Scenario Modeling and Restoration Implications

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Lower Columbia Estuary Partnership

CREST Columbia River Estuary Study Taskforce

Background

- Estuary Partnership works with our partners and stakeholders to address habitat loss and declines in fish & wildlife populations through ecological restoration.
- Many of the wetland/floodplain sights present similar challenges:
  - ✓ hydrologically altered
    - disconnected from main-channel(s)
    - reduced shallow-water habitat
  - ✓ monoculture(s) -invasive species
  - ✓ leveed/anthropogenic manipulations
  - ✓ landowner/social complexities

Karlson Island

E. Fork Lewis R.

Background

- We wanted to better understand how the site(s) are functioning and we used inundation scenarios to "test" potential management actions and to evaluate:
  - increased habitat for juvenile salmonids and aquatic and native vegetation communities?
  - evaluate risks to adjacent landowners
  - cost : benefit(s)
- Connect modeling efforts with attributes of a properly functioning system and physical processes.

Recovery Trajectories…..

Case Study 1 - East Fork

- Evaluate project feasibility related to levee breaching using hydrodynamic modeling at two sites.

- **East Fork Lewis River**:

  Question 1- is levee limiting flow- how /where?
  Question 2- current vs. potential habitat?
  Question 3- risks to landowners?
  Question 4- what are egress/ingress inundation flows?

Case Study 2- Karlson Island

- **Karlson Island:**
  Question 1- is the levee limiting flow at high tidal and fluvial events- how where?
  Question 2- what is the site inundation under different hydrologic "events"?
  Question 3- what are the distributary velocity conditions?
  Question 4- what are the effects of removing the sediment plug?

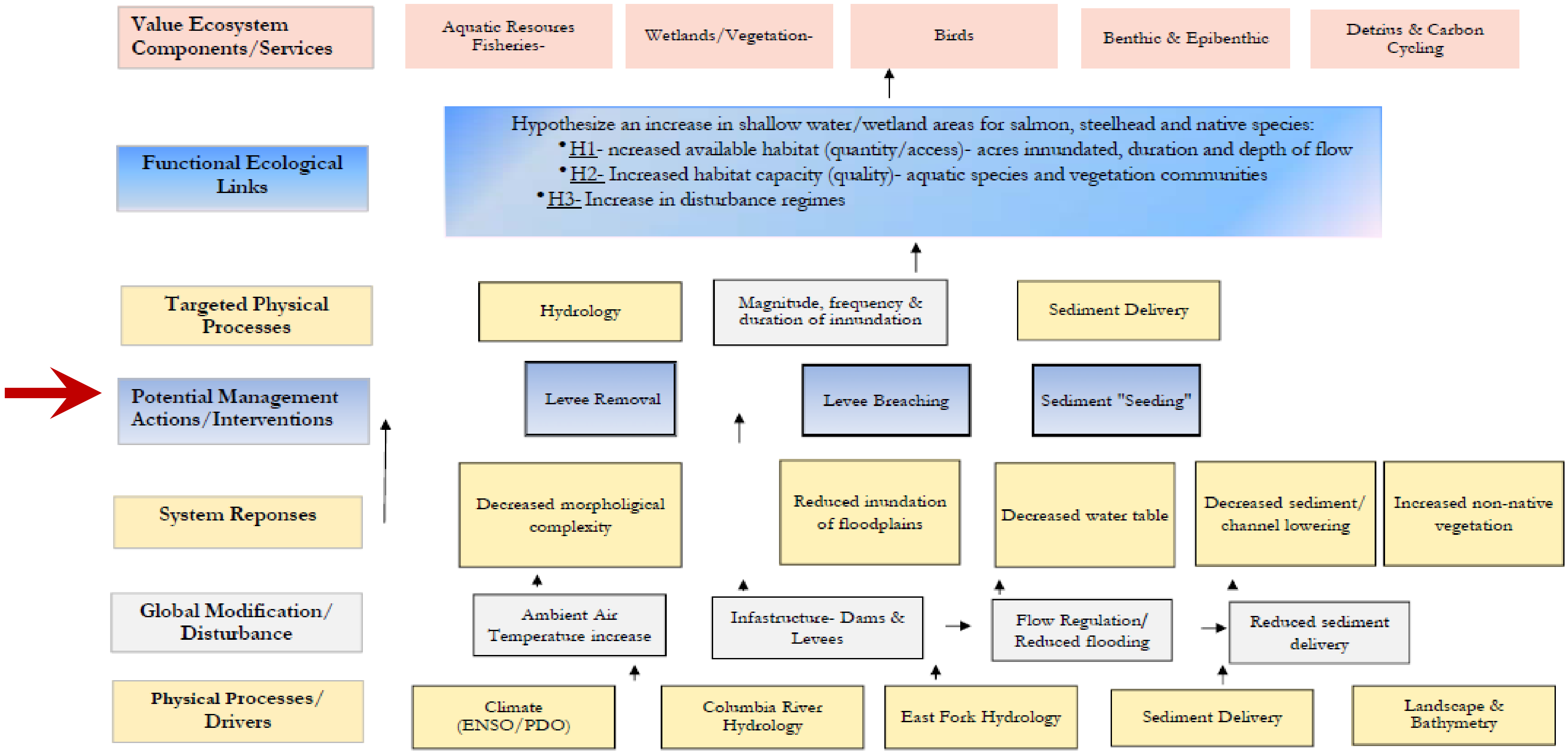
Methods

1) Conceptual modeling
   - Define problem and healthy attributes
   - Connect form to physical processes
   - Define expected ecological outcomes

2) Hydrodynamic modeling
   - 1D-HEC Geo-RAS
     - digital elevation modeling
     - hydrology- fluvial and tidal datum
     - Arc- GIS GUI interphase

Conceptual Model

Conceptual Model- Physical Processes
East Fork Lewis River *



* Model based on Trinity River Restoration Plan & Bottom et. al (2006 & 2011- in press)

Physical Processes and Form
Healthy Attributes

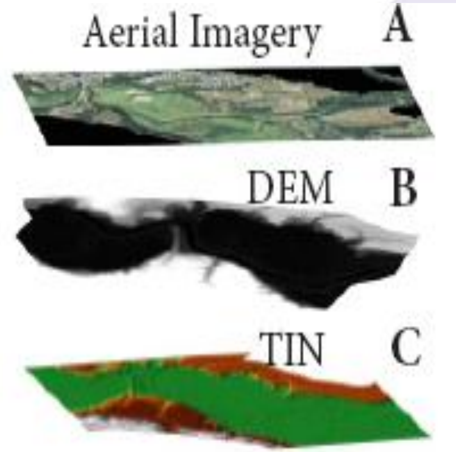
1. Spatially complex channel-to-floodplain morphology
2. Flows are predictably variable
3. Infrequent channel resetting floods
4. Minimum depth, velocity and "edge" requirements
5. Functional floodplain
6. Self-sustaining (native) riparian plant communities
7. Naturally fluctuating groundwater table

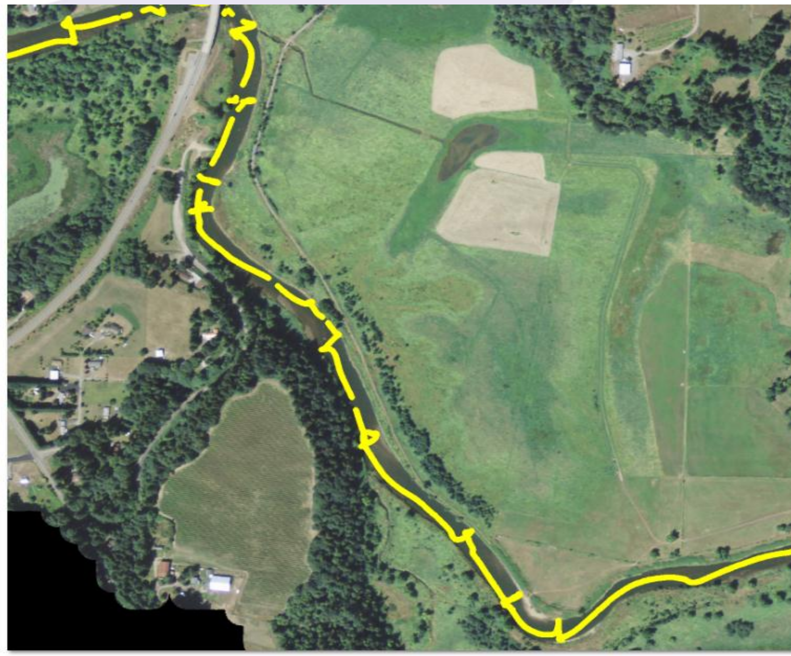
DISTURBACE REGIMES ARE KEY
CAN WE GET THERE?

* Based on Approach for the Trinity River (McBain & Trush, 2006)

Hydrodynamic Model Inputs

ELEVATION/LAND- USE

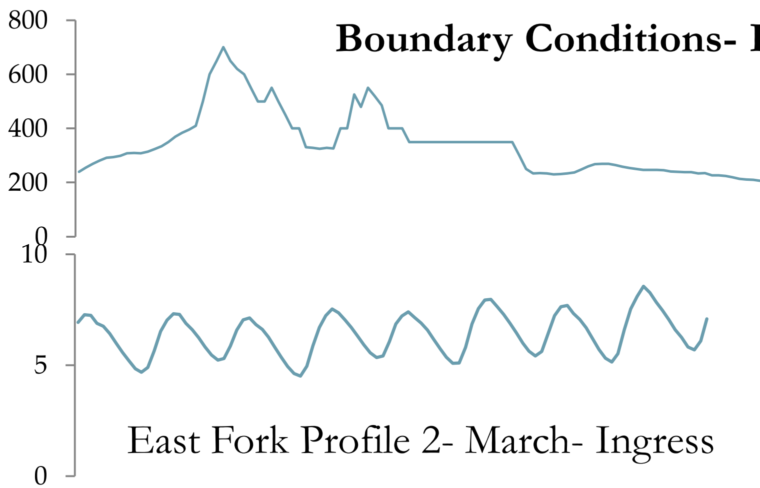




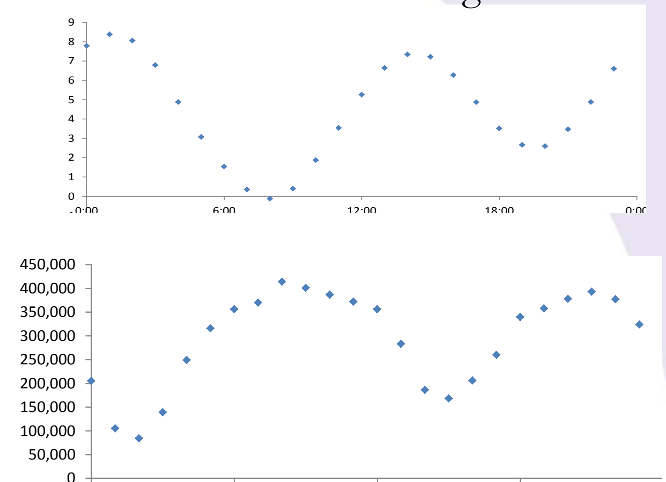
SEDIMENT – Grain Roughness

4–8 mm	0.157–0.31 in	Fine gravel
2–4 mm	0.079–0.157 in	Very fine gravel
1–2 mm	0.039–0.079 in	Very coarse sand
½–1 mm	0.020–0.039 in	Coarse sand
¼–½ mm	0.010–0.020 in	Medium sand

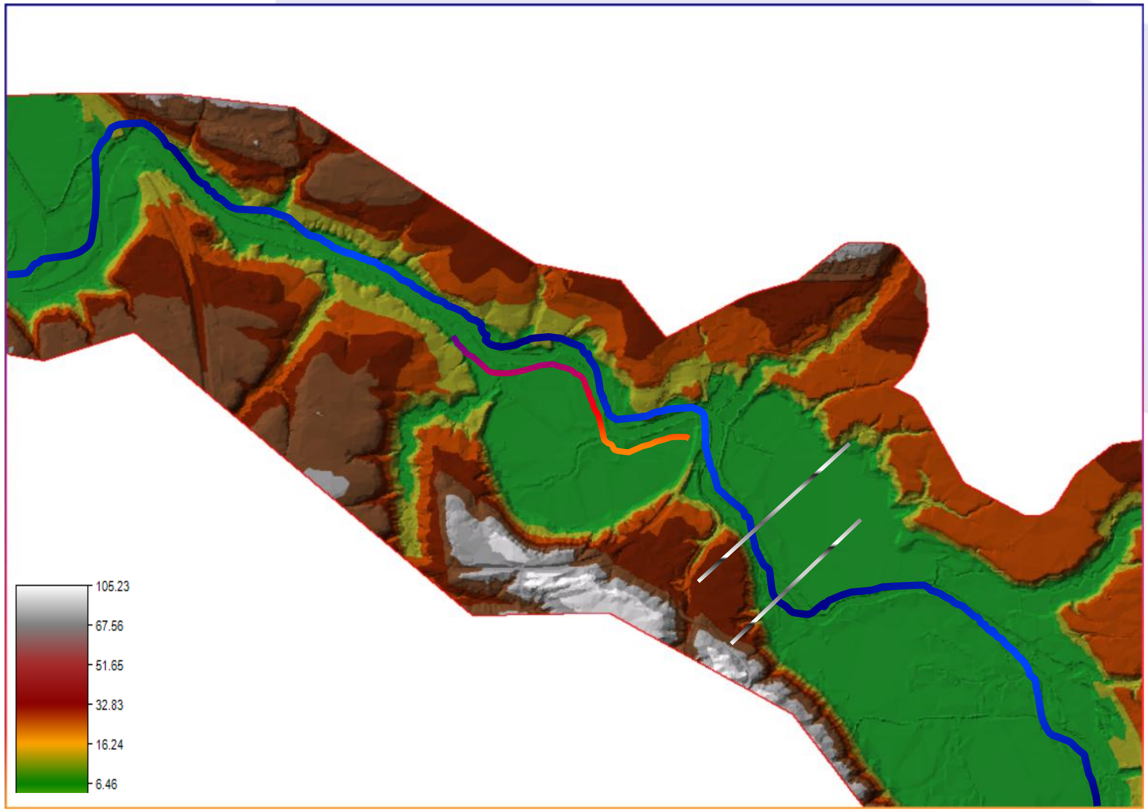
Boundary Conditions- Hydrology



Karlson Island Signature



Model Geometry- E. Fork



Model Geometry Arc- GIS

- Cross- sections
- Center Line
- Streambank line
- Levees

Results: E. Fork- Current Conditions

Profile 1
Nov-
ingress

Profile 2
March-
ingress/
egress

Profile 3
March-
ingress/
egress

Profile 4
June-
egress

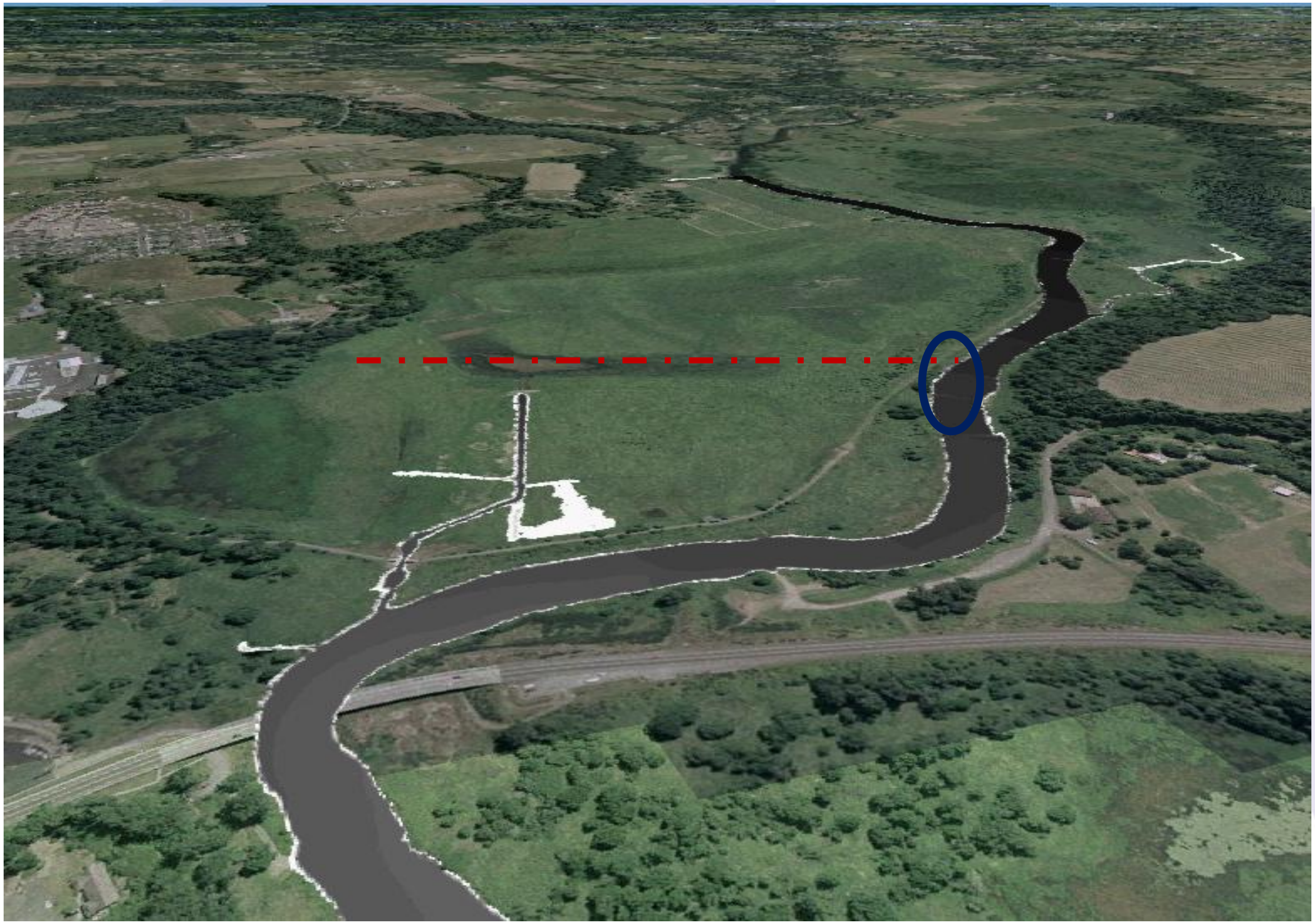
Results: E. Fork-Levee Breach

Profile 1
Nov-
ingress

Profile 2
March-
ingress/
egress

Profile 3
March-
ingress/
egress

Profile 4
June-
egress



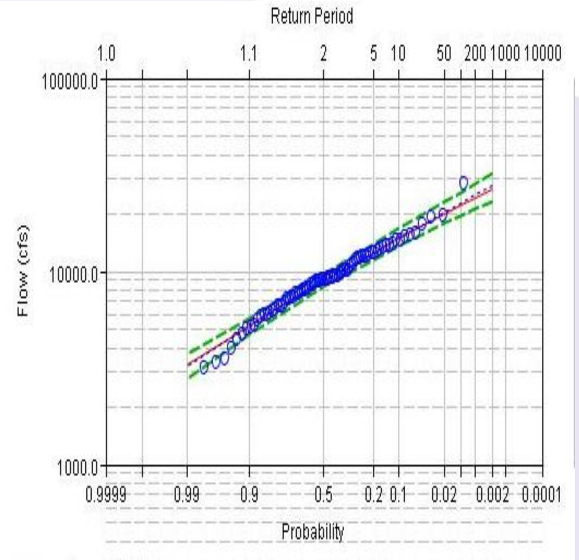
Results: Inundation flows

	Existing (blue) & Levee Breach (red)							
Variable	Profile 1		Profile 2		Profile 3		Profile 4	
Depth (ft)	0.3	0.4	.42	.85	0.6	1.1	1.3	2.2
Wetted Perimeter (acres)	1	1	14.5	44	17	60	60	70

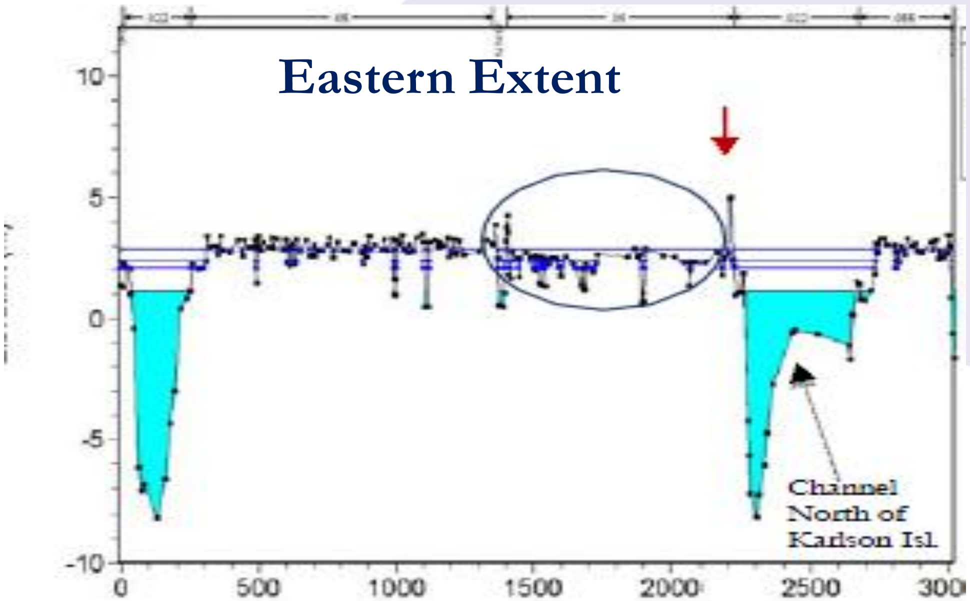
	Change from Existing Conditions			
Variable	Profile 1	Profile 2	Profile 3	Profile 4
Depth (ft)	.1	+ 0.45	+ 0.5	+ 0.9
Wetted Perimter (acres)	-	+ 29.5	+ 43	+ 10

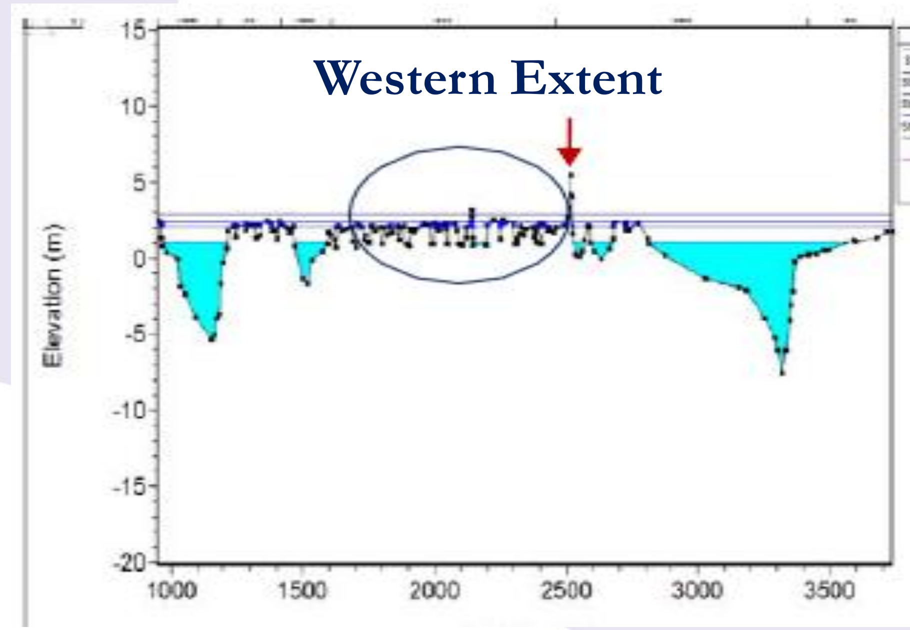
Results: Levee Functioning

2009- 12,500 cfs



Results: Karlson Island Levee

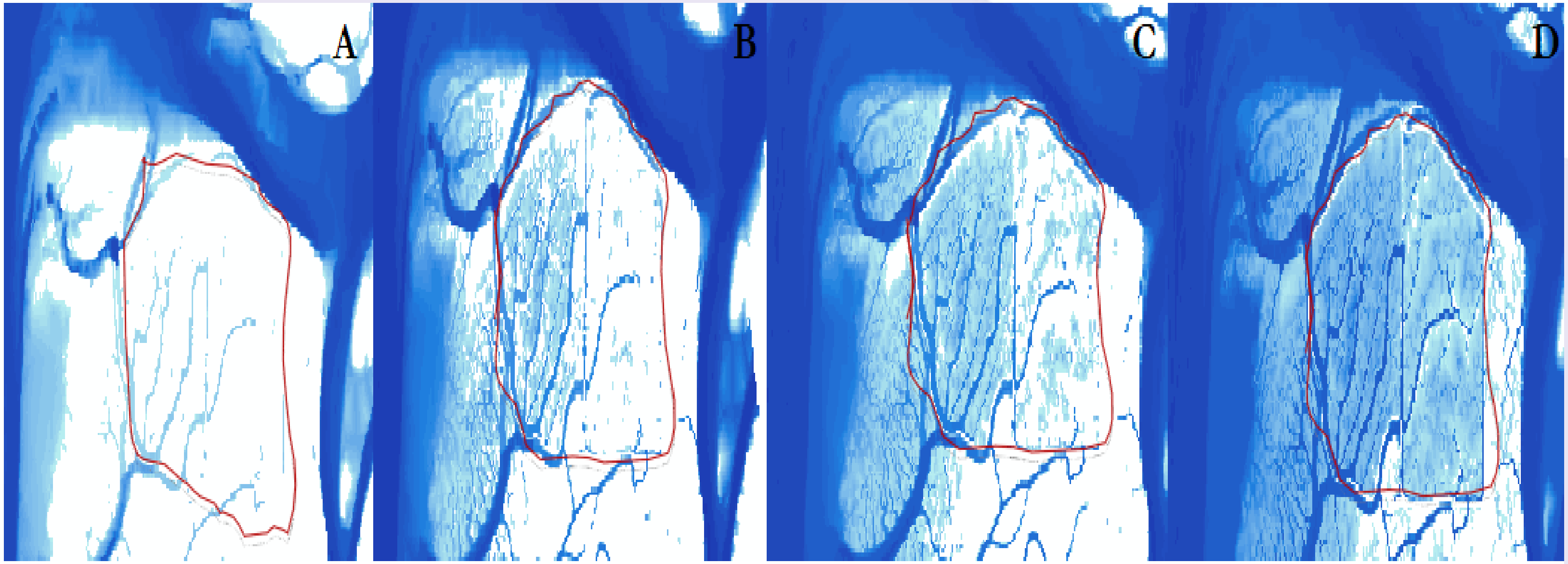




- Levee is not overtopped even at highest stage modeled
- Limited floodplain inundation
- In-channel hydraulics not known

- Levee is not overtopped even at highest stage modeled
- Greater floodplain inundation

Results: Karlson Island Inundation



- Modeled four tidal signatures/Columbia River flows- tidal stage increased from: 1.53 ft. to 9.19 ft.

East Fork Lessons

- There is evidence that levee breaching at the E. Fork could improve habitat conditions for salmonids during ingress and egress "windows".
- The levee is not currently providing flood protection and is overtopped every year.
- The cost of levee breaching is significantly cheaper than levee removal.
- East Fork hydrologic processes are "intact", however sediment processes have been altered (upstream removal) and dredging has occurred in main channel.

→ **This effects the site's long-term ability to maintain healthy attributes/disturbance regimes…**

Karlson Island Lessons

- Site dynamics are tidally driven (not fluvial).
- The levee at the northern extent is not overtopped under tidal events that equal ~ 2-year MHW.
- 1D modeling was not able to answer questions related to the internal distributaries, levee breaching and removal of sediment plug.
- There is evidence that breaching along the western end of the levee could increase habitat availability and opportunity.
- 1D approach can't really answer questions 3 & 4.

Location Matters

- East Fork- alluvial/tidal interphase:
  - wetland habitat driven by alluvial processes
  - juvenile salmonids use is seasonal (Nov.- May)
  - large floods on drive physical processes
- Karlson Island - tidally driven
  - mixed diurnal and semi-diurnal
  - year-round juvenile habitat use
- Up-river ESU stocks may enter tributaries for refugia (water temperature) and other reasons…..

Lesson Learned

- 1D models can be effective tools in rapidly evaluating inundation scenarios depending on the site/complexity.
- There are hydrology, landscape and bathymetry data and "open source"/free models that can be used to drive modeling efforts.
- 1D models can't answer 2D questions.
- East Fork of Lewis River and Karlson Island present similar problems- but they function (physical processes) differently and have different potential restoration solutions.

Lower Columbia River Estuary Partnership

Scenario Modeling to Evaluate Restoration Actions within the Lower Columbia River Estuary Case Study: East Fork of the Lewis River

1. INTRODUCTION

In the Lower Columbia River Estuary (LCRE) restoration of critical habitat for ESA listed salmonids, steelhead, and other species of concern is a priority. In this case study modeling is used to evaluate current conditions and to assess the feasibility of a levee breach to enhance salmonid habitat. A digital elevation model (DEM), ArcGIS and a hydrodynamic model is used to evaluate current habitat and to predict future habitat benefits, assess project feasibility and increase certainty of project success. The data, and the tools used in this case study, are freely available and this approach can be used within the LCRE to evaluate other potential restoration projects.

2. THE STUDY SITE - EAST FORK LEWIS RIVER

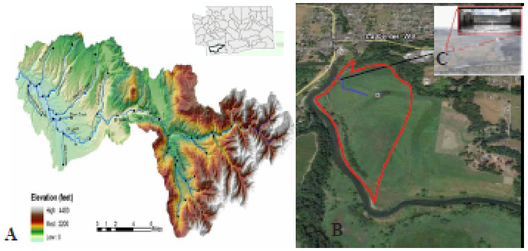


Figure A: Basin location (TIN).[1]
Figure B: Project area (red). Blue line existing connection with E. Fork (Google). Site is currently being managed by Clark County.
Figure C: Weir- 30 ft upstream from existing connection with E. Fork.[2]

Hydrology (post-1980)	Floodplain	E. Fork Dynamics
E. Fork Drainage Area- 212 m^2	Multi-use	Sand bed
Q_{peak} E. Fork- 28,000 cfs	Levee elv.- 20ft	Slope- .01%
Q_{peak} Columbia R.- 820,000 cfs	Floodplain elv.-12ft	Tidally influenced

Historically, this area was a complex of wetlands and sloughs which was inundated on a regular basis. This 100 acre floodplain site is isolated from the E. Fork by an existing levee, which is setback 50-250 feet from the river. Overall, the floodplain is disconnected from physical and hydrologic processes, with the exception of the existing weir connection (Fig. C). Salmon (and other fish) currently utilize about 10 acres and it is expected that an additional upstream levee breach would increase available habitat and survival of salmon and steelhead.[2]

3. MODELING & CASE STUDY

Modeling is a tool used by scientist, engineers and natural resource managers to explain, predict and forecast a variety physical (and other) conditions that affect aquatic habitats over space and time. Different types of modeling approaches can be used to evaluate ecological benefits, including conceptual, scenario, numerical and GIS based. Hydrodynamic models are a special case of numerical models and they can be used to study the motion of liquids (NOAA).[3]

Hydrodynamic models are frequently used in fluvial & tidal environments to understand the movement of water & sediment perpendicular to defined cross sections (1D) and within the x-y plane (2D). In this case study we are using 1D hydrodynamic modeling to 1) understand fluvial and tidal variables (e.g. water depths) and 2) to evaluate existing and proposed management actions related to habitat benefits for salmon and steelhead.

4. THE MODEL - HEC-GeoRAS & HEC-RAS

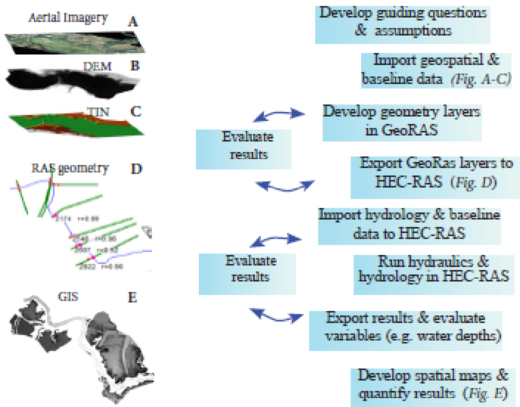
HEC-GeoRAS was chosen because geospatial data (LiDAR) was readily available at this site. GeoRAS allows for the processing and preparation of geospatial, and geometric data, in Arc-GIS. Processed geospatial data is then imported into HEC-RAS. HEC-RAS is designed to perform one-dimensional hydraulic and hydrologic calculations for rivers and floodplains using levee and floodplain storage themes.[4]

The HEC modeling platform can be used to evaluate management actions and ecologically important hydrologic and hydraulic variables using different scenarios such as those outlined in Table 1:

Table 1- Potential management actions that can be evaluated.

	Management Action			
Variable	Levee Breach	Remeander Channel	Revegetation	Replace Culvert
Water Depth	✓	✓	✓	✓
Velocity	✓	✓	✓	✓
Wetted Perimeter	✓		✓	
Water Quality/ Sediment Transport		✓	✓	✓

5. MODELING STEPS



6. GUIDING QUESTIONS & ASSUMPTIONS

These questions were used to guide model development:

1) How many acres within the site are currently inundated and to what depth?
2) Would there be additional habitat benefits (for aquatic species) if an upstream levee breach occurred?

The following assumptions were used:

- LiDAR can be used to represent topography and channel bathymetry (LiDAR was flown when E. Fork <100 cfs)- this was deemed acceptable to represent channel geometry);
- Tributaries/hillslope hydrology are not considered to drive ecological flows (e.g. Freshet);
- Differences in stage between the site and the Columbia R. are approximately 0.5-1.0 ft when stage >12 ft.

7. DATA SOURCES

Data Sources:

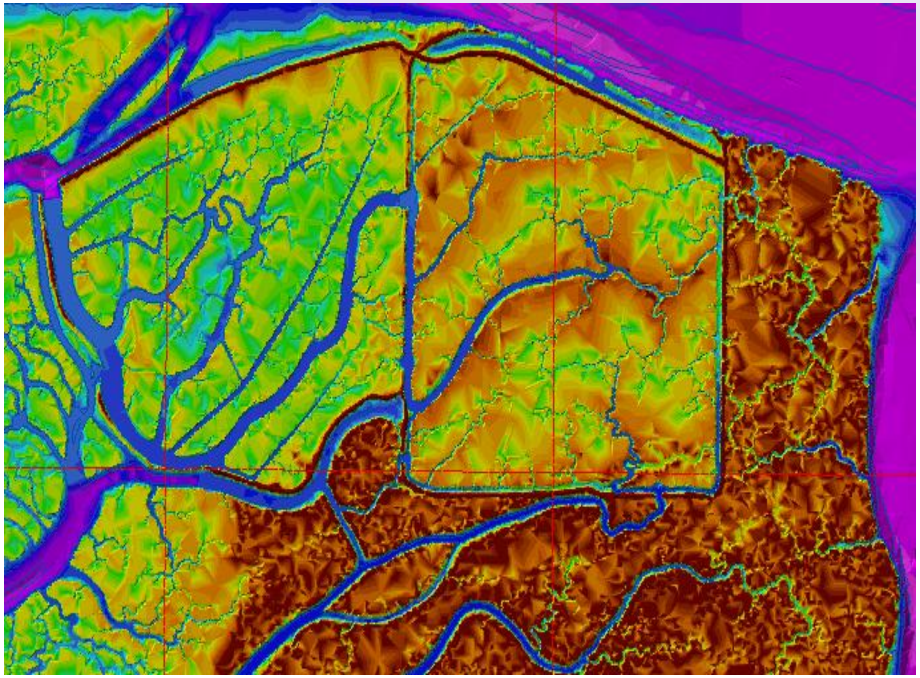
The following sources were used:

- LiDAR- 1 m resolution (LCREP);
- Aerial photos- visual reference (USACE, USGS);
- Stream Gage- hydrology inputs (USGS, USACE, NWIS);
- Tidal datum- hydrology inputs (NOAA, CORIE);
- Roughness- hydraulic inputs: floodplain- (LCREP GIS layer) & E. Fork- (Cramer Sciences).

[1] *Cramer Sciences. (2005). Prepared for LCFRB*
[2] *Baker, C.F. (2008). Dissertation- Seasonal Floodplain Wetlands as Fish Habitat in Oregon and Washington.*
[3] *http://www.nauticalcharts.noaa.gov/csdl/learn_models.html*
[4] *USACE- http://www.hec.usace.army.mil*

THE END…

Process vs. Form Scenario Tool



Physical Processes “drive” Ecological functions & form(s)

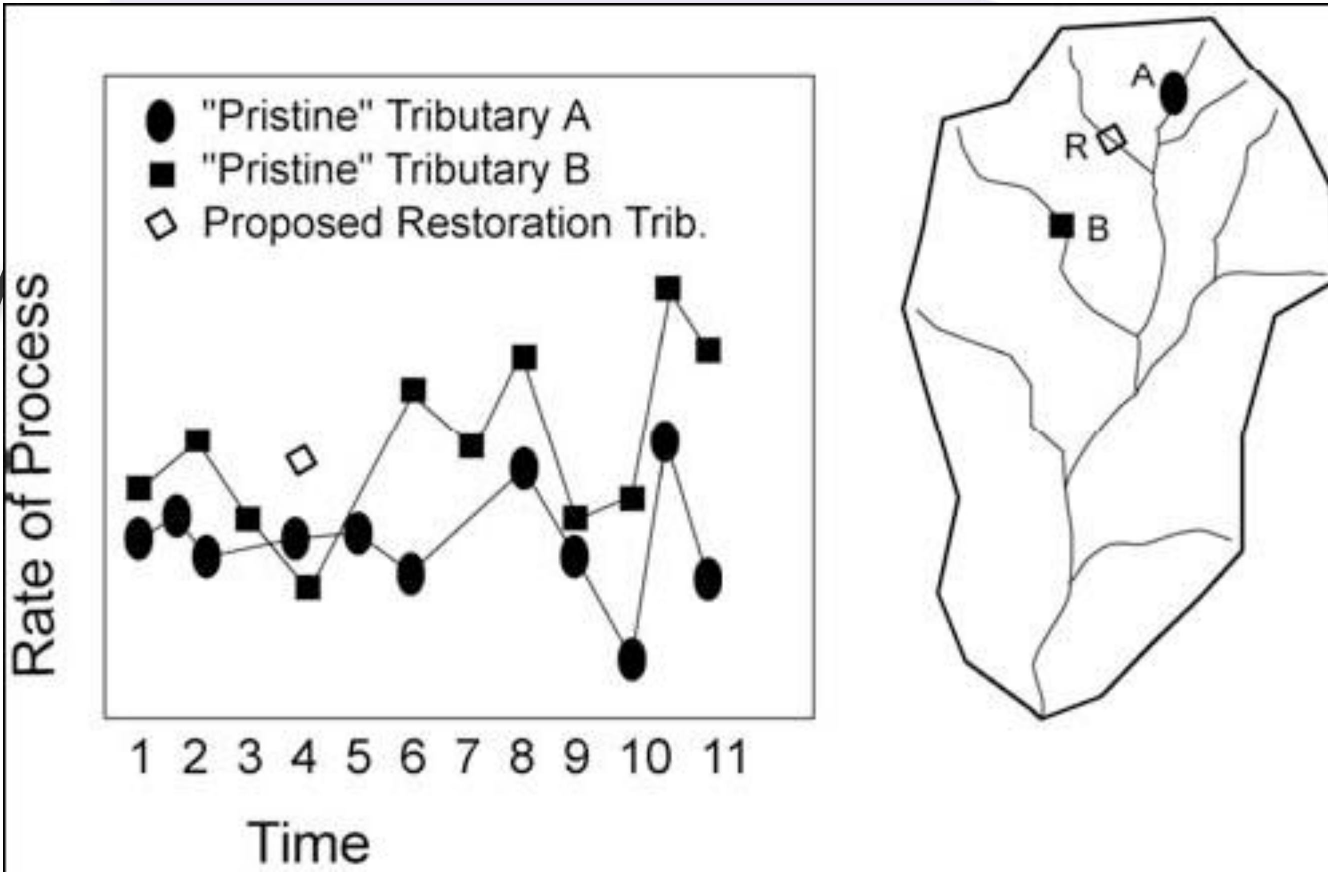
“Temporal as well as spatial considerations are fundamental to river science. The natural timing, frequency, duration, magnitude, and rate of change in flows (the“natural flow regime” [Poff et al., 1997]) are each vital in governing ecological processes along a stream.”
Any particular segment of a river has continual erosion and deposition through time. The energy of the river segment, as determined by hillslope and channel
gradients, stream discharge, and sediment supply, will create a distinct geomorphic process and disturbance regime that in turn influences the aquatic and riparian communities [Montgomery, 1999].

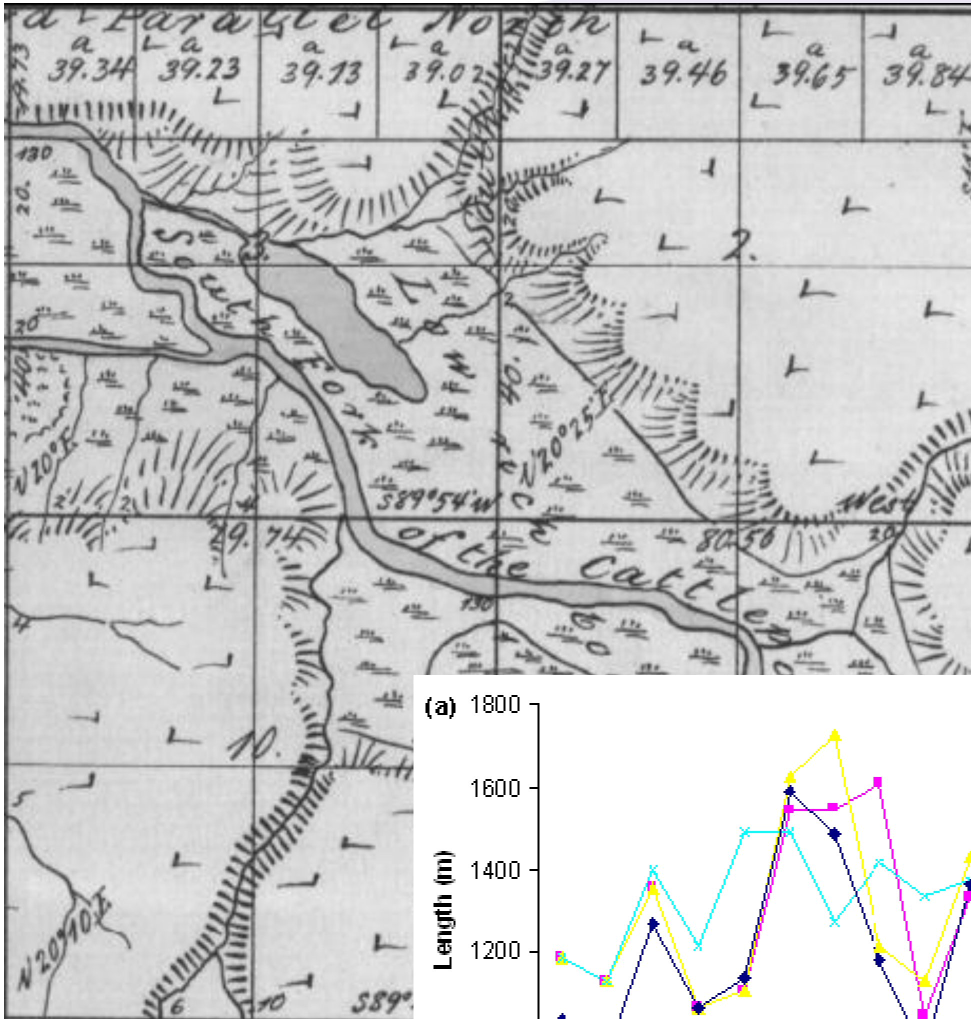
Biological scientists have emphasized the importance of lateral connections between stream channels and floodplains [Junk et al., 1989; Bayley, 1991; Molles et al., 1998]; patterns of downstream continuity or discontinuity in physical and biological parameters [Vannote et al., 1980; Fischer et al., 1998; Poole, 2002; Benda et al., 2004]; and vertical connections between the channel and underlying hyporheic zone [Ward, 1989; Stanford and Ward, 1993].

First, because natural variability is an inherentfeature of all river systems, we hypothesize that restorationof an acceptable range of variability of process is morelikely to succeed than restoration aimed at a fixed endpoint that precludes variability.

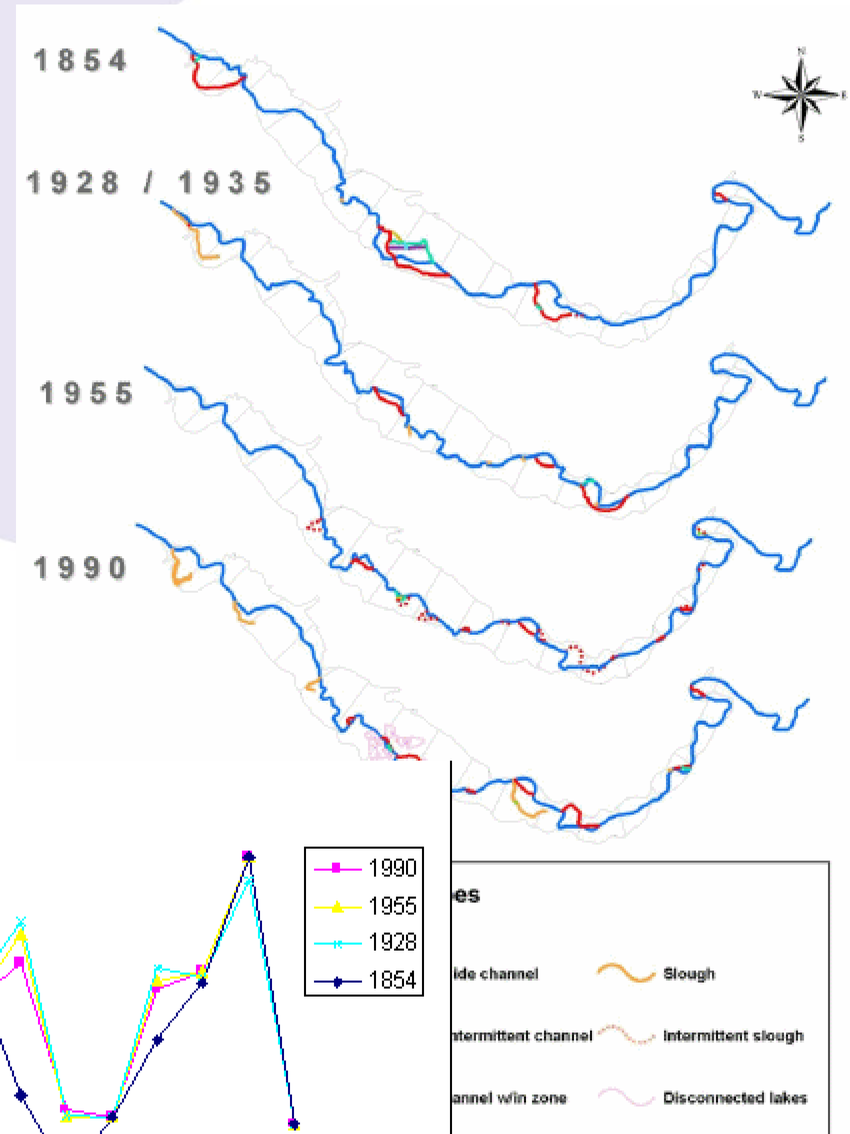
River ecosystems are constantly responding to environmental
flux and human activities. Distinctly different states (e.g., channel position, levels of productivity) are the norm, not the exception [Palmer et al., 1997]. However,
natural variability in ecological systems does have boundaries
and for some rivers the variability is predictable in
probabilistic terms [Suding et al., 2004].

Outputs

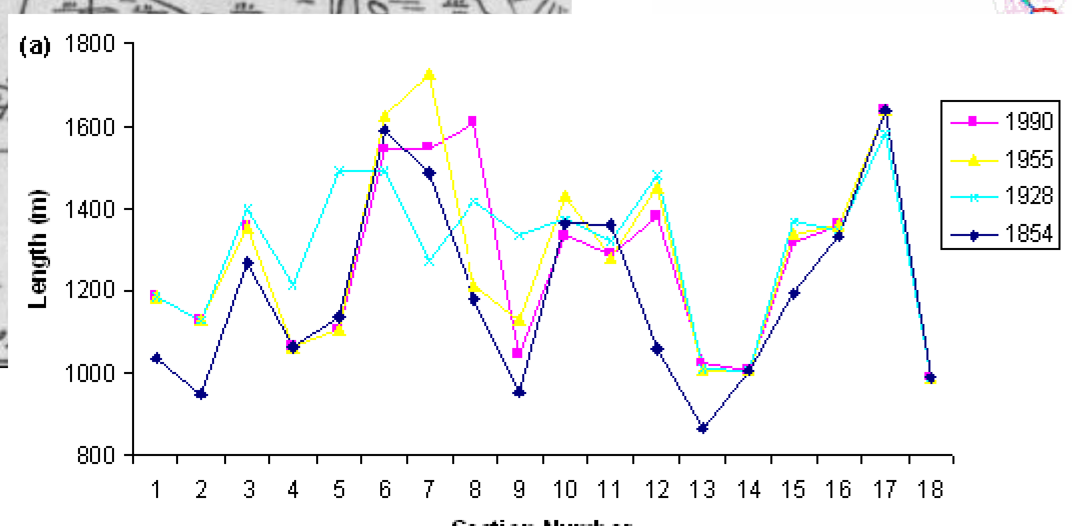

"Pristine" Tributary A
"Pristine" Tributary B
Proposed Restoration Trib.
Rate of Process
1 2 3 4 5 6 7 8 9 10 11
Time
A
R
B



39.34
39.23
39.13
39.02
39.27
39.46
39.65
39.84



1854
1928 / 1935
1955
1990
Slough
Intermittent slough
Disconnected lakes



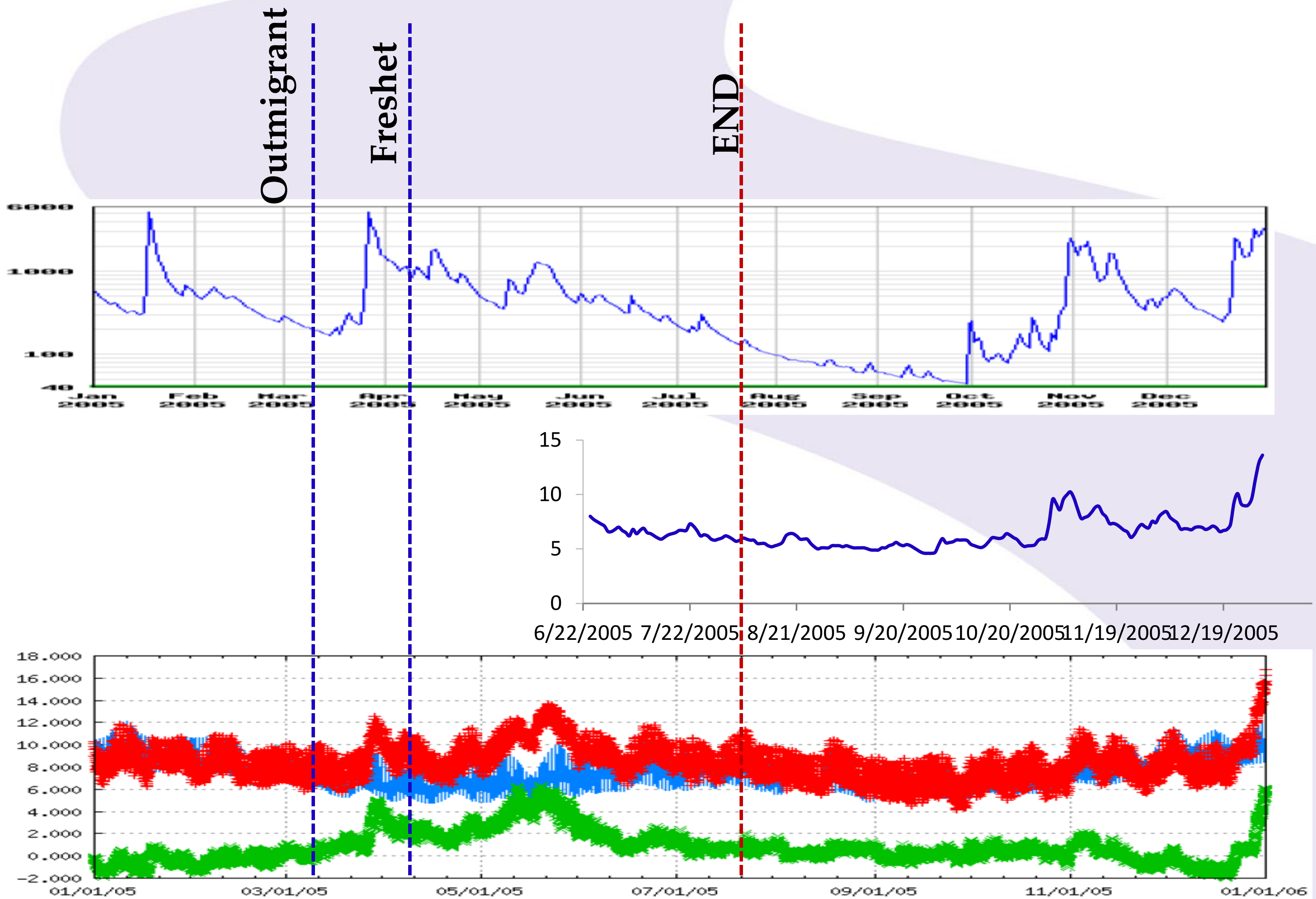
(a)
Length (m)
1800
1600
1400
1200
1000
800
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
1990
1955
1928
1854

Site Dynamics- Hydrology

Discharge- E. Fork

Stage- E. Fork

Stage- Columbia R.



Lower Columbia River Estuary Partnership

Objectives

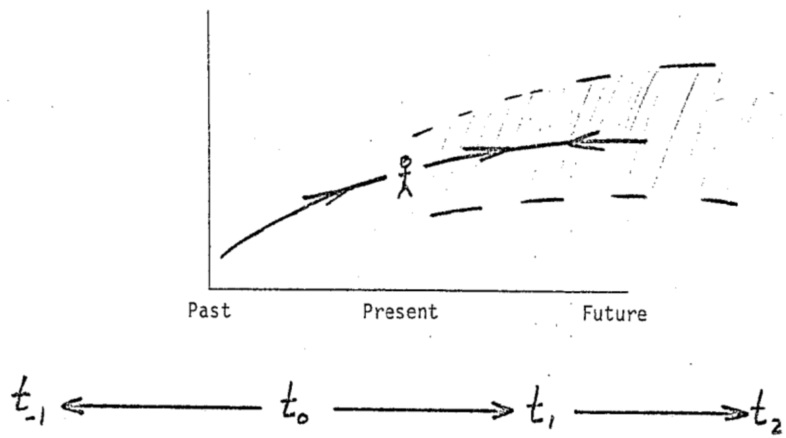
1) Understand site conditions and capacity to restore aquatic habitat conducive to juvenile salmon conditions.

2) Evaluate project feasibility and potential habitat benefits during early phases of project development.

3) Quantify site physical dynamics and watershed scale drivers.

4) Develop flow regimes and scenario modeling approaches.

5) Evaluate short and long-term management actions



	Past	Present	Immediate Future	Long-Range Future
Major Emphasis	Knowledge of trends and events	Understanding of "ambient conditions"	Extrapolative and visionary capability	
Key Question	What will be the point in time that will act as a basis for plotting trends?	What conditions will describe adequately the present?	What is the strength of the projective envelope?	What visions, commitments, or desired futures can be brought forward?

Time perspectives in impact assessment.

Restoration Steps

1) Review existing studies/limiting factors
2) Site investigation- hydro./morph./ veget
3) Build conceptual model / Goals
4) Empirical – adjacent sites
5) Analytical Approach- numerical modeling
6) Evaluate restoration scenarios
7) Management/ Monitoring

"We define river restoration as assisting the establishment of improved hydrologic, geomorphic, and ecological processes in a degraded watershed system and replacing lost, damaged, or compromised elements of the natural system".

Wohl E., et al. 2005

But of course this is quite a task and there are other factors that preclude complete "restoration". ……..

What is Restoration?

What is possible…….
What is probable………….
What is preferable……………………..

Approach	Description	Best suited for problems	Techniques associated with the approach [b]
A priori Leibniz	Formal models from which one deduces insights about the world, with little need for raw data	Well defined conceptually	Interpretive structural Models Relevance trees Simulation models
Empirical Locke	Beginning with data gathering, one inductively builds empirical models to explain what is happening	Well defined with available data	Monitoring [c] Opinion measurement Probabilistic techniques Policy capture Trend extrapolation
Synthetic Kant	Combines the a priori and the empirical so that theories are based on data, and data gathering is structured by preexisting theory or model	More complex and ill structured	Checklists Cost–benefit analysis Cross-effect matrices Decision analysis Export base models Scenarios Sensitivity analysis
Dialectic Hegel	Opposing interpretations of a set of data are confronted in an active debate, seeking a creative synthesis	Ill structured where conflict is present	Adversarial proceedings [c]
Global Singer	A holistic broadening of inquiry by questioning approaches and assumptions	Nonstructured requiring reflective reasoning	Brainstorming

[a] Based on Mitroff and Turoff (1973).

Gage Analysis

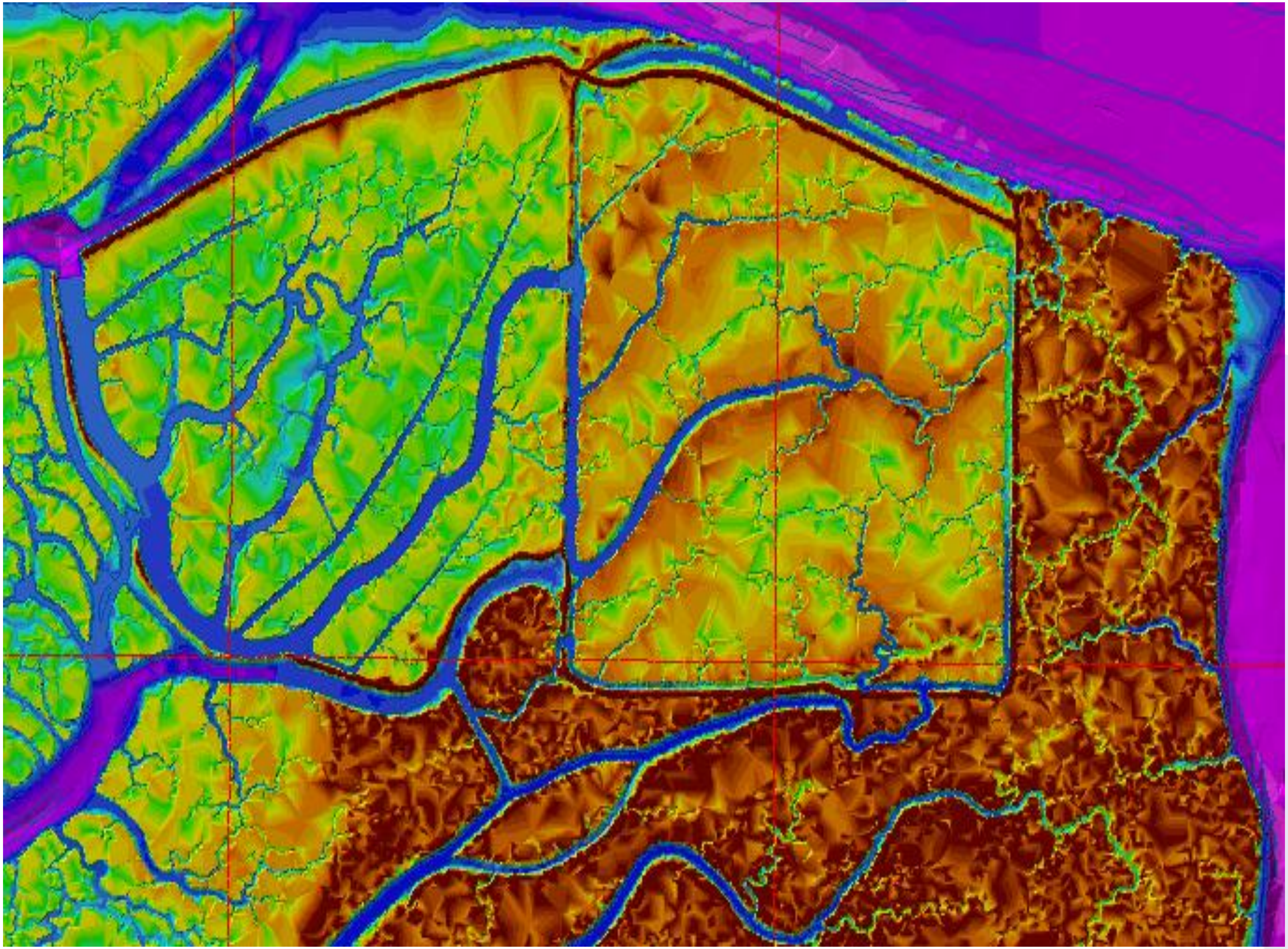
Devlope flow duration curves for 4 fish flow windows/seasons

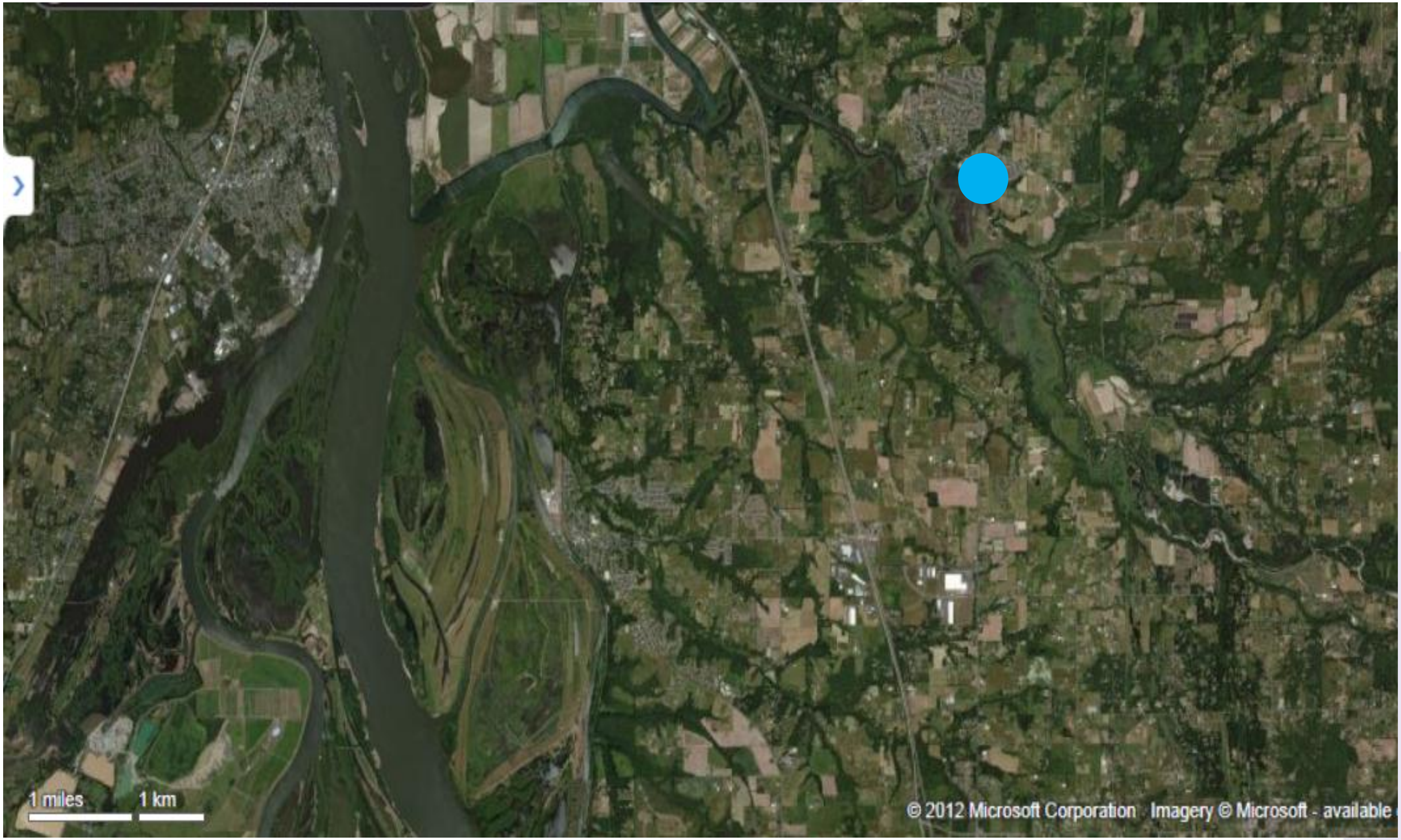
Model inputs

Karlson Isl.
Astoria
1 miles
1 km


Karlson Island
2000 feet
500 m


Karlson Island, Oregon
Image State of Oregon
760 ft
6/28/2005
1994
46°11'52.91" N 123°36'15.85" W elev 7 ft




1 miles
1 km
© 2012 Microsoft Corporation Imagery © Microsoft - available

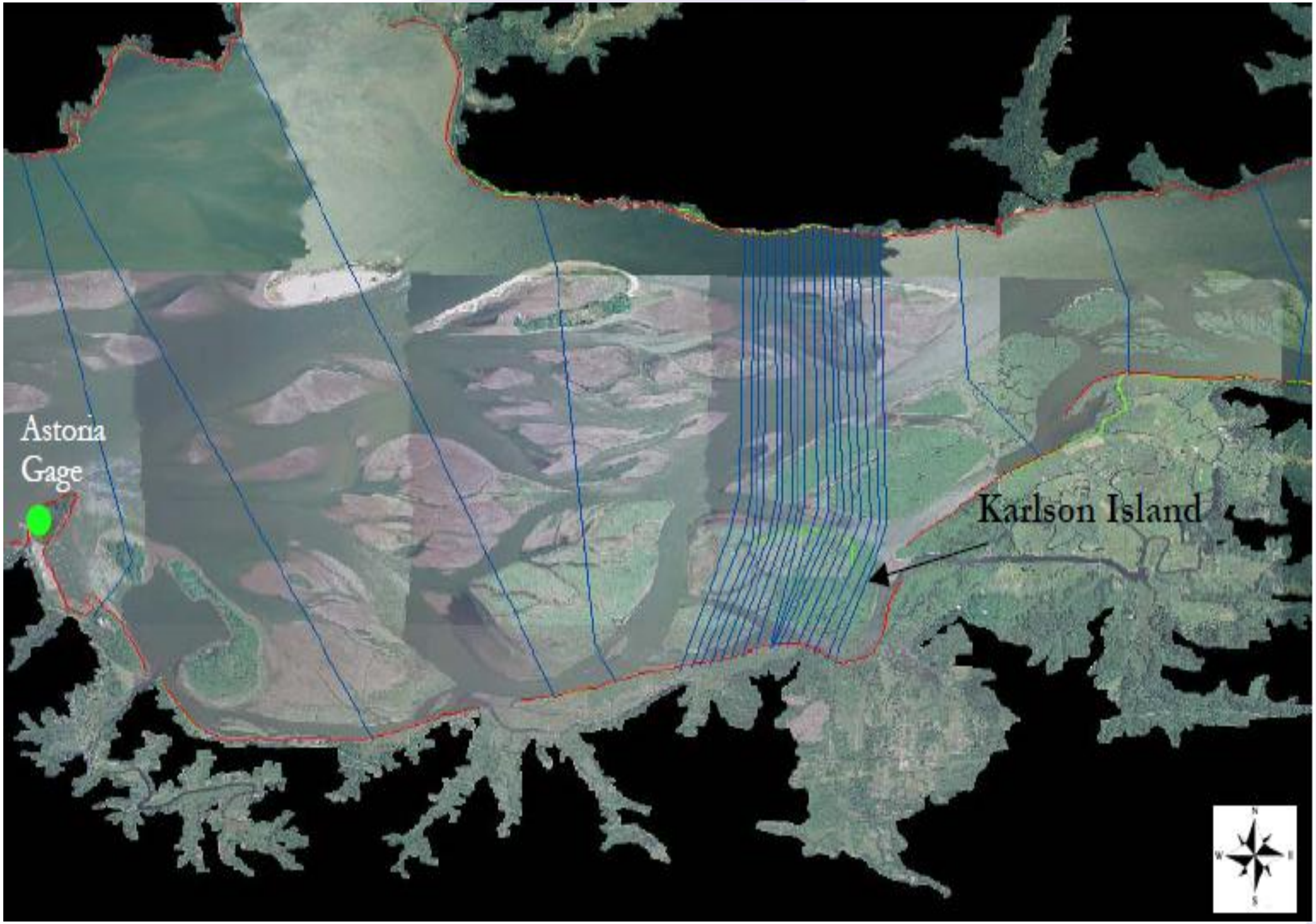

0 feet
100 m
© 2012 Microsoft Corporation Pictome

Overview

- We utilize available data and an open source model to rapidly evaluate project feasibility.
- We evaluate current conditions and forecast potential changes in aquatic

Goals

1) Capture site seasonal “average” hydrologic conditions in order to quantify water depths, inundation and velocities.
2) Evaluate engineering solutions at the site scale- will site manipulations (e.g. levee breaches) make a difference/ are they cost effective?
3) Understand the sites regional physical processes. Will interventions effect: Hydrology- magnitude, frequency, duration of flood events? Sediment- is it important to consider?
4) Develop an understanding of potential ecological responses.
5) Evaluate flows for climate impacts?


Astoria
Gage
Karlson Island