ESTUARINE WETLAND RESTORATION

Lessons Learned at the
South Slough National Estuarine Research Reserve
Coos Bay, OR

Craig Cornu
Stewardship Coordinator
South Slough NERR

Outline

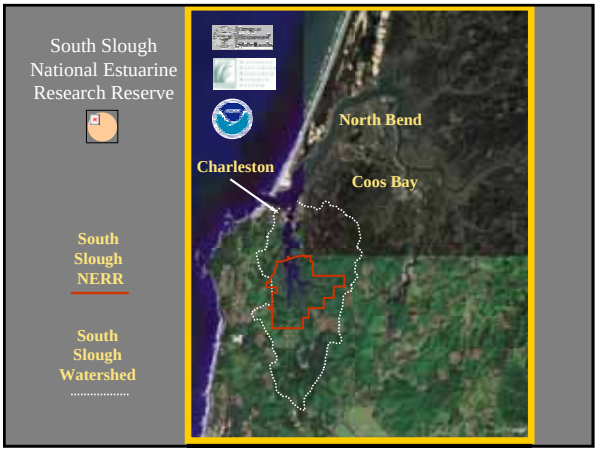
- Orientation/Coos estuary alterations
- Coho salmon life history/estuarine residence
- Restoration Approach
- Demonstration projects:

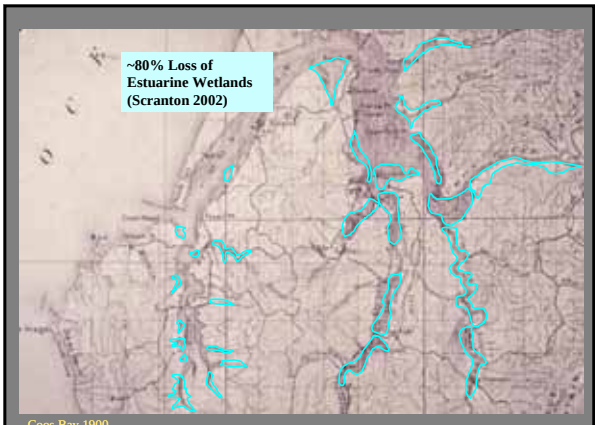
  Kunz Marsh: subsidence adjustment

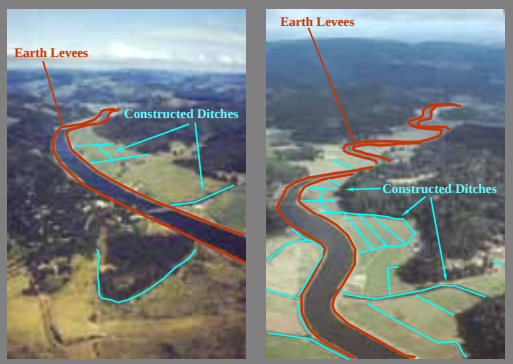
  Dalton Creek Marsh: tidal channel restoration

  Anderson Creek Marsh: non-tidal channel restoration

  Winchester Creek : large wood





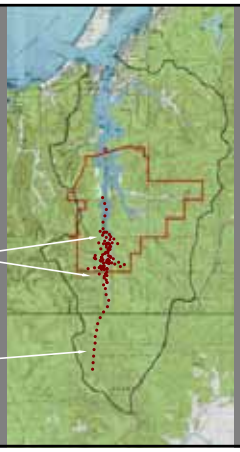


Coho Salmon

South Slough Watershed

Fry/Age 0 Movement

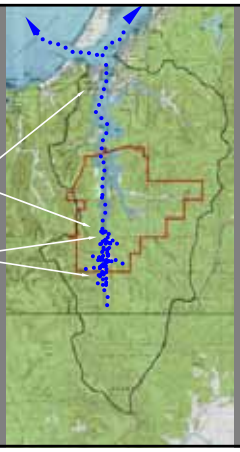
(March-October)



Source: Miller and Sadro 2003 and Koehler and Miller 2003 (report) mark-recapture/acoustic tagging

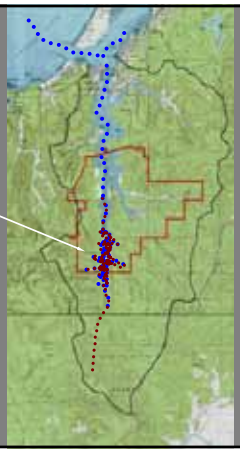
Smolts/Age 1 Migration

(Feb-June)



Source: Miller and Sadro 2003 and Koehler and Miller 2003 (report) mark-recapture/acoustic tagging

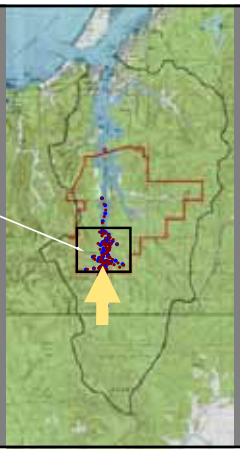
South Slough Watershed

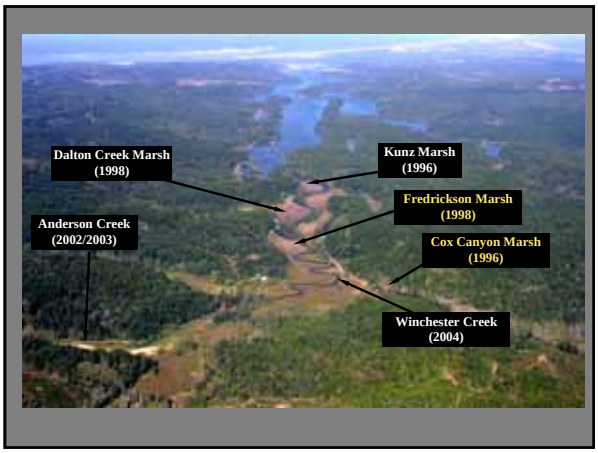


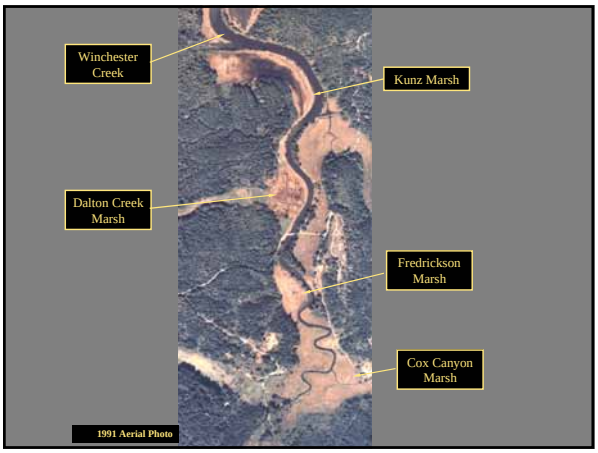
Rearing/Foraging Habitats:
- Main channel
- Marsh channels
- Marsh plain
- Tributary streams
- Beaver ponds

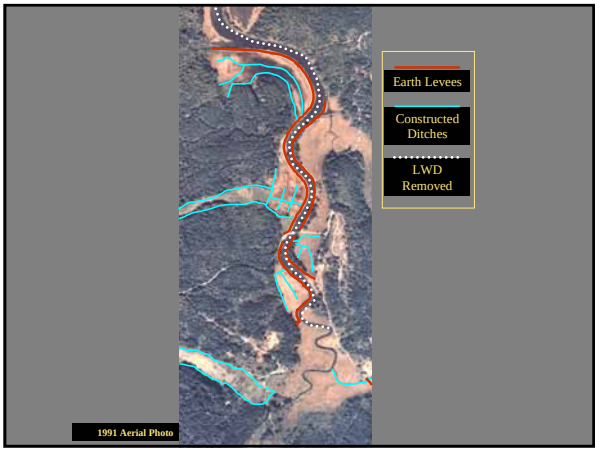
Winter salinity: 0.0 ppt.
Summer salinity: ~20 ppt.

South Slough Watershed









Winchester Tidelands Restoration Project Approach

- Estuarine Wetland Advisory group
- Informal Information Gaps Assessment
- Demonstration projects
- Advisory Group/Coastal Decision Maker and Restoration Practitioner Workshops
- Publications/Outreach Documents

Restoration Approach

- Use Reserve as outdoor lab to test innovative restoration techniques
- Restore to pre-contact conditions as represented by relatively undisturbed reference sites in Reserve
- Self design methods used (manipulate key site attributes and allow natural processes to do the rest of the work)
- Demonstrate “accessible” restoration methods-methods within reach of most restoration practitioners (e.g., watershed associations)

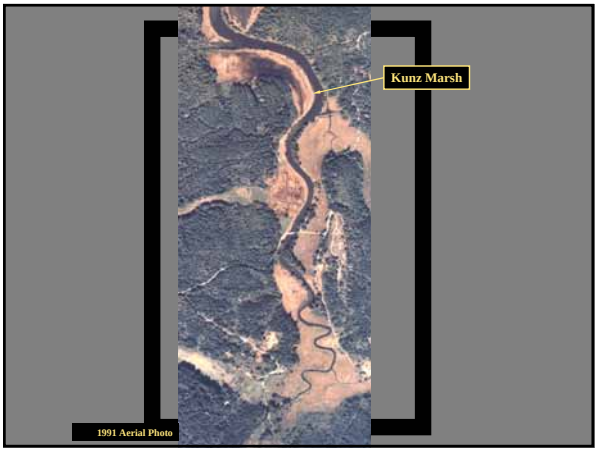
Restoration Approach (cont.)

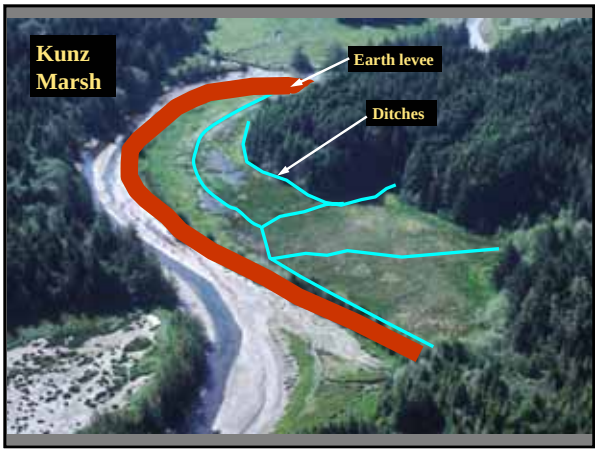
- Approach is largely focused on "single family": salmonidae a.k.a. salmonids

Restoration Approach (cont.)

- Projects are adaptive on multiple levels:
  - Take corrective actions at sites based on project monitoring information
  - Apply lessons learned from each project to future projects in Reserve
  - Projects contribute to broader regional/national efforts to improve the practice of habitat restoration by testing and evaluating experimental or innovative methods

Kunz Marsh Restoration Project



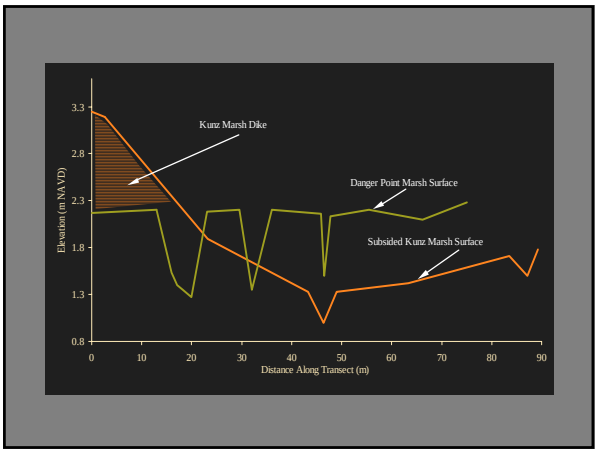


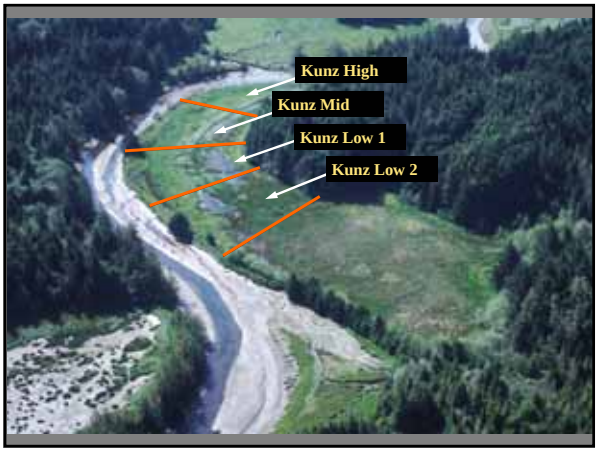
Kunz Marsh

Major Issues:

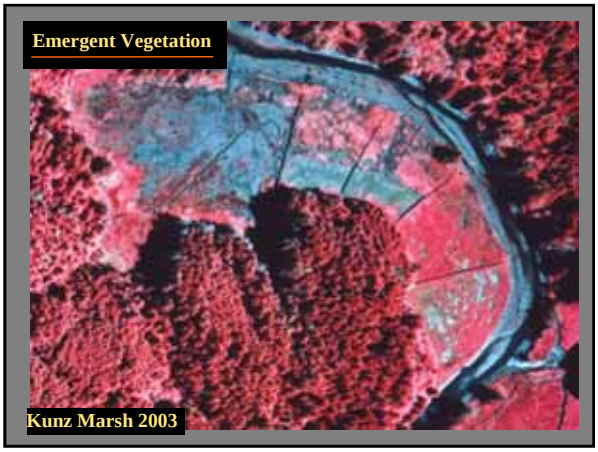
- Subsided marsh surface (0.80 m)
- Little or no salmonid access to marsh plain/edge
- Tidal channel network reduced to linear ditches
- Little or no connection with rest of estuary (nutrient exchange)

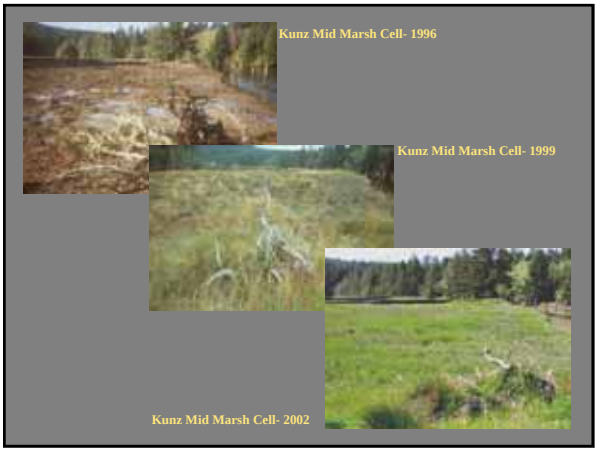

Kunz Marsh
Kunz Marsh Profile
Danger Point Marsh Profile

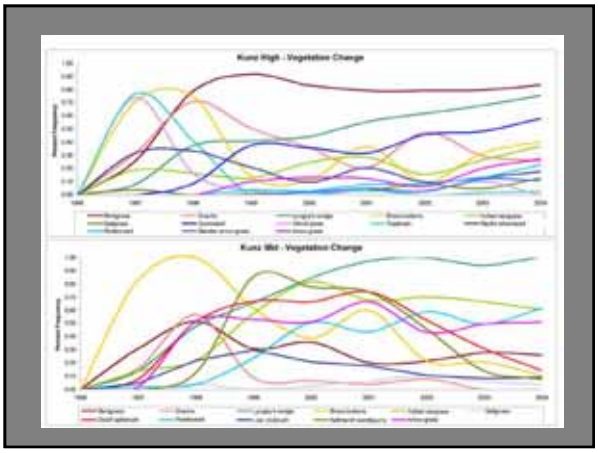

Kunz Marsh Dike
Danger Point Marsh Surface
Subsided Kunz Marsh Surface
Elevation (m NAVD)
Distance Along Transect (m)
3.3
2.8
2.3
1.8
1.3
0.8
0
10
20
30
40
50
60
70
80
90

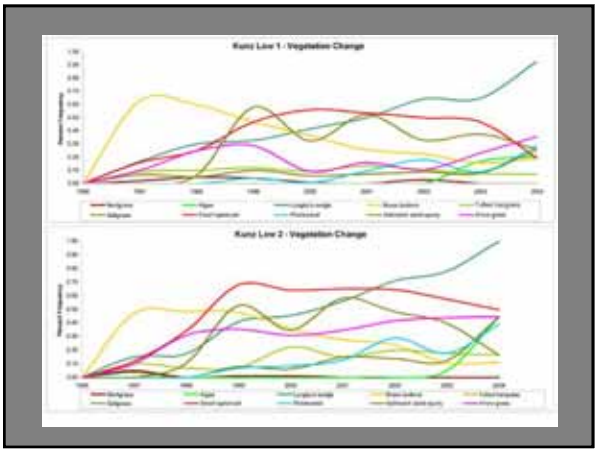

Kunz High
Kunz Mid
Kunz Low 1
Kunz Low 2

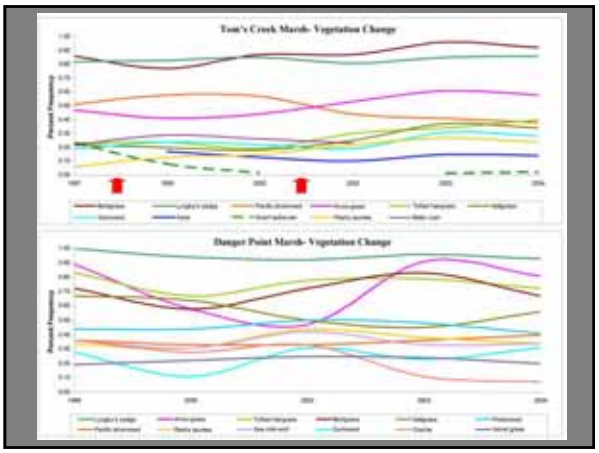

High- 2.2 m
Mid- 1.8 m
Low 1- 1.5 m
Low 2- 1.5 m
Elevations tied to NAVD '88

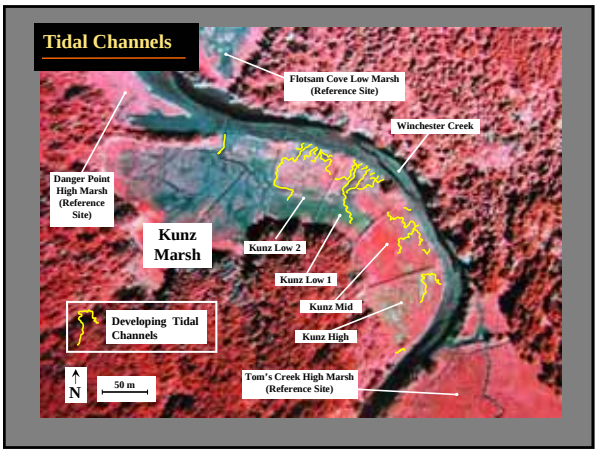

Emergent Vegetation
Kunz Marsh 2003


Kunz Mid Marsh Cell- 1996
Kunz Mid Marsh Cell- 1999
Kunz Mid Marsh Cell- 2002









Number of Tidal Channels:

- 23 in 2005
- 7 in 1999
- More channels developing at lower elevations

Cell	Channel	Length (m)	Mouth Width/ Depth (cm)	Mouth Area (m^2)	Sinuosity Ratio	Connections with Lower Order Channels
Kunz High	North	7 (65)	n/a	n/a	n/a (2.27)	0 (2)
	South	9 (15)	n/a	n/a	n/a (1.43)	0 (0)
Kunz Mid*	Main	30.5	105/65 (80/25)	0.34 (0.13)	1.5	2
	Trib.1	45 (50)	57/36	0.17	1.2 (1.4)	2 (2)
	Trib 2	15.0	37/30	0.08	1.2	1
	Tmy W.	1.5	37/22	0.06	1.2	1
	TmyE.	2.5	52/57	0.23	1.1	1
Kunz Low 1	West 1	101 (75)	245/60 (210/95)	1.44 (1.6)	1.2 (1.2)	9 (0)
	Trib	33.6	116/41	0.29	1.4	5
	West 2	2.9	65/30	0.14	1.3	0
	West 3	44 (30)	195/67 (290/85)	1.12 (1.24)	1.1 (1.0)	5 (1)
	East 1	3.7	63/23	0.11	1.5	1
	East 2	1.0	57/17	0.06	1.0	0
	East 3	4.5	70/17	0.09	1.2	1
	East 4	14.6	80/44	0.26	1.2	4
Kunz Low 2	West 1	3.5	66/17	0.07	1.1	0
	West 2	61.5 (28)	110/29 (90/10)	0.27 (0.09)	1.2 (1.3)	6 (3)
	West 3	104 (88)	83/35 (95/21)	0.19 (0.13)	1.7 (1.3)	6 (12)
	West 4	4.5	180/30	0.41	1.3	0
	Tmy 5	0.7	19/5	0.09	1.0	0
	East	26.0	54/32	0.13	1.2	0
	N.East	6.0	53/30	0.13	1.4	1
	South	4.9	54/17	0.08	1.1	1

Channels existing in 2000 are indicated in **bold**
Channels dimensions in 2000 are indicated in (parentheses)
* In 2000, there was only one channel in Kunz Mid. By 2004, that channel turned into the current Trib. 1.

Evolution of Tidal Channels:

- Channels not evolving at high elevation
- 71% developing lower order channels

Cell	Channel	Length (m)	Mouth Width/ Depth (cm)	Mouth Area (m^2)	Sinuosity Ratio	Connections with Lower Order Channels
Kunz High	North	7 (65)	n/a	n/a	n/a (2.27)	0 (2)
	South	9 (15)	n/a	n/a	n/a (1.43)	0 (0)
Kunz Mid*	Main	30.5	105/65 (80/25)	0.34 (0.13)	1.5	2
	Trib.1	45 (50)	57/36	0.17	1.2 (1.4)	2 (2)
	Trib 2	15.0	37/30	0.08	1.2	1
	Tmy W.	1.5	37/22	0.06	1.2	1
	TmyE.	2.5	52/57	0.23	1.1	1
Kunz Low 1	West 1	101 (75)	245/60 (210/95)	1.44 (1.6)	1.2 (1.2)	9 (0)
	Trib	33.6	116/41	0.29	1.4	5
	West 2	2.9	65/30	0.14	1.3	0
	West 3	44 (30)	195/67 (290/85)	1.12 (1.24)	1.1 (1.0)	5 (1)
	East 1	3.7	63/23	0.11	1.5	1
	East 2	1.0	57/17	0.06	1.0	0
	East 3	4.5	70/17	0.09	1.2	1
	East 4	14.6	80/44	0.26	1.2	4
Kunz Low 2	West 1	3.5	66/17	0.07	1.1	0
	West 2	61.5 (28)	110/29 (90/10)	0.27 (0.09)	1.2 (1.3)	6 (3)
	West 3	104 (88)	83/35 (95/21)	0.19 (0.13)	1.7 (1.3)	6 (12)
	West 4	4.5	180/30	0.41	1.3	0
	Tmy 5	0.7	19/5	0.09	1.0	0
	East	26.0	54/32	0.13	1.2	0
	N.East	6.0	53/30	0.13	1.4	1
	South	4.9	54/17	0.08	1.1	1

Channels existing in 2000 are indicated in **bold**
Channels dimensions in 2000 are indicated in (parentheses)
* In 2000, there was only one channel in Kunz Mid. By 2004, that channel turned into the current Trib. 1.

Evolution of Tidal Channels: ***Elevation isn't everything***

- Channels dimensions ~increasing in Kunz Mid and Kunz Low 2
- Channel dimensions decreasing in Kunz Low 1

Cell	Channel	Length (m)	Mouth Width/ Depth (cm)	Mouth Area (m^2)	Sinuosity Ratio	Connections with Lower Order Channels
Kunz High	North	7 (65)	n/a	n/a	n/a (2.27)	0 (2)
	South	9 (15)	n/a	n/a	n/a (1.43)	0 (0)
Kunz Mid*	Main	30.5	105/65 (80/25)	0.34 (0.13)	1.5	2
	Trib.1	45 (50)	57/36	0.17	1.2 (1.4)	2 (2)
	Trib 2	15.0	37/30	0.08	1.2	1
	Tmy W.	1.5	37/22	0.06	1.2	1
	TmyE.	2.5	52/57	0.23	1.1	1
Kunz Low 1	West 1	101 (75)	245/60 (210/95)	1.44 (1.6)	1.2 (1.2)	9 (0)
	Trib	33.6	116/41	0.29	1.4	5
	West 2	2.9	65/30	0.14	1.3	0
	West 3	44 (30)	195/67 (290/85)	1.12 (1.24)	1.1 (1.0)	5 (1)
	East 1	3.7	63/23	0.11	1.5	1
	East 2	1.0	57/17	0.06	1.0	0
	East 3	4.5	70/17	0.09	1.2	1
	East 4	14.6	80/44	0.26	1.2	4
Kunz Low 2	West 1	3.5	66/17	0.07	1.1	0
	West 2	61.5 (28)	110/29 (90/10)	0.27 (0.09)	1.2 (1.3)	6 (3)
	West 3	104 (88)	83/35 (95/21)	0.19 (0.13)	1.7 (1.3)	6 (12)
	West 4	4.5	180/30	0.41	1.3	0
	Tmy 5	0.7	19/5	0.09	1.0	0
	East	26.0	54/32	0.13	1.2	0
	N.East	6.0	53/30	0.13	1.4	1
	South	4.9	54/17	0.08	1.1	1

Channels existing in 2000 are indicated in **bold**
Channels dimensions in 2000 are indicated in (parentheses)
* In 2000, there was only one channel in Kunz Mid. By 2004, that channel turned into the current Trib. 1.


Kunz Low 1


Kunz Mid

Other Monitoring

- Sediment dynamics using feldspar horizon markers, surface elevation tables (SETs)
- Fish use of research cells using winged fyke nets
- Invertebrate community abundance and species composition using sediment cores and fallout traps

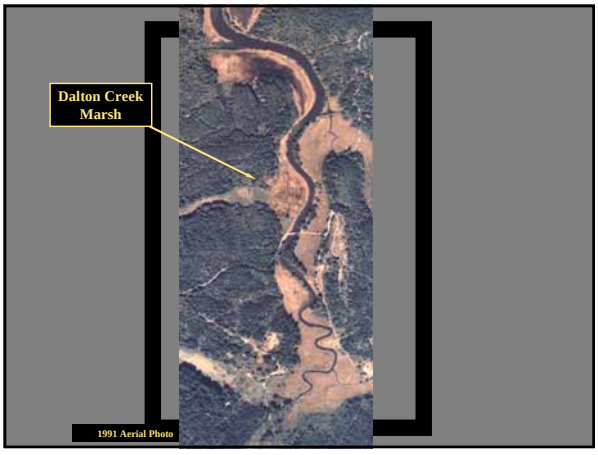
Lessons Learned

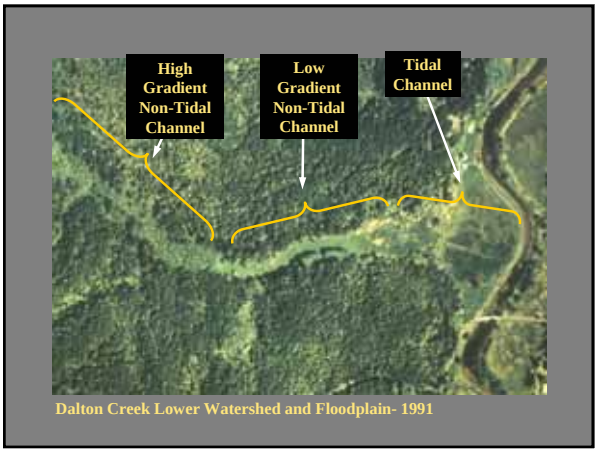
1. Manipulating the marsh surface to mid marsh elevations provided conditions favorable for relatively rapid emergent marsh vegetation colonization while allowing channel development over time.
2. Manipulating the marsh surface to low marsh elevations resulted in slower vegetation community development but allowed channel development and benefited more fish in the early stages of marsh recovery.

Lessons Learned

3. Manipulating the marsh surface to high marsh elevations sacrificed channel development for rapid vegetation colonization.
4. Channels developed initially by erosion/headcutting at different rates depending on marsh elevation, gradient and path of small tributary creek
5. Fill material at the project site consolidated as predicted and did not get exported off-site

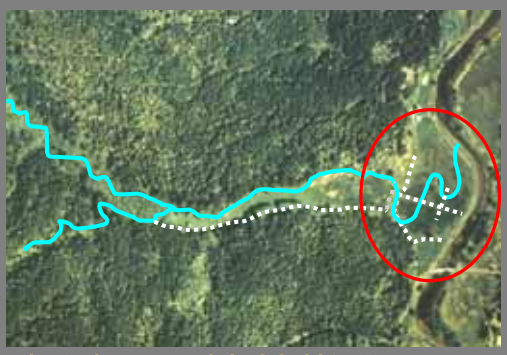
Dalton Creek Restoration Project





Dalton Creek Lower Watershed and Floodplain- 1991

Dalton Creek Lower Watershed and Floodplain- 1991


Dalton Creek Lower Watershed and Floodplain- 1991

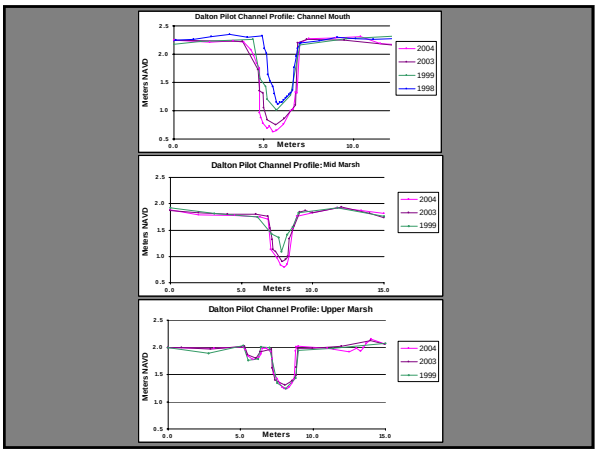
Dalton Creek Marsh

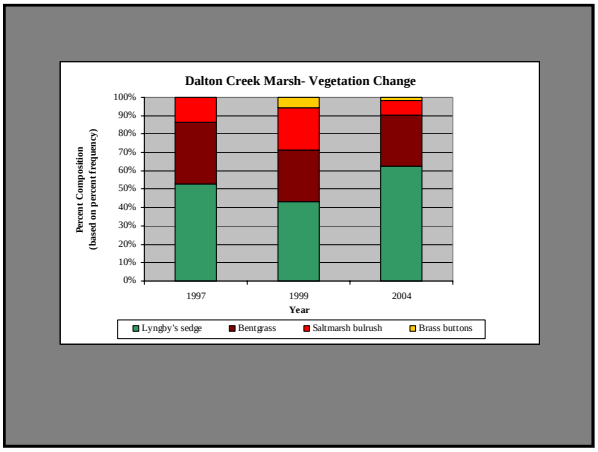
Major Issues:

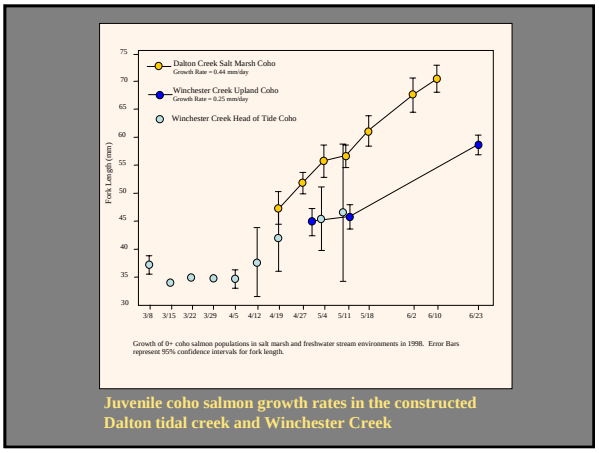
- Tidal channel network reduced to linear ditches
- Little or no salmonid access to marsh plain/edge
- Little or no connection with rest of estuary (nutrient exchange)
- Logistical: No access to marsh surface for excavating equipment except tracked vehicles between muted tides


1991 1999 2005


Dalton Creek Tidal Channel Blast Sequence







Juvenile coho salmon growth rates in the constructed Dalton tidal creek and Winchester Creek

Dalton Creek Salt Marsh- 2001

Ditch Filling

1998

1999

2003

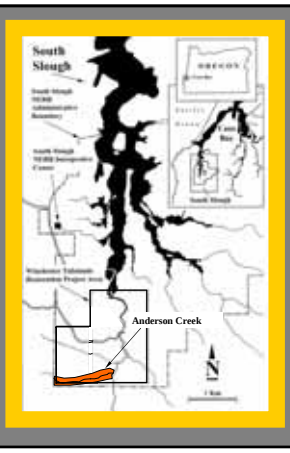
Lessons Learned

1. The use of explosives was a viable and cost-effective channel construction strategy (given specific conditions)
2. The establishment of a pilot channel appears to be a viable and cost-effective tidal channel establishment strategy
3. Constructed ditches over-filled with dike material appear to remain filled over time
4. Juvenile coho appeared in the upper Dalton Creek tidal channel at their first opportunity (and have been observed in the pilot channel in subsequent years)

Lessons Learned

5. Chronic stream turbidity did not appear to an issue for this project- the pilot channel was observed to be turbid only intermittently during the first winter after channel construction
6. Bury large wood in pilot channels to truly incorporate structure in channel development

Anderson Creek Restoration Project



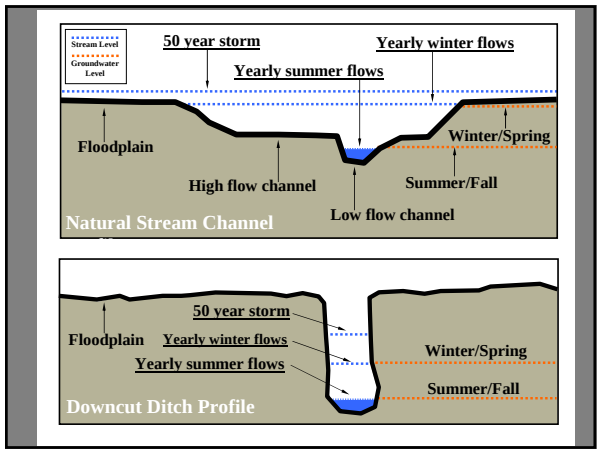
Anderson Creek Marsh 1991

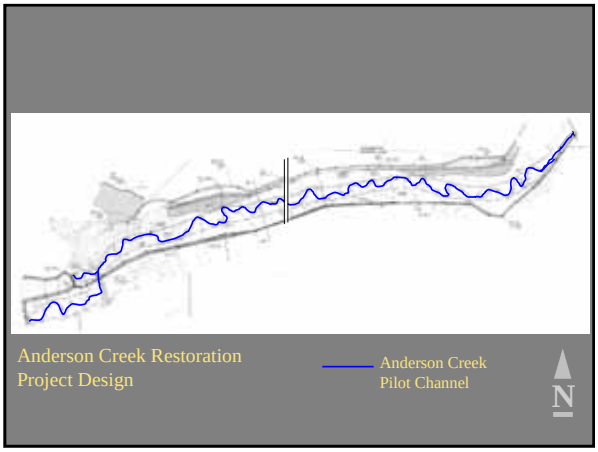
N

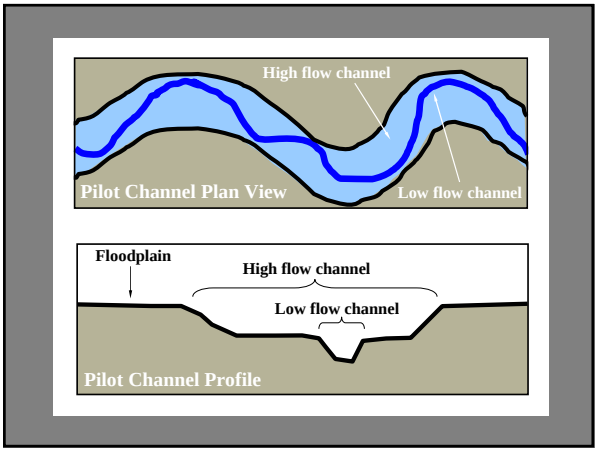
Anderson Creek Marsh

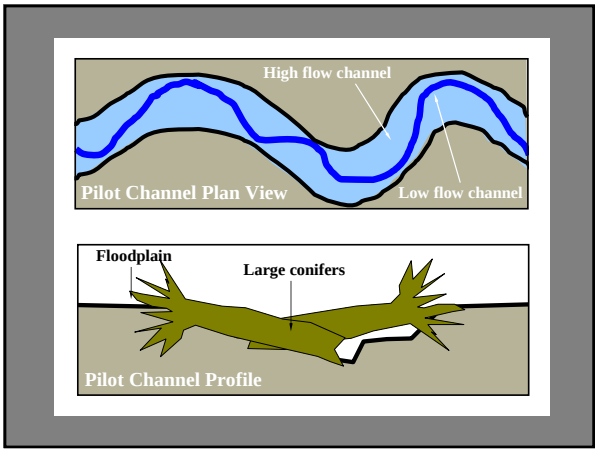
Major Issues:

- Non-tidal channel network reduced to a linear ditch
- Severe ditch downcutting- no hydrologic connection between stream and floodplain
- Salmonid habitat reduced in abundance and complexity
- Beaver pond habitat confined to linear ditch
- Suspected turbidity caused by "banging" of ditch banks.

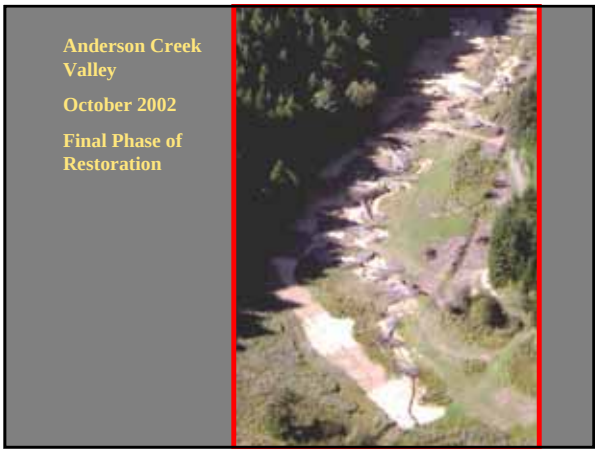






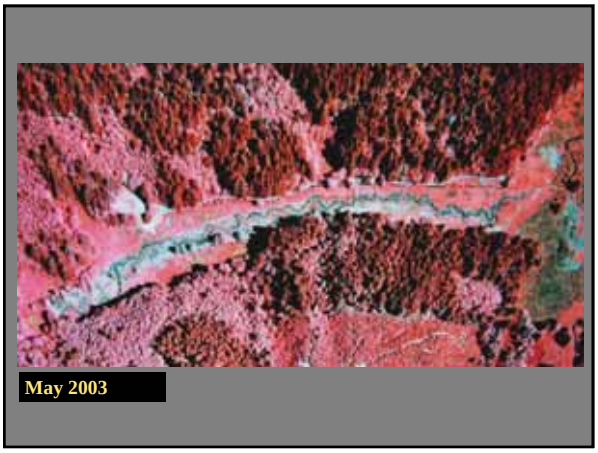



Anderson Creek Valley
October 2002
Final Phase of Restoration


Anderson Creek Valley
October 2002
Final Phase of Restoration

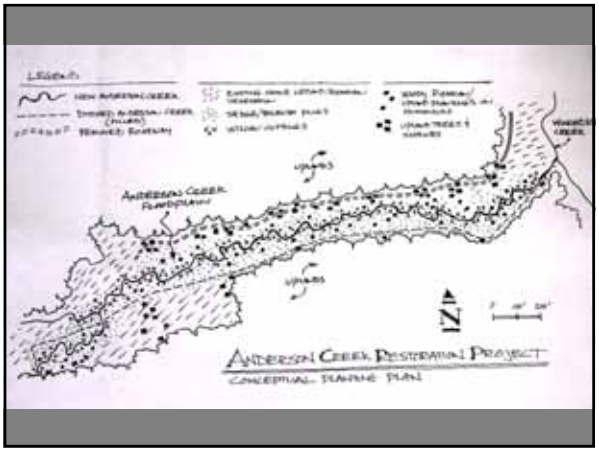

Slough Sedge (*Carex obupta*) hay, baled at an adjacent site, used as mulch


January 2003

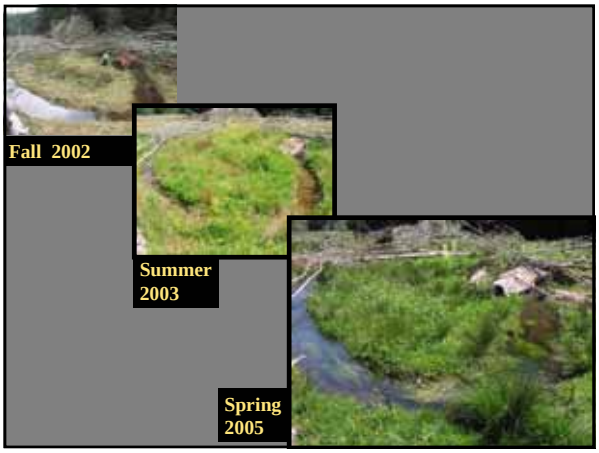

May 2003

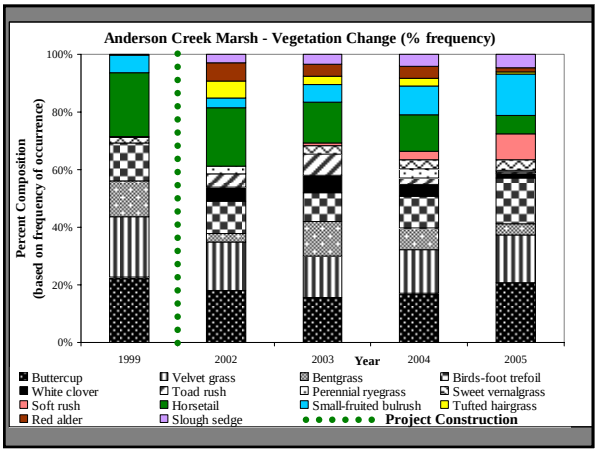

September 2005

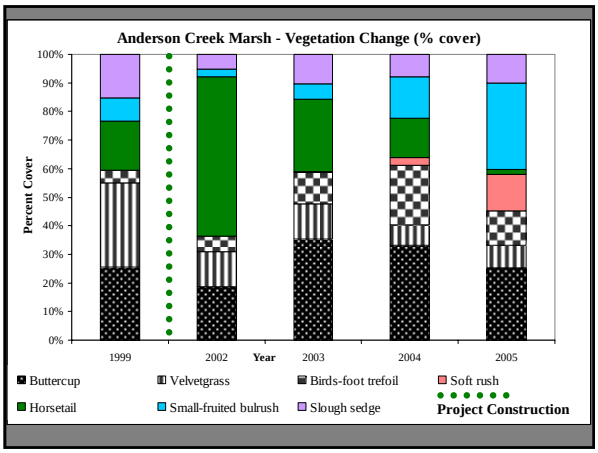

Biota Collection
Crew- 2002


Anderson Creek Restoration Project
Conceptual Planting Plan
N

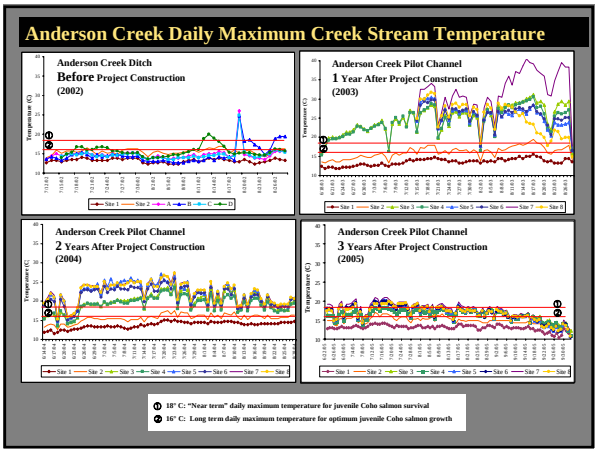

Upland trees, willows and sedge planting in the Anderson Creek floodplain
February 2003
Willow stakes

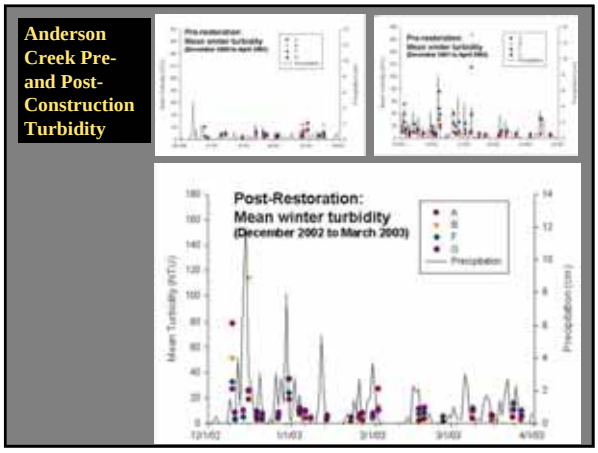

Fall 2002
Summer 2003
Spring 2005


Anderson Creek Marsh - Vegetation Change (% frequency)
Percent Composition (based on frequency of occurrence)
100%
80%
60%
40%
20%
0%
1999
2002
2003
2004
2005
Year
Buttercup
White clover
Soft rush
Red alder
Velvet grass
Toad rush
Horsetail
Slough sedge
Bentgrass
Perennial ryegrass
Small-fruited bulrush
Birds-foot trefoil
Sweet vernalgrass
Tufted hairgrass
Project Construction

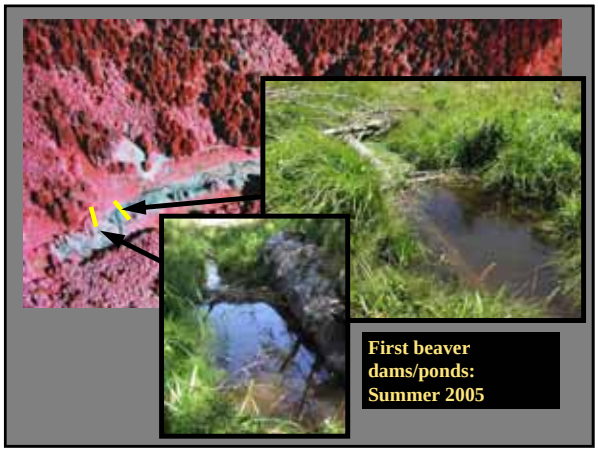

Anderson Creek Marsh - Vegetation Change (% cover)
Percent Cover
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1999
2002
Year
2003
2004
2005
Buttercup
Velvetgrass
Birds-foot trefoil
Soft rush
Horsetail
Small-fruited bulrush
Slough sedge
Project Construction


Invasive exotic vegetation:
Bull/Canada thistle
Blackberry
Reed canarygrass


Anderson Creek Daily Maximum Creek Stream Temperature
Anderson Creek Ditch
Before Project Construction
(2002)
Anderson Creek Pilot Channel
1 Year After Project Construction
(2003)
Anderson Creek Pilot Channel
2 Years After Project Construction
(2004)
Anderson Creek Pilot Channel
3 Years After Project Construction
(2005)
Temperature (C)
16
18
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
Site A
Site B
Site C
Site D
1 18° C: "Near term" daily maximum temperature for juvenile Coho salmon survival
2 16° C: Long term daily maximum temperature for optimum juvenile Coho salmon growth


Anderson Creek Pre- and Post-Construction Turbidity
Post-Restoration:
Mean winter turbidity
(December 2002 to March 2003)
Mean Turbidity (NTU)
Precipitation (cm)
Precipitation
12/1/02
1/1/03
3/1/03
3/1/03
4/1/03


Youth crew placing conifer stumps:
Summer 2005


First beaver dams/ponds:
Summer 2005

Lessons Learned

1. The establishment of a pilot channel appears to be a viable and cost-effective tidal channel establishment strategy
2. Some water quality impacts (high summer stream temperature) resulting from relocating the channel appear to be temporary and manageable
3. Other potential water quality impacts (turbidity) did not materialize
4. The aggressive native vegetation seeding and planting appears to have contributed to a plant community that is out-competing reed canary grass…

Lessons Learned

5. In non-tidal wetland, adaptive management is required the first 3-5 years (or more?) after project construction to help ensure native plants are out-competing invasive plants
6. Bury large wood in pilot channels to truly incorporate structure in channel development

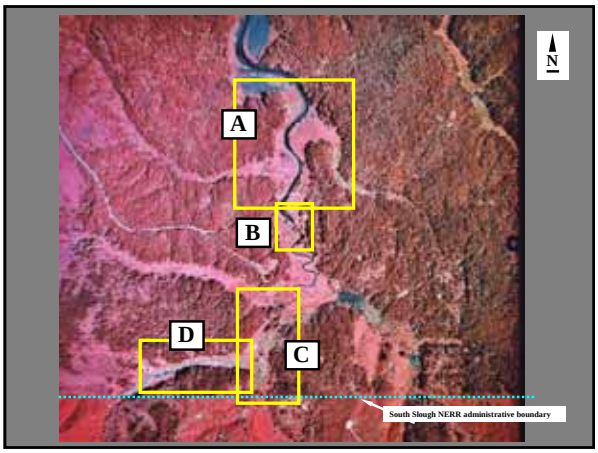
South Slough Salmon Rearing Habitat Enhancement Project

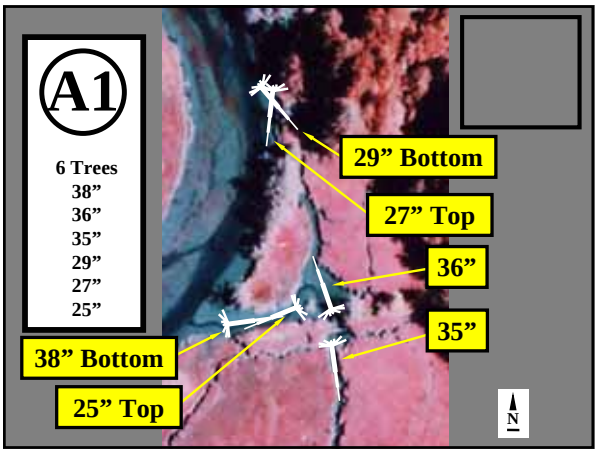
Project Location and Flight Path

Winchester Creek

Major Issue:

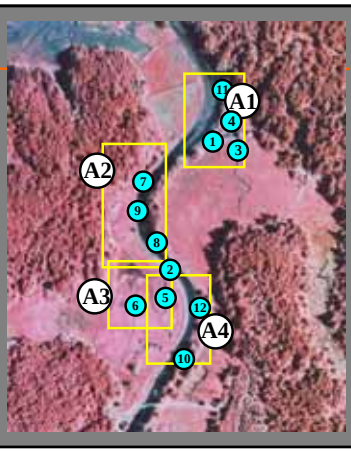
- Mainstem tidal channel without complex structure





Study Locations

- Mouth of Tom’s and Dalton Creek
- In tidal channels
- Mainstem Winchester Creek



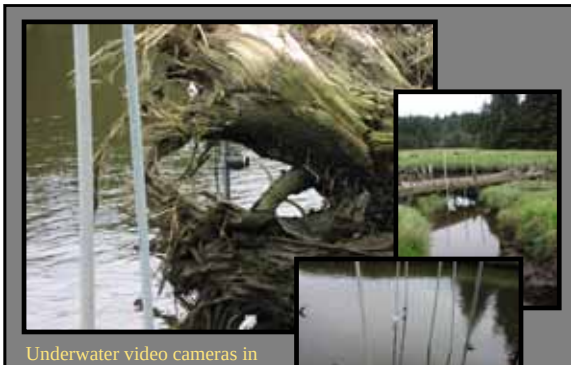
Restoration Monitoring- Juvenile Salmonids

Questions:

- Are there higher densities of fish near LWD compared with habitats lacking LWD?
- What is the behavior of fish around LWD?

Activities:

- Use underwater videography to monitor density and behavior of fish
- Monitor fish use of other subtidal habitats with underwater videography and beach seining



Underwater video cameras in place at the mouth of Dalton Creek tidal channel

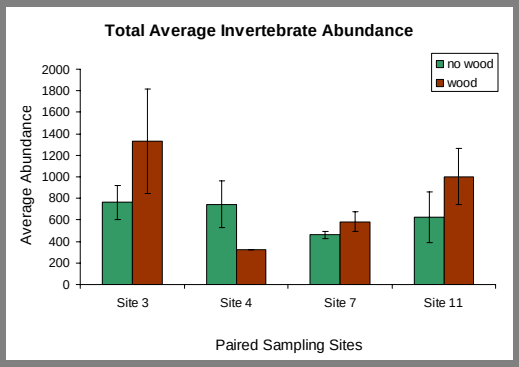
Restoration Monitoring- Invertebrates

Questions:

- Is the presence of wood increasing invertebrate abundance or changing invertebrate community composition?

Activities:

- Track changes in invertebrate abundance and composition near LWD and in areas without LWD using benthic cores



Restoration Monitoring- Physical Changes

Questions:

- What changes in channel morphology are associated with LWD placement?
- Does the wood move?

Activities:

- Record changes in channel morphology with detailed elevation surveys
- Detect wood movement with sub-meter level GPS

- What changes in temperature and microhabitat (hydrologic refuge) occur with LWD placement?

- Track water temperature and flow in locations near and away from LWD