Impacts of Rising Sea Levels on Puget Sound

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11 September 2007
Future Sea Level Scenarios

- Based on various models of climate change and of sea level response to warmer conditions.
- Wide range of predictions (5”-29”) by 2100
- High level of uncertainty
- Many scientists feel these projections may be conservative, due to unknowns regarding rates of ice sheet melting

Impacts of Rising Sea Levels

- Increased frequency of damaging storms and floods
- Gradual inundation of low-lying areas
- Increased erosion rates
- Loss or major shifts in nearshore habitats
- Escalating costs of maintaining and repairing infrastructure
- Effects on shellfish harvesting and agriculture in coastal areas
- Seawater intrusion into coastal aquifers
Vulnerability of Puget Sound to rising sea level

- Different environments
  - River deltas
  - Bluffs, Beaches, and Spits
  - Estuaries and Lagoons

- Different development types
  - Natural
  - Residential
  - Urban
  - Port and Industrial

2’ (red) indicates areas potentially subject to tidal inundation – approximate IPCC 0.7 m

20’ (yellow) indicates areas potentially subject to tidal inundation under a much more extreme scenario

Global Warming / Sea Level Rise Model
Puget Sound Region

Map Data Source:
15-meter Digital Elevation Model (DEM) http://nsidc.org/ems/geoportal
24 (8.6 meter) is the smallest average measurable elevation supported by the DEM data used above.
20’ (6.1 meters) depicts sea-level rise that could result from widespread melting of Greenland and West Antarctic ice sheets caused from average global temperature increase of greater than 1.5°C (1-3°F), causing sea-level rise of 3-5.3 feet (1-1.6 meters) over time.

Ecology, GIS Technical Services, 6/12/07
River Deltas

- Increased costs of repairing and maintaining dikes and levees
- Loss of nearshore habitats seaward of dikes
- Increased flooding, soil saturation, drainage problems
- Significant influence on long term decisions regarding agricultural use or ecological restoration
- Increased intrusion of saltwater into estuary

Low-lying river deltas are subject to extensive inundation. Extent will depend on degree of diking and commitment to maintaining protection as costs escalate. Most deltas are dominantly agricultural. A few are urban and industrial.
Coastal Bluffs

- Increased erosion rates and landsliding
- Escalating damage to seawalls, with need for progressively larger, more expensive measures over time
- Beach habitats squeezed out where shorelines armored
- Shift from forested bluffs to unstable bare slopes
- Changes in bluff erosion may impact beaches in elsewhere along shoreline

Widespread landform on Puget Sound. Primarily residential development. Often hazardous due to erosion and landslides. Extensive armoring, but existing concerns about long-term ecological impacts.
Spits and Barrier Beaches

- Increased frequency and severity of flooding and storm damage
- Rapid erosion and potential for breaching
- Failure of septic systems; threat to water supply and utilities
- Loss of beaches where shoreline is armored
- Loss of associated wetland and estuarine habitats

Spits and barriers are common on Puget Sound. Many protect valuable salt marshes and estuaries. Residential development common, although many remain as parks and reserves.
Urban Waterfronts

Shorelines of urban areas largely modified by landfill and seawalls. Extensive overwater development and marine facilities. Major investments in public and private infrastructure.

- Increased risks to infrastructure
  - Treatment Plants
  - Transportation Corridors
  - Commercial and Industrial Waterfronts
  - Parks

- Storm drainage systems require expensive fixes

- Increasingly steep public costs to maintain, protect, and repair public facilities and property

- Redevelopment opportunities
Ports

- Increased maintenance and repair of port facilities
- Increasing storm damage to piers and seawalls
- Need to reconfigure or elevate freight handling yards
- Increased corrosion of tanks and pipes; increased leaching of contaminated soils
- Opportunity to adapt during major facility updates

Ports usually have heavily engineered shorelines. Freight handling requires extensive rail yards near water level. Associated industrial areas may contain currently or historically contaminated sites.
Nearshore Habitats

- Habitats eliminated if they cannot migrate landward
- Tidal dynamics and sedimentation likely to change
- Viability of restoration actions will change or become less certain

Beaches, salt marshes, tide flats, stream mouth estuaries, and lagoons. Increasingly targets of restoration actions.
Local Inundation Maps

- Valuable for evaluating general risk, but should not be used to draw site-specific conclusions.
- Typically show arbitrary scenarios. 2’ zone within IPCC projections. 20’ only possible if dramatic melting of ice sheets.
- May not accurately reflect existing dikes and levees.
- Maps possible extent of maximum high water, not area of permanent flooding or of mean sea level.
- Looks only at modern topography – no accounting for future changes due to erosion, channel migration, subsidence, or engineering responses (new dikes).

Inundation maps draw attention to large low-lying areas, where extensive flooding is possible. These maps downplay high risk areas where flooding is not the primary hazard—e.g. downtown waterfronts, bluff landslides, contaminated shoreline sites.
Samish Bay and the Town of Edison
Port Townsend
Storms

- Damaging storms will occur more frequently
- *Damage* from storms will increase due to high water levels and increased wave action
- Severity of storms *may* increase – independently of sea level rise
Coastal Flooding

- Extreme high water levels will increase over time
- Flood events of any given magnitude will become more frequent
- Longer flood durations
- Drainage of low-lying areas more difficult
Flood Frequency

- On Puget Sound, the difference between 10 year and 100 year flood is about 1 foot.

- A 1’ rise in sea level will result in a 100 year flood becoming a 10 year event.
Number of >13’ tides in Seattle per year (average about 8)

- **1982-83 El Nino**
- **1997-98 El Nino**
Erosion and Landslides

- Erosion rates likely to increase in most locations
- Landslides more frequent and possibly larger
- Erosional events will occur more often
- Patterns of sediment transport on beaches will be altered, leading to complex, perhaps rapid shoreline changes
Barrier Beaches

Resilience depends on:

- *Rate of sea level rise*
- *Ability to migrate*
- *Sediment availability*
Armoring

- Sea level rise will result in progressive loss of upper beach, where shoreline cannot retreat landwards
Salt Marshes

Resilience depends on:

- Rate of sea level rise
- Ability to migrate
- Sediment availability
Thoughts

• Think about responding to events, not just chronic inundation over the next 100 years.
  – SLR will occur as escalating series of disasters
  – Storm damage and emergency repairs, insurance issues

• Different shorelines will respond differently
  – Geomorphic setting, Land use

• Resilience is the key to sustaining both natural and built environments
What Next?

• Develop scenarios of sea level response for different environments
  – Agricultural river deltas, Urban shorelines, Bluffs, Spits, Small estuaries
  – Characterize vulnerability in each setting and develop clear storylines

• Do what we’re already trying to do even better
  – Limit armoring, increase setbacks, restore shorelines, remove dikes
  – Improve processes for siting new construction in vulnerable areas

• Increase resilience
  – Set back development, protect/preserve areas that can accommodate
  – Protect key geomorphic processes, like sediment supply (rivers and bluffs)

• Identify critically vulnerable sites, areas, and settings
  – Natural places AND built environments
  – Develop creative funding mechanisms for acquisition in face of long-term threat

• Anticipate responses that will be driven by crises
  – Impacts of slr will a series of disasters

• Where engineering is inevitable, be imaginative