Hydromodification Regulation and Rehabilitation Approaches

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San Diego Region
Hydromodification Workshop

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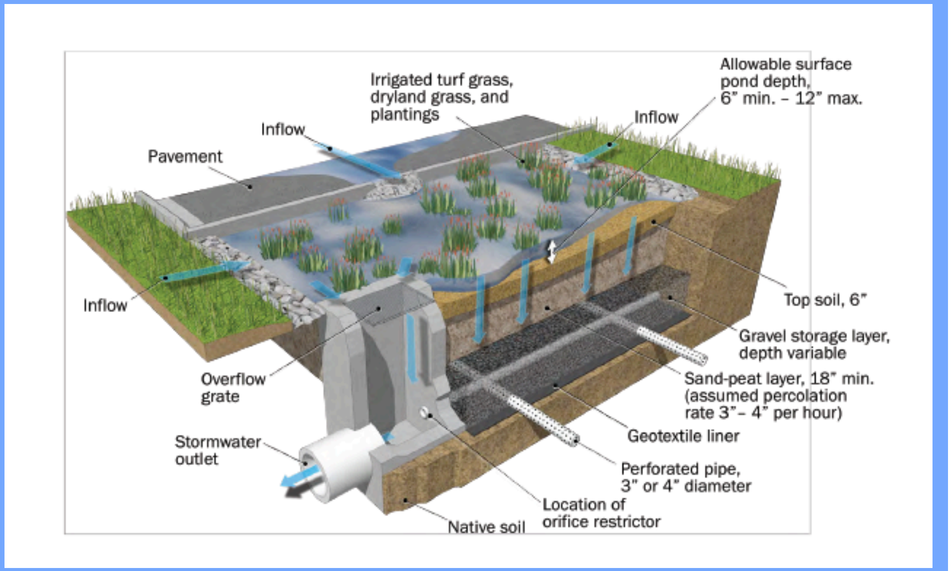
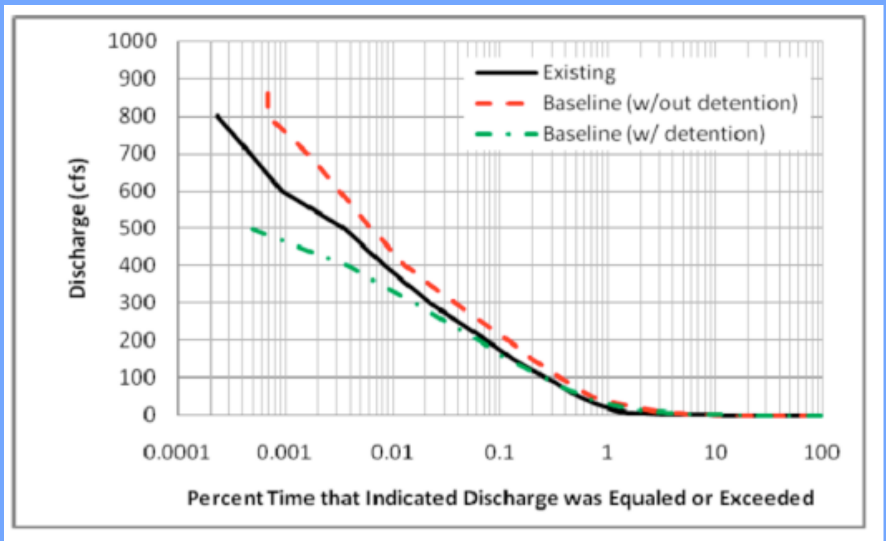
Overview

- Hydromodification regulation
- Rehabilitation approaches
  - Stream preparation
  - Mitigation banking
  - In-lieu programs
- Identification and Prioritization of opportunities, design tools
- Changing paradigms – case study

Hydromodification Regulation



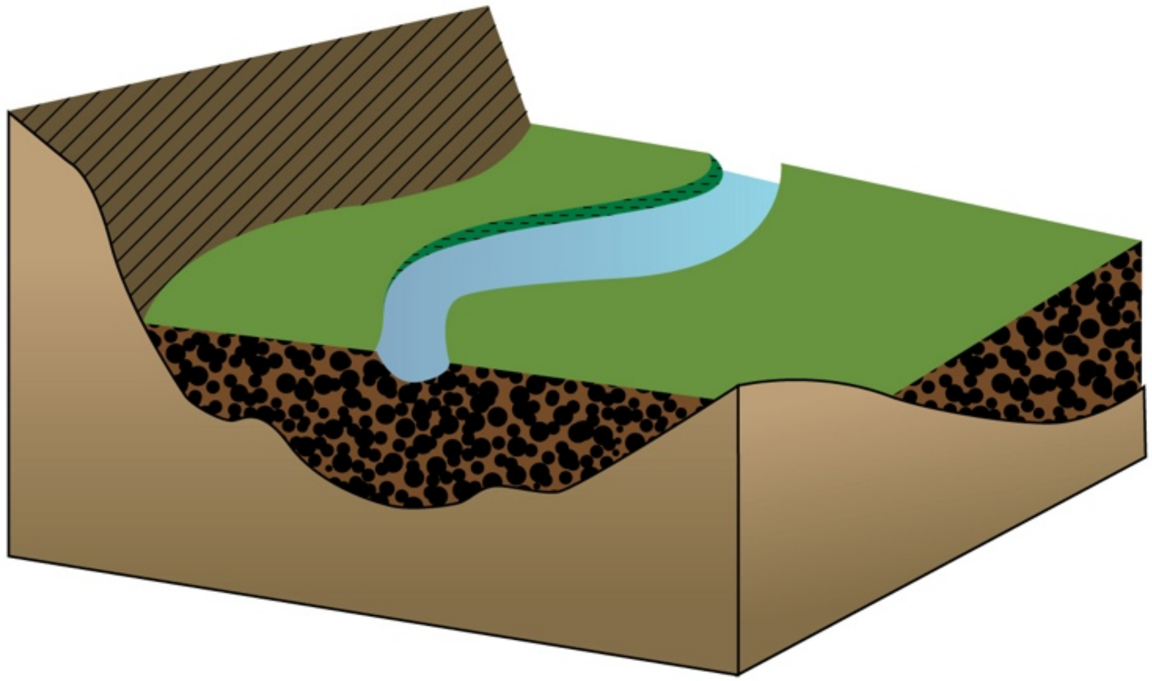
- Source control
  - LID, IMPs, BMPs
- End of pipe
  - Flow duration control basins
- Instream rehabilitation



Instream Rehabilitation

- Stream preparation
  - "Preparing the stream for what it is about to receive"
- Mitigation banking
- In-lieu programs

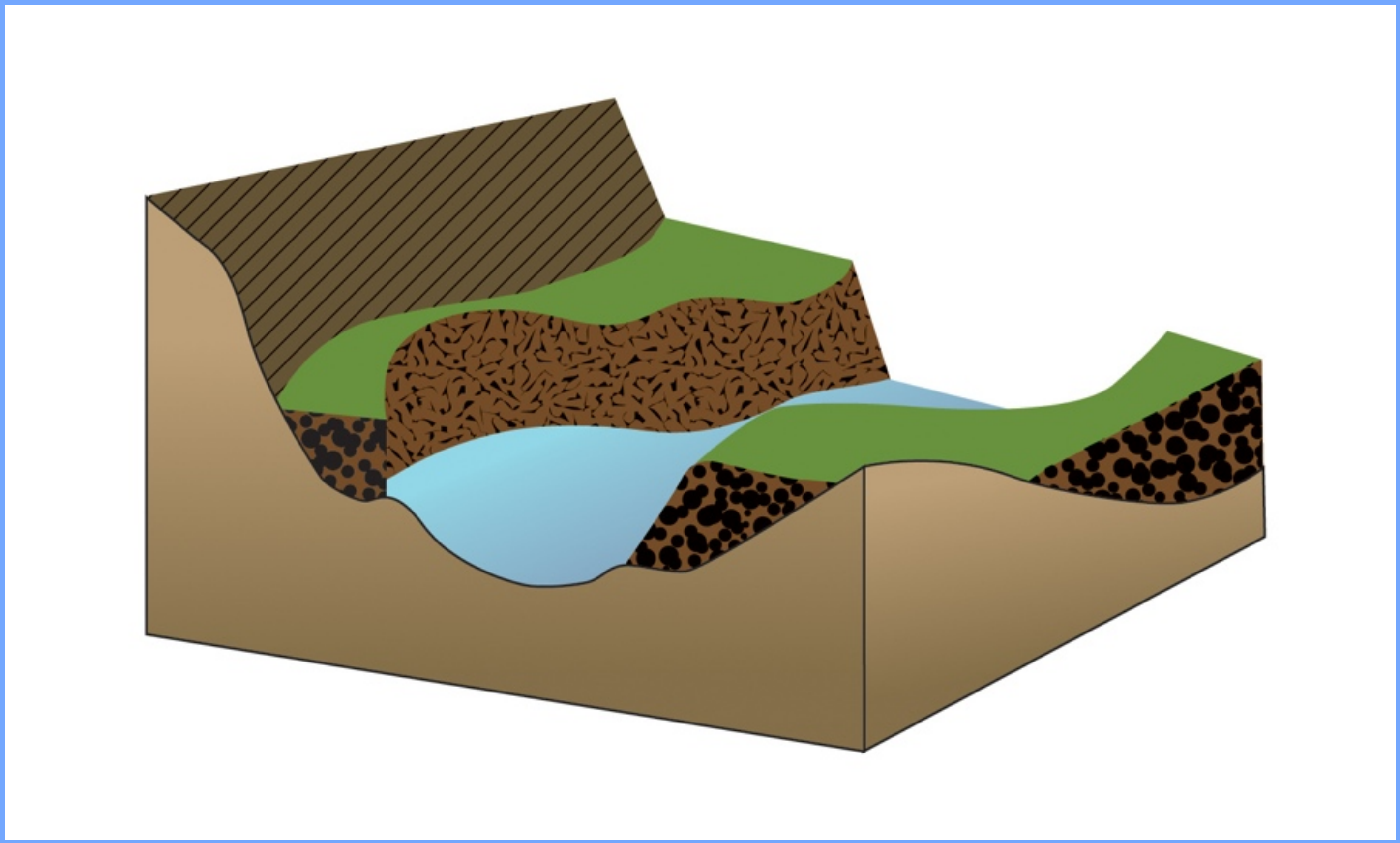
Actions appropriate for degree of degradation



PROTECT

- Manage runoff
- Provide riparian buffer to stream

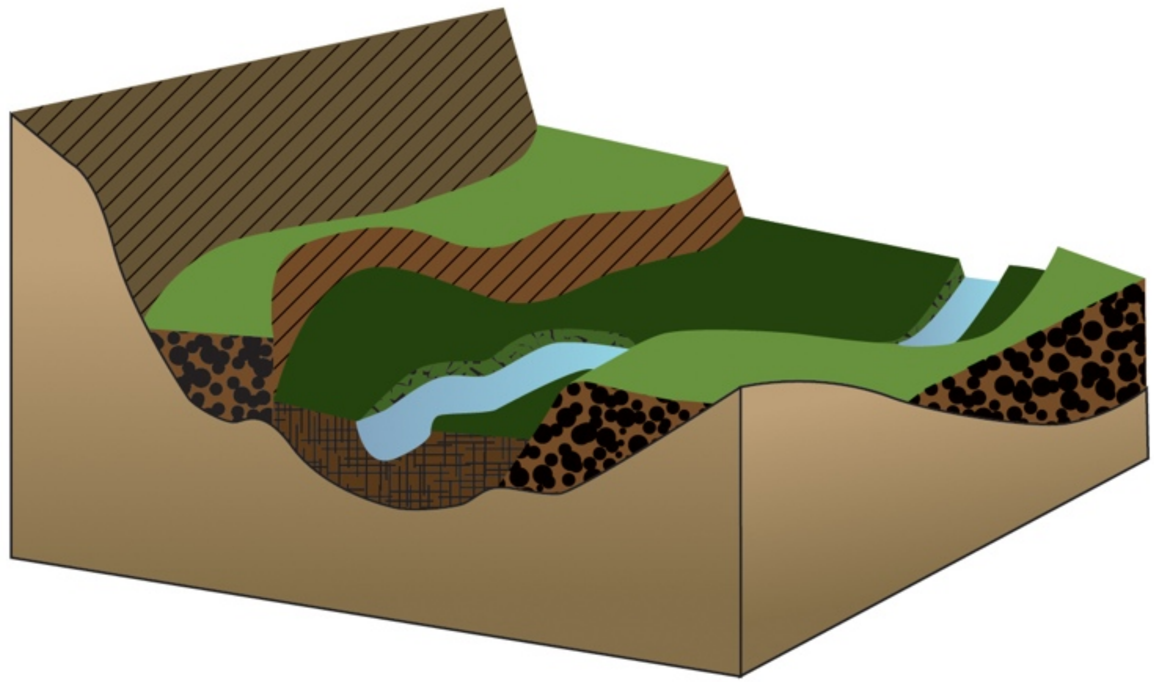
Actions appropriate for degree of degradation



RESTORE/REHABILITATE

- Stabilize
- Recontour

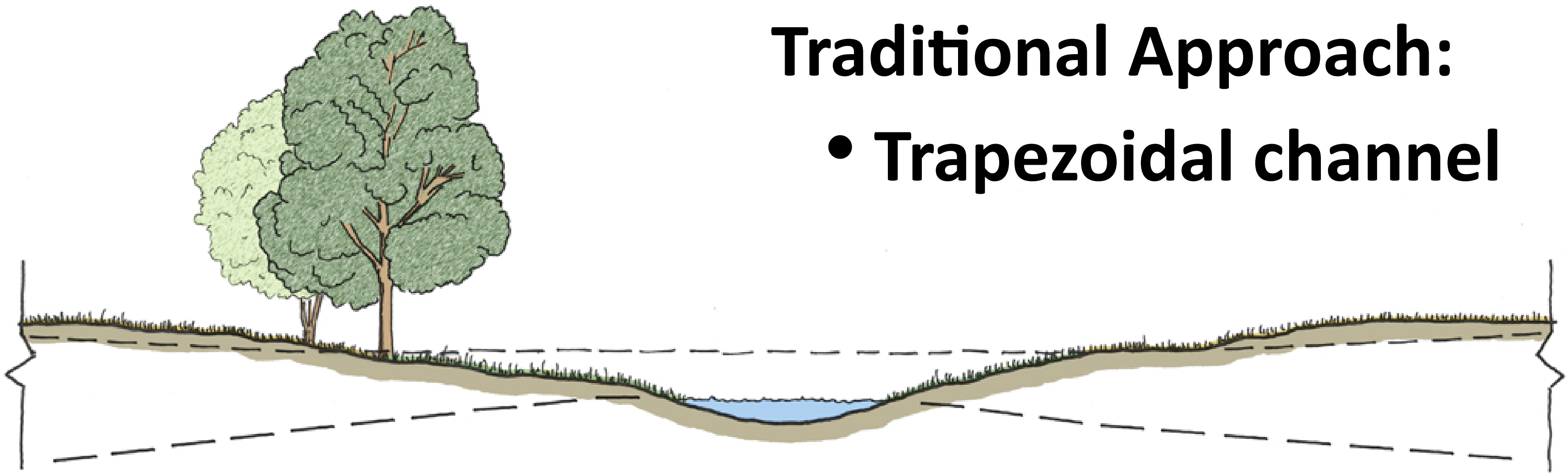
Actions appropriate for degree of degradation



MANAGE FOR NEW CONDITION

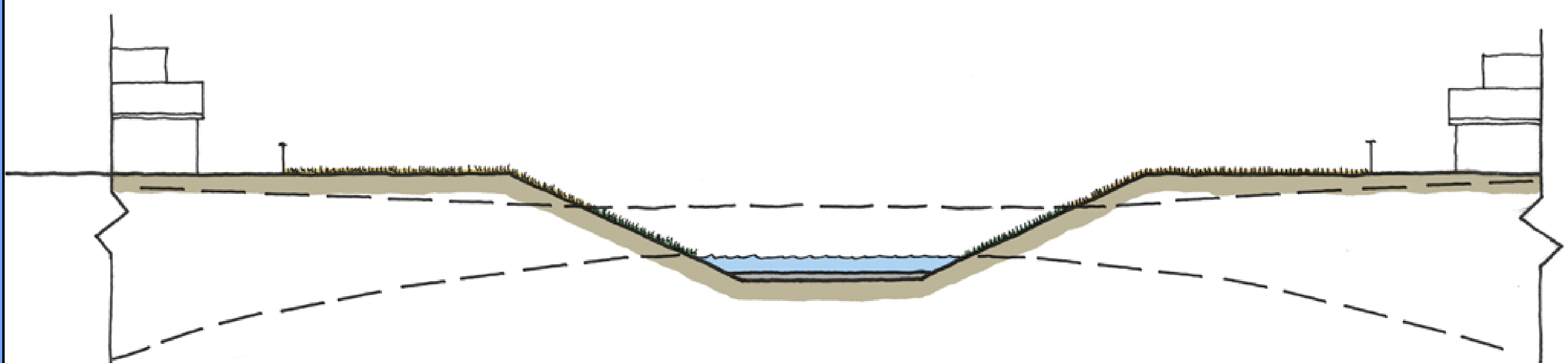
- Alternate stream type

Why should we use multi-objective creek corridors?



Traditional Approach:

- Trapezoidal channel



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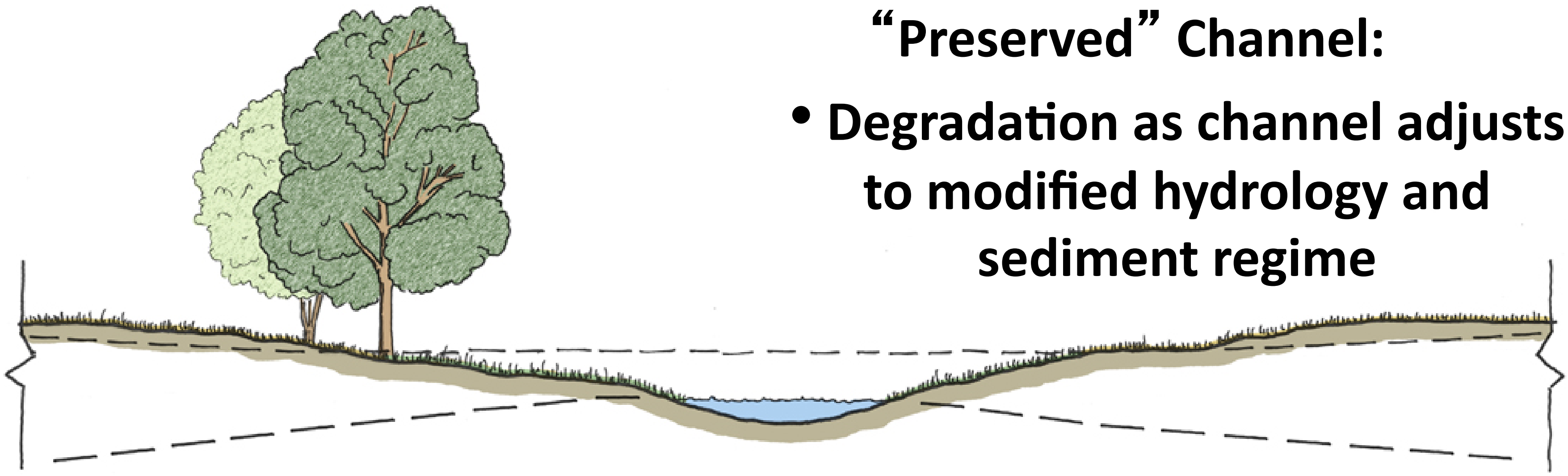
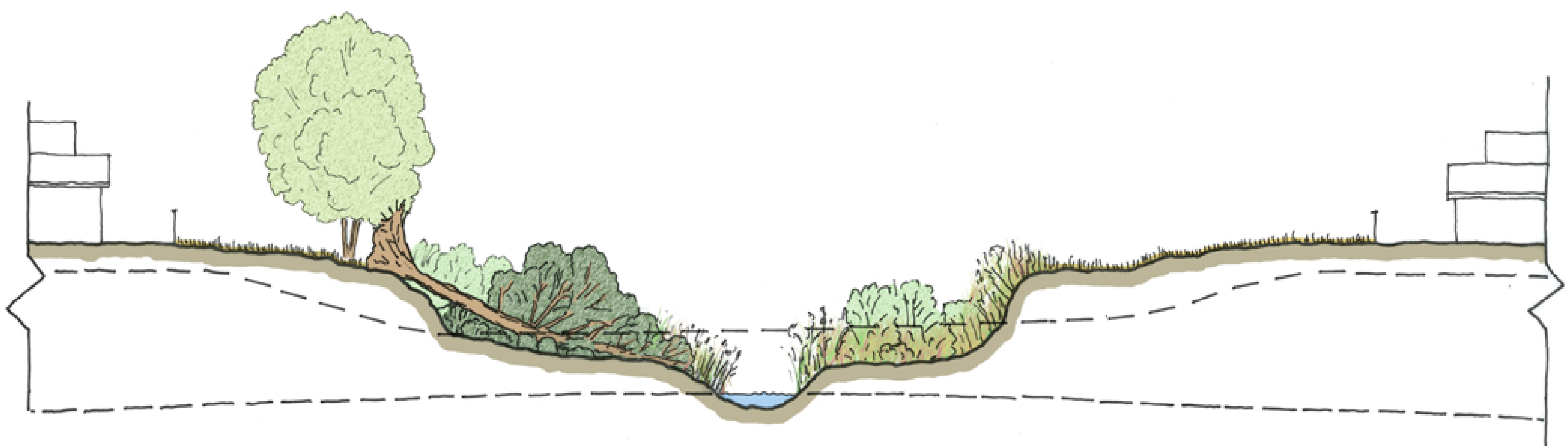


"Preserved" Channel:

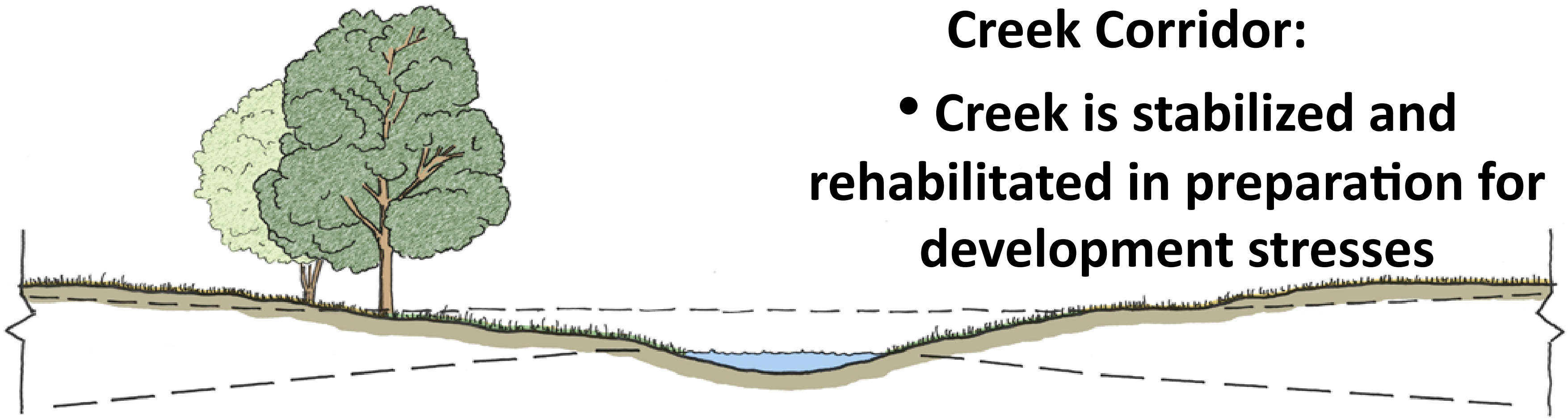
- Degradation as channel adjusts to modified hydrology and sediment regime

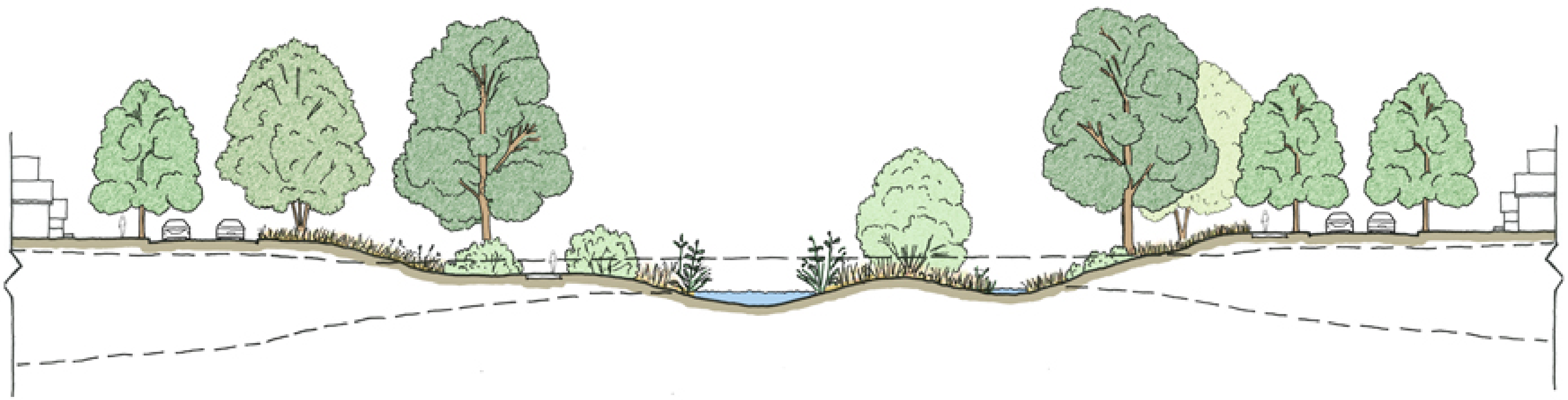


Why should we use multi-objective creek corridors?

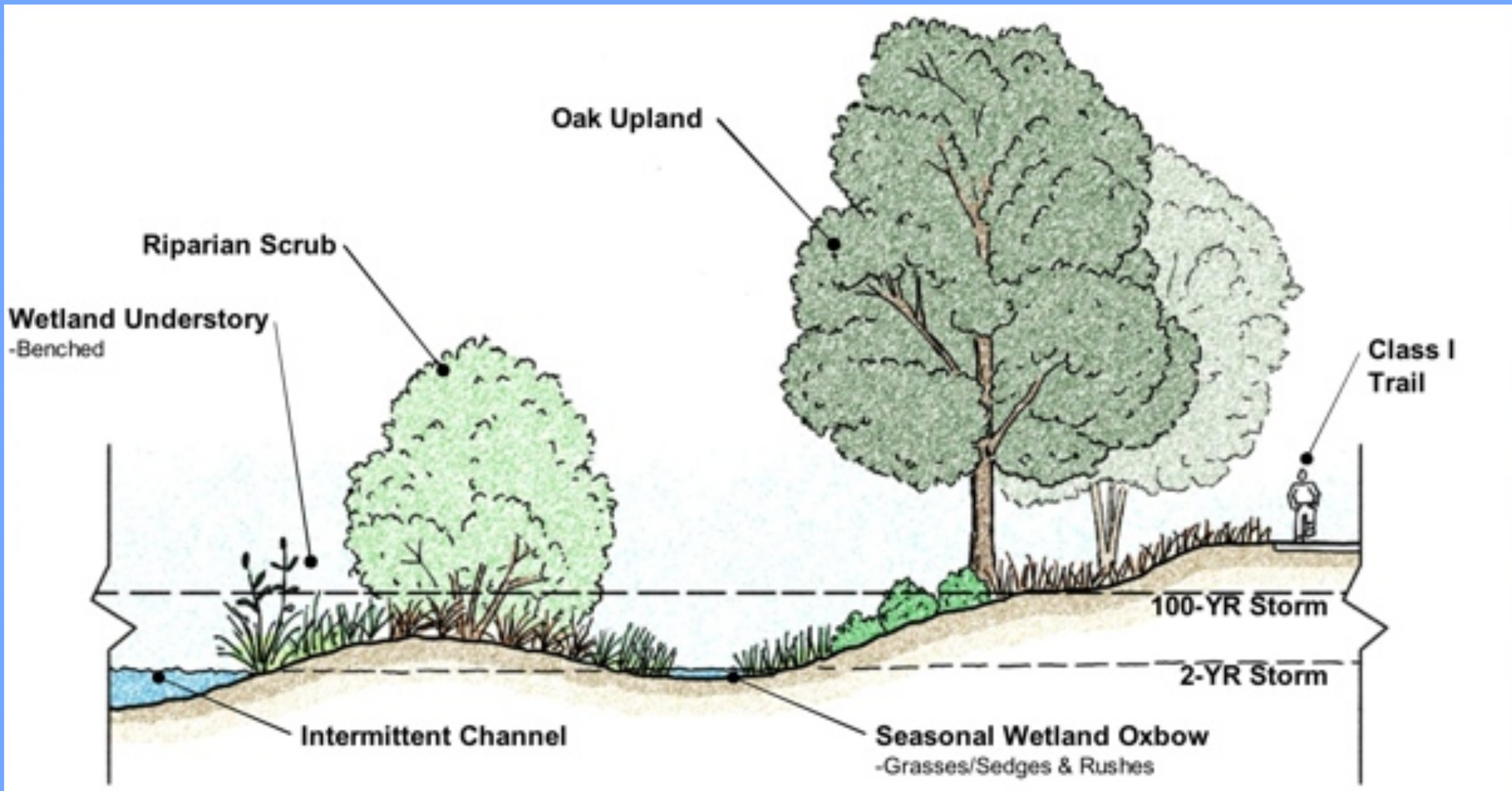
Creek Corridor:

- Creek is stabilized and rehabilitated in preparation for development stresses





What does "multi-objective creek corridors" mean?



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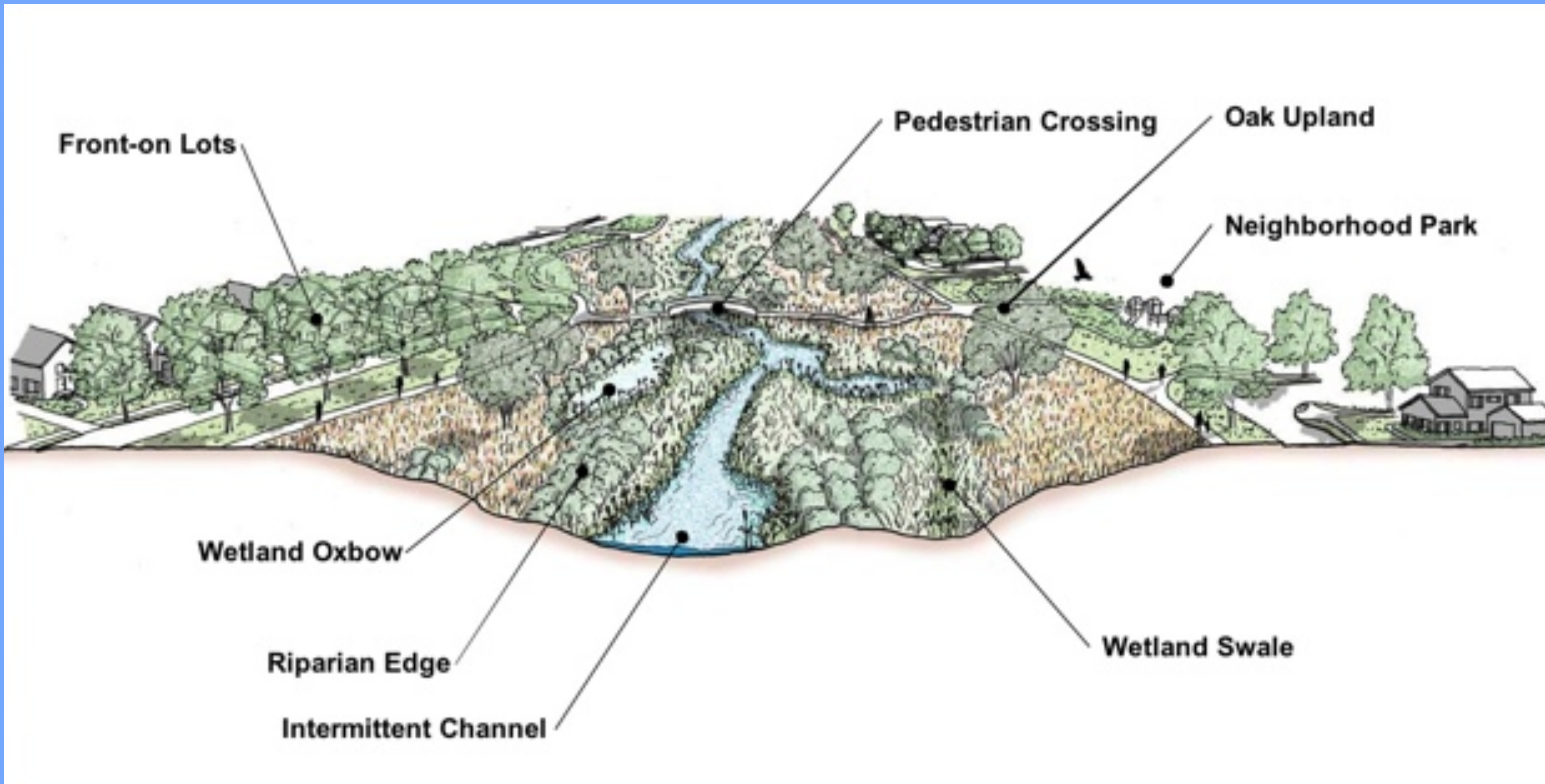

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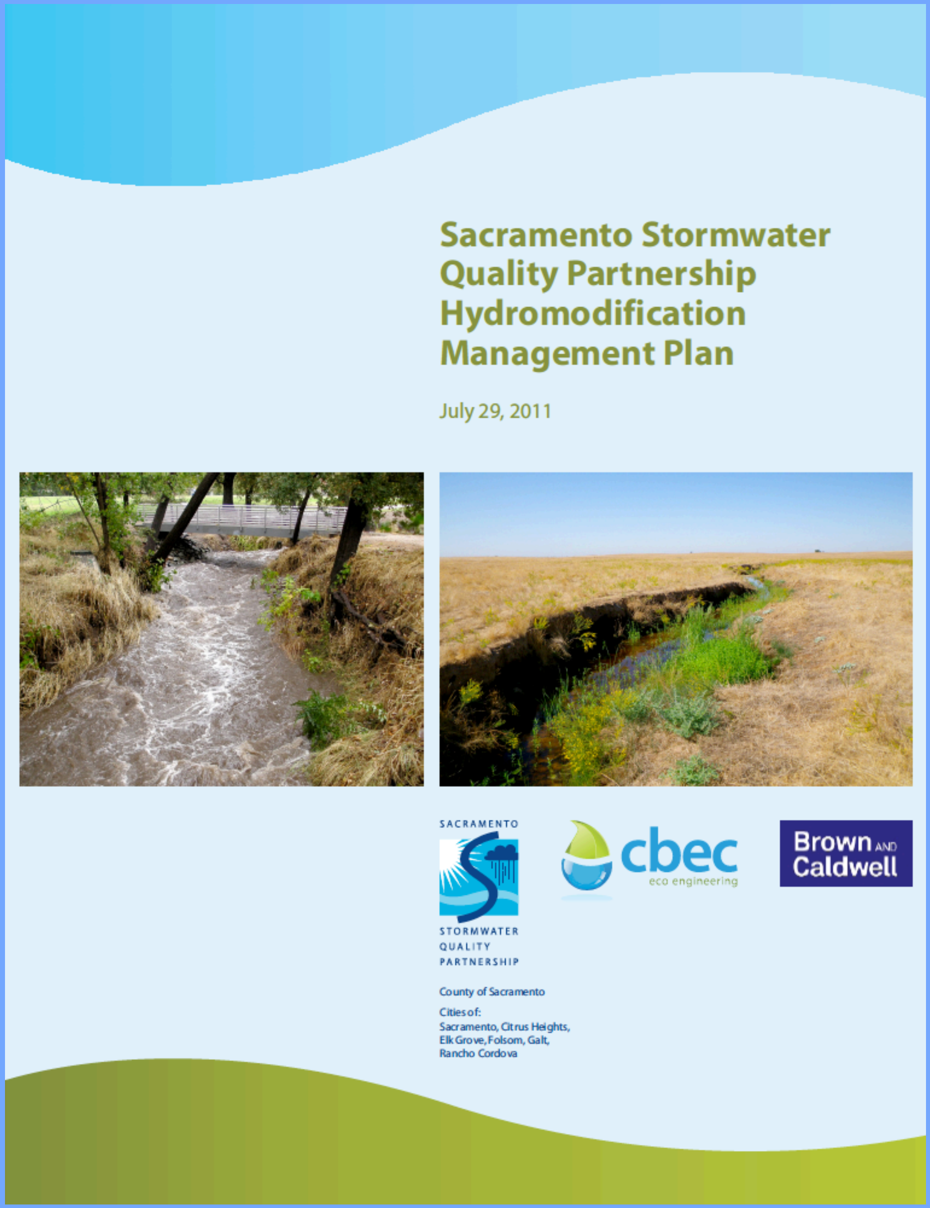
Instream Rehabilitation

In-stream approaches focus on managing stream corridors to protect stability and, if necessary, modify stream channels to accept an altered flow regime. In cases where development is proposed in an already degraded watershed it may be beneficial to focus on rehabilitating the stream channel with an altered flow regime in mind rather than retrofitting the watershed or only controlling a percentage of the runoff. In addition, in some cases where a master-planned watershed development plan is being implemented it may be more feasible to design a new channel to be stable under the proposed watershed land use rather than to construct distributed on-site facilities.



Instream Rehabilitation

United States Department of Agriculture

Natural Resources Conservation Service

Part 654 Stream Restoration Design
National Engineering Handbook

Chapter 8 Threshold Channel Design

654.0804 Allowable shear stress approach

The allowable shear approach (sometimes referred to as the tractive stress approach) is typically used with channels that are lined with rock, gravel, or cobbles. Limiting forces for soil bioengineering and manufactured protective linings can also be expressed as allowable shear, as well.

To design a threshold channel using the allowable shear stress approach, the average applied grain bed shear stress is compared to the allowable shear stress for the boundary material. The applied grain bed shear stress can be calculated from the hydraulic parameters determined for the design channel and the characteristics of the channel boundary material. The hydraulic parameters are calculated using the same methods as in the allowable velocity approach. For noncohesive soils, the average allowable shear stress can be calculated using a critical shear stress approach and then adding a factor of safety or by using an empirical equation with a factor of safety included. For cohesive particles, the electrochemical bonds related primarily to clay mineralogy, are the most significant sediment properties that determine allowable shear stress. Although some empirical data are available, laboratory tests to determine allowable shear stress for a specific cohesive soil are preferred.

(a) Calculate applied shear stress

The first step in applying this approach is to calculate the hydraulics of the study reach. The total average shear stress on the boundary can be approximated from equation 8–1, using any consistent units of measurement:

$$\tau_o = \gamma RS \qquad \text{(eq. 8–1)}$$

where:
τ_o = total bed shear stress (lb/ft² or N/m²)
γ = specific weight of water (lb/ft³ or N/m³)
R = hydraulic radius (ft or m)
S = energy slope, dimensionless

In wide channels where the width is more than 10 times the depth, R is generally taken to be equal to the depth. Spatial and temporal variation may result in a higher or lower point value for shear stress. The equation approximates average bed shear stress.

The shear stress can also be expressed as a function of the velocity and the ratio of hydraulic radius and boundary roughness. Keulegan (1938) presented such a formula.

$$\tau = \frac{\rho V^2}{\left(\frac{1}{\kappa}\ln\frac{R}{k_s} + 6.25\right)^2} \qquad \text{(eq. 8–2)}$$

where:
V = depth-averaged velocity, ft/s or m/s
ρ = density of water, lb-s²/ft⁴(slugs/ft³) or kg/m³
κ = von Karman's constant (usually taken to be 0.4)
k_s = roughness height, ft or m

Actual shear stress values should be calculated for the banks, as well as for the bed of a trapezoidal earth channel. Maximum stresses occur near the center of the bed and at a point on the bank about a third up from the bottom. The designer should note that computer programs such as HEC–RAS may only provide average boundary shear stress in the output. For most trapezoidal sections and depths of flow, bed stress values are somewhat higher than bank stress. Figures 8–5 and 8–6 provide actual shear stress values for the bed and sides of straight trapezoidal channels in coarse grained soil materials.

Grain shear stress
The total applied bed shear stress may be divided into that acting on the grains and that acting on the bedforms. Entrainment and sediment transport are a function only of the grain shear stress; therefore, the grain shear stress is the segment of interest for threshold design. Einstein (1950) determined that the grain shear stress could best be determined by separating total bed shear stress into a grain component and a form component, which are additive. The equation for total bed shear stress is:

$$\tau_o = \tau' + \tau'' = \gamma RS \qquad \text{(eq. 8–3)}$$

where:
τ' = grain shear stress (shear resulting from size of the material on the bed)
τ'' = form shear stress (shear resulting from bed irregularities due to bedforms)

Mitigation Banking/In Lieu Programs

- Stream rehabilitation should be assessed in terms of:
  - Physical Integrity
  - Chemical Integrity
  - Biological Integrity
- Policy Adjustments and Opportunities:
  - Emphasize change rather than endpoints
  - Different metric for different projects, released over time for metrics met
  - Allow flexibility in location: emphasize relative location rather than absolute location
  - Allow flexibility for large or unique projects
  - Flexibility in process: emphasize results not process

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
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COMPENSATORY MITIGATION FOR STREAMS UNDER THE CLEAN WATER ACT: REASSESSING SCIENCE AND REDIRECTING POLICY[1]

Martin W. Doyle and F. Douglas Shields[2]

ABSTRACT: Current stream restoration science is not adequate to assume high rates of success in recovering ecosystem functional integrity. The physical scale of most stream restoration projects is insufficient because watershed land use controls ambient water quality and hydrology, and land use surrounding many restoration projects at the time of their construction, or in the future, do not provide sufficient conditions for functional integrity recovery. Reach scale channel restoration or modification has limited benefits within the broader landscape context. Physical habitat variables are often the basis for indicating success, but are now increasingly seen as poor surrogates for actual biological function; the assumption "if you build it they will come" lacks support of empirical studies. If stream restoration is to play a continued role in compensatory mitigation under the United States Clean Water Act, then significant policy changes are needed to adapt to the limitations of restoration science and the social environment under which most projects are constructed. When used for compensatory mitigation, stream restoration should be held to effectiveness standards for actual and measurable physical, chemical, or biological functional improvement. To achieve improved mitigation results, greater flexibility may be required for the location and funding of restoration projects, the size of projects, and the restoration process itself.

(KEY TERMS: environmental regulations; stream restoration; aquatic ecology; rivers/streams; water policy.)

Doyle, Martin W. and F. Douglas Shields, 2012. Compensatory Mitigation for Streams Under the Clean Water Act: Reassessing Science and Redirecting Policy. *Journal of the American Water Resources Association* (JAWRA) 1-16. DOI: 10.1111/j.1752-1688.2011.00631.x

INTRODUCTION

The overarching goal of the United States (U.S.) Clean Water Act is to sustain and restore the physical, chemical, and biological integrity of the nation's waters. Under Section 404 of the Clean Water Act, permitted impacts to "aquatic resources" must be mitigated. The term "aquatic resources" includes both streams and wetlands, but although the science, policy, and economics of wetland mitigation have received considerable attention (NRC, 2001), stream mitigation has not (Lave *et al.*, 2008).

Mitigation under the Clean Water Act was regulated for years by a series of guidance documents, but in 2008, the "Rule for Mitigation of Impacts to Aquatic Resources" was finalized jointly by the U.S. Army Corps of Engineers (Corps) and the Environmental Protection Agency (EPA). This rule now governs mitigation (33 CFR Parts 325 and 332, "Compensatory Mitigation for Losses of Aquatic Resources," April 10, 2008; §332.5 and §332.6) and is hereafter referred to as the "2008 Rule." Mitigation prioritizes avoiding and minimizing impacts, and allows "compensatory mitigation," or the preservation, enhancement, or restoration of a site in order to

[1]Paper No. JAWRA-11-0029-P of the *Journal of the American Water Resources Association* (JAWRA). Received March 1, 2011; accepted October 26, 2011. **Discussions are open until six months from print publication.**

[2]Respectively, Professor (Doyle), Nicholas School of the Environment, Duke University, Durham, North Carolina 27708; and Research Hydraulic Engineer (Shields), USDA – ARS National Sedimentation Laboratory, Oxford, Mississippi 38655 (E-Mail/Doyle: martin.doyle@duke.edu).

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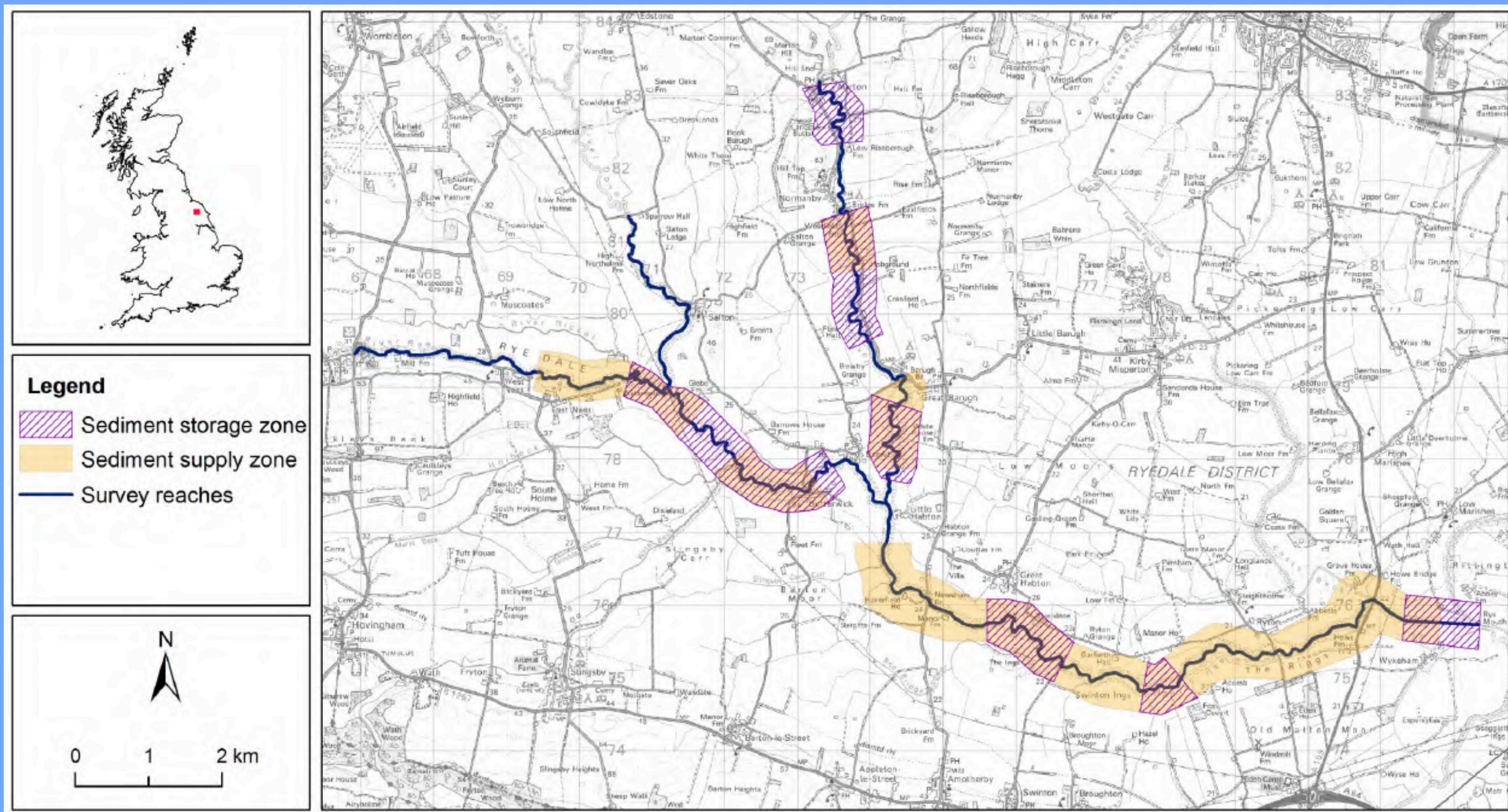
Mitigation Banking/In Lieu Programs

- Economic Instruments
  - Incentivizing monitoring via economic discounts
  - Restoration portfolios
  - Restoration trust funds for long-term adaptive management approaches

Tools – Fluvial Audit



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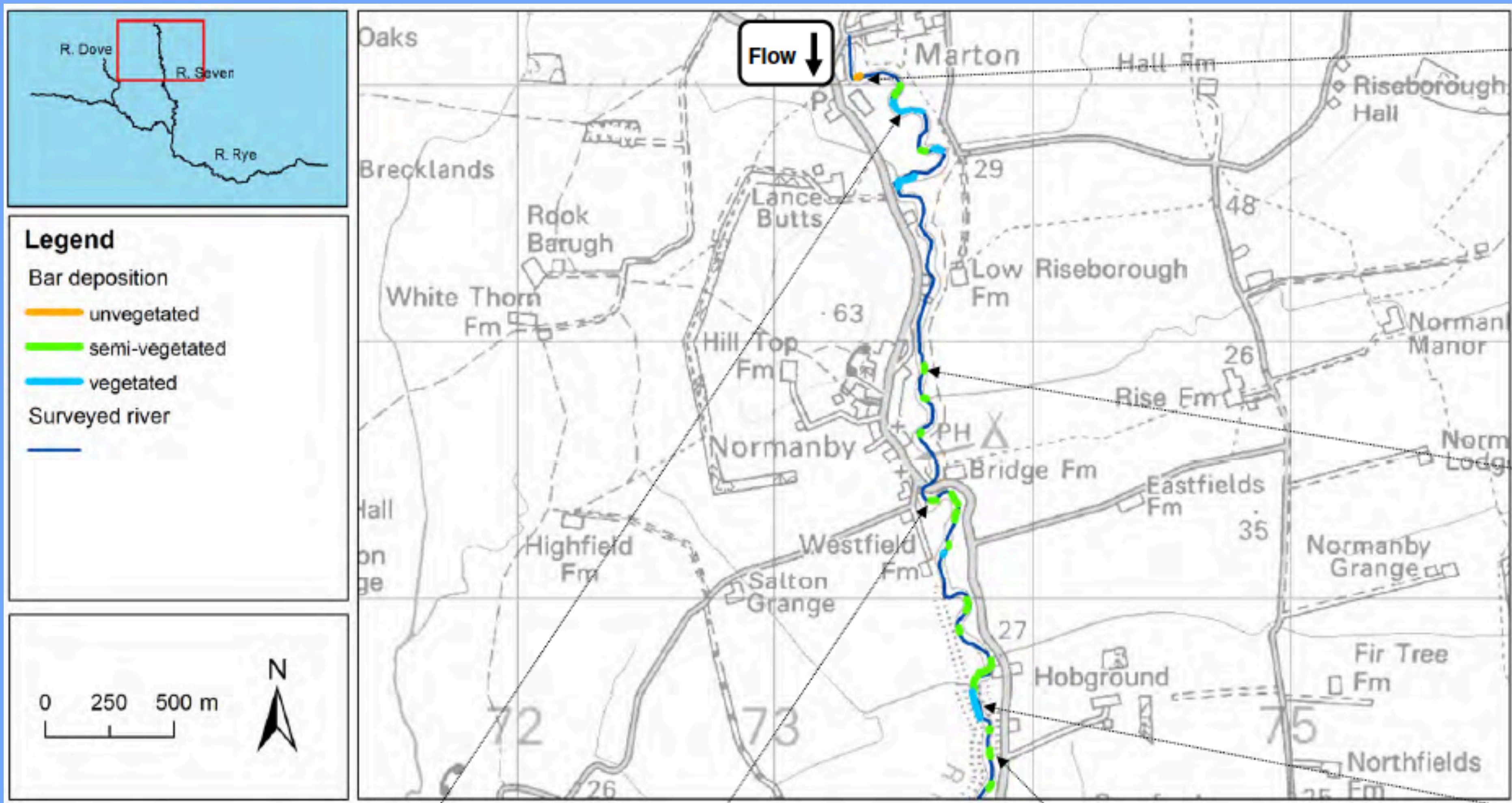

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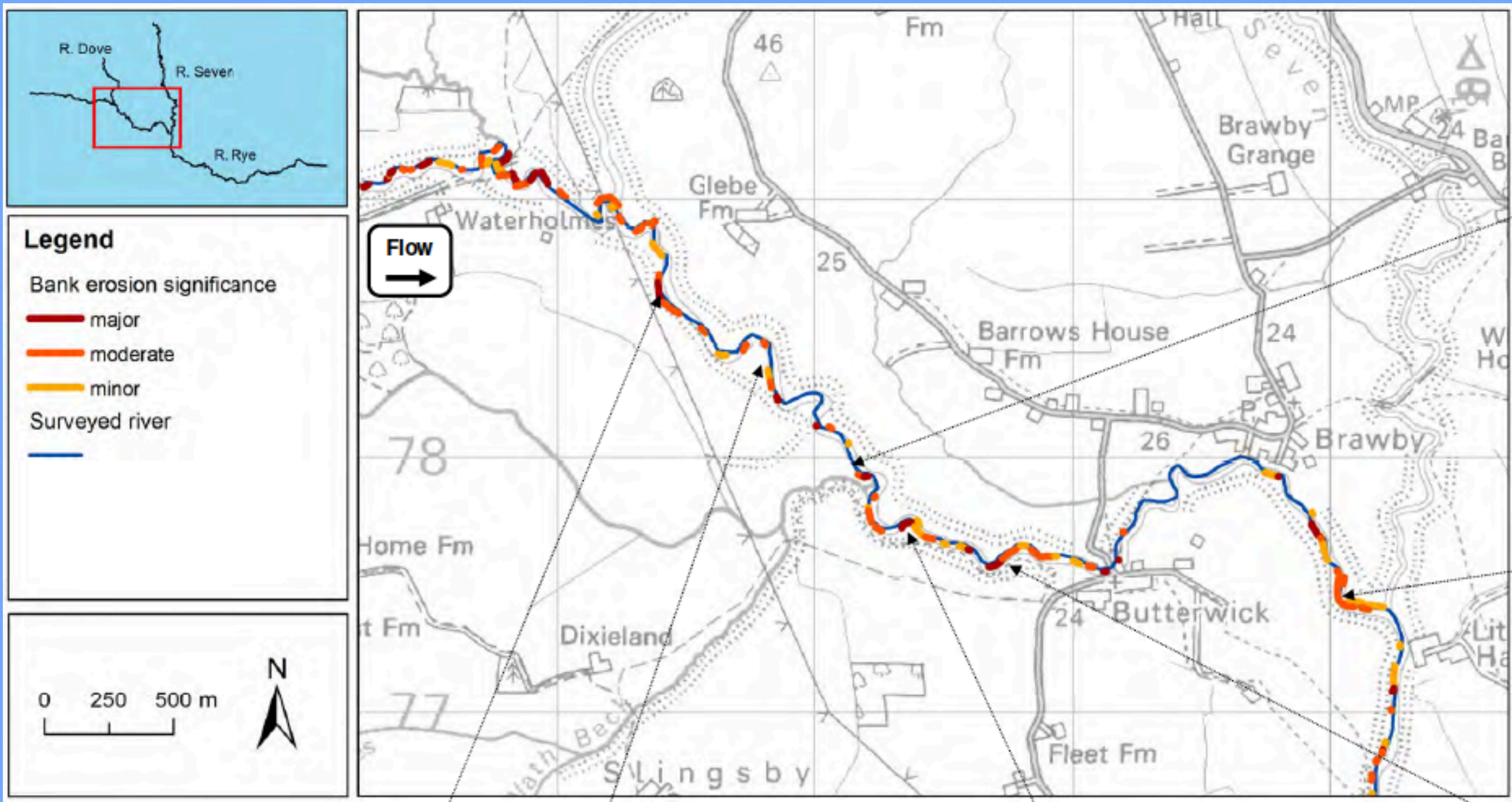
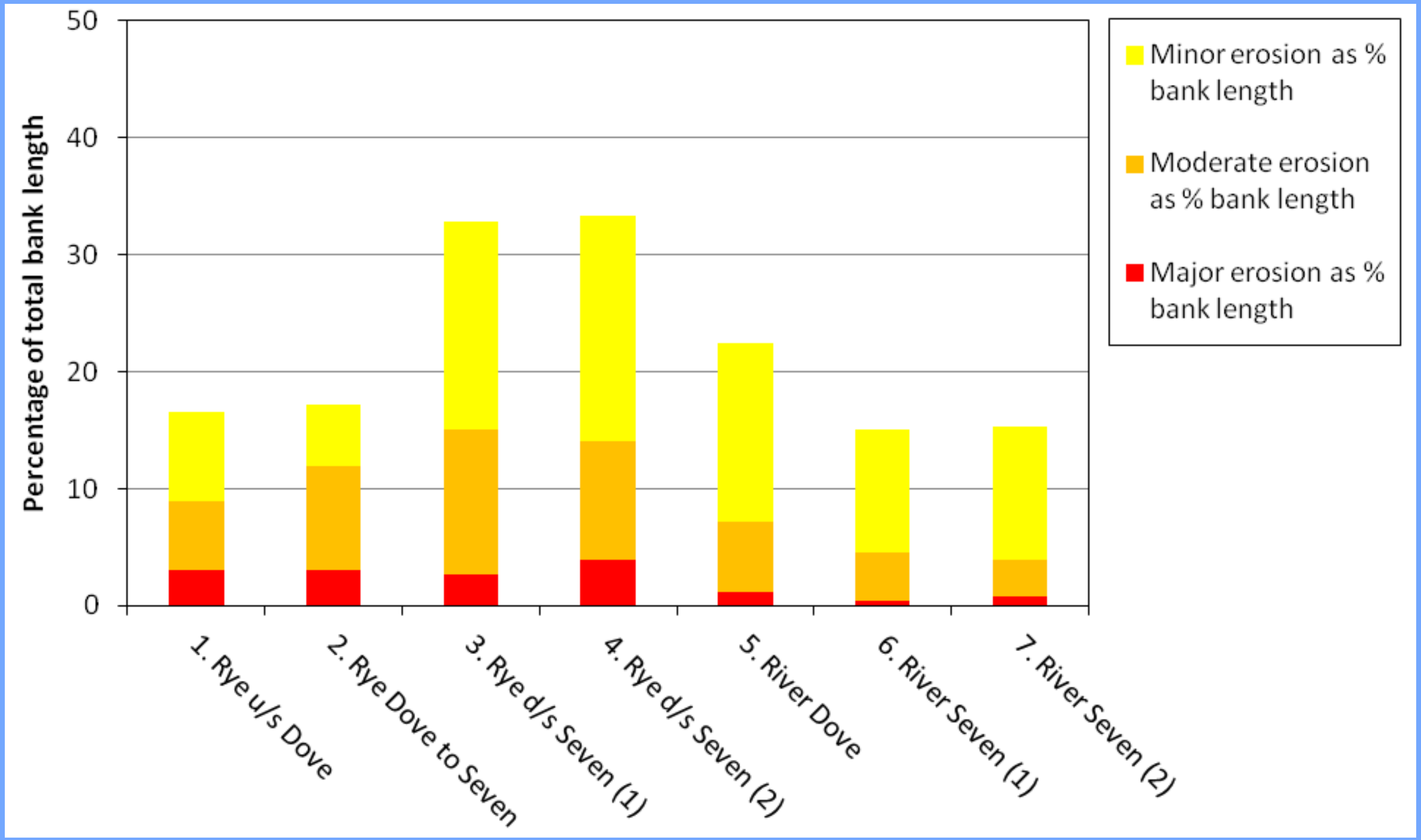


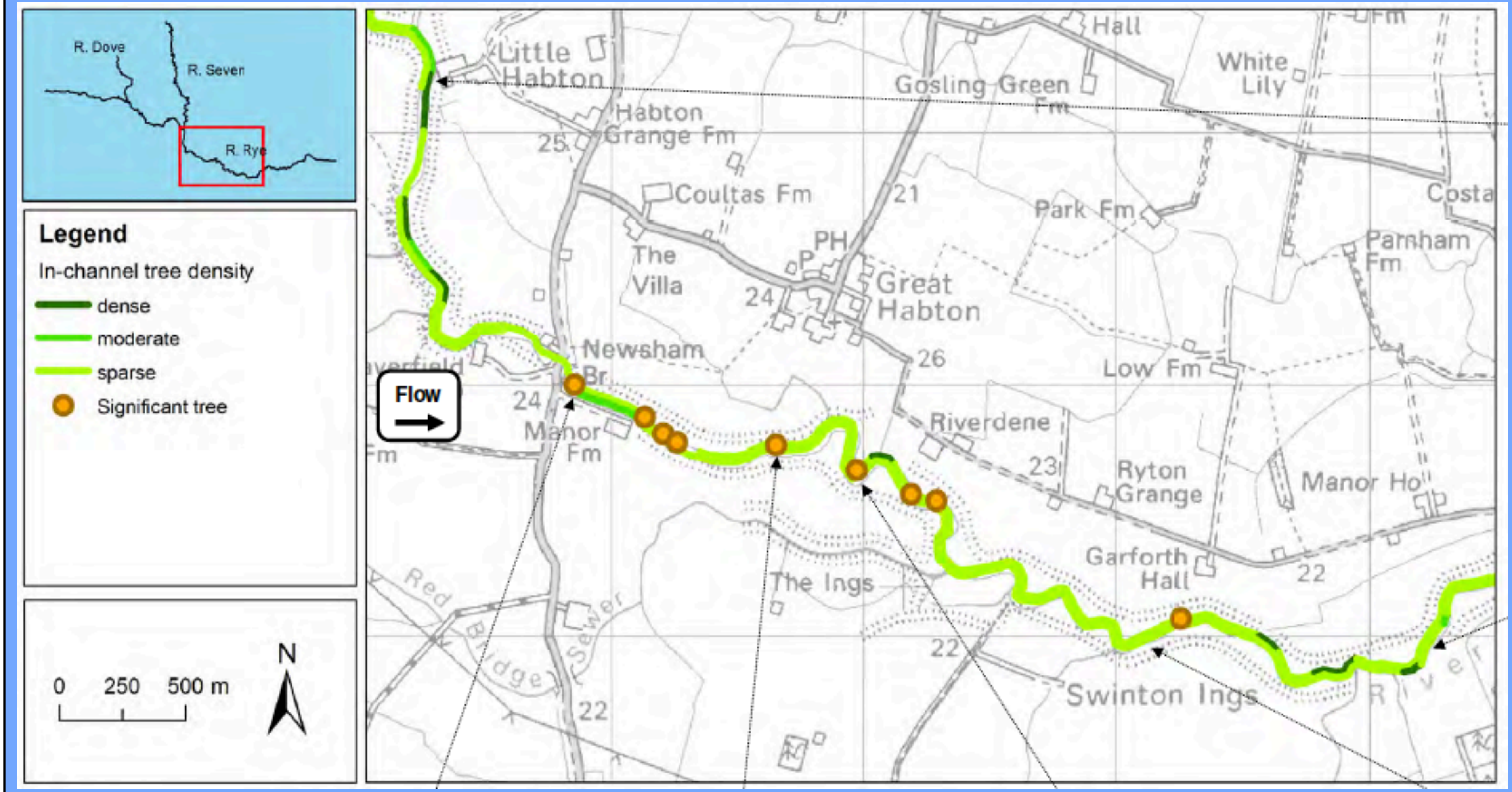
Key findings: Bank erosion rates

Bank erosion as % total bank length for the seven sections of the Rivers Rye, Seven and Dove



- Between 15% and 33% of banks eroding in each river section
- Highest erosion rates - Rye downstream of Seven confluence

Tools – Fluvial Audit



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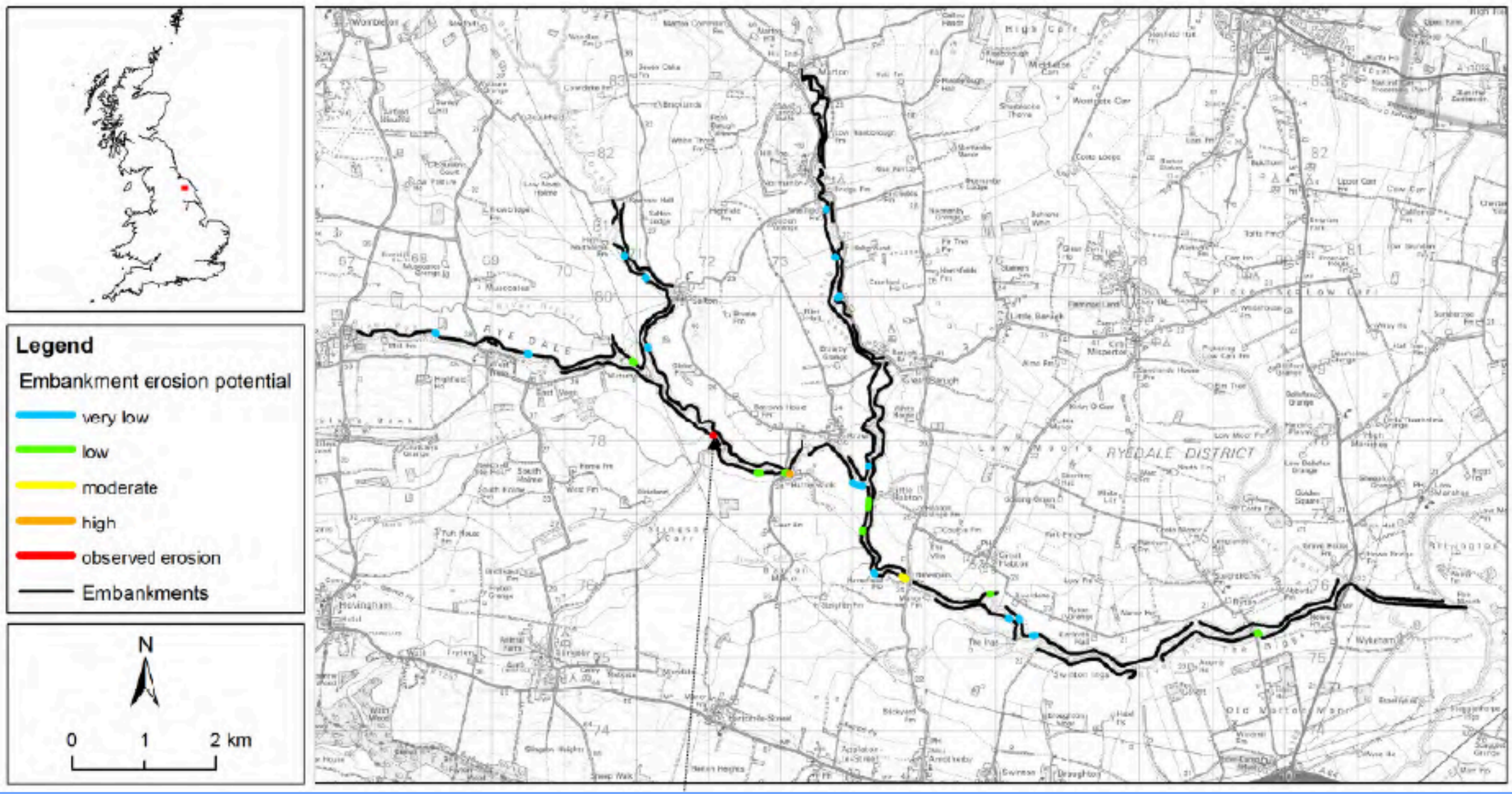
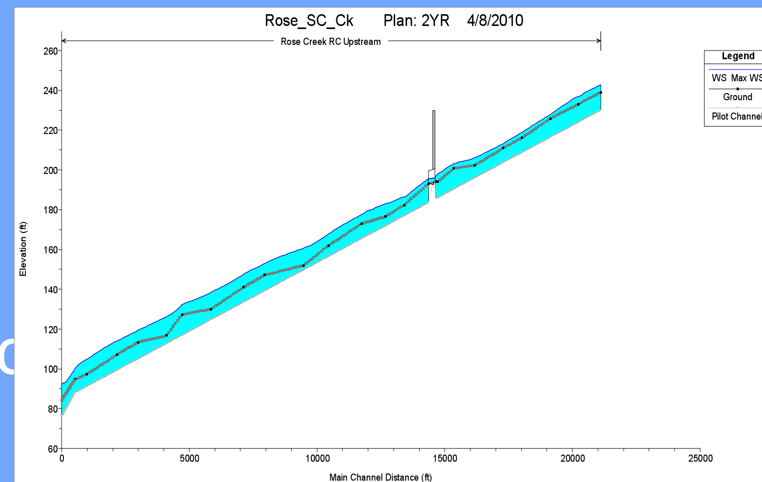


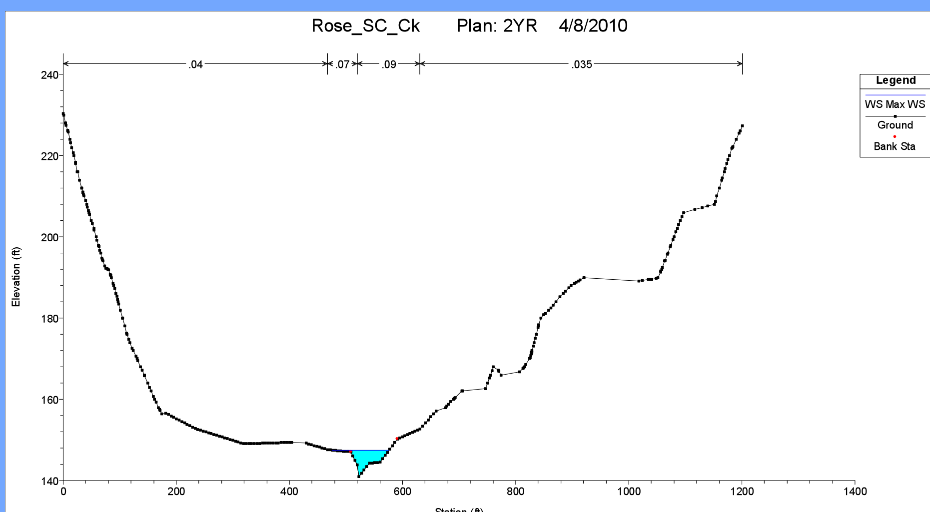
Tools – Rose and San Clemente Creeks

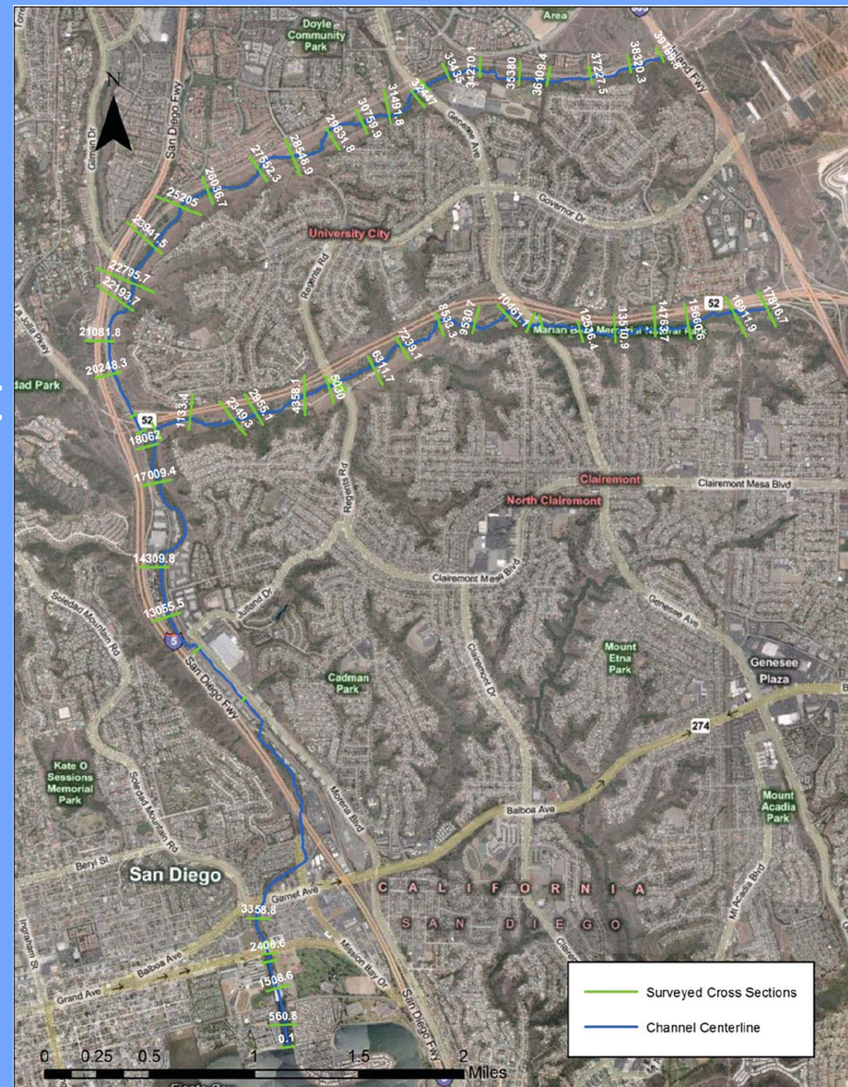
- Develop Modeling Tools for Watershed Scale Analysis
- Model Existing Conditions
- Formulate Restoration Alternatives Using Hydrodynamic Model
- Test and Refine Proposed Alternatives Using Hydrodynamic Model
- Examine Affects of Proposed Projects on Watershed Hydrodynamics



Bathymetric / Topographic Data Collection

- Transect Locations
  - 64 Survey Cross sections
  - 500 to 1000 foot spacing
  - Rose Creek and San Clement Creek (I-805 to Mission Bay)





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Hydrodynamic Model Development

- HEC-GeoRAS 1D Hydrodynamic Model

- Model Boundary Conditions
  - 100 and 50 year unsteady flow events
  - 2, 5, 10 & 25 year unsteady flow events (HSFP)

- Hydraulic Roughness (Manning's)
  - Estimated in the field per vegetation type along each surveyed cross section
  - Calibrated using measured stage and discharge data

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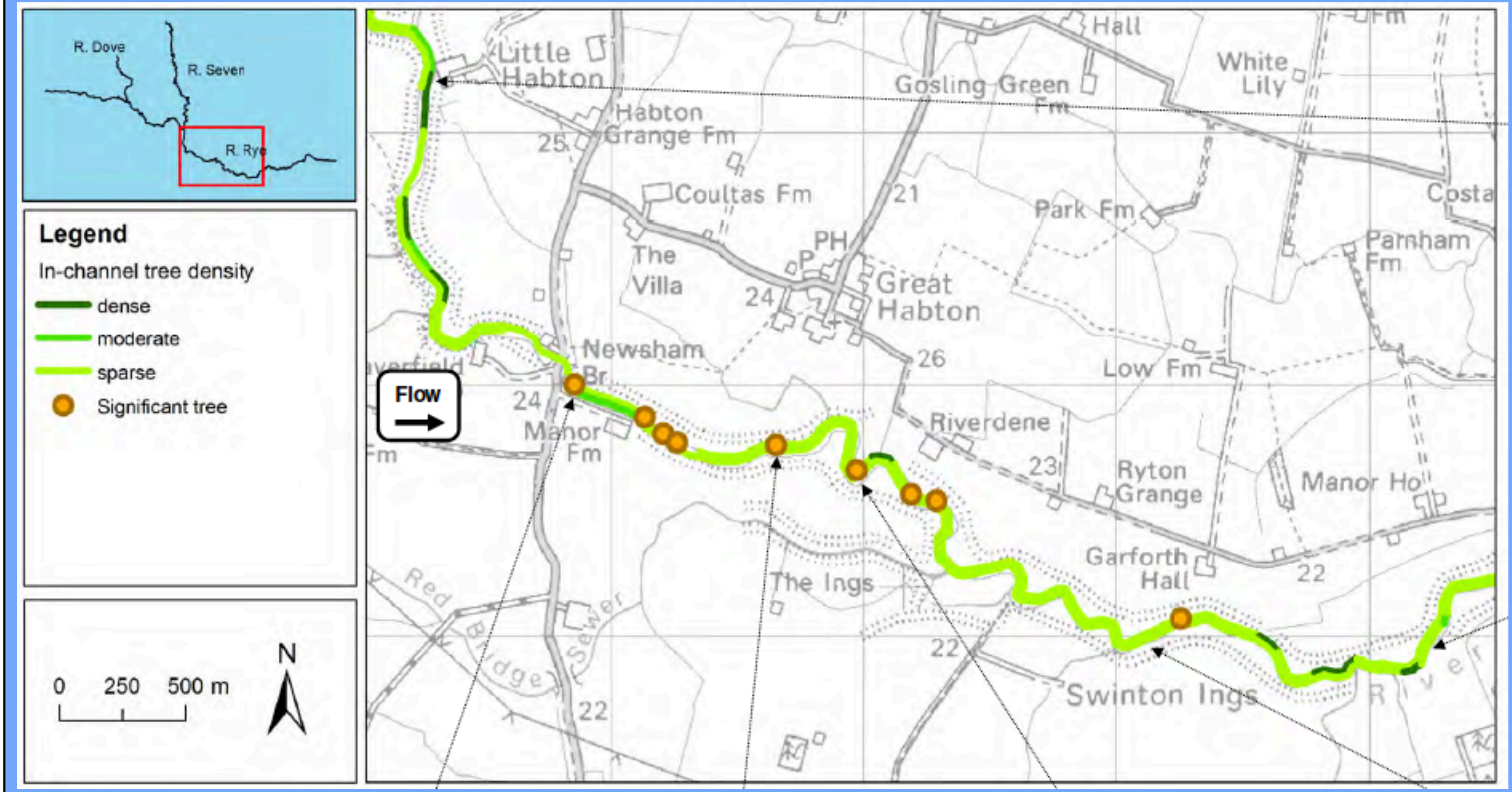

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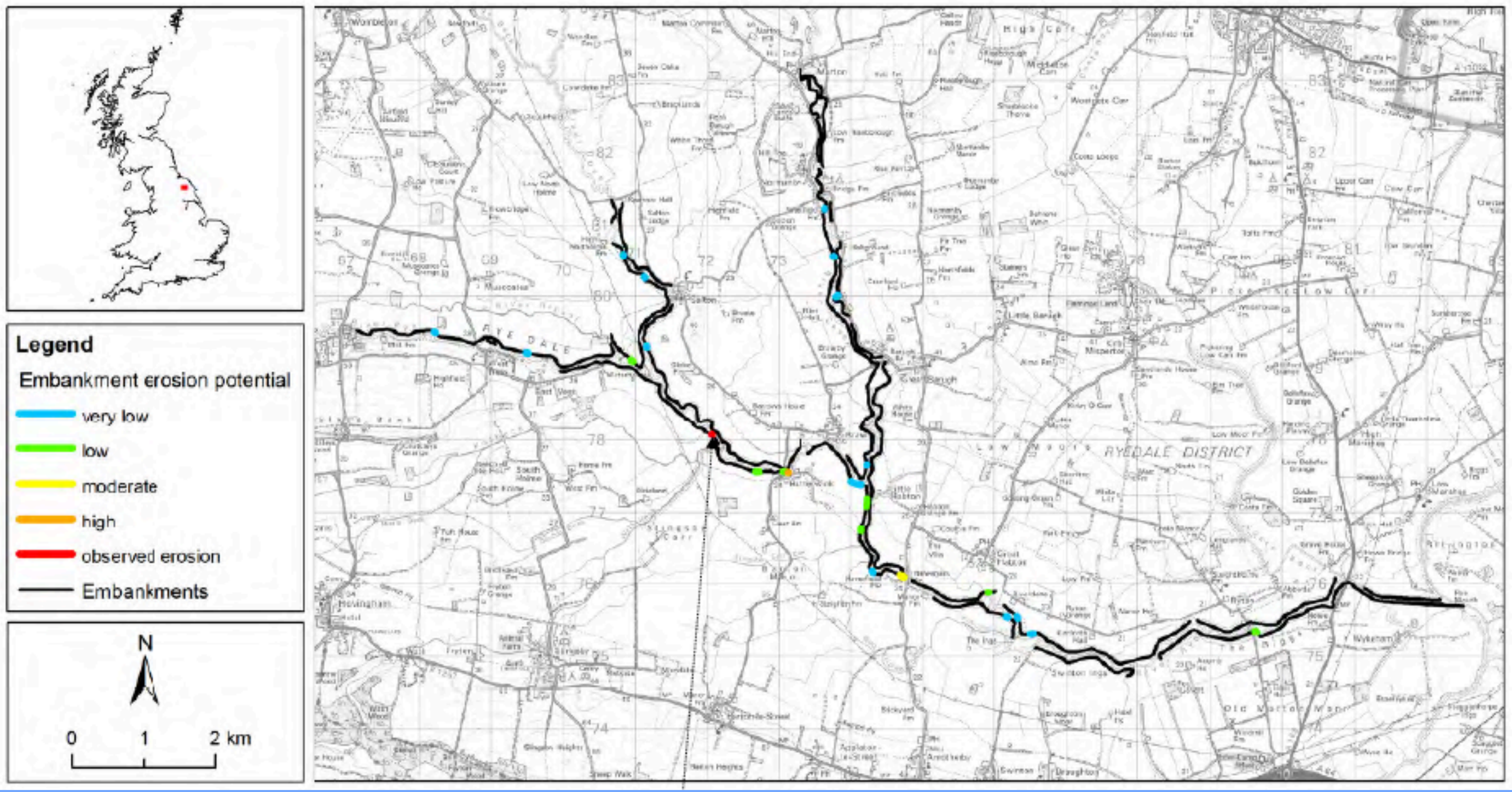

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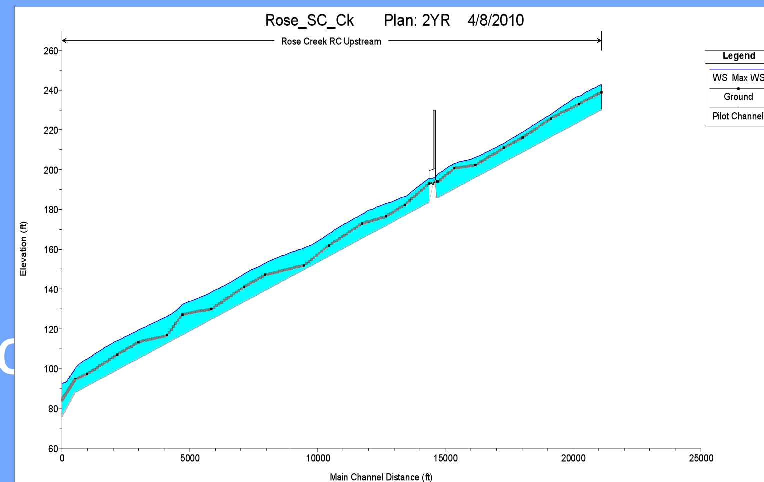

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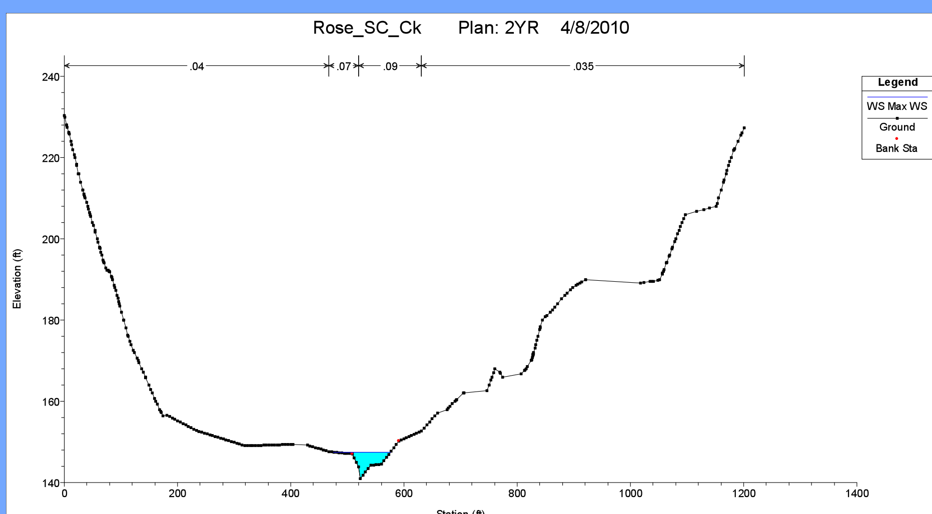

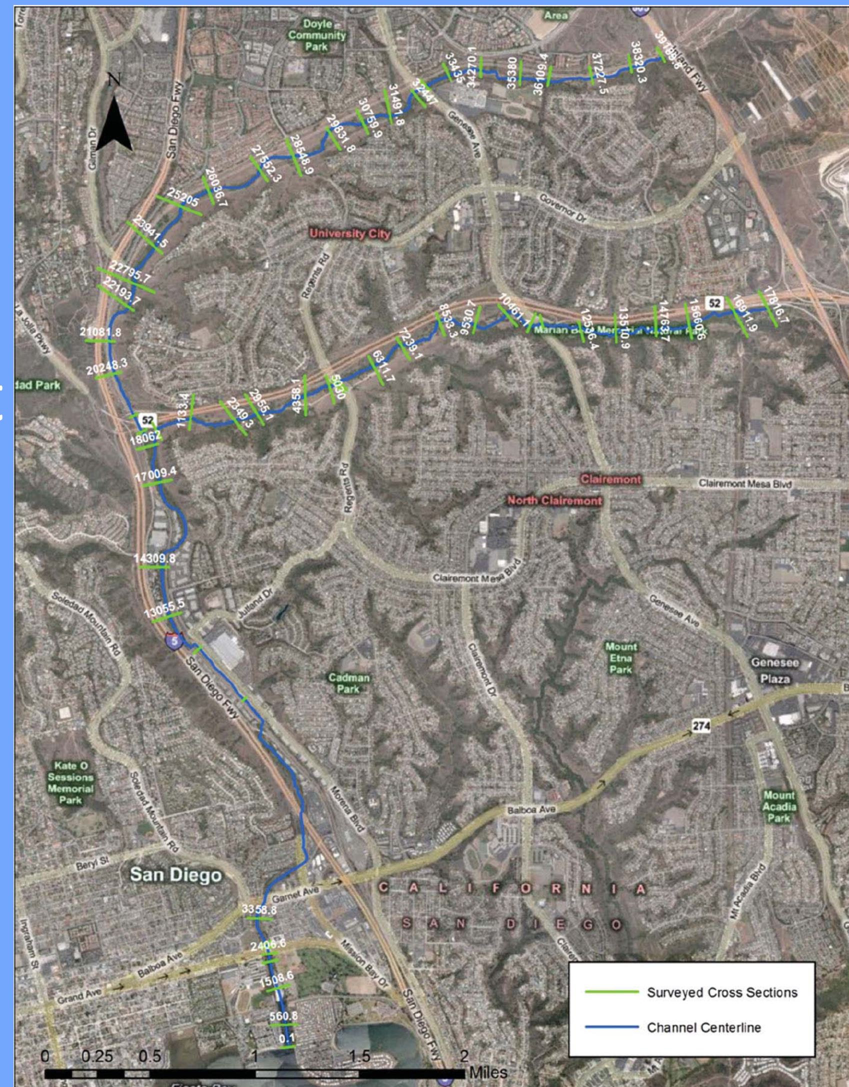

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