Shoreline Ecology

- Life on the Sound floor
  - "Benthic" = living on the bottom
    - May live on other organisms on the bottom
  - Three relationships with the substrate
    - Attached to rocks (e.g., barnacles)
    - Burrrowed in mud, sand, gravel (e.g., clams)
    - Mobile along the bottom (e.g., sole & flounder)

Types of Shoreline Primary Producers

- Algae
  - No true roots, flowers, leaves, etc.
  - Microalgae (single-celled or colonial)
    - Phytoplankton (free-floating)
    - Benthic microalgae (on bottom)
  - Macroalgae = seaweeds (rockweed, sea lettuce, kelp, etc.)
    - Attached to bottom by "holdfast"

Types of Shoreline Primary Producers

- Higher plants
  - Perennial with flowers
  - Rooted in & obtains nutrition from sediment
  - Eelgrass
    - Completely submerged by tides
    - Not a true grass
  - Marsh grasses
    - Partly submerged by tides
    - Coastal wetlands
    - Salt tolerant

Types of Shoreline Animals

- Invertebrates
  - Crustaceans (crab, shrimp, amphipods, copepods)
  - Mollusks (clams, snails, whelks, chitons)
  - Annelid worms
    - Lugworms burrow
    - Nereid worms migrate
    - "Feather duster" worms attached
  - Echinoderms (urchins, stars, cucumbers, dollars)
  - Plankton (microscopic free-floating) or benthic

Types of Shoreline Animals

- Vertebrates
  - Fishes
    - Bait or forage fishes (herring, sand lance)
    - Bottom fishes or flat fishes (sole, flounder)
    - Juvenile pelagic fishes (salmon, rockfish, pollock)
  - Birds
    - Herons, Gulls
    - Cormorants, coots, ducks, geese
    - Shore birds (e.g. sandpipers)
  - Mammals
    - Harbor seals, California sea lions

Functions of Vegetated Shorelines

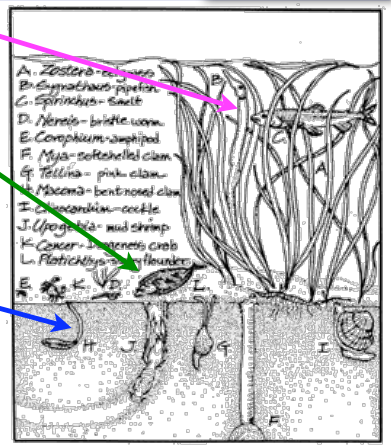
- Kelp beds
  - Life cycle
    - Prefers deep, fast-moving waters
    - Annuals with alternation of sexual & asexual stages
  - Nutrition
    - Grow fast, highly productive
    - Eaten by few animals, shed detritus
    - Support benthos where detritus accumulates
  - Habitat
    - Shelter for juvenile & adult fish
    - Substrate for microalgae invertebrates

Functions of Vegetated Shorelines

- Eelgrass
  - Life cycle
    - Prefers shallow, slower-moving waters
    - Perennial with sexual flowering & asexual rhizomes
  - Nutrition
    - Grows fast, more productive than crops
    - Eaten by few animals, sheds detritus
    - Supports benthos where detritus accumulates
  - Habitat
    - Shelter for juvenile & adult fish
    - Substrate for algae & invertebrates

Forage Fishes & Crabs in Estuaries

- Forage fish shelter
- Juvenile flatfish & crab
- Crustacean, mollusk, annelid prey



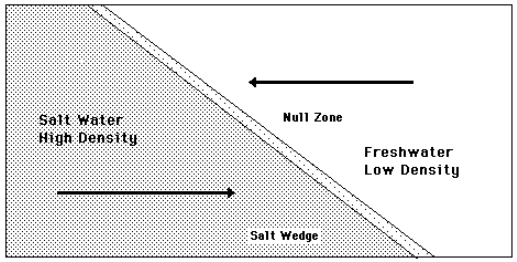
www.inforain.org/mapsatwork/oregonestuary/

Terrestrial/Marine "Ecotone"

- Ecotone = "zone of transition between adjacent ecological systems"
  - Estuary = where salt water is diluted by fresh water from rivers
    - Large-scale: all of Puget Sound
    - Small-scale" a river or stream mouth
  - Site where fine silt & mud from fast-moving rivers settles out
    - Fills shoreline & creates marshes
    - Promotes expansion of vegetated shallow areas

Terrestrial/Marine "Ecotone"

- Meeting of river & "salt wedge"
  - "Null zone" or "tidal front" of weak current
  - "Turbidity maximum" near bottom
  - Fine silt & organic matter sinks & accumulates



Terrestrial/Marine "Ecotone"

- River effects on marine environment
  - Fresh water affects salinity, pH (acidity), temperature
    - Greater effect in winter because of higher flow
  - Carries nutrients from watershed
    - May carry contaminants too

Terrestrial/Marine "Ecotone"

- Tidal effects on nearshore environment
  - Sharp gradients in tidal exposure
    - Near highest & lower water levels
    - Affects drying, heating (summer), chilling (winter), exposure to rain (mostly winter)
  - Strong currents in some channels
    - Tidal influence & salt extend several miles upriver
  - Weak tides & circulation in other areas

Terrestrial/Marine "Ecotone"

- Nearshore generally an area of high biological diversity
  - Sharp gradients in environmental properties
    - Salinity, temperature, tidal exposure, nutrients
    - Creates large number of adjacent ecological "niches"
  - Some organisms stay put (e.g. burrowers)
    - Must tolerate wide fluctuations in conditions
  - Some organisms are just passing through
    - Salmon adjust from fresh salt water environment

Tidal Freshwater Habitats

- No salt water penetration
  - But soil is saturated & water level rises & falls with tides
    - Occasionally flooded
    - Side-channels & sloughs
    - River current may reverse with tide
- Easily colonized by settlers
  - Originally forested
  - Very little intact habitat remains

Estuarine Marshes

- Brackish (low-salinity) marshes
  - Sedges & bullrushes
- Salt marshes
  - Pickleweed & salt grass

www.wsu.edu:8080/~wsherb/edpages/raingrass/raingrass.html

Estuarine Marshes

- Common properties
  - Both move seaward as shore "progrades"
    - Sediment & trapped organic matter
  - Incorporate organic debris from upstream
  - Extend seaward as shore "progrades"
    - Sediment & trapped organic matter
  - Mediate nutrient chemistry via sediments
    - Bacteria remove excess nutrients & contaminants

Estuarine Food Chain

- Based on detritus
  - Mainly from primary producers
    - Micro- & macroalgae, e elgrass
    - Marsh & terrestrial plants
  - Depositional environment
    - Especially in sloughs & protected marshes
- Fish & other predators on invertebrates
  - Marshes & forests provide habitat for prey
  - Some washed down from upstream
  - Insects key for juvenile chinook salmon

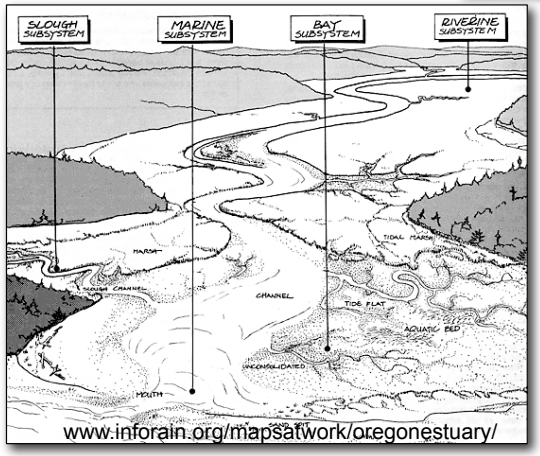
Juvenile Fish in Estuaries

- Feed at low-flow “tidal front” & “turbidity maximum”
  - Prey trapped as well as the organic matter they consume
- Residence length varies by species & size
  - Some salmon (chum) linger, others (pink) move offshore quickly
    - Separate from duration of fresh water rearing
  - Smaller smolts linger longer to adjust
  - Move farther offshore as they grow

Juvenile Fish in Estuaries

- Different “niches” by species & size
  - Smallest salmon found in marshes, mudflats, eelgrass meadows
    - Prey on small crustaceans & insects on bottom
  - Larger fish in open tributary channels & tidal fronts
    - Prey on larger benthic crustaceans, fish larvae, drift insects, planktonic crustaceans

Juvenile Fish in Estuaries



www.inforain.org/mapsatwork/oregonestuary/

Forage Fishes in Estuaries

- Small as adults
  - Prey for larger fish, birds, mammals
  - Occur in large, dense schools
  - Herring, Smelt, Sand Lance
    - Smelt & sand lance spawn on fine intertidal sand & gravel beaches
    - Herring spawn on subtidal estuary kelp & eelgrass
      - Generally spawn at site of hatching
    - Some anadromous smelt spawn in rivers & lakes

Forage Fishes & Crabs in Estuaries

- All forage fish short-lived & fast-reproducing
  - Subject to wide, rapid population fluctuations related to climate & habitat
  - All spend juvenile stage close to shore
- Dungeness crab juveniles also rear in nearshore estuarine habitat
  - Float there as larvae in plankton
  - Survival of benthic juveniles depends on shelter found on mudflats

Alterations to Estuaries

- Clearing of freshwater tidal forest
- Diking, draining, dredging, filling marshes & mudflats
  - Reduced area of habitat
  - Reduced source of detritus for food chain
- Channelizing & filling tidal creeks & sloughs

Early Duwamish Estuary

- Pioneer Square

www.historylink.org/Slide_show/index.cfm?file_id=7083&frame=7

Early Duwamish Esuary

http://www.historylink.org/_output.CFM?file_ID=2986

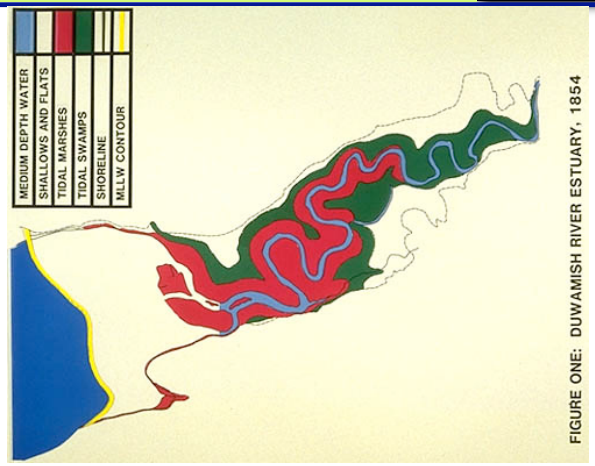
Early Duwamish Esuary

www.historylink.org/Slide_show/index.cfm?file_id=7083&frame=7

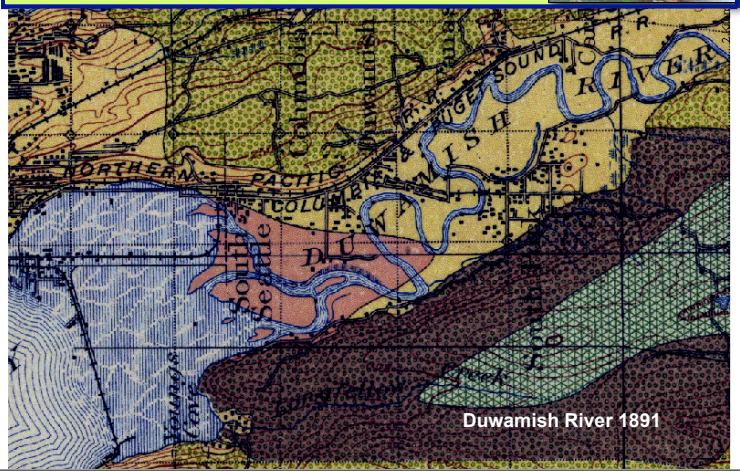
Early Duwamish Esuary

www.duwamishcleanup.org/

Brief History of the Lower Duwamish



Brief History of the Lower Duwamish



Brief History of the Lower Duwamish

- "Rectification" began 1913
- Duwamish 4.5 miles today
- Once 10 miles
- 60% flow lost

Alteration of Duwamish

- Today one remnant ox-bow
- 2% of historic mud-flat estuary area
- 11% of original tidal marsh area
- CSO's
- Hardening of banks
- Dredging of channel

Condition of Duwamish Salmon

- "Chinook have declined to such low numbers that people doubt that the population persists, even in remnant numbers."
  - Re-routing of river, hardening of banks
  - Upstream dam
  - Major role played by hatchery fish
    - Hatchery run persists as wild run declines
- Small numbers of pink & sockeye, wild & hatchery steelhead also present

Condition of Duwamish Salmon

- Formalized & coordinated habitat restoration activities began late 1990's
- Goal to return wild runs to 17,000 to 37,000
  - Productivity of 1.0, i.e., one fish returning for each spawner = full replacement
    - Would yield returns of 1,000 to 4,200 in next ten years
  - 50-100 year timeline

Condition of Duwamish Salmon

- Focus of estuary recovery
  - Area that has not been irreversible altered
  - River miles 7.0 - 5.5, possibly down to RM 4.8
  - "Estuary Transition Zone" (salt wedge or tidal front)
    - Where fish adjust from fresh to salt water
  - 15–20 acres intertidal habitat restored 1990's
    - "Showing some results"
  - Plans to acquire, recreate & revegetate shallow-water & side-channel habitat

Chemical Indicators in Duwamish

- Water quality
  - Dissolved oxygen, pH, temperature, fecal coliform bacteria, chemical contaminants, nutrients, suspended sediments (turbidity)
- Sediment quality
  - Most toxic chemicals are poorly soluble so accumulate in sediments
  - Sources: CSO's, conventional sewage, industrial effluents
  - Metals, organics

Federal Players on the Duwamish

- Army Corps of Engineers (ACE)
  - Regulates & alters navigable waters
- Fish & Wildlife Service
  - Regulates terrestrial & freshwater biota
- National Oceanic & Atmospheric Admin. (NOAA)
  - Regulates & researches salt water & Great Lakes
- Environmental Protection Agency (EPA)
  - Regulates toxins in environment

State & Local Players on the Duwamish

- Dept. Ecology
  - Regulates shorelines & pollutants
- Dept. Fish & Wildlife
  - Regulates terrestrial & aquatic biota
- Muckleshoot, Suquamish tribes
- King County (& others upstream)
- City of Seattle (& others upstream)
- Public & private property owners
  - Port of Seattle, Boeing

Shoreline Management

- Starting point: Federal Coastal Zone Management Act of 1972
  - Administered by NOAA
    - www.coastalmanagement.noaa.gov/czm/
  - "The nation's coastal and ocean resources are under increasing pressure from population growth and development."
  - Coastal areas host over 50% of the total U.S. population within only 17% of the nation's land area."
  - Voluntary, administered by 34 coastal states

Shoreline Management

- Goals of CZMA
  - Protect, develop, restore coastal resources
  - Encourage & assist the states in "wise use"
  - Promote special plans for special areas
  - Coordinate agency actions federal to local
  - Eligibility for federal grants
  - "Federal consistency"
    - Federal & federally funded & licensed actions must conform to approved state plans

www.coastalmanagement.noaa.gov/czm/national.html

Shoreline Management

- Washington State Shoreline Program
  - Shoreline Management Act passed 1971
  - 1st federal approval in nation (1974)
  - Dept. Ecology lead agency
  - Meshes with other laws
    - Clean Water Act, Clean Air Act (state versions)
    - Environmental Policy Act (state)
    - Growth Management Act (state)
  - Local governments develop "Shoreline Master Programs" under state guidelines

http://www.ecy.wa.gov/programs/sea/czm/index.html

Shoreline Management

- Washington State Shoreline Program goals:
  - "Shorelines are among the most valuable and fragile natural resources"
  - Encourage water-dependent uses
  - Protect shoreline natural resources
  - Promote public access
  - "Prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines"

http://www.metrokc.gov/shorelines/about.aspx

Shoreline Master Programs

- Both a land use & an environmental protection program
  - Shoreline inventory
    - Within 200 feet of water's edge
  - Plan & regulations for shoreline land use
    - >200 cities & 39 counties have developed
  - Subject to revision with public input
    - Most written 1974—1978
    - ~75% slightly or substantially revised
    - Must be approved by Dept. Ecology

http://www.ecy.wa.gov/programs/sea/czm/index.html

Essentials of Shoreline Master Programs

- Require permits for substantial development
- Establish preferred uses
  - Single family residential
  - Ports
  - Recreation
  - Water-dependent industry
  - Other
- Balance use & conservation
  - Unrestricted development on public or private shoreline is not in the public interest

http://www.ecy.wa.gov/programs/sea/czm/index.html

Controversy over CZM Revisions

- Legislature mandated revisions 1995
- 1st draft 1999, 2nd draft adopted 2000
- Challenged in court
  - Assn. of Washington Business (coalition of business, cities & counties)
  - Washington Aggregates & Concrete Assn.
  - Washington Environmental Council defended
  - Shorelines Hearings Board upheld challenge
- Negotiated settlement adopted Dec. 2003

http://www.ecy.wa.gov/programs/sea/SMA/guidelines/index.html

Superfund

- Law signed Dec. 1980
  - "Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)"
  - EPA lead agency with partner agencies
- Purpose: Federal funding to clean up "abandoned, accidentally spilled, or illegally dumped hazardous waste that pose current or future threats to human health or the environment."

http://www.epa.gov/superfund/25anniversary/

Superfund

- Motivation: Need to clean up sites quickly
  - When polluting party cannot be identified, is out of business, is bankrupt, etc.
  - When establishing legal liability is too slow.
    - E.g., if multiple parties may be responsible
    - Clean up first, sue for repayment later
- Include community in decisions & activities
- Restore area to productive use
- Research on fates of toxins & cleanup methods

http://www.epa.gov/superfund/25anniversary/

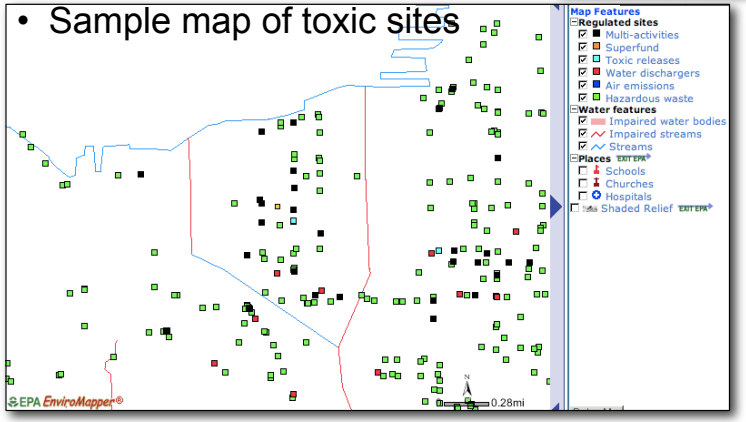
Duwamish Superfund Site

- Harbor Island listed 1983
  - Groundwater
    - Benzene, ethylbenzene, xylene, mercury, cadmium, lead, and zinc
  - Soil & Sludges
    - Heavy metals, polychlorinated biphenyls (PCBs), and petroleum
  - Sediments
    - Heavy metals, polycyclic aromatic hydrocarbons (PAHs), tributyl tin (TBT), and PCBs
  - Environmentally Sensitive Area for wildlife

yosemite1.epa.gov/r10/cleanup.nsf/5c8919bc41f032578825685f006fd670/5a64831b6521f46b8825650200836f1c?OpenDocument/

Duwamish Superfund Site

- Sample map of toxic sites



http://oaspub.epa.gov/enviro/fii_query_dtl.disp_program_facility?pgm_sys_id_in=WAD980722839&pgm_sys_acrnm_in=CERCLIS

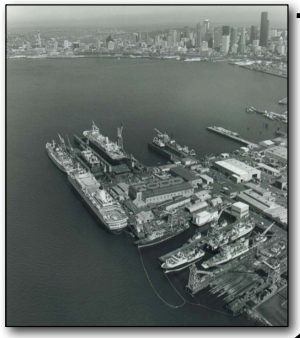
Harbor Island Sediments

- Todd & Lockheed Martin Shipyards
  - West Waterway heavy metals tackled 1st
  - East Waterway also contaminated
- Some areas dredged
  - Contaminated material taken to landfill
  - Advantage: material is removed
  - Disadvantage: expensive, can spread toxins
- Some areas capped with clean sediment
  - Cheaper but leaves contaminants in place

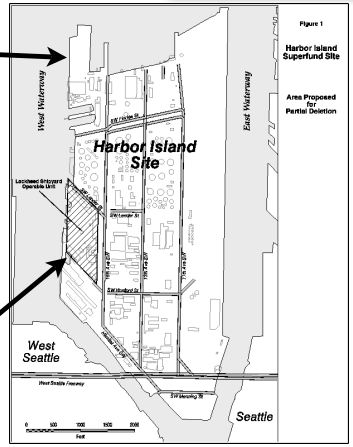
http://yosemite.epa.gov/r10/nplpad.nsf/88d393e4946e3c4788256312006 72c95/173f0efa24b8a8288525659200 77c26c?OpenDocument

Harbor Island Sediments

- Todd Site



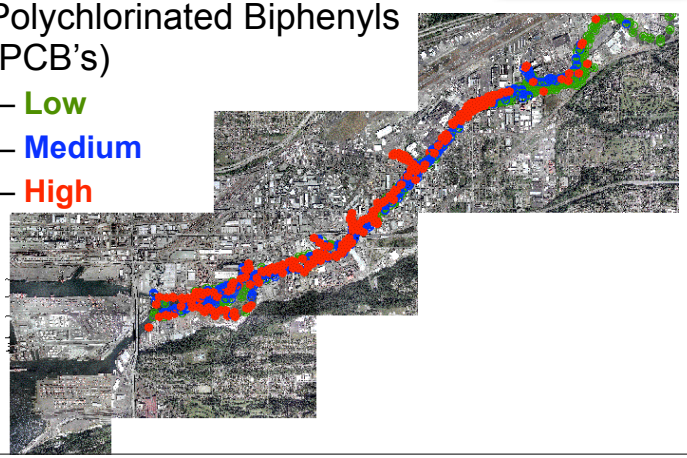
- Lockheed Site



www.epa.gov/r10earth/offices/oec/harbi.gif

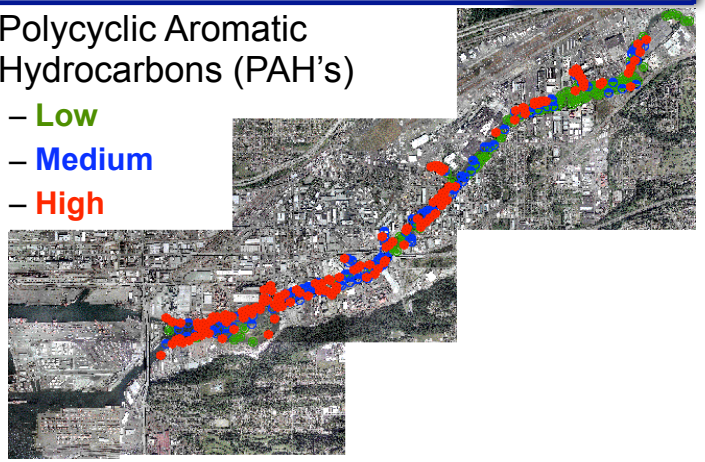
Contaminated Duwamish Sediments

- Polychlorinated Biphenyls (PCB's)
  - **Low**
  - **Medium**
  - **High**



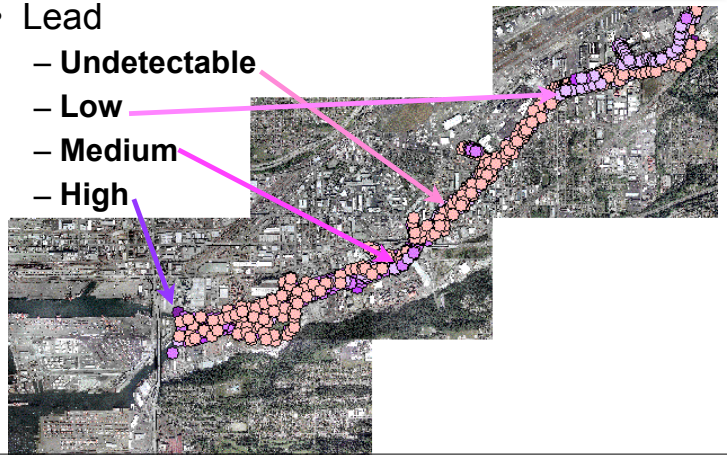
Contaminated Duwamish Sediments

- Polycyclic Aromatic Hydrocarbons (PAH's)
  - **Low**
  - **Medium**
  - **High**



Contaminated Duwamish Sediments

- Lead
  - **Undetectable**
  - **Low**
  - **Medium**
  - **High**



Partners in Duwamish Restoration

- City of Seattle (www.seattle.gov/mayor/issues/pdf/040913rowStrat.pdf)

General Condition of Seattle's Aquatic Environments

Marine Nearshore/Duwamish/Lake Washington/Lake Union/Ship Canal

- Water Quality issues include fecal coliform, ph, dissolved oxygen, temperature. Occasional beach closures due to fecal coliform.
- Sediment contamination found in the vicinity of some outfalls and historic industrial areas. Contaminant range from PCB's, metals, oil, bioassay, pesticides, to organics.
- Majority (over 90%) of shoreline is armored with little riparian vegetation.
- Reduced beach sand and gravel recruitment due to the high amount of bank armoring.
- Significant numbers of over-water structures (piers and docks).
- Non-native plant and fish species.
- Lack of backshore and estuarine environments providing adequate salt and freshwater transition for migrating salmon
- Small amount of intertidal mudflat, limited wetlands and shallow water habitat – areas that serve as rearing zone for salmon and foraging fish.
- Limited biological organisms.

Partners in Duwamish Restoration

- City of Seattle (www.seattle.gov/mayor/issues/pdf/040913rowStrat.pdf)
  - The Duwamish has been transformed from a Superfund site and industrial waterway to a vibrant and thriving ecosystem that coexists with resident industries. City and private sector sediment remediation and habitat restoration projects have reclaimed significant areas of inter-tidal and shoreline habitat, allowing wildlife to flourish along stretches of the river and providing areas of valuable public access. These areas are successfully intertwined with the City's maritime and industrial firms, and enhance their properties. Businesses and residents view the Duwamish as a vibrant and complex ecosystem, and they guard against renewed contamination and water pollution.

Puget Sound/Duwamish/Lake Washington/Lake Union/Ship Canal Shorelines	
Highest Priority	• ***Re-establish critical habitats.*** Create a physical chain of naturalized (restored & revegetated) refuge areas giving highest priority to: a) large contiguous areas; b) areas adjacent to available habitat; and c) critical gaps. • ***Control water quality and remove contaminated sediments*** in regulated areas and proximate to habitat refuge areas and public contact recreation points.
Medium Priority *	• Remediate contaminated sediments in non-refuge and non-public contact recreation sites.
Lower Priority *	• Revegetate 'non-refuge' shoreline areas with native plants.

Partners in Duwamish Restoration

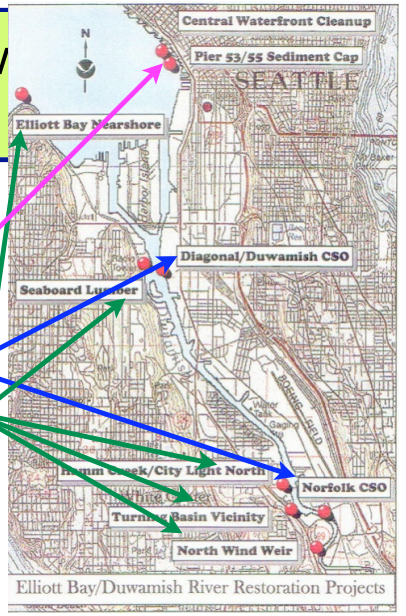
- King County (www.metrokc.gov/shorelines/about.aspx)
  - Shoreline Management Master Program 1978
  - Due for revision by 2009
  - Coordinates with County Master Plan & Critical Areas Ordinances

Partners in Duwamish Restoration

- NOAA (www.darp.noaa.gov/northwest/elliott/index.html)
  - Conducting Natural Resources Damage Assessment (NRDA) with city & county
  - Goals: sediment remediation, habitat restoration, contaminant source control

Partners in Duw Restoration

- NOAA (www.darp.noaa.gov/northwest/elliott/index.html)
  - Cap contaminated sediments
  - Clean up sediments at CSO
  - Restore estuarine habitat



Partners in Duwamish Restoration

- Washington Dept. Health
  - Monitors safety of seafood for consumption
  - Subsistence diet for low-income citizens
  - August 2005 advisory not to eat resident fish & shellfish from the lower Duwamish
    - Sole, perch, flounder, crab. other shellfish
    - Migratory salmon OK
    - Average >700 parts/billion PCB in sole
      - "Safe" level for 1 8 oz. serving per month = 200 ppb
  - Contaminant levels appear to be increasing
    - Stirred up by dredging contaminated sediments?

seattletimes.nwsource.com/html/localnews/2002419662_duwamish04m.html

Partners in Duwamish Restoration

- Non-profit organizations
  - Duwamish River Cleanup Coalition
    - www.duwamishcleanup.org
    - People for Puget Sound, Puget Soundkeeper Alliance, WA Toxics Coalition
    - Neighorhood, small business & tribal groups
  - Formally recognized by governmental bodies as citizen's advisory group
    - Hired technical adviser to monitor progress of cleanup & restoration