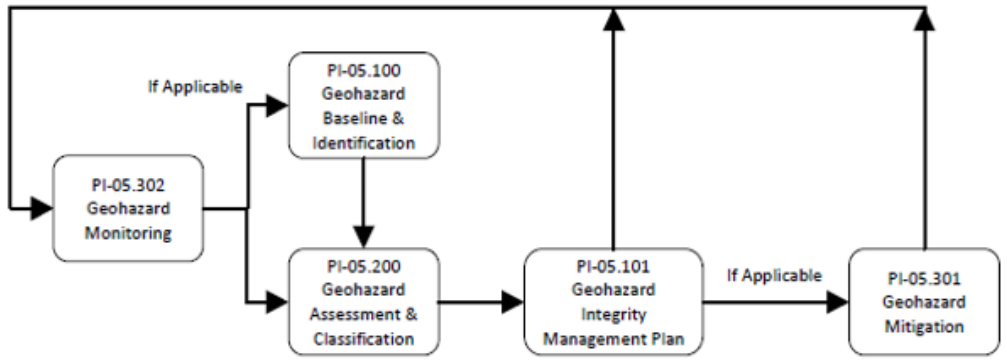
Damage Mechanisms -Vortex Induced Vibration (VIV)

- Phenomenon:
  - Water sheds alternating vortex behind pipe, pushing up and down
  - Creates fatigue crack that deepens until stress can fail pipe
  - Fatigue life very short
  - Unknown remaining fatigue life

Geohazard Program Management
Process Flow

- Baselining and Site Identification
  - New asset or post-disaster
- Assessment
  - Driven by monitoring or baseline (new assessment)
  - Tier 1, 2, and 3 assessments
  - Outcome is Response Level (R-Level) classification which drives integrity plan
- Integrity Plan
  - Contains monitoring frequencies or mitigation timeline
- Mitigation
- Monitoring
  - Restarts the process

Geohazard Base Process



Hydrotechnical Hazard Site Identification

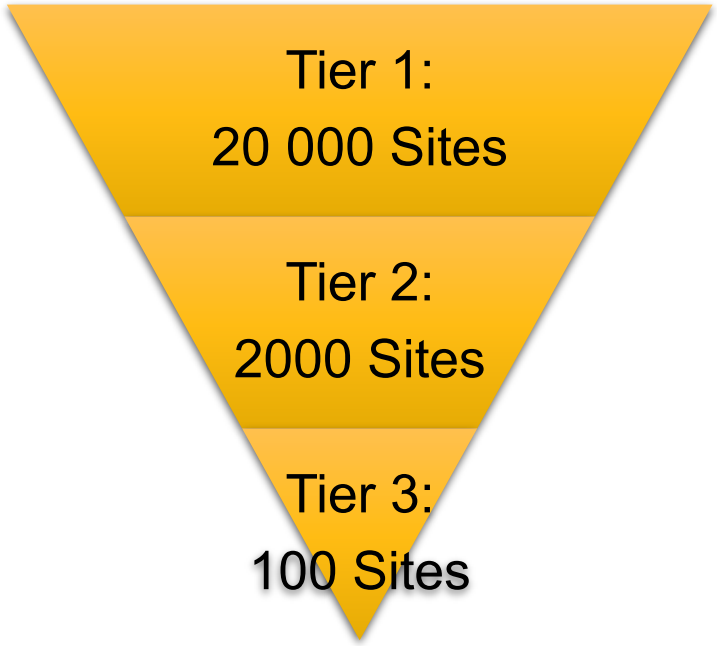
- New Pipeline, Pipeline Reroute, or Baseline Post-Disaster

- Largely GIS Exercise
  - Aerial Imagery
  - LiDAR
  - Watercourse and Pipeline Alignments

- Definition of Hydrotechnical Hazard Site
  - Areas where naturally flowing water may apply forces to a pipe

Site Assessment - Response Level Prioritization

- Tier 1: Bankfull Width/Crossing Length Estimate
- Tier 2: Quantitative POF Screening
- Tier 3: Detailed Hydrotechnical Assessment (Scour and Bank Migration), Qualitative POF estimate



*Numbers are for example only

Response Levels

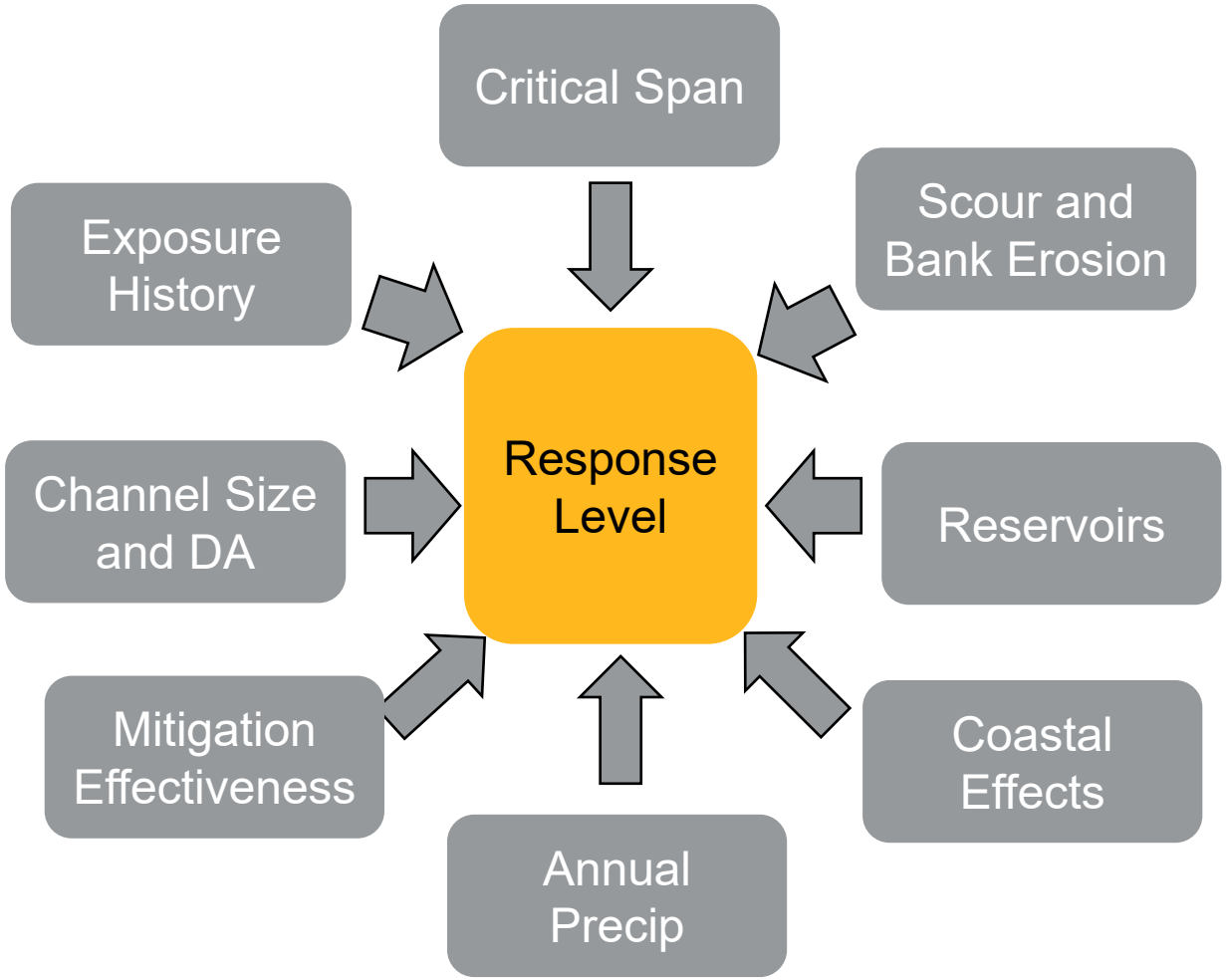
R1	R2	R3	R4	R5	R6	R7
Risk is broadly acceptable to the pipeline	All indications and results show acceptable risk to the pipeline and low probability of future elevated risk	No immediate risk exists to the pipeline, but large waterbodies or limited potential for channel movement.	No immediate risk exists to pipeline integrity, but long-term waterbody changes or deteriorating mitigation require more frequent monitoring on a site-specific basis.	No immediate risk exists to pipeline integrity, but the increased risk requires more frequent monitoring and potentially mitigation on a site-specific basis.	No immediate risk exists to pipeline integrity but will typically require mitigation within 2 to 3 years.	Elevated risk to pipeline integrity requires a site-specific monitoring plan and mitigation is typically required in less than 1 years.

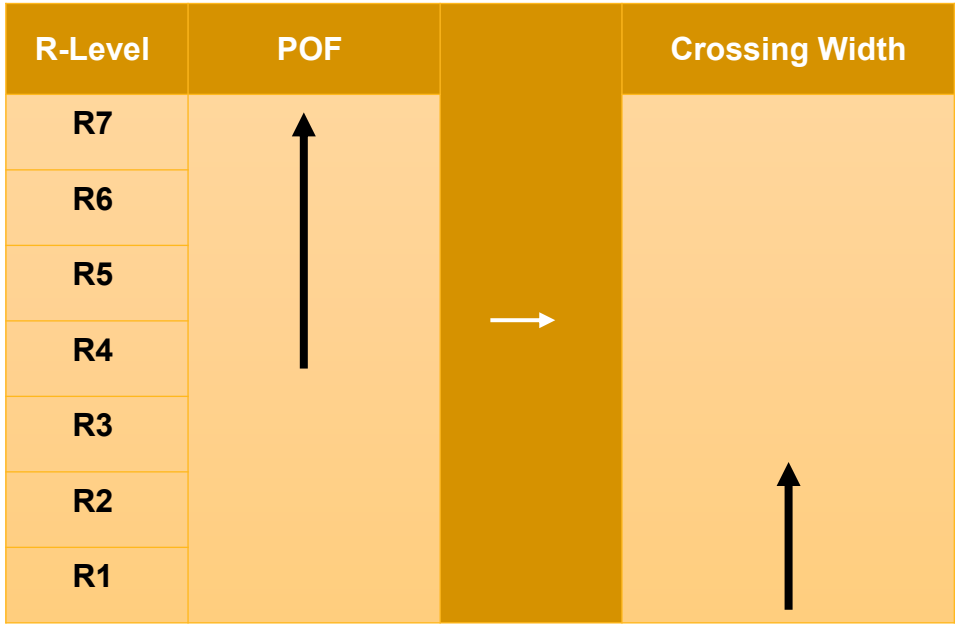
Tier 1 Assessment – Crossing Width Estimate

Tier 1 Assessment

R-Level	Crossing Width
R7	↑
R6	
R5	
R4	
R3	
R2	
R1	

Tier 2 Assessment – Semiquantitative POF Screening

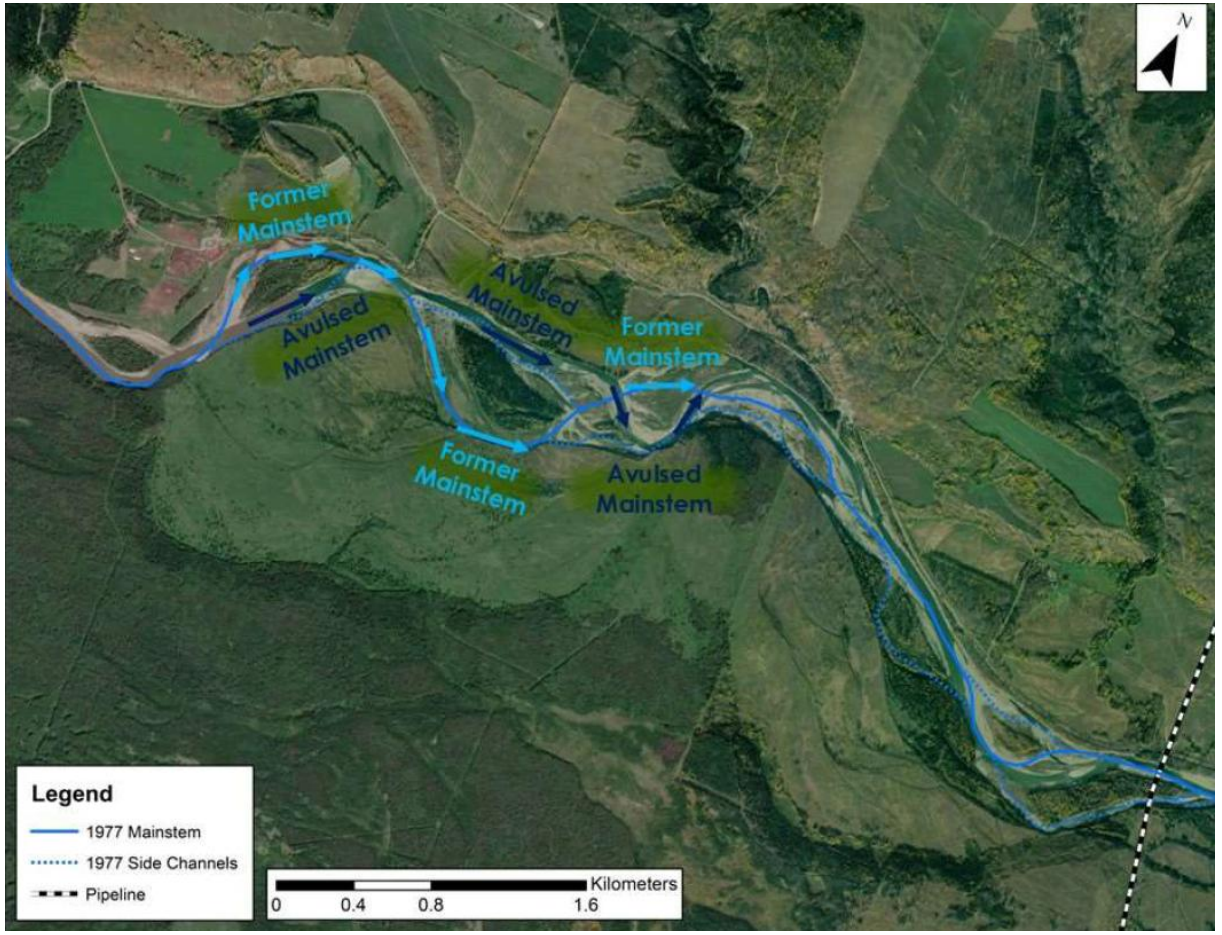




Tier 3 Assessment – Detailed Hydrotechnical Investigation

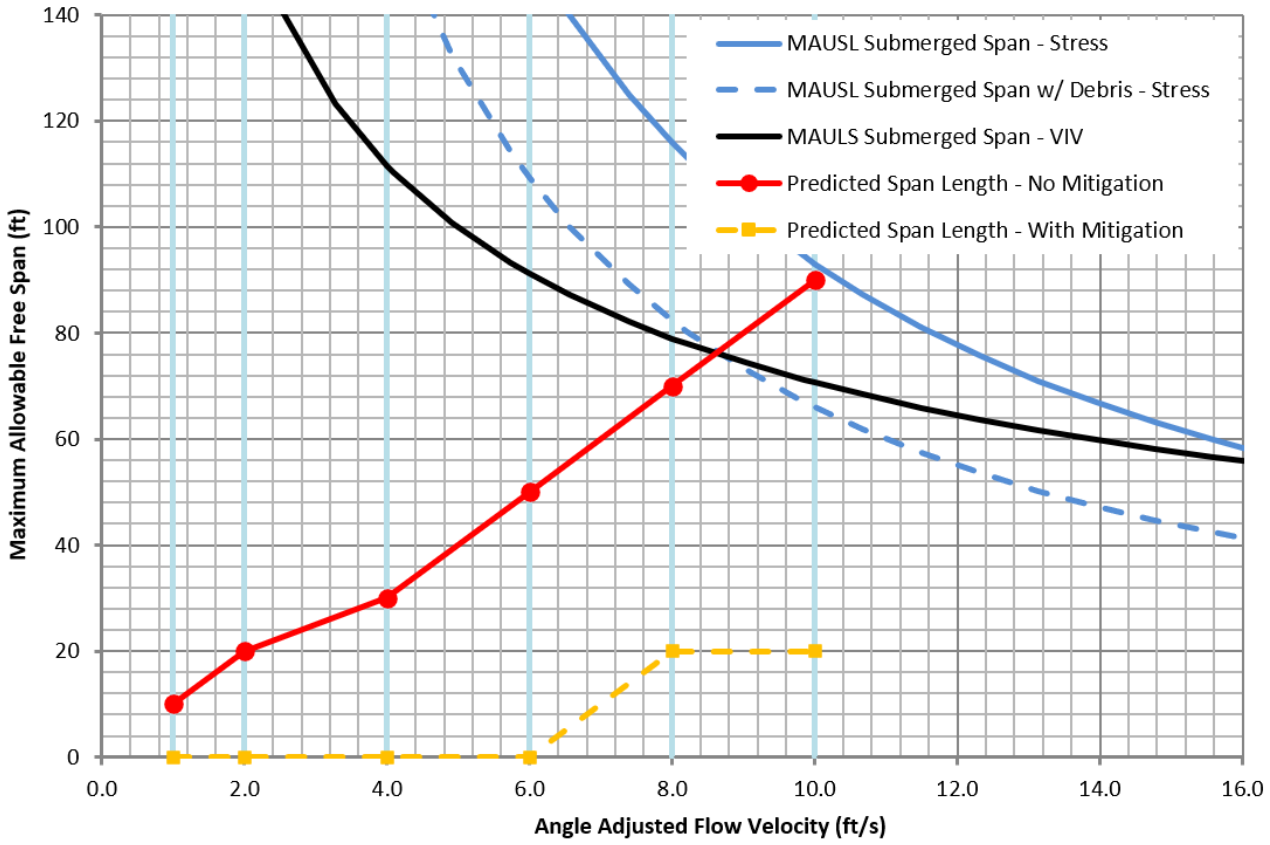
- When and Why?
  - Performed when Tier 1 or Tier 2 assessments are R4+, greater than 0.1% POF, or SME judgement.

- Site Specific
  - Field inspection and survey
  - Scour analysis
  - Geomorphological assessment (erosion, migration, avulsion potential, debris)
  - Unsupported span length calculations
  - Review of inline inspection data



Tier 3 Assessment - Detailed Hydrotechnical Assessment

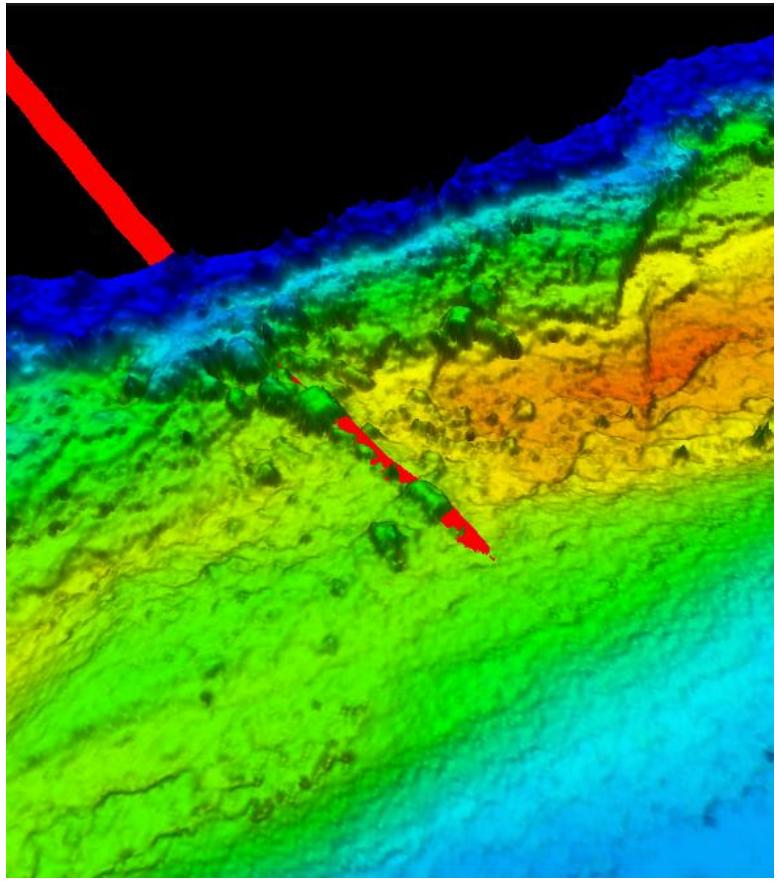
- Maximum Allowable Span Length Calculation
  - Compares predicted vs allowable
  - Identifies critical flood return period
  - Informs an MDR for classification
  - Allowable span can inform duration-based assessment



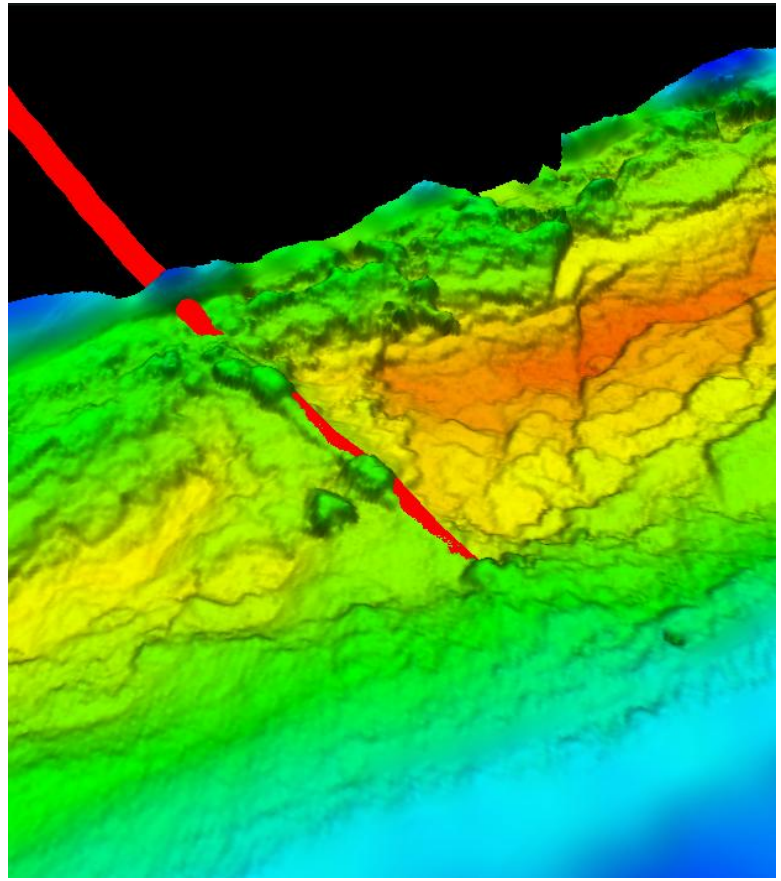
Integrity Plan - Response Level Actions and Timing

- Classification Informs Response
  - Frequency monitoring
    - Higher R-level, more frequent monitoring
  - Trigger monitoring
    - R4+ will have trigger set
  - Mitigation
    - R-Level influences mitigation priority
- Assessments Inform Frequency
  - Conservative return period scour and migration rates
  - Inspect before an issue
  - Calibrate with new data

2020 Bathy

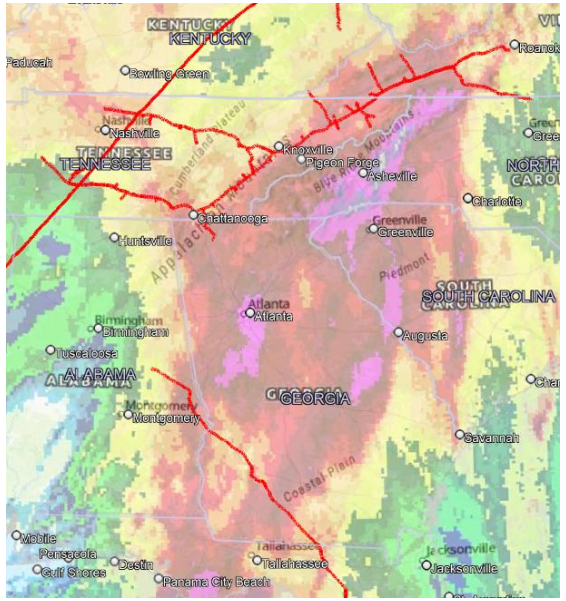


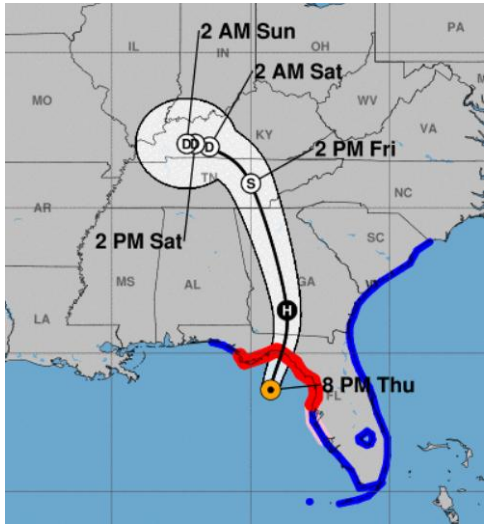
2024 Bathy

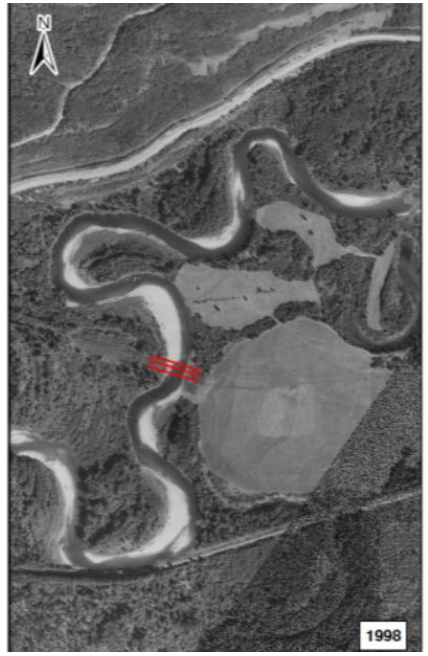


Monitoring

- Frequency Based
  - Based on classification and tied to integrity plan
- Event Based
  - Widespread natural disasters (hurricanes, floods, etc.)
  - Site specific
    - Threshold is set to a return period flood event based on site specific conditions
- Threshold Types
  - Critical flow
  - Flow of concern
- Monitoring Activities
  - Topographic/Bathymetric Survey
  - Visual site inspection
  - Aerial inspection
  - LiDAR
  - R&D (Green LiDAR, Satellite bathy, etc.)



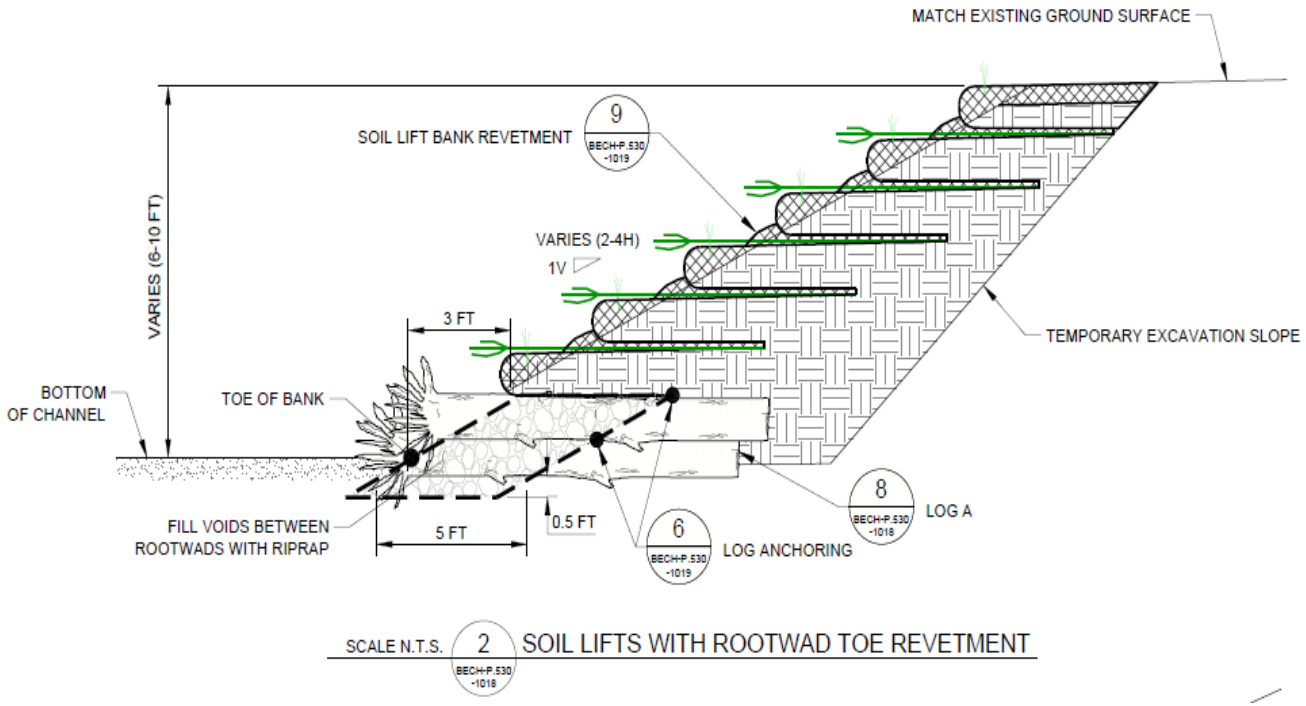




What Gets Mitigated? – Risk Informed Decision Making

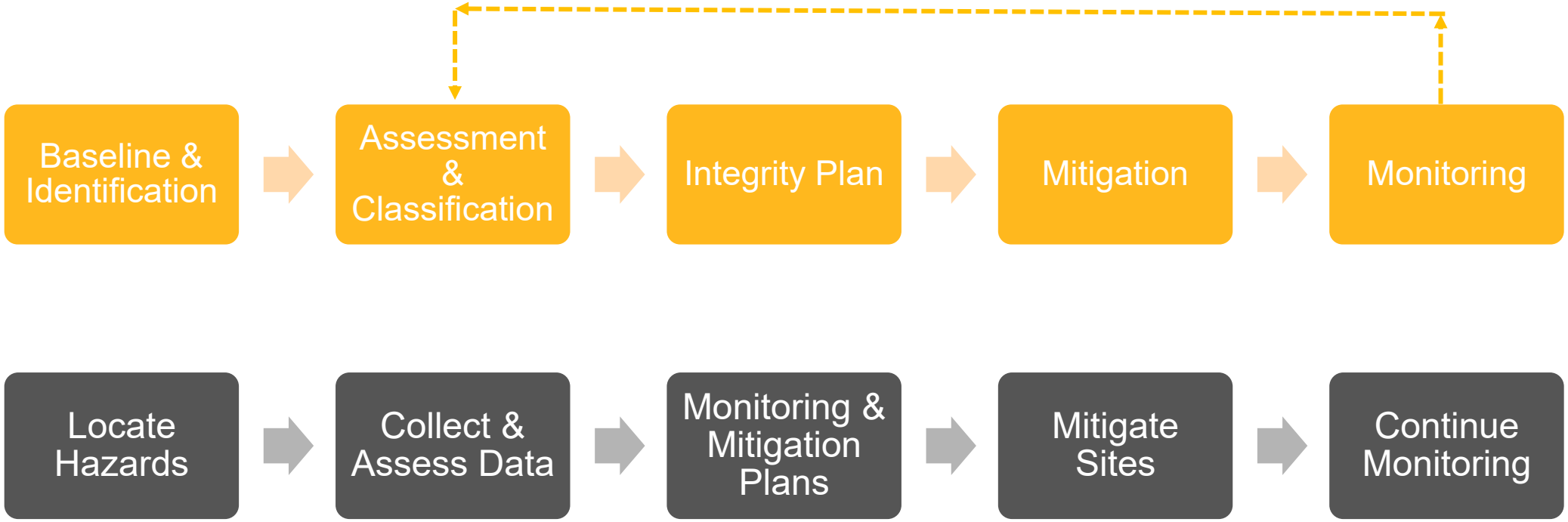
- Step 1: Risk Assessment
  - If High, it gets mitigated
  - If Medium, can we reduce the risk level?
- Step 2: Cost Benefit Analysis
  - Will look at Risk Return on Investment (RROI) of each treatment option and compare
  - Is the risk reduction worth the cost?
- Step 3: Compliance and Engineering Checks
  - Ensure selected option meets regulatory requirements and acceptable engineering practices

Mitigation Design Objectives



- Public Safety is Paramount
  - Design must adequately protect the asset, people, property, and environment
- Enable Efficiency and Flexibility
  - Outage windows are often short
  - Avoid unique materials
  - Allow variability in dimensions to field fit
  - Avoid prescriptive methods
- Expedite Permitting Process
  - Natural or hybrid design solutions should be evaluated for suitability

Summary - Process Recap



Q&A