Shifting Shorelines:
A process-based approach to sea level rise resilience in Grays Harbor estuary

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ABSTRACT

Shifting Shorelines: a process-based approach to sea level rise resilience in Grays Harbor estuary

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As sea levels rise, estuarine settlements and ecosystems alike must respond to inundation. How can this planetary phenomenon inform place-based resilience? This thesis explores the intersection of historical ecology and infrastructure through Seaport Landing, a shoreline redevelopment project along the lower Chehalis River in Aberdeen, Washington. Through analysis of environmental, social, and economic dynamics of sea level rise adaptation, this thesis finds that engagement with place-specific processes occuring at multiple temporal and spatial scales can further resilience to environmental disturbance. This inquiry produces a process-based design vision that catalyzes assisted habitat migration and economic revitalization in Grays Harbor. Leveraging a single site's potential to influence ecological trajectories, this proposal reframes Aberdeen's relationship to the water while reestablishing riparian processes in the face of sea level rise.

Shifting Shorelines:

A process-based approach to sea level rise resilience in upper Grays Harbor estuary

Jackson Blalock 2017

Many people and places have shaped this project. I am appreciative of them all.

I am indebted to my thesis committee, professors Julie Johnson and Ken Yocom, for their patience, humor, and encouragement as I explored a vast range of topics. You have helped me to better understand and communicate my own interests, while developing clearer vision of the world and of landscape architecture.

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Thanks to Phil Schoettle-Greene for peer review, fun travels, and assistance throughout this project. Thanks to Keith Hodson and the University of Washington Quaternary Research Center for use of facilities and equipment.

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Thanks to my parents, sisters, and grandparents for always encouraging me to explore, sharing knowledge and love.

Thanks to my classmates for inspiration, comradery, and too much talk of hyperobjects. What's next?

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Seaport Landing, Aberdeen, Washington: point cloud model of shoreline along the estuarine Chehalis River.

Fig. 1-1. The lower Chehalis River exchanges waters with Grays Harbor as it flows past Aberdeen and Seaport Landing to the Pacific Ocean. (image: Quinault Indian Nation)

Sea level rise resilience in Grays Harbor estuary:

How does flood infrastructure reflect place?
What does place-based climate change adaptation look like?
How can resilience be incubated at the site scale?

Sea level rise will threaten ecosystems and livelihoods in coastal zones. As planners, residents, and land managers prepare for sea level rise in Grays Harbor, Washington, habitat restorations breach levees while towns surround themselves with dikes. This approach reinforces a human-nature dichotomy, rather than acknowledging complex socio-ecological relationships which must be embraced in order to design for sea level rise resilience.

Walker and Salt's "Resilience Practice[1]" defines resilience as an ecosystem's capacity to maintain functional identity amidst disturbance. Recent rates of sea level rise provide an incredibly potent example of human interconnectivity with environmental systems. As new ecological relationships emerge from sea level rise, landscape architecture can help preserve critical habitat function through insightful design.

Design for climate change resilience moves beyond site and profession, linking environmental fields through interconnected interventions at multiple scales. As a field equipped to analyze and respond to socio-ecological trajectories, landscape architecture can connect sea level rise adaptation with place-based processes. Here, environmental design furthers social and economic systems. An in-depth theoretical analysis of place-based sea level rise adaptation offers new avenues for meaningful academic inquiry and outwardly-engaged scholarship. Resilience practice integrates interdisciplinary and intercultural knowledges, presenting exciting design opportunities with substantive potential to positively affect socio-ecological trajectories.

Chapters 2 and 3 present expected sea level rise impacts for Grays Harbor and potential adaptation measures, respectively. Here, I find that adaptation strategies reflect specific socio-ecological relationships. A review of resilience literature necessitates a specific, place-based strategy in order to orchestrate climate change resilience.

Chapter 4 discusses theories of "place", looking into historical sea level rise and related shoreline changes of Grays Harbor estuary. This landscape analysis finds that processes of landform change – erosion and deposition driven by hydrology and industry – are underpinning elements of local place-based relationships.

Chapter 5 uses this historical analysis to outline an adaptation vision for Seaport Landing, an innovative shoreline redevelopment site in Aberdeen. This adaptive design strategy employs landform change, drainage, and localized industry to allow Seaport Landing to respond to future sea level rise scenarios.

a. Landscape analysis and topology

Hansjörg Küster, Professor of Plant Ecology at Leibniz University's Institute for Geobotany, advocates for "landscape analysis" as a pertinent new discipline to inform design fields. A merger of geography, sociology, and ecology, landscape analysis is the "basis for landscape planning". It promotes the necessary act of "compil[ing] information about landscapes to educate the public[2]", promoting informed understandings of landscapes and interventions into them. Applied toward Seaport Landing and Grays Harbor estuary, landscape analysis not only unearths historical ecologies but also informs culturally and ecologically appropriate design.

Landscape analysis is comparable to critical cartography's use as a "productive and liberating instrument", described by landscape architect/theorist James Corner in "The Agency of Mapping[3]" and exemplified through revisionist mappings of the world by Joaquín Torres-García[4] and Buckminster Fuller[5] (Figs 1-2, 1-3 respectively). More recently the Amir Sheikh-led "Waterlines" map[6] (Fig 1-4) communicates pre-European place names, place meanings, and landscapes of present-day Seattle. In stripping away everyday biases, these works "decolonize and reinhabit" spaces as advocated by Greenwood[7], uncovering and advocating diverse trajectories for socio-ecological interaction. Fuller's and Sheikh's maps emphasize the importance of water for trade and sustenance, critiquing land-centric understandings of life.

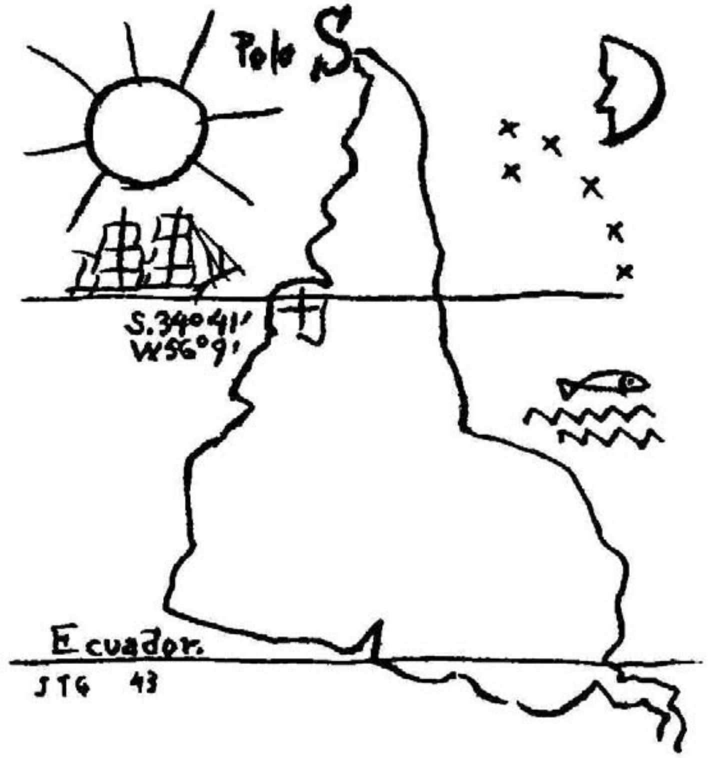

Fig. 1-2. Torres-García's inverted map of South America highlights dominant power structures which give disproportional attention to global north. (image: Khan Academy)

Christophe Girot, Chair of Landscape Architecture at the Swiss Federal Institute of Technology Zurich, extracts "topology" from landscape analysis. Topology is rooted in the Greek topos ("place") and logos ("language"). Topology, or place-language, is a terrain's essence, unbounded by fragmentation-inducing parcelization, floodwalls, or other borders. As such, topology can further critical place-based environmental inquiry[8].

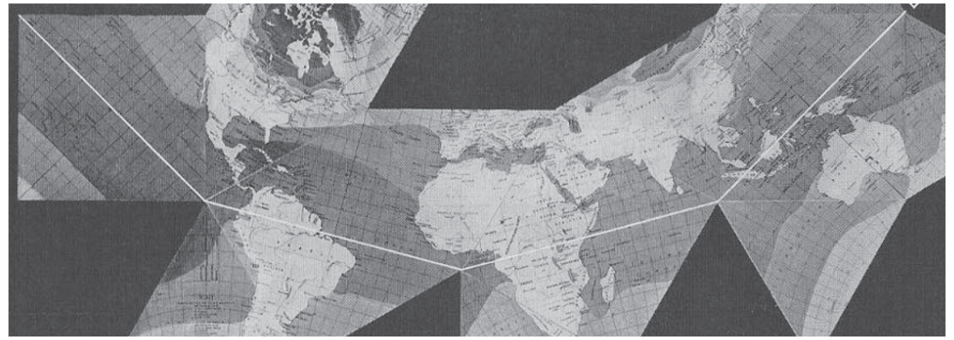

Fig. 1-3. Fuller's Dymaxion Map (top) reframed ways of laying out the Earth in 2-D, correcting distortions to emphasize the expanse of oceans. (image: Dezeen.com)

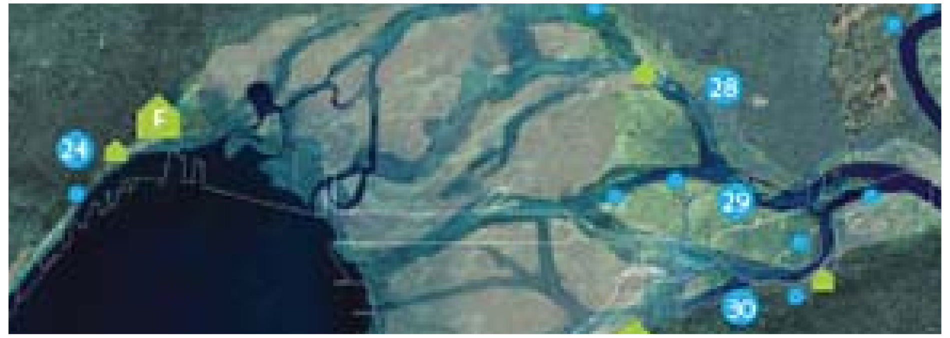

Fig. 1-4. Waterlines Project map (detail) shows orientation of settlements in relation to geographic features, reflecting place-based worldviews of Seattle's pre-European residents (image: Burke Museum).

Topology is a tool for "landscape chronology", which merges landscape analysis with studies of landscape succession in order to understand the cultural and symbolic meanings of a terrain. Place-meaning as such is rooted in a locale's interlinked topography and socio-ecological interactions through time. Terrain becomes the foundational element through which place-based relationships are born. Utilizing drone-based Structure From Motion technology, Girot brings substrates into detail and emphasizes substrates in a way that adds dimension to design inquiry. Girot proposes that terrain be given a front-seat in the design process, rather than relegated to being levelled by bulldozers in the name of site program[9].

This "program over terrain[10]" approach is counter to topology, as it prioritizes immediate and perhaps less inclusive goals over more holistic place-meaning and localized connectivity. A "terrain as program" approach, however, embraces topological concepts alongside ecological history, situating landforms as the focal point of place-based phenomena. Doing so reinstates local scales of activity while acknowledging and engaging processes shaping a place — morphologically as well as phenomenologically.

This is a particularly relevant method to design along estuarine shorelines, where landforms are created, altered, and exploited through a complex mix of social, environmental, and economic processes. Sea level rise adds an additional layer of substrate-sculpting activity to the mix, as rising tides will redefine water levels, shoreline morphology, and the socio-economic processes which rely upon these conditions.

b. Critical stance

As climate change becomes increasingly relevant for sustainable design, new opportunities arise for designers to engage in ecological resilience planning. Typical sea level rise adaptation strategies focus on anthropocentric protection rather than ecologically-attuned resilience. Attention to socio-ecological relationships reinstates the local within global climate change, and can further support local economies in post-industrial settings which have been impacted negatively by globalization.

By incorporating place-based processes through landscape analysis, sea level rise adaptation can engage with social, economic, and environmental processes over time. This approach better incubates resilient systems by framing sea level rise and associated flooding as ongoing multiscalar ecological processes rather than isolated events.

A focus on multiple temporal and spatial dimensions of sea level rise bridges fields of landscape architecture, restoration ecology, and environmental planning through topologically-driven landscape analysis. Design for adaptive resilience benefits from acknowledgment of complexity inherent in ecological design. Ensuing scenario planning forgoes a static masterplan, instead embracing multiple divergent opportunities for designed environments through a kit of loose parts which can be selectively applied in an unknown future.

Sea level rise will drastically alter the character of ecoregions which support place-based livelihoods and species. Design for sea level rise resilience must push existing flood management infrastructure to better engage aquatic ecosystems and allow habitat migration. By defining the essence of "place" as the past, present, and future processes which shape a region, fluvio-tidal geomorphology becomes part of the design toolbox. How do flux-based place-creating processes relate to sea level rise resilience? The following inquiry, analysis, and proposal tests this question through Seaport Landing, a shoreline redevelopment project along the Grays Harbor estuary in Aberdeen, Washington.

By problematizing societal relationships to aquatic ecology as reinforced by prevailing flood infrastructures, this thesis seeks to peel back existing control-based approaches to the land-water interface, creating room for beneficial process-based ecosystems to grow. In doing so, elements of critical cartography and landscape analysis are utilized.

c. Context

Grays Harbor, Washington

Grays Harbor is a large estuarine embayment along the Pacific coast of Washington. Freshwaters enter predominantly from the Chehalis River, 16 miles inland from the harbor's mouth. The estuary's tidal regime extends several miles up the lower Chehalis River, past Aberdeen, through tidal swamps, almost to the town of Montesano. The inner extents of the estuary are encompassed by the Chehalis River surge plain, which hosts the states most extensive coastal wetlands[11].

The Chehalis River drains Washington's second-largest watershed[12], and is also the only basin in the state whose salmon are not listed by the Endangered Species Act[13]. The extensive mudflats of outer Grays Harbor are home to productive shellfish beds and host the largest population of migratory shorebirds on the entire eastern Pacific coast[14].

Historically, the shorelines of Grays Harbor held numerous Native American settlements and more recently were crucial for the region's timber industry. Aberdeen and neighboring Hoquiam flourished during the early 1900s, but shifting industrial practices, regulation, and unsustainable forestry practices have led to a sharp decline in the local economy. Presently, many former industrial sites along the harbor's shores lie fallow, covered with asphalt and novel ecosystems, or "ecosystems without historical precedent in an era of rapid ecological, environmental and cultural change[15]" as described by ecologist Eric Higgs of University of Victoria, British Columbia. The soils of these sites hold contaminants harkening back to days of limited environmental sensitivity.

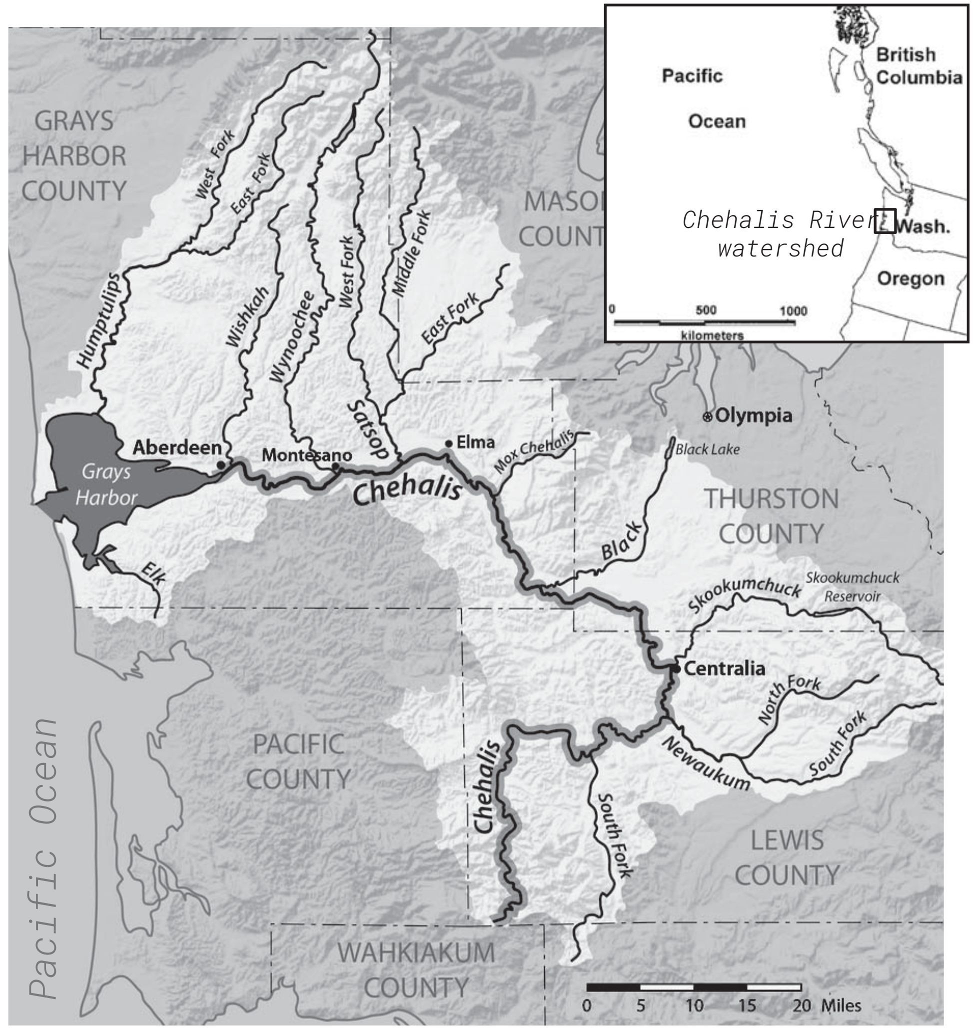

Fig. 1-5. The Chehalis River flows into Grays Harbor. (images: Wikimedia, Geologic Society of America)

Local sea level rise

Sea level is expected to rise by as much as one meter along the Washington coast by the year 2100. As a shallow low-gradient estuary, the ecosystems and associated economies of Grays Harbor are particularly threated by sea level rise. Rising tides are expected to wipe out 97% of estuarine forests, predominantly located just upstream of Aberdeen in the Chehalis River Surge Plain Natural Area Preserve. These changes will dramatically alter habitat for juvenile salmon, lamprey, Olympic mudminnow, and other species of concern[16].

Sea level rise will compound existing flooding of settlements along Grays Harbor. Aberdeen and Hoquiam's joint Timberworks Resiliency and Restoration Master Plan, proposes strategies for protecting developed lands from flooding. These efforts address coastal flooding and high flows of the Chehalis River with levees along the shores of Aberdeen, while daylighting and floodplain restoration for urban streams target local drainage.

The Timberworks plan does not address climate change impacts outside of the two municipalities. The Wild Fish Conservancy has proposed ecological restoration strategies for assisting habitat migration induced by sea level , though restoration and resilience strategies for urban areas and adjacent wildlands are largely independent.

Fig. 1-6. Tidal swamps of the Chehalis River surge plain, at risk of devastation from sea level rise. (image: Washington DNR)

Fig. 1-7. Flooding in Aberdeen and Hoquiam will be compounded by sea level rise. (image: PBS)

Seaport Landing, Aberdeen, WA

Seaport Landing is a proposed mixed-use development project on the south shore of the lower Chehalis River in Aberdeen. Formerly a Weyerhaeuser sawmill, the site is currently owned by the Grays Harbor Historical Seaport Authority (GHHSA). This non-profit plans to outfit the site for public use, with a focus on local history, science education, and maritime economy. Current site work involves demolition of decaying structures and assessment of contamination.

As the first major redevelopment of Grays Harbor's urban industrial shorelines, Seaport Landing will be a precedent for sea level rise adaptation elsewhere in the estuary. The mission-driven vision of GHHSA presents an opportunity to engage the public through adaptation measures, while encouraging new holistic approaches to Aberdeen's underutilized industrial shorelines.

GHHSA's proposed program for Seaport Landing will intervene in local social, environmental, and economic dynamics through increased public space, a remediated shoreline, and new business opportunities, respectively. As a large public space, Seaport Landing is sited at an economically advantageous position along Highway 101, which carries approximately 5 million visitors through Aberdeen annually[17]. The threatened Chehalis River surge plain ecosystem begins just upstream of this site, providing opportunity to impact environmental dynamics as well.

Fig. 1-8. Seaport Landing lies along the south bank of the lower Chehalis River as it flows through the Chehalis River surge plain and through Aberdeen. (base image: Google Earth)

Fig. 1-9. Seaport Landing today, awaiting redevelopment. (image: Grays Harbor Historical Seaport Authority)

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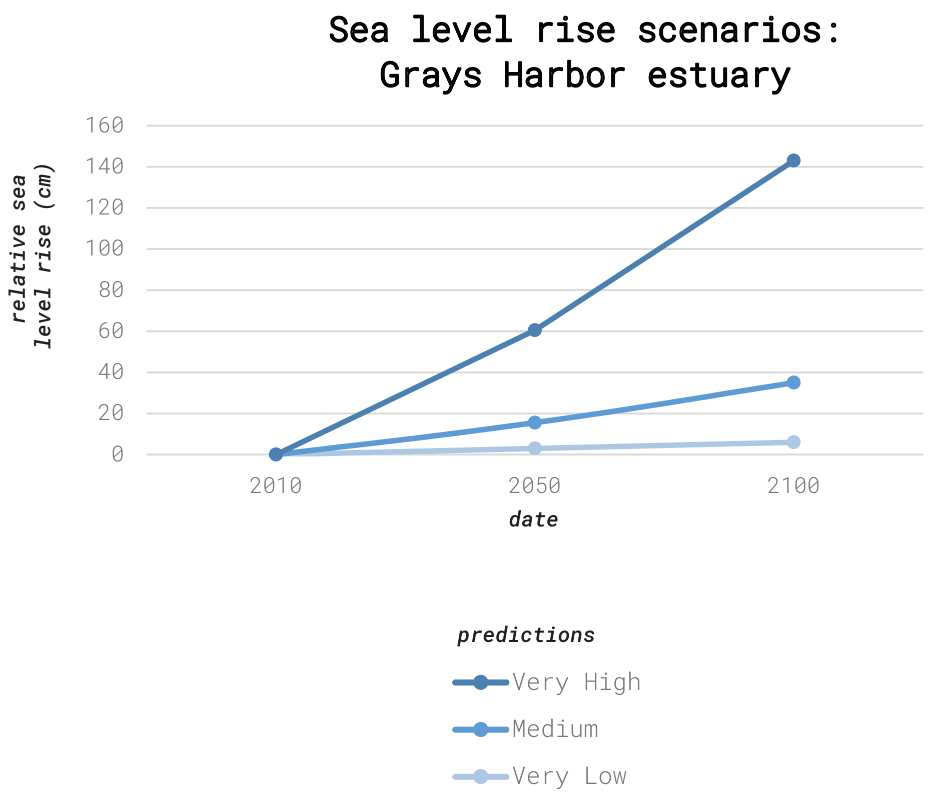
chapter 2

Sea level rise and Grays Harbor estuary

Sea level rise is expected to destroy Washington's largest coastal wetland complex, while restoration plans target abandoned industrial shorelines.

Dike breach and tidal restoration at former Markham Lumber Company site, Johns River Wildlife Area, south Grays Harbor. The Wild Fish Conservancy hopes that salmon habitat will migrate here as sea level rises.



a. Sea level rise scenarios

As sea levels rise through the 21st century, upland migration of littoral habitats will be impeded by shoreline armoring and other property protection strategies. Open water will increase, while ecologically significant aquatic-terrestrial transition zones will become more narrow. This loss of littoral habitats due to sea level rise and commonly-constructed shoreline defenses is referred to as "coastal squeeze"[1]. As a result, ecosystems will lose ability to function in the same manner – i.e. lose resilience - causing the disruption of long-established cycles. The same impermeable surfaces that today allow toxic runoff to imperil key aquatic species will tomorrow keep shoreline habitats from migrating upland.

The Intergovernmental Panel on Climate Change (IPCC) has presented multiple models for potential sea level rise scenarios. Of these, the "A1B" model represents a moderate increase in sea level rise and ocean temperatures with an expected sea level rise of 24-48cm (0.79-1.57ft)[2]. These models, however, may be lower than current expectations as they were created in 2007 and do not reflect data on the instability of the Earth's major ice sheets[3].

Sea level rise scenarios for the southwest Washington Coast have been modeled by the University of Washington Climate Impacts Group and the Washington State Department of Ecology (2008[4]). According to the Climate Impacts Group's "very high" projections, sea level around Seaport Landing is expected to rise 108cm (3.54ft) by 2100 (Fig. 2-2). This rise in elevation is driven by global-scale processes of glacial melt and eustatic sea level rise (the expansion of ocean water's volume due to increased atmospheric temperatures), along with local geologic activity such as subsidence and tectonics.

Fig. 2-1 (left), 2-2. Sea level rise predictions according to Mote et al. 2008, via UW Climate Impacts Group.

Sea Level Rise Estimates	2050			2100		
	NW Olympic Peninsula	Central and Southern Coast	Puget Sound	NW Olympic Peninsula	Central and Southern Coast	Puget Sound
Very Low	-12cm (-5")	3cm (1")	8cm (3")	-24cm (-9")	6cm (2")	16cm (6")
Medium	0cm (0")	12.5cm (5")	15cm (6")	4cm (2")	29cm (11")	34cm (13")
Very High	35cm (14")	45cm (18")	55cm (22")	88cm (35")	108cm (43")	128cm (50")

These sea level rise predictions are applied to Grays Harbor estuary in the Wild Fish Conservancy's (WFC) 2013 "Climate Change in the Chehalis River and Grays Harbor Estuary[5]", 2015 "Grays Harbor Estuary Salmonid Conservation and Restoration Plan[6]", and 2015 "Lower Chehalis River and Surge Plain Fish Use Assessment[7]". Aberdeen-Hoquiam's joint 2016 "Timberworks Restoration and Resiliency Master Plan[8]" ("Timberworks") takes these forecasts into account as well, as it proposes designs to address flooding within city limits.

The three WFC reports focus on habitat impacts from sea level rise, recommending response via restoration of target habitats. Timberworks, on the other hand, focuses on strategies to reduce flooding in the urbanized areas of Aberdeen and Hoquiam. In the latter report, habitat improvement is mentioned primarily as a means to reduce flooding of human settlements through the restoration of urban waterways. This activity is coincidentally beneficial for salmonids and other aquatic species, but is not necessarily a priority action as it is in the WFC documents.

In their 2014 report, "Sea-level scenarios for evaluating coastal impacts," Nicholls and colleagues[9] advocate adaptation based upon both extreme events and mathematically down-scaled approaches in order to obtain comprehensive adaptation. These expected sea level rise scenarios are compounded by king tides, high discharge events of the Chehalis River, and elevated wave and water level conditions from El Niño cycles[10]. In order to account for unexpected extreme events, this thesis responds to the higher of the above predictions and assumes a 1.08m (3.54ft) rise in sea level by the year 2100. By focusing on this highest sea level rise prediction, the ensuing design proposal encompasses most predicted sea level rise scenarios. This proposed intervention can be scaled back as necessary in order to respond to real-world water levels.

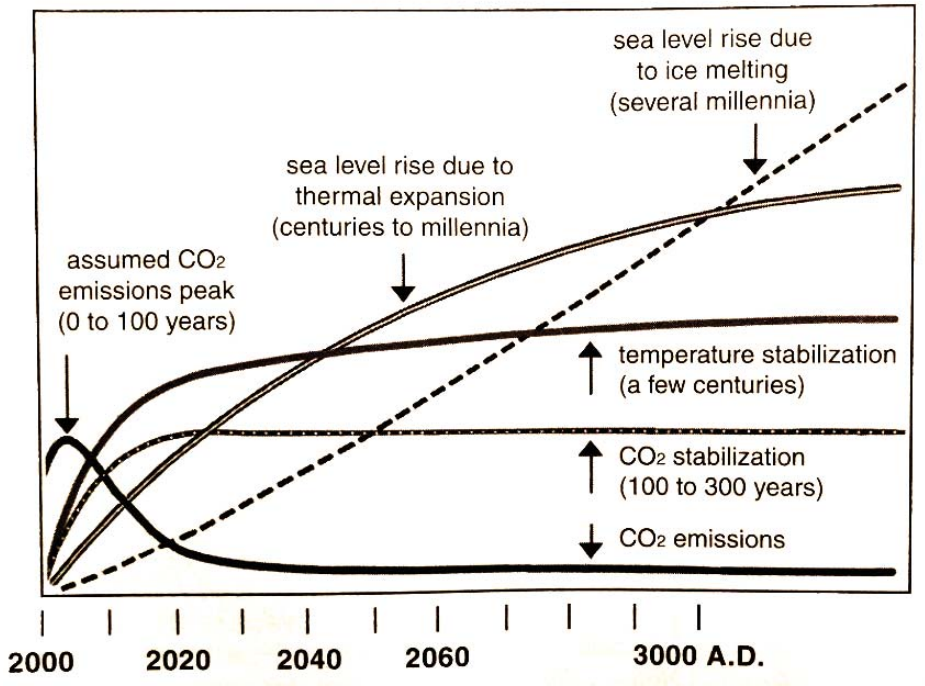


Fig. 2-3. Generalized depiction of climate change indices stabilizing over time. SLR is long-term process, part of a global climate system and spanning generations. Planning for the impacts of sea level rise entails embracing time scales beyond our lifespan. (image: IPCC via "Design for Flooding")

In assessing sea level rise adaptation strategies, Nicholls and colleagues[11] describe the physical impacts of sea level rise which may result in significant socioeconomic effects. While the socioeconomic context of these impacts is human-centric, the "habitat loss/change" impact category encompasses other ecological effects of climate change in Grays Harbor as described by the Wild Fish Conservancy's 2015 "Grays Harbor Estuary Conservation Plan"[12].

Physical impacts include:

1. Inundation of developed areas
2. Habitat loss/change
3. Morphological change (erosion, deposition)
4. Saltwater intrusion

The degree of these impacts will vary based on local relative sea level rise, extreme water levels influenced by periodic atmospheric storminess, and site-specific conditions. These potential impacts guide this paper's sea level rise adaptation strategies.

Fig. 2-4. Coastal wetland loss in the Mississippi River delta comes from a multitude of factors, but exhibits impacts similar to those of sea level rise. Here, saltwater intrusion causes habitat loss and morphological change. (image: USGS, Cochise.edu)

b. Local impacts of sea level rise

1. Inundation of developed areas

The lower Chehalis River's floodplains lie at low elevations, with much of Aberdeen and Hoquiam built upon tidal floodplain terraces at or below 5m (16.4ft) elevation. This location places them at risk of coastal flooding during present extreme high tide levels, particularly when combined with upland rain-driven flooding or high storm surges[13]. Much of Aberdeen and Hoquiam lie in 100-year (1% annual chance) floodplains as designated by the Federal Emergency Management Agency (FEMA).

Coastal flooding occurs when extreme high tides, winds, and waves push the estuary's waters over the banks of local streams and shorelines. While this flooding may appear to come from rivers, it is actually caused by marine conditions pushing water upstream[14]. Here, inundation is considered the flooding of low-lying areas due to regular high tides ("coastal inundation[15]") or storm events.

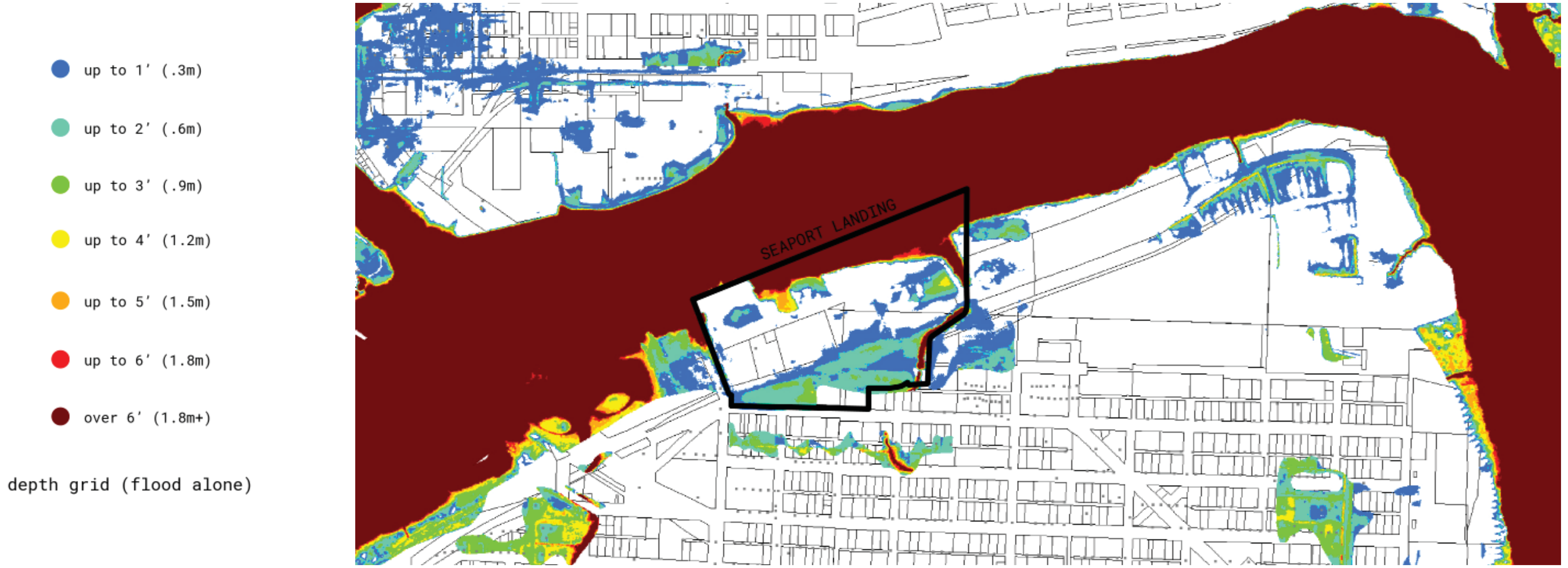
To put this into context, a 100-year high tide today reaches 4m (13.2ft). Figure XX shows Seaport Landing during a receding king tide at approximately the 100-year height (meaning a 1% annual chance of occurring).

Fig. 2-5. Seaport Landing during a receding king tide at approximately the 100-year height of 4m or 13.2ft (a 1% annual chance of occurring).

As sea levels reach higher elevations, occurrences and magnitudes of coastal flooding will increase. Low-lying coastal communities such as Aberdeen and Hoquiam may experience loss to property, resources, and life/livelihood. Rain-driven flooding and coastal inundation can combine to produce significant flood events, as occurred in January 2015, when over 8 inches of rain in a 24-hour period overwhelmed municipal drainage and led to standing water over 2 feet deep[16].

Currently, flood insurance rates for Aberdeen and Hoquiam are some of the highest in the state of Washington[17]. This was compounded in 2012, when Congress passed legislation to adjust National Flood Insurance Program (NFIP) rates to better reflect actual risks of flooding. In Aberdeen, some resident saw rate spikes over 300%, overshadowing mortgages on homes[18]. This is of particular concern for Aberdeen, which has some of the highest poverty and unemployment rates in Washington[19]. Flood insurance rates combine with low economic opportunity to create much disinvestment in low-lying areas of Aberdeen, exemplified by empty storefronts and blighted housing stock. As described by a community member at a Timberworks public meeting, it is extremely cost prohibitive to renovate homes to sit above FEMA's base flood elevation, while the lifecycle cost of owning property is infeasible as well due to NFIP rates[20].

While many Aberdeen residents see coastal flooding as a non-issue, the potentials for such events – and their ability to compound regular inland flooding – will increase dramatically as sea levels rise. Figure XX depicts potential inundation to Aberdeen due to incremental sea level rise, overlayed with flooding from the Chehalis River.



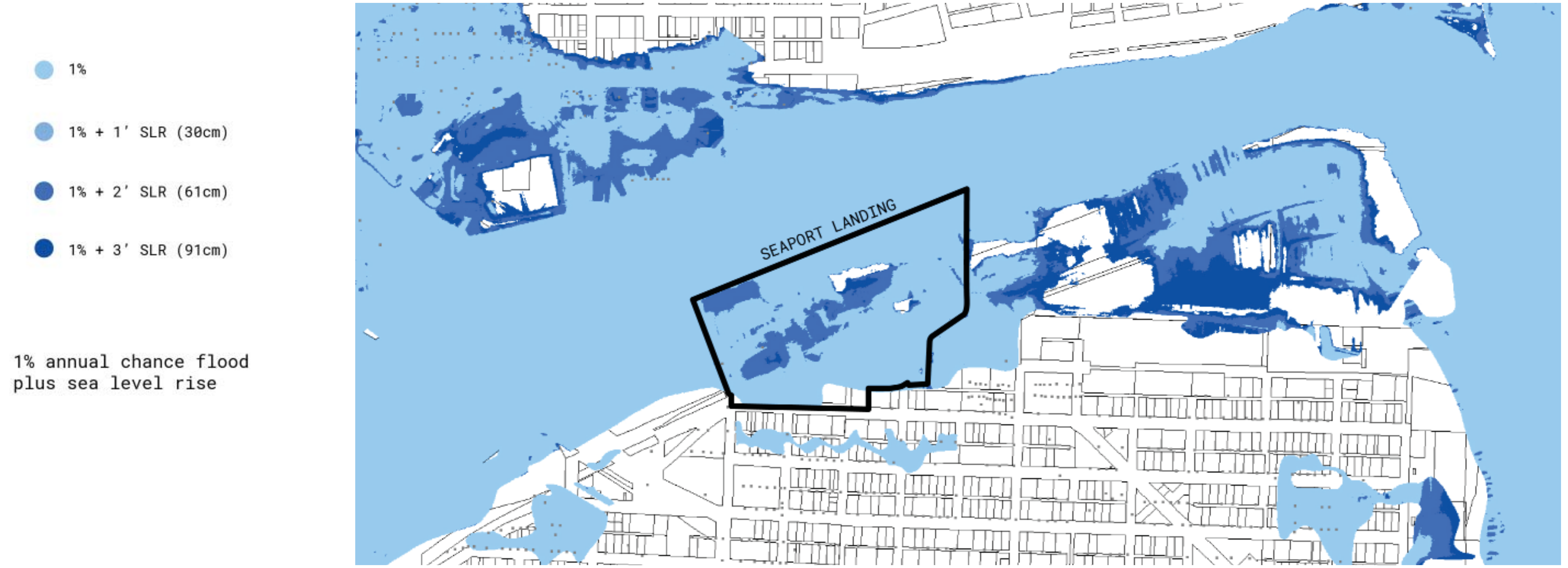


Fig. 2-6. Flooding predictions for sea level rise and Chehalis flooding combined, along with flood depth grid (below). Note unflooded areas along industrialized shorelines between town and estuary. (model and data source: University of Washington Institute for Hazard Mitigation and Research, for Department of Homeland Security; in progress)

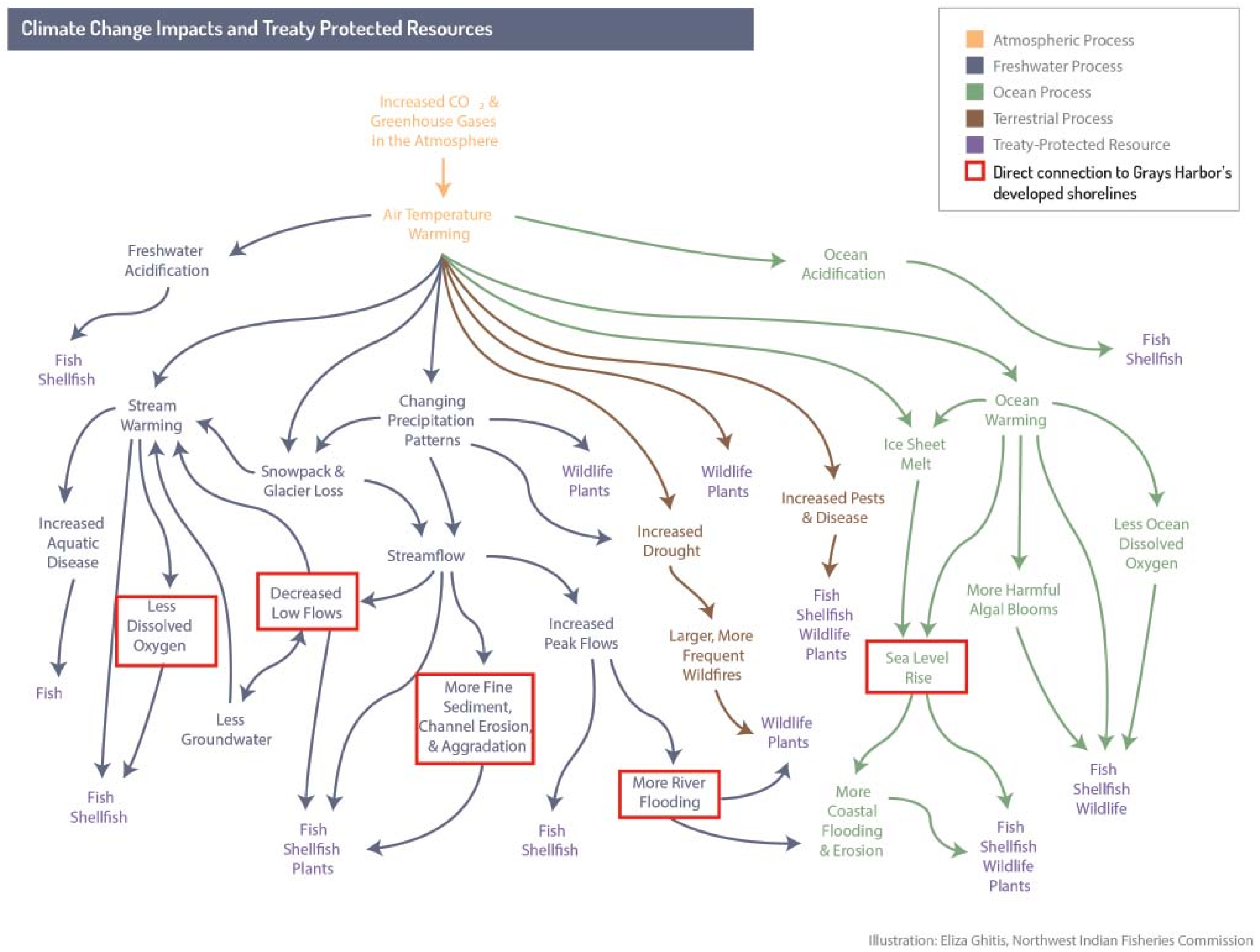


Fig. 2-7. The Northwest Indian Fisheries Commission report, "Climate Change and Our Natural Resources" (201624F) describes links between climate change, tribes of the NWIFC, and the resources which they de-pend upon. In doing so, it outlines a web of climate change impacts upon ecosystems and habitats of coastal Washington.

2. Habitat loss/change

Habitat changes in Grays Harbor estuary are expected to wreak havoc upon the Chehalis River surge plain ecosystem, as trees and other vegetation die off due to inundation and inability to tolerate increasing salinities. This loss of habitat heavily used by rearing juvenile salmon, juvenile lamprey, Olympic mudminnow, and other species of concern may be compounded by other local anthropogenic factors and effects of climate change. Upland habitat migration will be limited due to hardened and steepened shorelines of the greater Aberdeen urbanized area, a phenomenon known as "coastal squeeze.[21]"

A major reason for sea level rise -induced habitat loss is salinity encroachment. Many tidal lands – such as the Chehalis River Surge Plain – experience low ranges of salinity. Waters ebb and flow with the tides, but much vegetation and other biota only experiences fresh water, which sits atop salt water due to a lower density.

While sea level rise is a major concern for developing at Seaport Landing, climate change is expected to produce other changes to the area as well. Several of these changes are particularly related to habitats also affected by sea level rise and saltwater inundation: continued human alteration of shorelines, instream flow and temperature regime shifts, and ocean acidification.

The Northwest Indian Fisheries Commission (NWIFC) report, "Climate Change and Our Natural Resources" (2016[22]) describes links between climate change, tribes of the NWIFC, and the resources which they depend upon. In doing so, it outlines a web of climate change impacts upon ecosystems and habitats of coastal Washington (Fig. 2-7).

Fig. 2-8. Tracing the edges of the estuary's floodplain highlights overlaps between the historic Chehalis River surge plain and developed lowlands of Aberdeen. (photo: Anna Tamura, National Parks Service)

Grays Harbor is a shallow embayment, with a wetland habitat complex consisting of three general habitat types: open water, mudflats, and vegetated tidal wetlands. As discussed by Simenstad and colleagues (1982[23]), estuaries play a particularly multi-purpose and important role in salmonid life histories. These mixing zones between saline and fresh waters provide migration paths to the open ocean, forage for growth and rearing, refuge habitat from predators, and a place for physiological shifts to enable the fish to exist in higher salinities.

Salmonids originating in the Chehalis River and other regional streams use all or part of Grays Harbor during their outmigration and rearing stages. The harbor's brackish water provides a suitable environment for anadromous juvenile salmonids' transition to salt water habitat, while the surge plain's off-channel habitat provides refuge from the high waters of winter. The surge plain is especially important rearing habitat for over-wintering Coho salmon (Oncorhynchus kisutch)[24].

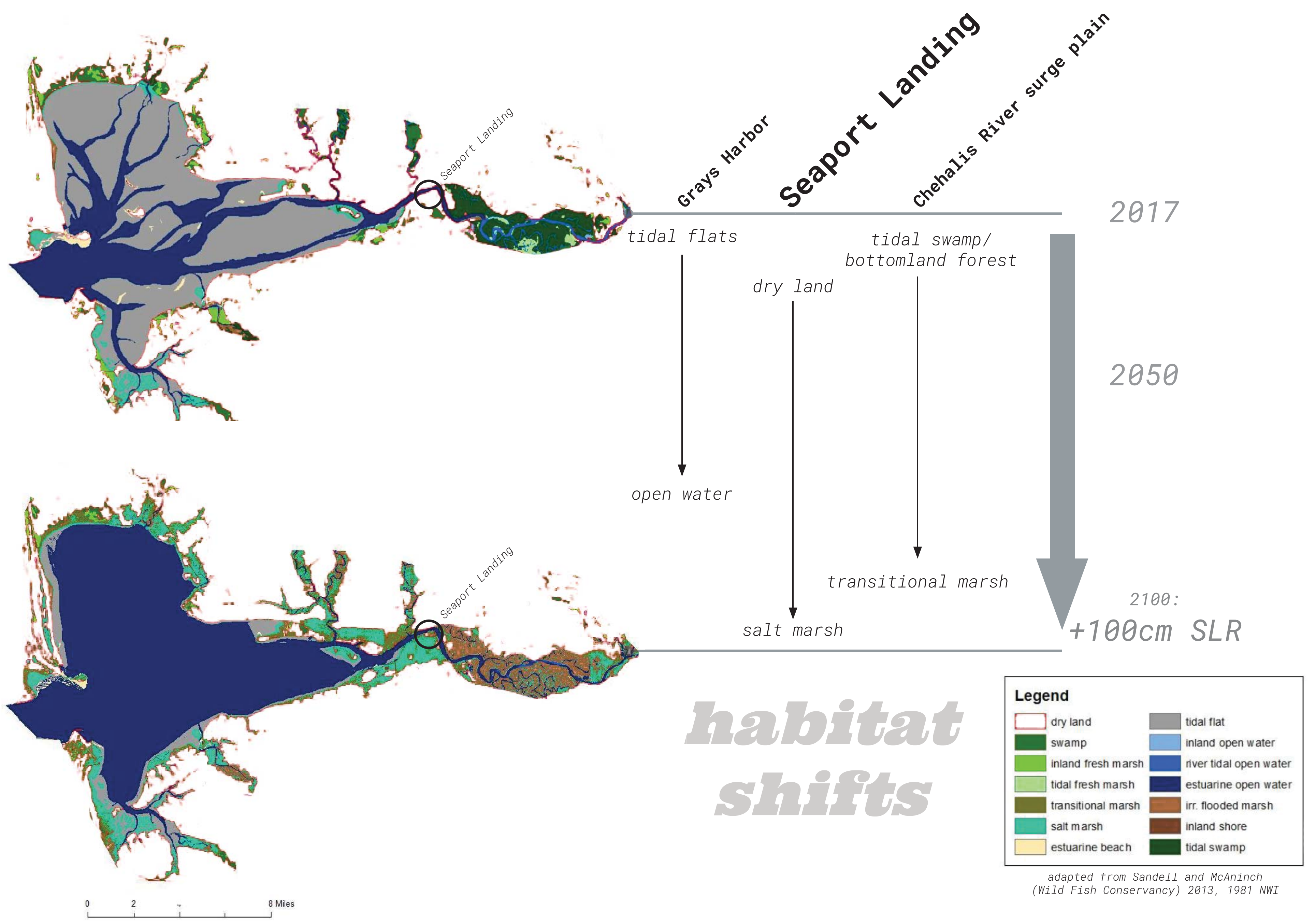
Starting at the oceanward edge of the estuary and moving upstream, open water transitions into tidal channels interspersed among expansive tidal mudflats covered periodically by a thin column of water. Further upland, we find vegetated tidal lands. Saltwater tidal marshes are dominated by herbaceous vegetation, and are currently found mostly in Grays Harbor's upper basin. Freshwater tidal marshes can be found interspersed through the Chehalis River surge plain as well in the outer estuary along low-energy shores and at mouths of estuarine streams such as the Johns and Humptulips Rivers. Tidal swamps are primarily found in the lower Chehalis River surge plain, where they receive fluvial and freshwater influence. Vegetation communities here are dominated by Sitka spruce (Picea sitchensis), many which were never logged due to difficulty of access[25]. As Seaport Landing lies at the edge of the Chehalis River surge plain and sits at an elevation just above, this tidal swamp ecotype is of most concern for this proposal. At some earlier point in time, Seaport Landing may have been part of this surge plain.

As sea level rises, the head of tides will reach further up coastal streams. In the case of the lower Chehalis River, the head of tides is expected to extend past the upper extents of the present Chehalis Surge Plain Natural Area Preserve - further toward Montesano - adding tidal influence to farmlands and other developed areas. This increase in tidal influence will perhaps most immediately affect habitat in the estuary.

The Wild Fish Conservancy (WFC) described expected habitat changes in Grays Harbor and the lower Chehalis River in 2013 and 2015[26]. Primary causes of habitat change in the estuary include heightened water levels (inundation), and salinity increase due to heightened waters. In all climate change scenarios discussed, WFC expects tidal mudflats to decrease greatly by 2100, with significant reductions in surge plain swamp habitat along the lower Chehalis River (Fig. 2-9). These habitats may be inundated to a point which creates open water or tidal marsh habitats, respectively.

According to the WFC's 2015 assessment of juvenile fish habitat in the estuary, the lower Chehalis River Surge Plain's tidal swamplands are expected to convert to irregularly flooded marsh by 2025 – even in conservative sea level rise scenarios – **with potential for loss of 97% of Grays Harbor estuary's forested areas.** Open water and tidal marsh habitats are expected to increase across Grays Harbor estuary. Sea level rise also has potential to undermine the many ongoing ecological restoration projects in the area[27].

Fig. 2-9 (opposite page). 100cm sea level rise will destroy much tidal flat and tidal swamp habitat. (base image: Wild Fish Conservancy)



Habitat loss: Chehalis River surge plain

The Chehalis River surge plain ecosystem — much encompassed by the DNR-managed Chehalis Surge Plain Natural Area Preserve — is comprised of several habitat types[28]:

- Sitka spruce swamp (Picea sitchensis), with understory of red osier dogwood (Cornus sericea) and skunk cabbage (Lysichiton americanum)

- Scrub-shrub wetlands of red osier dogwood (C. sericea) and willow (Salix spp.)

- Herbaceous vegetation communities, with the following species exhibiting dominance at different sites: lady fern (lady fern (Athyrium filix-femina), softstem bulrush (Schoenoplectus tabernaemontani). Lyngby's sedge (Carex lyngbyei), and cattail (Typha latifolia)

Fig. 2-10. Pacific lamprey in the Chehalis River surge plain.

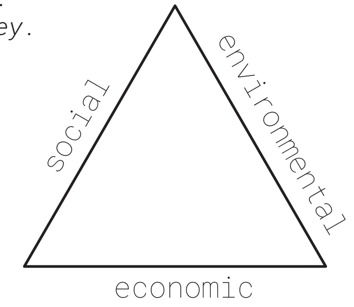
The Chehalis River Surge Plain Natural Area provides critical habitat for many species. Coho and Chinook salmon (Oncorhynchus kisutch, O. tshawytscha) use cool tidal groundwater channels as rearing habitat, while backwaters with higher acidity are favored by Olympic mudminnow[29], a species of concern for management of the preserve[30].

The resident (non-anadromous) western brook lamprey (Lampetra richardsoni) is a federal species of concern which can be found in the surge plain[31], while this area is known for anadromous Pacific lamprey (Lampetra tridentate) as well[32]. Juvenile lamprey utilize the silty bottoms of off-channel waters[33].

Other species of management concern in the surge plain include bald eagles, pileated woodpecker, osprey, band-tailed pigeon, wood duck, reticulate sculpin, and mink[34].

Fig. 2-11. Salmon in the Chehalis River surge plain.

Fig. 2-12. Graphic key.



A likely sea level rise scenario, primarily informed by Wild Fish Conservancy reports, may result in the following ecological succession:

- sea level rise will inundate the Chehalis River surge plain, and this salinity increase will kill off much riparian vegetation.

- Loss of vegetation will lead to erosion and channel migration[35], which will provide disturbed sites for opportunist species to colonize. These sites could host a novel mix of species, including upland-migrating native species (such as sedges and other more hydrophilic plants), introduced vegetation, and early seral riparian vegetation

- Loss of riparian Sitka spruce trees will change nutrient make-up and water quality in sloughs[36]. Snags will provide perch spots for birds to predate upon fish species with little visual obstruction.

- Loss of safe off-channel surge plain habitat will reduce salmonid survival rates, which will in turn affect fisheries and local economies.

Habitat loss: Mudflats

Due to the low gradient of mudflats, coastal marshes, and tidal swamps in the Grays Harbor estuary, even modest changes in sea level rise will affect these wetlands. The extensive mudflats of outer Grays Harbor are home to productive shellfish beds and host the largest population of migratory shorebirds on the entire eastern Pacific coast[37]. Much of shorebird forage habitat is found in the north basin of Grays Harbor, particularly Grays Harbor National Wildlife Refuge. Birding is a popular activity here, attracting thousands of visitors every spring.[38]

Primary productivity for Grays Harbor is driven by benthic algae in nearshore mudflats, as they are an important contributor of carbon to the estuary[39]. A diversity of macroalgal species exist in the harbor. Species-specific habitats in the intertidal zone include mud, rocks, woody debris, and epiphytic relationships with submerged aquatic vegetation.

These species will see habitat reductions due to sea level rise, as mudflats are converted to open water. However, this open water will provide increased habitat suitable for eelgrass (Zostera spp.)[40] and subtidal drifting macroalgae — species which also contribute significant carbon and other ecosystem function similar to benthic macroalgae[41]. It remains to be seen what effects this potential community shift may have.

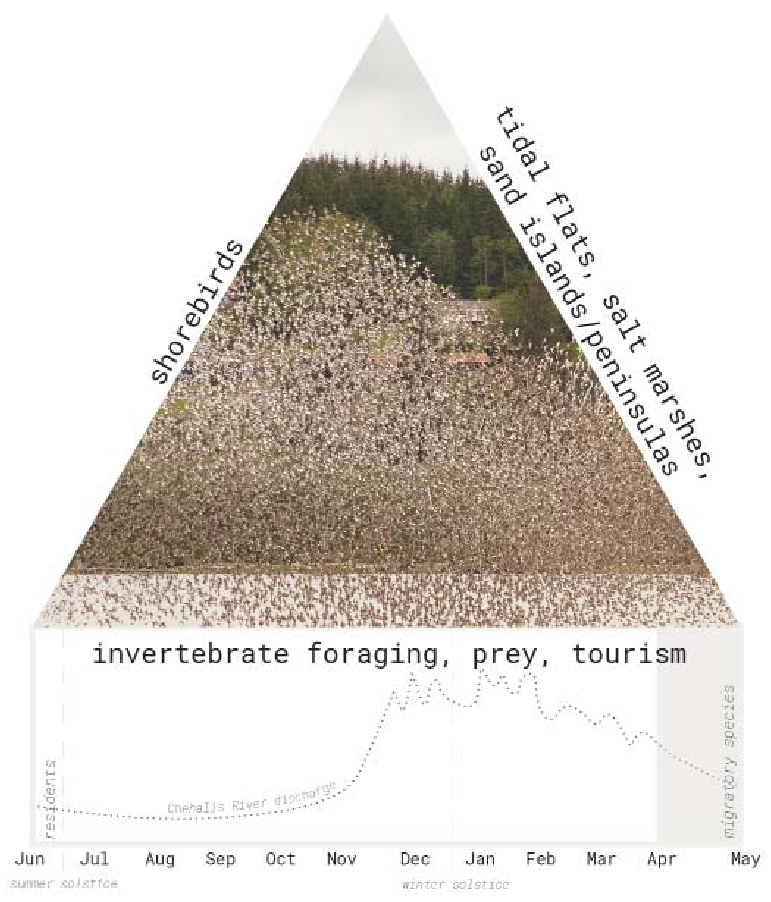


Fig. 2-12. Shorebirds of Grays Harbor's mudflats.

Change to water quality

As a rain-dominant watershed, the tributaries to Grays Harbor are fed predominantly by precipitation. This means that flow regimes of local rivers such as the Chehalis, Wishkah, Hoquiam, Humptulips, and Johns will be affected less than other snow-dominated basins in the Pacific Northwest. With in-stream water levels remaining comparable to present day, migration-based life history patterns of greater Grays Harbor's salmonids and other aquatic species may be less disrupted than elsewhere in the region. Water temperatures are expected to rise, however[42]. This may be compounded by loss of shading from overhanging vegetation, which expected in the Chehalis River surge plain.

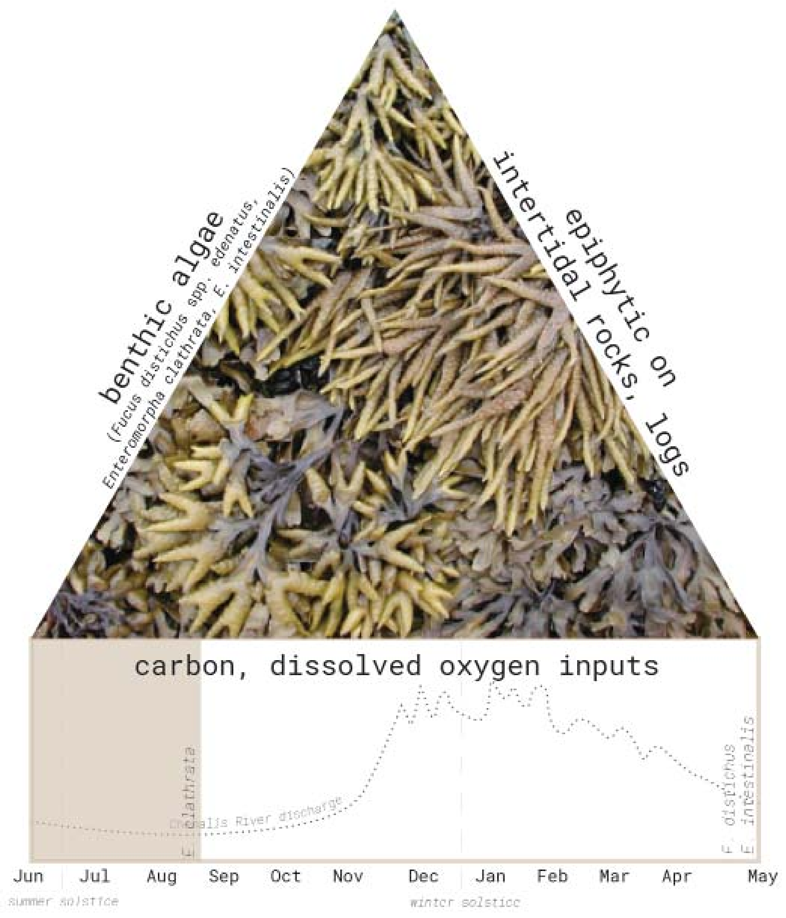


Fig. 2-13. Benthic algae of Grays Harbor's mudflats.

An additional stress on marine habitats is ocean acidification, which has already wreaked havoc on the region's shellfish beds and associated economies. As climate changes and the ocean absorbs more human-generated CO2, a rise in pH occurs. This acidified water is pushed from the open ocean into estuaries by ocean upwelling. As sea levels rise, more volumes of low-pH (acidic) water reach further inland and upstream[43]..

As the Chehalis River surge plain channels are already acidic — evidenced by acidic soils[44] and the presence of low-pH-thriving Olympic mudminnow populations[45] — it will be important to monitor how pH levels in off-channel habitats affect aquatic species and how pH levels themselves are dually affected by increasing vegetative die-off and ocean acidification.

Fig. 2-14. Lower Chehalis River surge plain, a rich habitat at risk. (image: Washington DNR)

Habitat loss summary

In summation, habitat loss will affect the entire estuary in different ways, with the primary agent of change being increased immersion of presently periodically inundated areas. This will have great effects on rearing habitat for outmigrating juvenile salmon and other sensitive species of the Chehalis River surge plain, while shorebirds and benthic flora and fauna of the outer estuary's mudflats will also experience much habitat change. Shifts in habitat as well as vital species in the estuary's trophic has potential for trophic cascade or other novel relationships which may present hardships for some species.

Are there mechanisms for controlling this change? While current proposals for damming the upper Chehalis River will cause various ecological consequences downstream, this may also provide a mechanism for control of irregular in-stream flows associated with climate change. This potential to marginally control a solitary impact of climate change raises an interesting question: If unexpected and irregular hydrologic events are to be the new norm, is regularity desirable for ecosystem adaptation? In-stream habitats exist through continual (though often cyclical) disturbance. Do terrestrial settlements need to take a cue from aquatic habitats and seek adaptation to irregularity? This "new normal" may produce an urbanism integrated with the water cycle, embracing aquatic ecosystems, "slow" processes, resilience, and complex ecological

Fig. 2-15. A distant dredge works through the night, while the Port of Grays Harbor looks on from land built atop filled tidelands along Aberdeen's north shore.

3. Morphological change

Sea level rise will cause morphological change to landforms and substrates largely through erosion. However, Grays Harbor's shorelines are relatively protected from high-energy waves. Erosional processes in Grays Harbor are compounded by sea level rise, but also by shoreline alterations such as jetties and armoring. This points to an interesting situation: humans are heavily involved in morphological change around Grays Harbor, leading dredging and disposal operations to be "one of the most pervasive elements of change in the estuary[46]"

Climate change can influence landform change, particularly through erosion. Higher precipitation rates can create landslides, while high tides combined with storms and sea level rise can cause significant episodic erosion events. Erosion from sea level rise is a complex process which will vary by site, and is very dependent upon shoreline conditions. For example, shorelines with little riparian vegetation or shoreline armoring may be most susceptible to erosion. Intermittent flooding or constant tidal energies can affect both vegetated and hardened shorelines, however. All present shoreline stabilization – vegetative, built, or otherwise – will be tested against heightened sea level conditions[47].

While erosion is of great concern for the outer coast of Washington – particularly the mouths of Grays Harbor and Willapa Bay – the inner shores of Grays Harbor are largely protected from high wave energies by the sand spits which hold Westport and Ocean Shores. There is potential that elevated waters from sea level rise could cause erosion of banks which will release stores of legacy contaminants into Grays Harbor. These could contribute to present water conditions already characterized by high dioxin levels[48].

The mouth of Grays Harbor is held open by jetties which keep the harbor's shipping channel open. High wave energies passing through this dredged channel have been linked to declining mudflats in Grays Harbor, while the jetties prevent replenishment of sediments from the Columbia River Littoral Cell. As sea level rises, wave energies will increase and cause additional loss of mudflat habitat[49].

The same dredging processes which maintain Grays Harbor's navigation channel have been instrumental in changing the bay's morphology. According to a 1976 study[50] , over 11% of Grays Harbor's intertidal area has been covered by dredge spoil since 1940. The Grays Harbor National Wildlife Refuge is even made of spoil, as vegetation colonization of these sandy silts has been studied by ecologists Armstrong, McGee, and Weinmann in "Salt Marsh Establishment on Dredged Material in Grays Harbor: A Feasibility Report" (1979[51]). Aberdeen and Hoquiam's shorelines today largely consist of filled tide flats. Dredge spoil was a regular fill element here, as well, discussed further in Chapter 4.

In "Landscape allometry: from tidal channel hydraulic geometry to benthic ecology" (2002[5]), Hood analyzes tidal channels of the Chehalis River surge plain. He finds that Sitka spruce (Picea sitchensis) needles are a major contributor to sediment, and appear to be a primary allochthonous organic input to aquatic ecosystems. Spruce needles were found in particularly dense concentrations in small tidal channels.

Saltwater in the Chehalis Surge Plain (and other tidal swamps) may kill off Sitka spruce and other vegetation[53]. This eventual loss of functioning riparian zone will increase erosion, and could lead to changes in channel form as well as increased sediment inputs and turbidity in localized and downstream waters. Given Hood's observance of spruce needle importance to nutrient content, many other effects could occur from loss of this forest.

Hood (2007[54]) also discusses the impact of large woody debris in creating microtopography and upland elevations suitable to vegetation which is otherwise stressed by flooding. Large woody debris provides various ecological functions and influences morphology. Wood recruitment into the estuary may slowly increase as saltwater inundation kills of old-growth swamp forests of the Chehalis River surge plain.

Seismic events can produce momentary changes in sea level which alter morphological characteristics as well. For example, tsunami inundation can leave deposits which become long-term landforms. While tsunamis are a threat to settlements of Washington's coast, this topic is not covered here in depth.

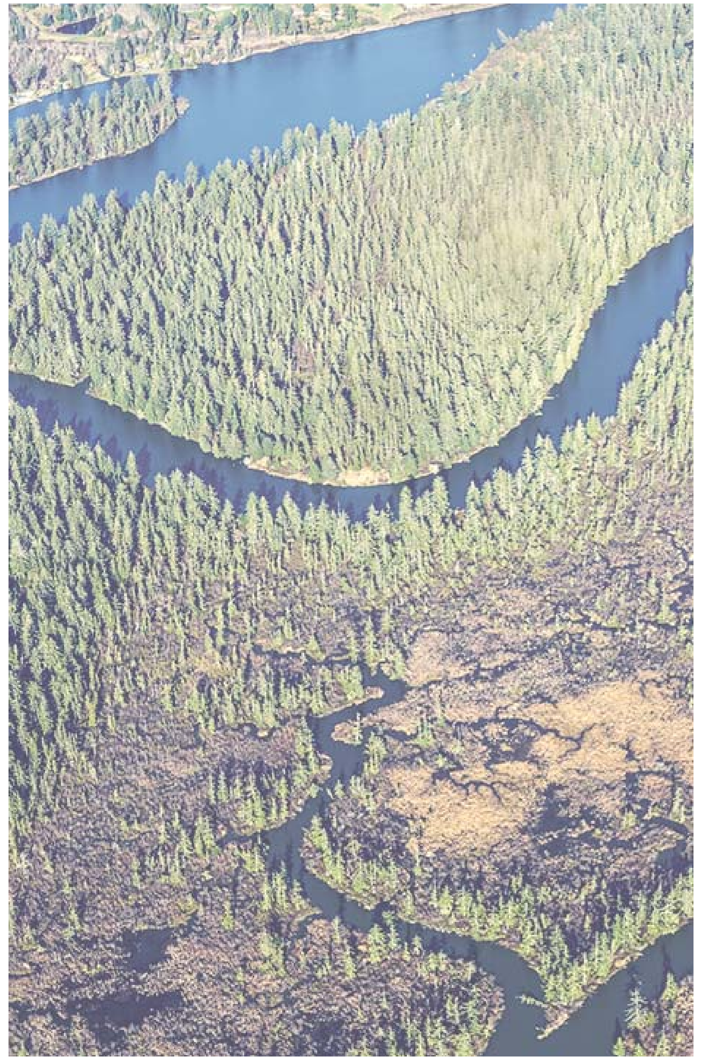


Fig. 2-16. Sitka spruce surround tidal inlets in the surge plain. (image: Chehalis Basin Strategy)

4. Salinity intrusion

The effects of saltwater inundation upon habitats are discussed above, and included with the "Habitat Loss/Change" topic. As saltwater intrusion is not a concern for local water supplies, it is not discussed beyond this section. However, saltwater intrusion will threaten past sources of water, limiting resilience in the scenario that water supplies become unusable.

Aberdeen's drinking water comes from the headwaters of the Wishkah River, impounded as the Aberdeen Reservoir by the Malinowski Dam[56] . As Aberdeen's water source is located over 20 miles from Grays Harbor – at an elevation of approximately 142m (465ft)[57], saltwater intrusion is of no consequence here even if all of the planet's . Other impacts of climate change related to precipitation, snowpack, and runoff volumes may have an effect on volumes of water available for municipal use. This is not covered in this paper.

While saltwater intrusion does not affect Aberdeen's present drinking water supply, it does have potential to affect lower-elevation streams that were once used for regular potable water. Such past water sources include Stewart Creek (in North Aberdeen) and Charley Creek (downstream of South Aberdeen). Stewart Creek was the City of Aberdeen's first source for drinking water, tapped in 1892[58], while the former Native American settlement near today's Seaport Landing recommended use of Charley Creek to early white explorers[59]. If conditions prevented use of a centralized water source – such as the Aberdeen Reservoir – smaller, decentralized water sources such as Stewart and Charley Creeks as well as aquifers may become more relevant. Salinity intrusion due to sea level rise may preclude the availability of water from these sources.

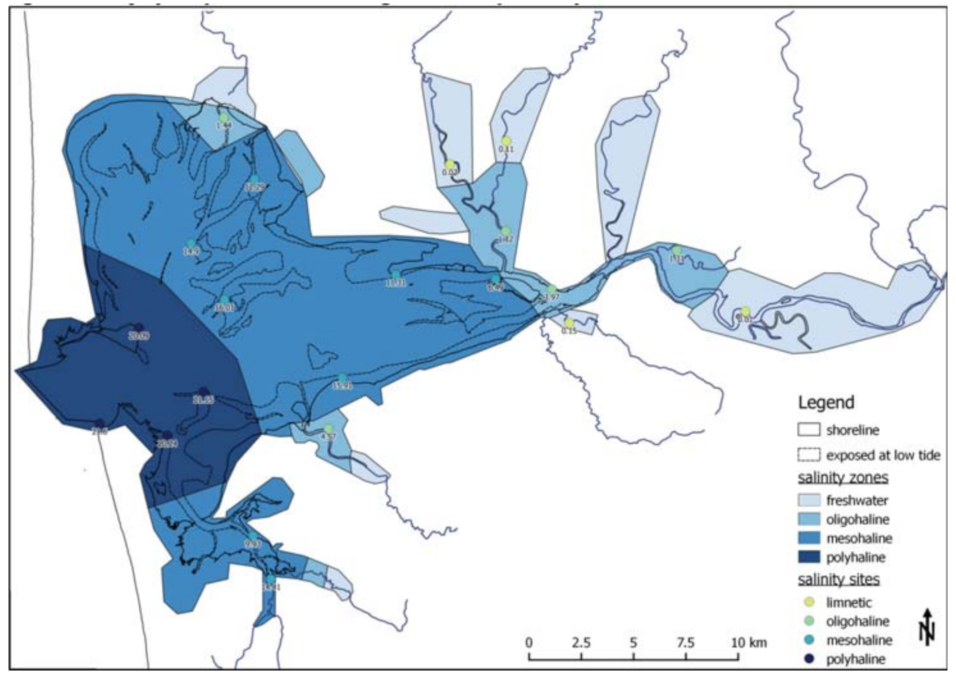


Fig. 2-16. Average salinities in Grays Harbor estuary. Salinity can be expected to increase up-stream most where channel/estuary gradient is shallow. (source: Wild Fish Conservancy)

Fig. 2-17. Proposed path of Aberdeen's North Shore Levee (image: Timberworks Plan)

c. Local adaptation to sea level rise

Local adaptation for sea level rise along the inner Grays Harbor estuary is most visible through Aberdeen and Hoquiam's Timberworks Resiliency and Restoration Master Plan, the Wild Fish Conservancy's sea level rise planning, and community-based and organizational initiatives.

Timberworks Resiliency and Restoration Master Plan

The Timberworks Resiliency and Restoration Master Plan was produced in 2016 by the neighboring cities of Aberdeen and Hoquiam. The plan is concerned primarily with reducing flooding in developed areas, and all projects are within city limits. However, several of the projects proposed by the Timberworks Plan respond to coastal flooding or restore ecological function in order to address floodwaters.

The Timberworks Plan proposes multiple strategies for flood management, to be adopted as resources and desire allow. Some projects, such as levee construction, operate at a scale of the entire urbanized reach of the lower Chehalis River. Others, such as rain gardens and water management along street edges, can be incorporated by residents in a decentralized manner.

The two most prominent projects through the plan are construction of the North Shore Levee and restoration of Fry Creek – both in north Aberdeen, across the Chehalis River from Seaport Landing. The North Shore Levee will run along the inland edge of industrial site, parallel to the Chehalis River. This plan to protect north Aberdeen and Hoquiam is partially funded with 60% design development[60].

At the October 2016 community meeting surrounding the Timberworks Resiliency and Restoration Master Plan, coastal flooding was discussed as a far-off threat of little concern. As such, proposals to address coastal flooding in North Aberdeen were seen as beneficial for reducing flood insurance rates and spurring reinvestment, but disconnected from actual flood protection needs[61] South Aberdeen currently has a levee, built in the 1970s and currently undergoing recertification by the Army Corps of Engineers[62].

Fry Creek runs through north Aberdeen, emptying into the Chehalis River as it flows into Grays Harbor. The creek is covered, culverted, channelized, and otherwise degraded in multiple locations. Plans include daylighting and restoring the Fry Creek riparian zone, creating public space and trails. These actions preserve and restore ecosystem function, though the main sell of this project is to manage floodwaters caught behind the proposed North Shore Levee[63].

Wild Fish Conservancy

The Wild Fish Conservancy monitors fish populations in the lower Chehalis River and Grays Harbor estuary. Their 2013 report "Climate Change in the Chehalis River and Grays Harbor Estuary[64]" informs project proposals in 2015's "Grays Harbor Estuary Salmonid Conservation and Restoration Plan[65]."

These works and others emphasize critical habitat for juvenile salmonids, pointing to the need to restore and preserve surge plain and estuarine tidal sloughs. Sea level rise-related restoration recommendations target floodplain reconnection by breaching dikes in the Chehalis River surge plain and along shorelines of the estuary and local creeks.

While the Timberworks Plan does not look outside of the city limits, the Wild Fish Conservancy's recommendations approach both rural and urban areas for restoration. They highlight the underutilized Weyerhaeuser site adjacent to Seaport Landing as a restoration area of interest, as it lies next to the Chehalis River surge plain and occupies a large floodplain site. This has potential to connect with adaptive reuse work at Seaport Landing.

Fig. 2-18. Proposed Wild Fisheries Conservancy restoration site next to Seaport Landing. (base image: Google Earth)

Local organizations

Grays Harbor Historical Seaport Authority assists in sea level rise resilience by supporting the Grays Harbor Stream Team. The Stream Team plants vegetation, removes invasive species, and collects trash from local streams[66]. Housed at Seaport Landing, this group can address sea level rise at the grassroots scale, educating citizens in a hands-on immersive way.

Local groups such as the Chehalis Basin Partnership and Chehalis Lead Entity are involved in policy, planning, and coalition-building around habitat resilience. I initially came to the Seaport Landing project through recommendation by Kristen Harma, Watershed Coordinator at Chehalis Basin Partnership and Chehalis Lead Entity.

While much effort goes toward preventing flood damage, some organizations provide resources in post-disaster settings. Coastal Community Action Program has assisted Aberdeen and Hoquiam residents affected by flooding and landslides, working with more than 420 families after January 2015 flooding[67].

Other actors working toward local ecosystem resilience include Washington Sea Grant, Forterra, Surfrider Foundation, Quinault Indian Nation, and Grays Harbor Shoreline Master Program.

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chapter 3

Sea level rise strategies

Case studies from New Orleans, the Netherlands, Washington, and New York City exhibit how sea level rise strategies reflect socio-ecological relationships.

a. Adaptation

- *i. Protect*
- *ii. Accommodate*
- *iii. Retreat*

b. Resilience

c. Discussion of strategies

Flooding in Aberdeen, due to a mix of high tides and heavy precipitation. (image: KXRO)

a. Adaptation

Protect, accommodate, retreat

Flooding can take various forms, generally delineated by its source waters. Types of flooding include inland and coastal flooding, where the former is influenced predominantly by precipitation and drainage while the latter is influenced by high tides, winds, storms, and sea level rise. Both can be affected greatly by land use[1]. Aberdeen is sited along the lower Chehalis River as it blends into Grays Harbor estuary, affected by both inland and coastal flooding. The following discussion is focused on coastal flooding due to sea level rise alone. However, many of these adaptations are applicable to inland flooding too. There are many additional and quite detailed sea level rise adaptation strategies that concern the construction and assemblies of structures. The following section is concerned primarily with land management strategies as they pertain to sea level rise adaptation.

The 1990 Intergovernmental Panel on Climate Change's Coastal Zone Management Subgroup describes three strategic typologies for sea level rise adaptation and coastal flooding: protect, retreat, or accommodate[2]. For each typology, specific strategies contribute to resiliency in varying degrees. Analysis of protect, accommodate, and retreat strategies links them to three influential entities with differing approaches to shoreline management: the United States Army Corps of Engineers, the Northwest Indian Fisheries Commission, and the Dutch DeltaWorks, respectively.

Many of these strategies are implemented in settlements along (and often in) low-gradient estuarine river mouths — similar to Grays Harbor. The Netherlands, the Mississippi Delta (greater New Orleans), and the Washington Coast (Columbia River Littoral Cell) all exhibit these physiographic characteristics. These areas have all been altered by humans for various social, economic, and environmental ends involving water management. Their current relationships with water all are applicable to sea level rise adaptation. Adaptation strategies and social relationships are particularly relevant to look at in greater New Orleans and the Mississippi River delta, because many of sea level rise's physical impacts are already occurring there.

Below, each specific strategy is described and its resilience potential ranked according to its social, economic, and environmental impacts (-1 = negative; 0 = neutral; 1 = beneficial). These scores are aggregated at the end of this section to inform later design decisions. This resiliency analysis of these approaches finds benefit in a mixed-strategy approach. Strategies which are existing in Aberdeen are emphasized. Strategies discussed include:

Protect
- Levees and floodwalls
- Shoreline armoring
- Surge barrier

Accommodate
- "Living with water[3]"
- Densification
- Wave attenuation

Retreat
- Assisted habitat migration
- Preservation of ecosystem function
- Relocation

i. Protect

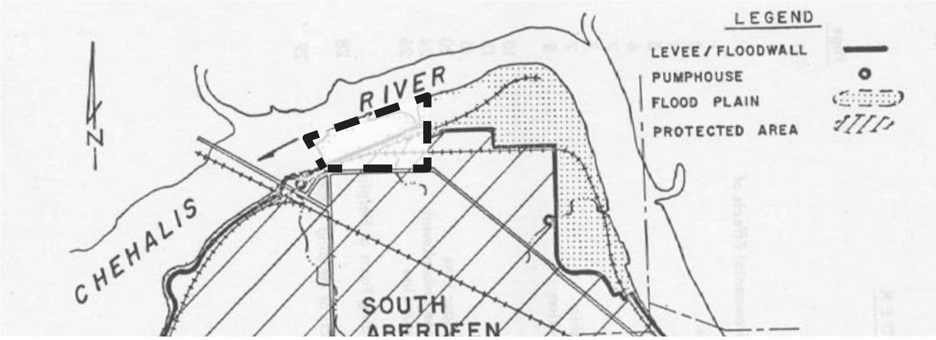
Protection of coastal settings from sea level rise can involve a wide range of interventions, particularly applicable to inundation and morphological change. The commonality between protection strategies is that they allow elements targeted for protection to remain in situ. They can create an impermeable barrier between settlement and aquatic ecology. Potential strategies discussed here include the construction and maintenance of levees and floodwalls, shoreline armoring, and surge barriers

Levees and floodwalls

Perhaps the most obvious means of protecting a site or settlement from sea level rise is to erect a wall. At the site or reach scale this takes form as a levee or floodwall, and may be complemented by tide gates if a channel of water passes through the barrier. Seaport Landing sees all three meet: Shannon Slough passes through a tide gate right where the South Aberdeen levee transitions to a floodwall (Figs. 3-1, 3-2).

Levees and floodwalls enable use of areas which would otherwise be inundated – such as the residential, commercial, and industrials areas of Chehalis River tidal floodplain encompassed by Aberdeen. Without levees, Aberdeen's residents would be severely affected by regular flooding.

Figs. 3-1, 3-2. South Aberdeen flood protection system (top; image: US Army Corps of Engineers). Inside of floodwall at Seaport Landing, looking east (bottom).



Regardless of services they may provide, infrastructure's visibility is often is a reason for public opposition of projects[4]. The programmed and adaptive uses of infrastructure are of interest for designing for human experience.

As broad earthen mounds stretching to seemingly infinite distances along shorelines, levees invite longitudinal and lateral interaction. Levees can provide a sense of prospect-refuge, particularly in areas with little perceptible topography. South Aberdeen's bike path-topped levee is a location for children to run and play on bicycles with each other and adults.

As infrastructure such as levees ages alongside a settlement, it can become ingrained into vernacular activities and lifestyles. Mississippi River levees upstream of New Orleans host massive annual bonfire traditions. In some locations, these levees' battures (riversides) have been built out with houses raised above the floodplain – a typology which accommodates the river's flood stages, dating back to squatter settlements of the past[5].

Fig. 3-3, 3-4, 3-5, 3-6 (from top to bottom). Batture dwelling along Mississippi River. Note space for regular flooding. (image: HouseCrazy.com) Lateral interaction with levees by industry in Reserve, Louisiana. Christmas eve celebrations upstream atop the levee at Gramercy, reappropriating infrastructure as public space.

Regardless of their social value, levees and other "impermeable" structures have ongoing ecological implications. Structural shoreline protection measures are known for disconnection lateral habitat: floodplains are disconnected from river channels, removing vital off-channel habitat for aquatic species. Lower "toe" portions of levees are likely covered with armoring (discussed next), while upland areas are maintained relatively vegetation free.

This is discussed by the US Army Corps of Engineers' final environmental impact statement for the South Aberdeen levee (1977[6]): vegetation including brush, trees, forbs, grasses, and marshland would be removed from the project way… Species which are tolerant of human activity and an open landscape would resettle." This statement acknowledges that early seral species who thrive in disturbed settings — such as many invasive species and noxious weeds — will be most likely to recolonize this site. In the place of native riparian forest is now a grassy berm with an assortment of novel vegetation communities. These 53 acres of vegetated tidal lands were sacrificed to protect 1,318 acres of occupied land and associated livelihoods.

The ecologically disruptive impacts of levees are especially visible in southern Louisiana, where seasonal flooding no longer distributes sediments across floodplains to assist wetland elevation stabilization. In undeveloped areas of the Mississippi delta, this results in coastal subsidence, which combines with sea level rise/saltwater intrusion to increase rates of wetland loss and threaten coastal communities. In developed areas of the delta - such as greater New Orleans — this disconnection for sediment accumulation leads to extensive site-based and district-scale subsidence compounded by hydrologic disconnection via impermeable surfaces. This causes hassles day-to-day inconvenience (Figs. 3-7, 3-8) but also increases flood risk drastically.

Fig. 3-7, 3-8. Subsidence affects daily life in New Orleans (top, source: blogs.agu.org) and in Aberdeen.

Ecological impacts of levees are well-known. Levees of larger scales impact larger riparian zones. While longitudinal stream connectivity remains alongside levees, lateral habitat connectivity is diminished through vegetation removal and landform manipulation. Set-back levees have been employed recently at restoration sites such as the Nisqually River delta, where levees were removed but a degree of flood protection was still desired[7]. This approach provides a middle ground between the ecological benefits of floodplain connectivity and the human-centric benefits of protected lowlands.

Social phenomena surrounding levees are less studied. Kids today bike along Aberdeen's south levee, while others cross the levee, crashing through riparian thickets of willow and alder in order to reach tidal marshes covered in driftwood on the other side of the forest (Figs. 3-9, 3-10). Here we see longitudinal and lateral use of flood management infrastructure, drawing comparisons to lateral and longitudinal riparian function. Perhaps levees and flood management infrastructure of the future can embrace lateral and longitudinal habitat linkages as well, exemplified by the Northwest Indian Fisheries Commission-driven levee setbacks at Nisqually River National Wildlife Refuge.

Fig. 3-9, 3-10. Aberdeen youth use the towns levee for play and bike riding (top), while I also observed children crossing through the trees to reach the marsh and woody debris.

Shoreline armoring

As natural shorelines experience ongoing erosion and deposition, development at these sites often employs structural measures such as bulkheads or revetments to ensure that morphological change does not continue to occur. Bulkheads are armoring structures which — due to their vertical orientation — deflect wave energy in a manner which can cause rapid erosion seaward of the wall. This eventually can lead to structural failure[8]. Revetments are armored slopes made of various materials which absorb wave energies.

This strategy is applicable to address sea level rise-induced morphological change, and can be incorporated alongside levees in order to protect uplands from inundation. Presently, most of the developed shorelines of Aberdeen and Hoquiam employ rip-rap revetments. Though much steeper than the tidelands atop which they sit, the significant lateral breadth of rip rap revetments precludes inhabitation by many vegetation species - though invasive Himalayan blackberry (Rubus armenicus) and Scotch broom (Cysticus scoparius) seem to have little problem in this environment. As such, rip rap armoring disconnects aquatic and terrestrial shoreline components of ecosystems.

Fig. 3-11. Typical rip rap revetment. (image: ecy.wa.gov)

While bulkheads and rip-rap armoring may help stabilize upland areas, they can have problematic effects for ecosystems — especially when installed at a large scale as is evident along Washington's shorelines. Such is the case in the Puget Sound, where absence of shoreline armoring is listed as a "Vital Sign" indicator of ecological health and recovery by the Puget Sound Partnership[9]. The ecological importance of riparian zones has been well-documented, and shoreline armoring can have detrimental effects on these processes.

Shoreline armoring removes vegetation and disconnects aquatic-terrestrial exchanges which are vital for aquatic food webs and nutrient cycling (Fig. 3-12). Overhanging vegetation creates dappled light in waters below, providing insect drop and refuge from visual predation for juvenile salmon and other fish[10]. Armoring removes this function in favor of protecting upland development.

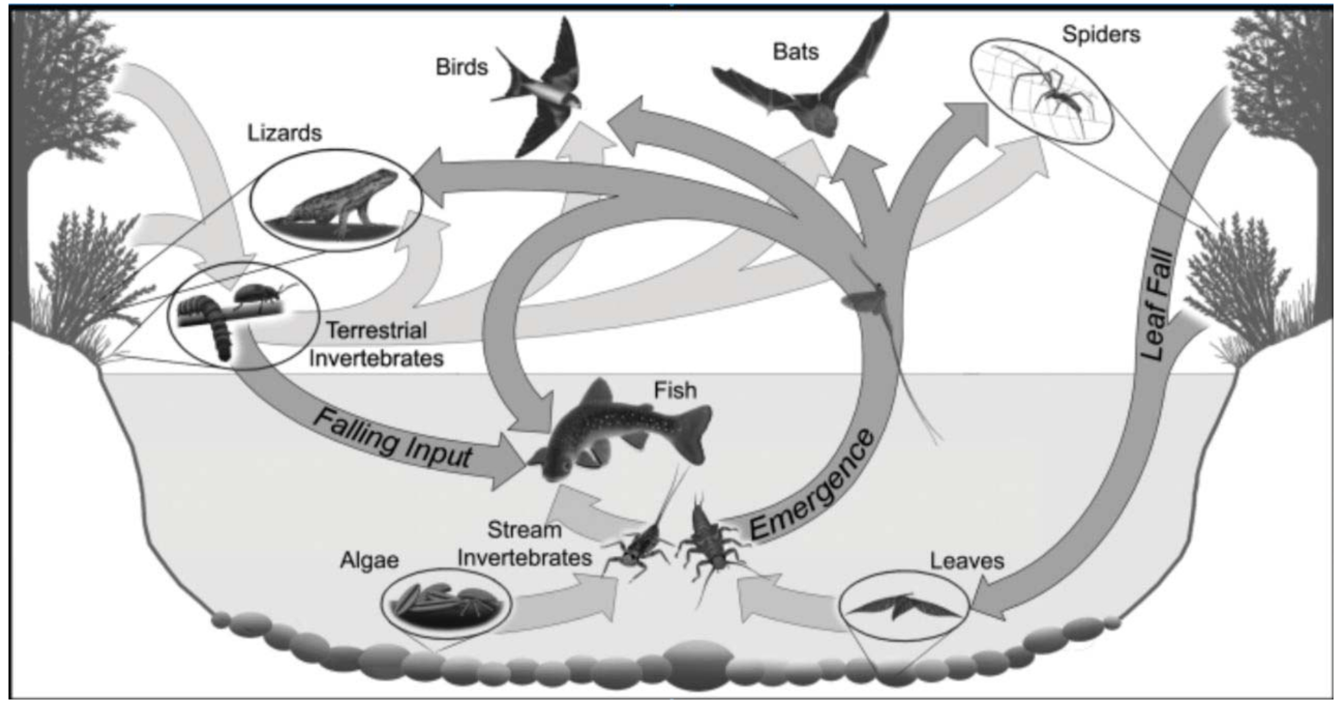


Fig. 3-12. Aquatic-terrestrial interchanges are vital for riparian and aquatic ecosystems. These relationships can be disrupted by shoreline armoring. (image: Baxter et al. 2005, Freshwater Biology)

Surge barrier

A potential strategy for protecting an entire estuary from SLR is to develop a large surge barrier at the mouth of the embayment. Such a structure is in place at the Oosterschelde estuary in the Netherlands (Figs. 3-13, 3-14), and has been tested to reduce SLR-caused tidal ranges in the Chesapeake Bay[11].

The Oosterschelde surge barrier was initially designed as a dam, but local protests surrounding the potential destruction of marine habitat and associated livelihoods led to a redesign which incorporates a movable tide gate, only deployed during threat of flooding from the North Sea[12]. Much of the estuary's mouth remains cut off by this dam-like structure and associated artificial islands. While a Dutch strategy, the dam-like Oosterschelde Surge Barrier is classified here as protective, since it removes high flows and floods from the ecological equation, altering natural disturbance regimes and disconnecting floodplains in order to create predictable hydrologic patterns that further human settlement of lowlands.

Fig. 3-13, 3-14. Oosterschelde estuary tidegate in action (top; image: Wikipedia), managing coastal flooding for an entire region (image: Google Earth)

Fig. 3-15. Hypothetical surge barrier protection at the mouth of Grays Harbor. (satellite image: Google Earth)

At the basin scale, "protection" from the impacts of sea level rise may be obtained through massive infrastructure. This is perhaps most imaginable in Grays Harbor as a storm surge barrier stretching from Westport to Ocean Shores, connecting the respective South and North Jetties across the mouth of Grays Harbor (Fig. 3-15). Akin to structures found in the Netherlands, this barrier could maintain regular tidal and commercial passage, protecting inland wetlands from destructive saltwater inundation during extreme high-water events. This strategy can be expected to hold a much larger ecological cost as various spatial links between stream and sea are disconnected.

Given the continual subsidence of Grays Harbor's South Jetty at Westport[13] and low population of Grays Harbor, the structural and financial feasibility of this storm surge barrier is unlikely. Perhaps most importantly, this structure would have great impacts to anadromous fish and other species — violating Tribal Treaty Rights and designating it as unpermittable.

A smaller scale version of the basin-scale surge barrier could be placed laterally across the Chehalis River or smaller streams and sloughs to protect upstream habitat for saltwater. Perhaps more akin to a large tide-gate, this would cause habitat disconnection as mentioned above, negating its efficacy toward a resilient ecosystem.

ii. Accommodate

The commonality between accommodate strategies is that they allow settlements to remain in situ but redesigning the urban environment in a manner which also allows flood occurrences and living shorelines. This can inform environmental education programs while also increasing urban habitat value. Potential strategies discussed here include "living with water", increasing urban density, and wave attenuation.

Living with water

"Living with water" has become the catch phrase for New Orleans' Dutch Dialogues, which brought water management experts from the Netherlands to the table with New Orleans-based urban designers, spearheaded by Waggonner and Ball Architects. These workshops addressed both regular nuisance flooding as well as large-scale disaster floods. This approach came as designers realized that monolithic water management strategies advocated by the Army Corps of Engineers were insufficient and fracture-critical, leading to massive loss of life and the most expensive "natural disaster" in United States history during Hurricane Katrina[14].

While "living with water" is primarily concerned with flooding from rain events[15], it involves reframing public perceptions of water on the landscape, presenting water as a resource which defines the city's deltaic character rather than a threat to be removed from settled areas.

Figs. 3-16, 3-17, 3-18 (descending). Stormwater management reflects socio-ecological relationships in Aberdeen, New Orleans (image: US Green Building Council), and the Netherlands (image: USGBC) .

In doing so, "living with water" embraces this abundant liquid as a vital element of place. Per the Dutch Dialogues visions, the future "delta city" will be built around accepted unpredictability of flows and surges through greater designed capacity for flooding, acknowledging the link between water, soils, biota, and the region's landforms[16]. This is directly applicable to sea level rise scenarios, as urban infrastructure is reframed to accommodate coastal flooding rather than defend against this phenomena. As structures are raised above future sea level rise-influenced flood levels (i.e. well above FEMA's 100-year base flood elevation), hard protective structures such as floodwalls and levees become less necessary: waters flow below and around buildings, providing greater area for potential habitat and giving a distinctive identity to coastal towns (Fig. 3-19).

A similar project is New York City's "Dry Line" (also called the "Big U", Fig. 3-20) designed by Bjarke Ingels Group and proposed as part of the Rebuild by Design competition. While relying on traditional protective measures such as floodwalls and berms, the project incorporates elements of "living with water" by overlaying a temporal factor to these infrastructures: the same areas that are inundated by floods are at other times public resources such as promenades, parks, and pavilions. This proposal is also of note as it divides Manhattan into three separate basins each hosting multiple strategies through which to manage flood waters. This allows sea level rise adaptation to occur in phased increments without waiting for a single massive built intervention which would take much more time to complete.

Making such changes to the built environment can occur through a coalition-based approach which engages private, public, institutional, and community-based entities to re-envision infrastructure at various scales and take advantage of these opportunities as they arise. The Timberworks Master Plan shares these characteristics as it asks in moderate fashion how Aberdeen can reapproach its relationship with tidal creeks. As sea level rise shifts local littorals, Seaport Landing's design can propose new relationships with shoreline dynamics as well.

Figs. 3-19, 3-20. South Aberdeen apartments elevated on a berm (top) allow flooding around the perimeter. Not much adaptive development like this exists as new local real estate invesment is minimal. BIG's "Dry Line" creates protective and recreational transition zones between urbanization and water (image: Lafarge Holcim Foundation)

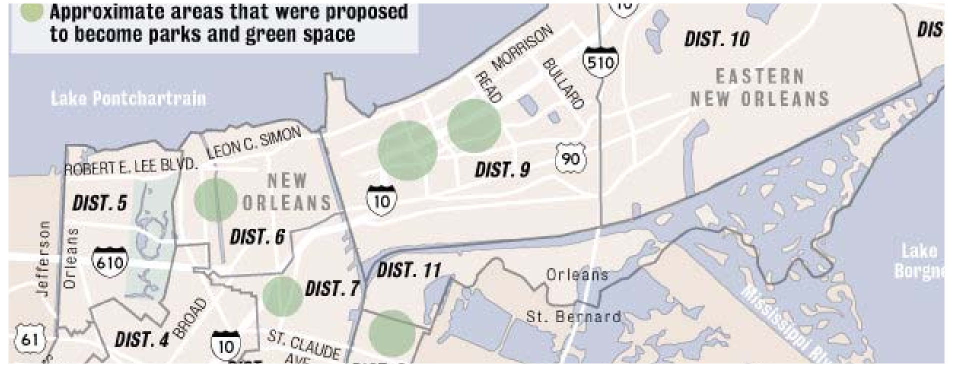
Densification

By consolidating the area which urban settlement occupies, greater urban density can be achieved, reducing the scale of protective measures required and localizing service provision from day-to-day as well as in the wake of a disaster. Greater settlement density without much population increase opens territory for habitat migration in the face of sea level rise, paired with restoration of ecosystem function. This fits hand-in-hand with the strategies of "living with water".

Increasing density by decreasing the footprint of settlements is a particularly relevant approach in municipalities with much abandonment and blighted housing stock - such as Aberdeen. Following Hurricane Katrina, the Bring New Orleans Back Commission (BNOBC) proposed to shrink the footprint of the city by creating zones of green infrastructure in heavily damaged and previously blight-ridden areas (Fig. 3-21). This would create less demand for sprawling physical infrastructure and speed recovery[17]. While this plan was geared towards rebuilding the city after a disaster, this approach can be applied before (or during) an oncoming threat of disaster such as sea level rise in order to provide anticipatory resilience strategy. As a downsized version of "relocation", densification would target development at higher-elevation areas as possible. Social dynamic are of note here: BNOBC brought great criticism from residents who saw their homes replaced by "green dots" representing parks and natural areas, while other neighborhoods would benefit from their relocation. Whereas retreat-based relocation involves migration of most or all of Aberdeen, densification has potential to favor particular neighborhoods and as such equity is of concern with this strategy.

Densification can begin to be enacted by creating multi-use social and economic hubs of commerce, industry, and recreation. Grays Harbor Historical Seaport is already planning for such a hub with Seaport Landing. At the site scale, strategic retreat from areas of higher potential habitat value can inform density-driven development on-site. At the site and reach scales, costs will be entailed removing structures from future habitat (buildings, shoreline armoring, and impervious surfaces) as well as through construction of new density-driven development. Comparable to New Urbanist development which advocates for clustered development and walkable cities, this action may create new social gathering spaces and revitalize some economies.

Fig. 3-21. The Bring New Orleans Back plan to increase green space was met by opposition. (image: nola.com)



Wave attenuation

Just as wetlands and oyster reefs provide buffers for storm surge, in-water structures can decrease wave energies and increase habitat diversity. This is most simply exemplified at San Pablo Bay National Wildlife Refuge (just south of Sonoma, California; Fig. 3-22), where sediment has been placed in mounds to calm waves and protect wetland restorations inland of the berms. As waters slow around these mounds, suspended sediments are dropped and nearshore habitat becomes more complex, providing islands and bars for vegetation to colonize and refugia for endangered birds such as the California clapper rail. Floating wetlands and engineered oyster reefs are additional modern wave attenuation structures with natural analogs, used also for habitat rehabilitation.

Fig. 3-22. Following tidal restoration, wave attenuation mounds turn flat farmlands back into viable intertidal habitat at San Pablo Bay National Wildlife Refuge.

The Jamaica Bay Watershed Protection Plan in New York City, NY, is currently developing floating wetland structures which function as wave attenuation devices in order to minimize shoreline habitat loss and morphological change due to storm surge and wave action[18]. This method of shoreline protection may provide habitat value for birds, insects, and fish, though studies on floating wetland aquatic habitat values are limited and their primary proven results concern water quality in closed systems[19].

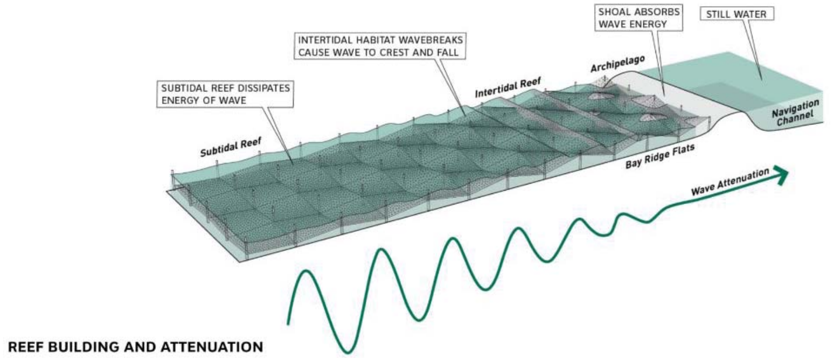
The lifecycle of floating wetlands is of concern for environmental and economic efficacy: Jamaica Bay's floating wetland wave attenuation program was discontinued after one structure went missing and another was destroyed, presumably through collision with a boat[20].

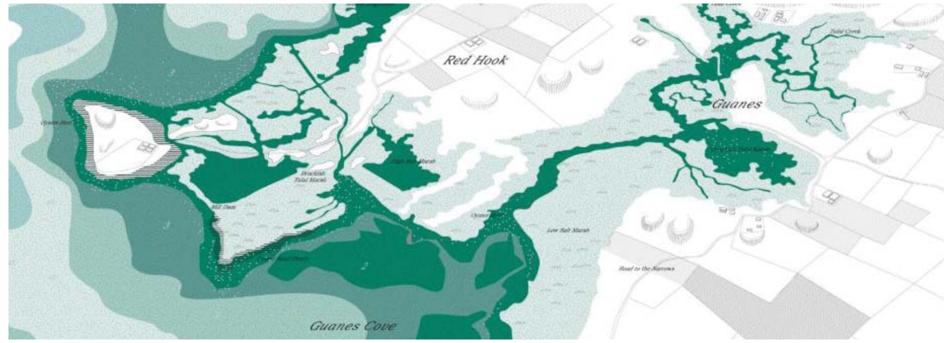
Fig. 3-23. Floating wetlands with an open structure promote dappled light penetration and salmon refuge at Brightwater Treatment Plant, Woodinville, Washington. (image: MacDonald 2016)

General consensus among Washington permitting agencies and tribes says that such structures are likely to invite predation on juvenile salmon and interfere with tribal gillnet-based fishing practices. As such, they may violate Tribal Treaty Rights and require much research in order to be implemented in a place-sensitive manner[21]. Typical floating wetland design is similar to that of overwater structures such as docks, usually made of controversial chemical-based materials (though bioplastics floating wetlands are in development[22]) and casting deep shade – an ambush environment favored by introduced predators such as smallmouth bass (*Micropterus dolomieu*) and accordingly avoided by juvenile salmon (Fig. 3-24)[23].

Given these constraints, design-based opportunities exist to reframe floating wetlands as regionally appropriate habitat structures more akin to woody debris installations which encourage dappled light with materials which can naturalize and decompose. As these structures decay in littoral zones, they can slow currents and cause suspended sediments to drop, building substrate in a manner which can facilitate colonization by upland-migrating species. The floating character of these habitat structures allows for adaptation to rising sea levels, as vegetation rooted in benthic substrates would be inundated as waters rise. This topic is part of ongoing research with the University of Washington Green Futures Research and Design Lab.

Fig. 3-24. Smallmouth bass below pier. (image: Mike Long, Pinterest)





Figs. 3-25, 3-26 (left). SCAPE's Oyster-tecture attenuates waves through recreating a historical ecological reference (images: SCAPE).

Fig. 3-27 (below). Large woody debris traps material at Grays Harbor National Wildlife Refuge (image: Grays Harbor Shorebird Festival)

New York is also home to a much-lauded proposal to use oyster reefs for wave attenuation, water quality improvement, and habitat in the Gowanus Canal. While SCAPE's "Oyster-tecture[24]" is once again a structure-based aquatic project developed outside of the salmon-sensitive Pacific Northwest permitting context, it does not employ any semblance of over-water structures and has a more clearly visible analogue in natural aquatic environments. Figures 3-25 and 3-26 show how SCAPE's design fuctions and reflects back to historic ecology prior to development of New York City.

While this project is currently in development (see construction drawings and prototype siting, figures XX and YY), similar oyster reef reconstruction projects currently exist along Alabama's shores of the Gulf of Mexico, developed by NOAA and the Nature Conservancy[25]. As sea levels rise, Grays Harbor's oyster beds may migrate upstream – perhaps with human assistance - and act more efficaciously as wave attenuators in the narrower parts of Grays Harbor than they now do.

Of interest for wave attenuation is also the installation of large woody debris via engineered log jams, which has historic analog in the area and is a popular stream and estuary restoration technique in the Pacific Northwest. ELJs slow currents to trap sediment and organic material, building bars and contributing to habitat/channel complexity through productive morphological change (Fig. 3-27). As sea levels rise, LWD along shorelines will be moved around, inundated, and create new microtopography. This naturalistic intervention may be relevant for reducing wave energy as well as creating mudflats in the outer Grays Harbor Estuary as well as along restored urban shorelines that would otherwise be flooded and converted to open water by sea level rise.

iii. Retreat

Retreat from sea level rise can be strategically employed to varying degrees. The commonality among retreat strategies is that they remove, prohibit, or lessen the impact of humans upon floodplain or aquatic settings. Potential strategies discussed here include assisting habitat migration, preserving ecosystem functions, and relocation of human settlement through permanent as well as temporary means.

Assisted habitat migration

Following the last peak of glacial coverage approximately 16,000 YBP, the global mean sea level rose drastically as ice caps melted, eventually stabilizing. Stratigraphy analysis shows layers of sediments that have been built over time, clarifying how shoreline ecosystems adapted to sea level rise (Fig. 3-28). By migrating upland, coastal marshes avoided increased frequency of inundation and exposure to salinity[26].

Thousands of years before massive human shoreline alterations, sea level rise was but another ecological disturbance which ecosystems responded to on a decadal time scale. Shoreline biotic communities maintained bits of character and function as vegetation gradually colonized new upland substrates. Slow-migrating wetlands and bottomland forests were (are?) the epitomy of resilience and adaptability[27] to disturbance. Shoreline armoring has taken away much of this resilience.

The direction of habitat migration has historically been determined by geographies of viable habitat rather than human selection and dereliction. Miller and Bestelmeyer[28] describe how theories of ecological succession now include social elements. As hardened shorelines contribute to coastal squeeze, humans now can choose to rehabilitate shorelines and provide sites for species to migrate, determining the fashion through which future marshes and tidal swamps regain ground after sea level rise-induced displacement. Case studies for armored shorelines abound, with particular reference to the Puget Sound and visible through Washington Sea Grant's Green Shores program. In "Avoiding the Hardened Shoreline: Alternative Management Approaches for Shoreline Erosion," Castellan and colleagues[29] survey approaches to living shorelines across the United States, emphasizing the importance of outreach and education initiatives to infuse change into socio-ecological relationships as manifested through the built environment.

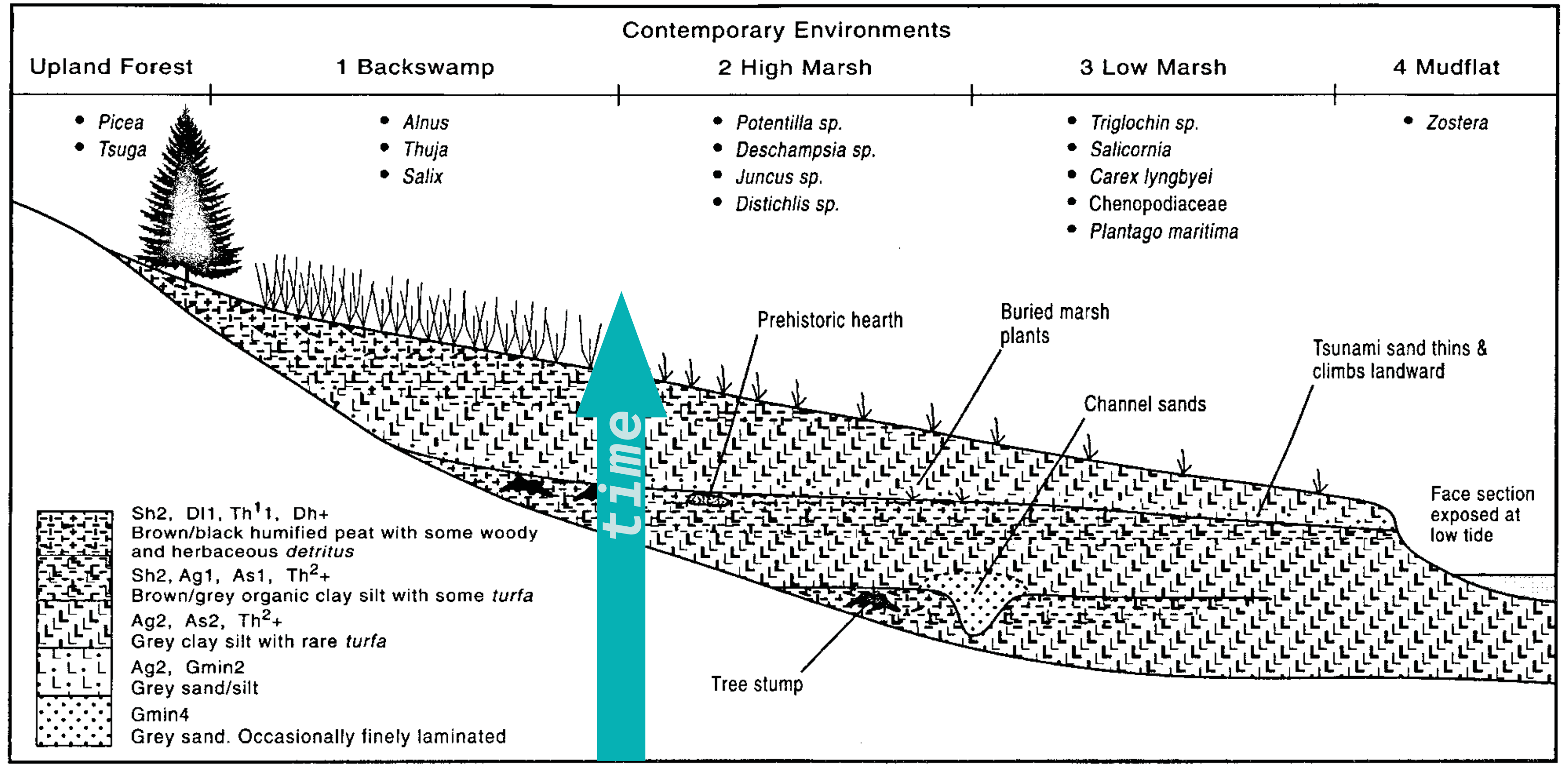


Fig. 3-28. *Schematic diagram of contemporary and fossil sedimentary environments recorded in the coastal marshes of Washington and Oregon. The stratigraphic symbols used are based on the Troels-Smith (1955) scheme. Physical characteristics are not included, since they are likely to vary spatially.* (image and caption: Long 1999)

Furthering ecosystem resilience through land management can cause controversies involving various affected parties. Many of southern Louisiana's river diversions, however, have stoked fears within communities relying upon oyster farms, as fresh water inputs can negatively alter productive bedland ecologies[30]. Many people rely upon place-based ecological dynamics in order to make ends meet, and changes to these dynamics can threaten local livelihoods. A similar case study of mismatches between place-based and regional groups has occurred in the Puget Sound, as Marine Protected Areas set aside by the Washington Department of Fish and Wildlife were incongruous with needs of the Northwest Indian Fisheries Commission. As stated by late NWIFC chairman Billy Frank, Jr.,

"Because tribal rights are place oriented,
tribes cannot simply move around.
Marine protected areas could deprive tribes of
their livelihood and way of life.

This is not speculation,
as tribes have already witnessed situations
where their rights have been challenged by
ill-conceived plans and efforts[31]."

The lower Chehalis River and Grays Harbor estuary are part of a Usual and Accustomed fishing area for the Quinault Indian Nation — a NWIFC member tribe — and as such site development at Seaport Landing must engage tribal concerns through site development. Ideally, restoration-based activities at Seaport Landing would come with full Quinault support, however contamination present in the tidelands of the site bring concerns of contaminant resuspension and negative impacts to aquatic ecosystems and fisheries[32]. Capping this contamination with an impermeable surface may provide ecological benefits as well. As sea levels rise, sediments may eventually cover over this cap, comparable to the layering of sediments as shown by the Johns River stratigraphy diagram (Fig. 3-28).

An additional ecological stressor of habitat migration is competition with invasive species. Opening of lands to habitat migration will create novel ecosystems. Previously-developed lands exhibit disturbed conditions which cater to pioneer communities made up of native, introduced, and designed/selected species (Higgs 2016[33]).

This predictability of vegetative colonization must be taken into account in order to successfully assist habitat migration: adaptive monitoring and management of these sites by researchers and community groups will be of great importance in determining most efficacious methods and best practices for enabling habitat migration. For a start, prepping a site for habitat migration would include removal of impermeable surfaces, remediation of contamination, establishment of relevant vegetation for desired succession, and removal of structures which could negatively impact future habitat.

Habitat migration — as with many riparian processes — may not look tidy, and often clashes with "protect" actions discussed above. Nonetheless these sites may further social activities alongside environmental goals. Each change of land use from industrial (or otherwise) to nascent wildland will provide recreation and education opportunities as well as supporting ecosystem services which further place-based livelihoods such as fishing, ecotourism, and environmental education.

Analog processes, or biomimicry, can be useful to restore natural functions. This entails a retreat from monofunctional infrastructure so as to incorporate ecological processes into built environments that are unlikely to change significantly in the short-term. These processes are experimental (Fig. 3-28), and hold great potential as well as unintended consequences.

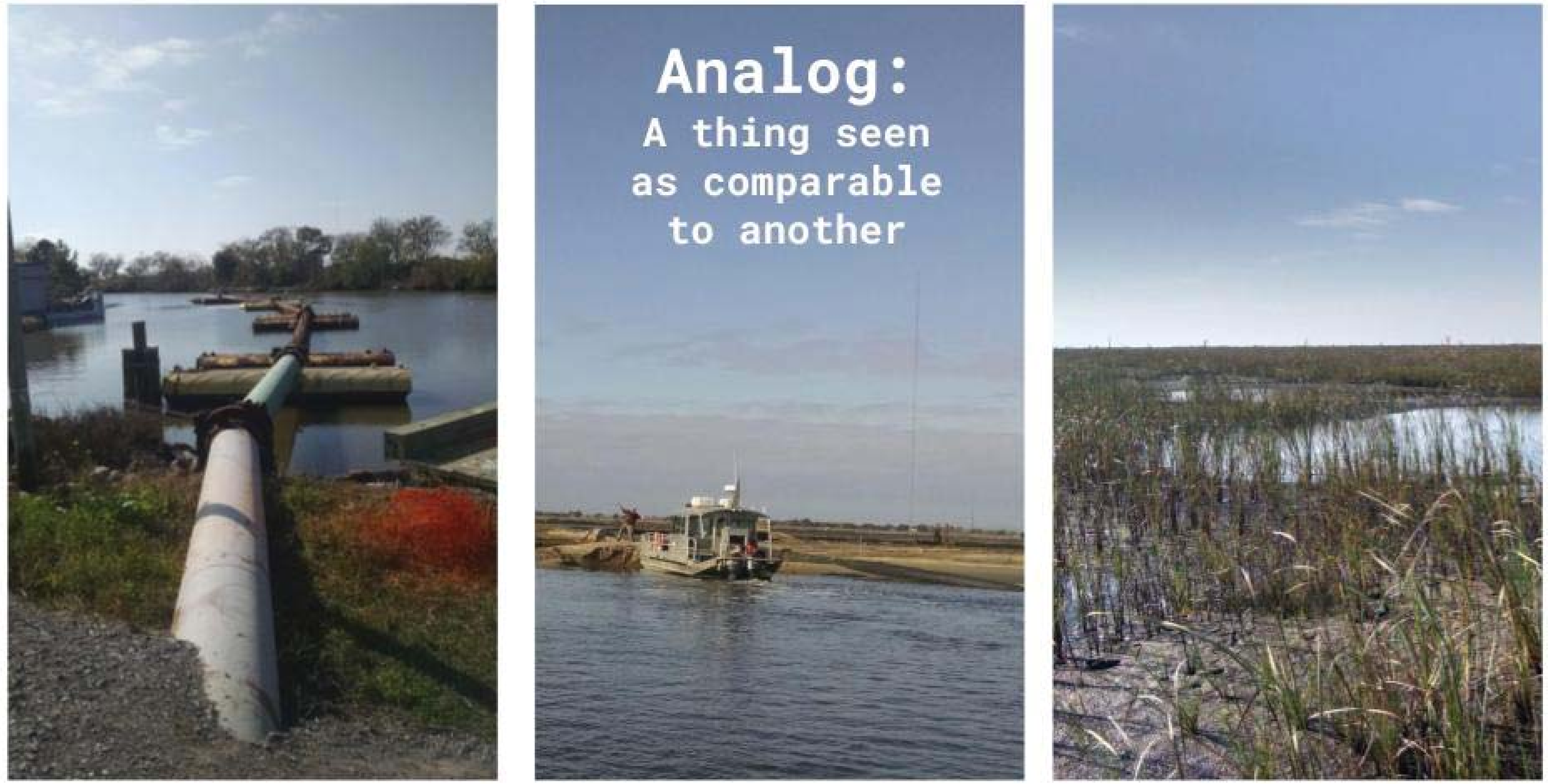


Fig. 3-28. Sediment diversion from the Mississippi River replicates seasonal sediment deposition through analog mechanical means, creating new wetlands in east Barataria Bay, Louisiana.

In order for this to happen, property valuations would need to incorporate potential ecological services into "highest and best use" appraisals. The conversion of shoreline properties to rehabilitated habitats would entail significant costs, though much could be offset by federal and state funds. Development of an economic network surrounding these restoration and resilience projects would provide a means to leverage government funding to support local economic investment instead of simply paying for projects as products. This strategy is discussed further in Chapter 5's proposal.

Preservation of ecosystem function

While structural protection such as levees or floodwalls is a common defensive measure, protection of natural features which provide ecosystem services is extremely relevant and perhaps less noticeable. While structural protection is likely to adversely affect ecosystems, preservation-based protection of habitats can reduce stresses upon ecological services. As such, these ecosystems retain their natural capacity to migrate or absorb some stresses of sea level rise, while also providing habitat value. This can be accomplished through policy (delineating areas as preserves), planning (leaving areas undeveloped), or active restoration (revegetation, hydrologic reconnectivity, slope stabilization, etc)[34].

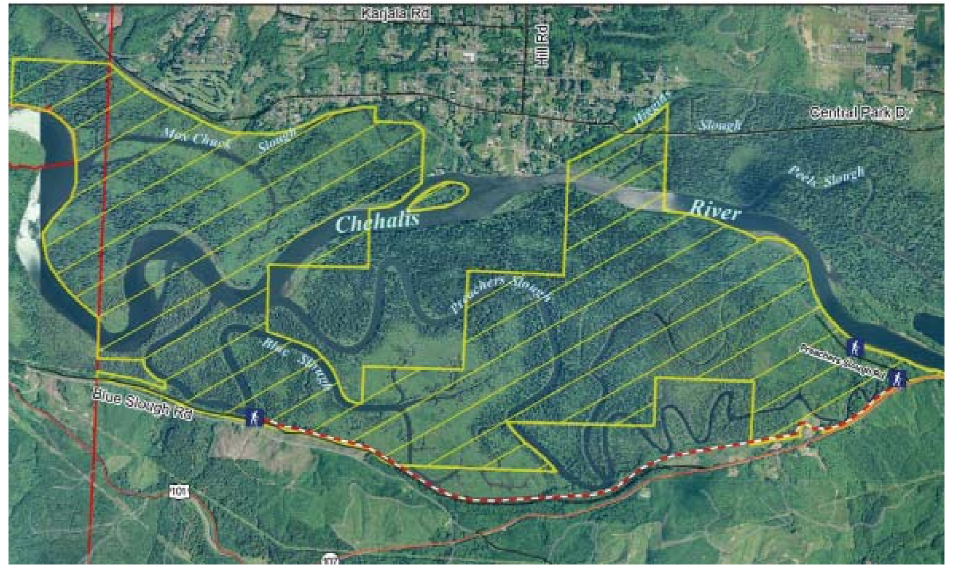


Fig. 3-29. Chehalis River Surge Plain Natural Area Preserve, just upstream of Aberdeen and Seaport Landing. (image: Washington DNR)

Ecological preservation strategies can apply to urbanized areas as well, approaching flood protection of social and economic assets in a systems-based or biomimetic manner and as such is also a component of resilient design. Natural features which can play a role in mitigating sea level rise-related flooding and should be protected include detention basins such as wetlands, conveyance paths such as streams and tidal inlets, geological features such as uncompacted permeable substrates, and buffers such as tidal wetlands or forests[35]. Of additional importance is the connectivity between each of these elements, which may be limited by urban development which is either unplanned or unconscious of such connective value.

Such is the case in Aberdeen, where creeks and tidal inlets have been channelized, covered, or placed in culverts (Fig. 3-30). The Timberworks Plan is working to address these ecosystem functions at the reach scale through multiple habitat and public space rehabilitations (3-31). A similar situation occurs in South Aberdeen, where Shannon Slough exchanges tidal waters with the Chehalis River though culverts at Seaport Landing (Fig. 3-32). Alder Creek is the other main watercourse of the South Aberdeen neighborhood, and is largely covered over as well.

Fig. 3-30. Fry Creek, Aberdeen (in channel to left) as it meets Grays Harbor (right). Armored shorelines, landfill, railroad dikes, and a proposed oil-by-rail terminal.

Fig. 3-31. A Timberworks vision for a revitalized and healthy Fry Creek at Simpson Avenue, Aberdeen. (image: Timberworks Plan)

Fig. 3-32. At Seaport Landing, Shannon Slough flows through narrow channels and small culverts, limiting habitat value. Several native trees have been planted here.

Relocation, permanent and temporary

Relocation can be seen as the human version of habitat migration. As potential for inundation of property and livelihood rises higher, relocation to higher ground is a viable option. Doing so entails large financial costs and lifestyle changes, but can incubate ecological resilience in flood-prone areas which have been left in favor of higher ground. Given the long temporal scale of sea level rise, this option is perhaps best advocated through policy and planning rather than site design. By setting the stage for habitat migration, however, present-day site design can anticipate future resettlement elsewhere due to sea level rise: ecologically-sensitive retreat from developed shorelines would remove impervious surfaces, contaminants, structures, and other ecological disruptive elements.

These relocation processes are already happening regionally. Examples of local sea level rise-induced relocation include the Quinault Indian Nation's village of Taholah on the Olympic Peninsula's coast, as well as the Makah Nation's settlement at Neah Bay, further north along the Olympic Peninsula. Just south of Grays Harbor, the Shoalwater Bay Tribe is battling erosion compounded by sea level rise. Of particular note with the Taholah relocation plan is how typical planning processes and professional design goals were in ways insufficient for working with place-based lifestyles, as described by Lehman (2017[37]; Fig. 3-33).

Shortcomings in addressing social, environmental, or economic dynamics can compromise communities' resilience, and are particularly relevant for place-based communities such as regional tribes. Landscape architects have facilitated context-sensitive upland migration plans with Native Americans in Louisiana, as the New Orleans-based firm of Evans and Lighter worked with the Biloxi-Chitimacha-Choctaw Tribe of Isle de Jean Charles to further "restoration of culture and community cohesion[38]" while retreating from rising sea levels and related wetland loss.

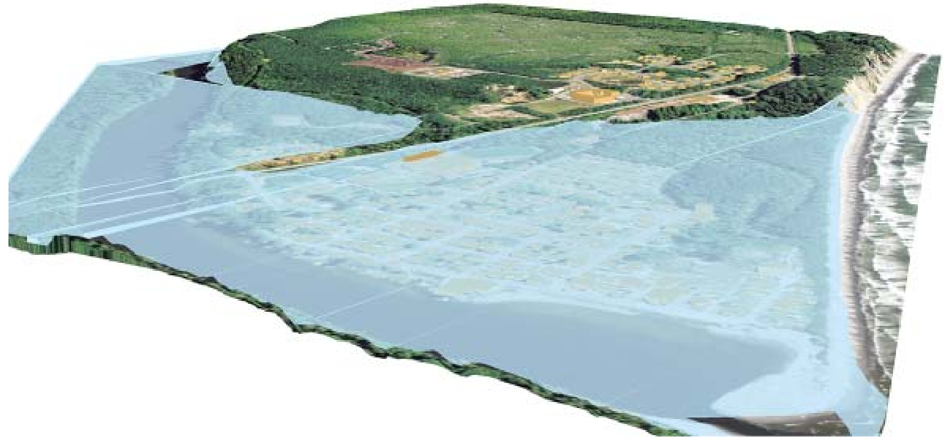


Fig. 3-33. Projected sea level rise risk at Taholah, a main village of the Quinault Indian Nation north of Grays Harbor on the Olympic Peninsula.

Relocation can also serve temporary needs, as exemplified by tsunami relief shelters. Tsunamis are characterized by an extreme momentary rise in sea level, and are a very real threat to lowland residents of Grays Harbor. One Grays Harbor Historical Seaport Authority employee noted that they kept a bag full of evacuation supplies in their car, and have a clear evacuation plan outlined with loved ones elsewhere in town[39].

Across the harbor, Westport has developed a forward-thinking strategy toward temporary relocation in a tsunami event, adapting Ocosta Elementary School to become the nation's first vertical tsunami evacuation structure[40]. This solution provides a means for people to get out of harm's way, though property losses will still occur.

If incorporated into existing building program, such a structure can benefit associated social systems. If placed upon the landscape as a separate entity, a vertical tsunami structure can present an opportunity for public space which presents new heights accessible in lowland environments. Such is the case with Japan's Moerenuma Park (Fig. 3-34), where landscape architect Isamu Noguchi employed a design which artfully abstracts the social elements of large levees as discussed above. The design for this park is reminiscent of the ever-popular hill at Seattle's Gas Works Park, providing views looking over Moere Marsh. Landscape-oriented vertical tsunami evacuation structures are a potential resilience opportunity for towns of Grays Harbor, as these structures will likely prove less expensive than such structures integrated into enclosed building envelopes.

Fig. 3-34. Mound at Moerenuma Park, Japan, by Isamu Noguchi. This type of constructed landform can provide tsunami relief alongside space for play. (image: TripAdvisor.com)

b. Resilience

These three general sea level rise adaptation strategies target social, environmental, and economic adaptation in ways which span a gradient from living adaptation (e.g. assisted migration, relocation) to static one-time interventions (e.g. levees, floodwalls, and armoring). The following discussion describes basic components of a resilient ecosystem - which is the goal of this thesis — and describes an additional set of target ecosystem characteristics which sea level rise adaptation strategies can engage with in order to further a resilient ecological system.

Watson and Adams' "Design For Flooding" states that the "first step in resilient design … is to identify and map areas of any existing natural features … that provide ecosystem services" (103[41]). This approach emphasizes the interconnection between built anthropic systems and the simultaneously surrounding and interwoven ecosystems which provide foundational support for human use of places. Reflecting complex ecological webs, the authors go on to advocate for structural protections against sea level rise to be part of a more robust and redundant system of strategies rather than solo monolithic elements. This multiscalar approach is supported by Thomas Fisher in "Designing to Avoid Disaster: The Nature of Fracture-Critical Design[42]", as he elaborates on the need for redundancy in design in order to approach resilience, in contrast to infrastructure which relies on single-dimensional "fracture-critical" interventions.

In discussing resilience-building strategies, Walker and Salt describe the need to respond to multiscalar impacts of disturbance at specific appropriate scales in order to maximize efforts and activate synergies of larger networks. Scales of action are described as "fine scale", "focal scale", and "higher scale". Actions at the fine scale may have limited effect, while focal scale actions can result in maximum efficacy. By working at higher scales, an organization or entity will need to embrace partnerships and build coalitions in order to build capacity for transformability, or the ability to manage disturbance by changing in a managed way. This trifecta of scales is mirrored in process-based habitat restoration practice, as Beechie and colleagues[43] break the watershed into the basin, reach, and site scales.

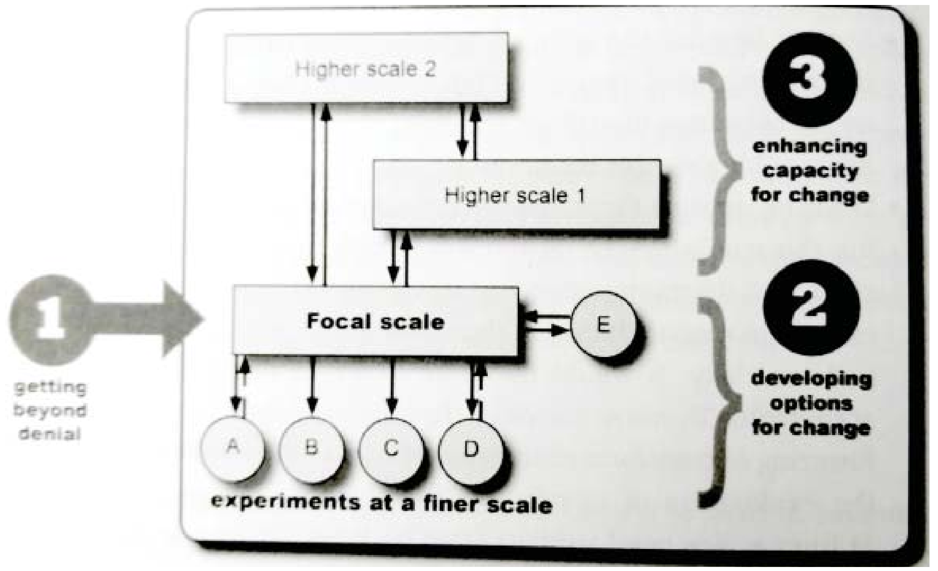


Fig. 3-35. Walker and Salt's "Components of Transformability" highlights the need for a diversity of inter-related multiscalar approaches to achieve resilience.

"Design for Flooding" and "Designing to Avoid Disaster" rarely discuss beneficial human intervention within non-human-centric ecosystems. But what of designing for ecosystem resilience to sea level rise, rather than simply human-centric flood resilience? One could argue that industrialized shoreline settlements must up and leave, removing all traces of industry and impermeability (e.g. "retreat" strategy) if ecosystem resilience is to truly be prioritized. Aside from being unrealistic and ignoring the needs and desires of humans as living things just as salmon, lampreys, and plovers are, doing so takes industrialized human settlement out of the immediate physical realm while the omnipresent threat of industrialization-driven sea level rise remains. This highlights the relevance of coastal squeeze: are ecosystems better left to their own devices in migrating with sea level rise, or is human assistance beneficial? Timpane-Padgham, Beechie, and Klinger (2017[44]) find that some ecosystems are more resilient to climate change impacts if they are exposed to a continual disturbance regime, and that the presence of humans can at times provide such disturbance which builds ecological capacity for greater shock absorption.

Perhaps the long-term processes of habitat migration over several seral stages may lead to a more enduring dynamic ecological regime than if assisted habitat migration is planned and executed largely by human hands. But built development has placed barriers in the way of upland habitat migration (seawalls, rip rap, etc.), and it is most efficient and appropriate that human hands (or machines) remove these barriers - along with contaminants and impermeable surfaces - to free up potential habitat migration zones. Doing so decolonizes space and allows for diverse biotic communities to reinhabit these disturbed landscapes via their own agency rather than human choosing. This "decolonization and reinhabitation" is a cornerstone of Greenwood's (2013[45]) "place-conscious education," pointing to the productive human dimensions of this socio-ecological activity. However, the presence of invasive species may limit the ability for habitats to migrate without a degree of human aid, as regionally invasive littoral species such as Spartina alterniflora have been noted by Sun et al (2017[46]) to dominate disturbed tidal flats preclude the colonization of native vegetation.

Economic ecologist C.S. Holling describes resilience as "the magnitude of disturbance that a system can tolerate before it shifts into a different state (stability domain) with different controls on structure and function[47]." While disturbances of sea level rise and the outcompetition of native species are of concern here, an additional existing pressure upon aquatic ecosystems is the loss of riparian function and aquatic-terrestrial connectivity across shorelines. By addressing this very tangible ecological stressor, the "magnitude of disturbance" is lessened, presumably allowing for increased adaptive capacity amidst other disturbances such as sea level rise.

Fig. 3-36. A tale of two shorelines, riparian zones of the Chehalis River surge plain (top) compared to adjacent shores of Aberdeen. Are they inter-transformable? (image: Wild Fish Conservancy)

Many of the above sea level rise adaptation strategies may take some time to gain public support and be implemented, as resilience-based planning embraces long-term risks and opportunities as well as long-lasting incremental development of effective interlaced strategies to accomplish stated and emergent goals. Per Walker and Salt's "Resilience Practice[48]," social, economic, and environmental elements interact to provide resilience to specific known and unknown shocks to a system. While the details of sea level rise (degree of inundation, timeline, ecological impacts, etc.) may not be fully appreciated until they occur, there have at least been multiple studies which analyze the potential habitat shifts in Grays Harbor (see Wild Fish Conservancy reports, Chapter 2) and provide near-term goals of habitat restoration and preservation to further resilience of ecosystems and dependent human populations.

To supplement these habitat restoration strategies, "A systematic review of ecological attributes that confer resilience to climate change in environmental restoration" (Timpane-Padgham, Beechie, and Klinger 2017[49]) identifies ecological characteristics which bolster climate change resilience through multiscalar ecosystem recovery. They assert that intense ecosystem shifts, plummeting populations, and compromised ecosystem services can be mitigated by "restoring dynamic processes that promote natural variability and biodiversity within ecological systems."

Six primary ecological concepts support resilience: habitat connectivity, biological diversity, species and ecosystem adaptability, habitat variability, presence of refugia, and natural disturbance history. Of these, three (habitat connectivity, habitat variability, and presence of refugia) are physical components which landscape architects, environmental planners, and restoration practitioners have ability to engage with directly. Ecosystem adaptability can be encouraged through these fields by opening new areas to vegetative colonization. Natural disturbance history and habitat complexity, on the other hand, has been altered due to shoreline interventions in Grays Harbor throughout the 1900s (discussed in Chapter 4).

Ecological resilience can be disrupted by external conditions acting alone or in tandem: social, environmental, or economic phenomena which cause the system to pass over a threshold into an alternate state (Scheffer 2009[50]). In a grossly oversimplified manner, let us assume that social and economic factors can be accounted for due to well-managed and prescient planning, regulation, design, and communication. This leaves only environmental factors – e.g. sea level rise and other impacts of climate change – as the primary variable mechanisms which can tip the balance of the estuary's ecosystems toward a critical transition point and onward to an alternative state, represented by a separate "basin of attraction" (a term also referred to as a "regime" or "stability domain" by Walker and Salt[51]).

Passing through this critical transition stage to an undesirable ecological regime (e.g. limited population counts, primary productivity, or habitat diversity) is what resilience practice seeks to avoid. As described by Arthur Winfree[52], the "phase shift" between existing and potential regimes may occur during a "vulnerable phase" of an existing regime. Stresses increase the magnitude of disturbance upon the system, and a shift between basins of attraction may occur when a vulnerable phase is reached.

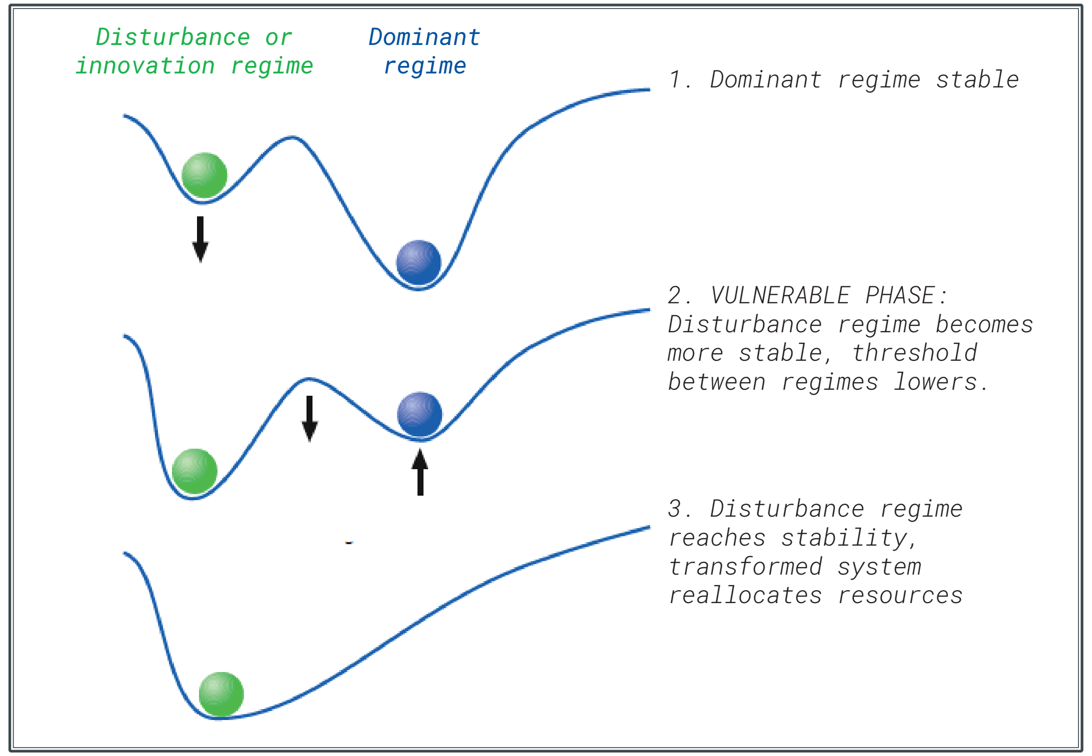


Fig. 3-37. Attraction basins transforming from a dominant regime to an alternate state (adapted from Walker and Salt by Williams)

In Grays Harbor estuary, resilience to reaching the critical ecosystem transition of a climate change-induced vulnerable phase can be incubated at the site scale by focusing on the following ecosystem attributes through designed intervention:

- ***habitat connectivity,***
- ***habitat variability,***
- ***refugia access,***
- ***opening of new habitat,***
- ***and restoration of riparian processes.***

While many of the case studies mentioned above employ multiple approaches to adapt to sea level rise, the Greater New Orleans Urban Water Plan and New York City's strategies (the Dry Line as well as wave attenuation in Jamaica Bay) are of particular interest for resilience design as they engage multiple scales of intervention which address social, economic, and environmental dynamics of the built environment. These multiscalar approaches can employ resilience-based ecosystem attributes to encourage retention of ecosystem character in the face of sea level rise.

c. Discussion of strategies

While adaptations presented above are all designed to mitigate the effects of sea level rise, each offers different potentials for incubating resilience. Strategies can be utilized at multiple scales, through specific designs, and in combination with other efforts to affect resilience-based ecosystem attributes. Protect, retreat, and accommodate strategies each reflect differing approaches toward interactions with aquatic ecology. These tactics toward managing, restoring, and living with water represent different socio-cultural interactions with place.

Priority strategies toward resilience

Fig. 3-38. Chart summarizing this chapter's analysis, ranking each strategy in terms of social, economic, and environmental effect toward resiliency. Highlighted interventions are targeted for a resilient Seaport Landing design.

adaptation strategy	intervention	impact addressed: inundation	impact addressed: habitat change	impact addressed: morphological change	impact addressed: saltwater intrusion	expected consequences: lifestyle change	expected consequences: property loss	expected consequences: habitat change	scale: site	scale: reach	scale: basin	effect (-1, 0, +1): social	effect (-1, 0, +1): economic	effect (-1, 0, +1): environmental	total score	potential for synergistic redundancy
protect	levee/floodwall	x						x	x	x		0	1	-1	**0**	x
	shoreline armoring			x				x	x	x		-1	1	-1	**-1**	x
	storm surge barrier	x	x	x	x	x		x	(x)	(x) v	x	-1	-1	-1	**-3**	
retreat	assisted habitat migration		x	x	x		x		x	x	x	1	0	1	**2**	x
	pres. of ecological services	x	x	x		x	x		x	x	x	1	1	1	**3**	x
	relocation (permanent)	x	x		x	x	x		x	x		0	-1	1	**0**	x
	relocation (temporary)	x					x		x	x		1	1	1	**3**	x
accommodate	living with water	x	x			x			x	x		1	1	1	**3**	x
	densification	x	x		x	x	x		x	x		0	1	1	**2**	x
	wave attenuation	x	x	x				x	x			1	0	1	**2**	x

Figure 3-38 compares protect, retreat, and accommodate strategies, and ranks them by their potential for incubating resilience, informed by a review of the available literature. Figure 3-39 highlights the scale of geographic impact for each intervention. This analysis points to the value of employing multiple strategies at once.

The only strategies which operated at all scales – site, basin, and reach – were "storm surge barrier", "assisted habitat migration", and "preservation of ecological services". The surge barrier stands out as the only measure of the three with both an overall negative ranking and an implementation strategy that would entail massive infrastructure rather than site-scale intervention. "Assisted habitat migration" could be realized through a combination of site-based ecosystem rehabilitation efforts and policy guiding development in and around Grays Harbor estuary. Such is the case with "preservation of ecological services," which relies upon preservation-minded site design and policies supporting or mandating such activities. Policy and institutional support would also be useful with these strategies for coordinating activities at multiple sites for greatest benefit.

Of particular interest is the realization that all three "protect" strategies have negative environmental effects, largely due to their utilization of separation as a means to minimize sea level rise's effects. This same separation is precisely the reason why these structural protection practices are in use so widely in Grays Harbor, as they provide reasonable assurance that flooding will not occur given status quo conditions. Sea level rise (and interrelated inland flooding) provide the exact outlier-event conditions that push "protect" structures to be built larger and larger in anticipation of the continual "next and worse flood event".

Flood infrastructure currently exists along Aberdeen's shorelines in the form of levees and floodwalls, and it is unlikely that the financial impetus will arrive anytime soon to change this condition. As such, "retreat" and "accommodate" strategies can be utilized to address sea level rise resilience at new development sites, providing ecological services for humans and other species alike. While Aberdeen's economy is lagging, many organizations and individuals in the town are working to revitalize parts of town which could employ these schemes.

A robust and redundant approach to sea level rise must be employed to boost resilience of communities and ecosystems. Strategies discussed here can complement others if designed accordingly, with varying social, environmental, and economic outcomes. Design for Flooding advises that if a project does not contribute to resilience, then it detracts from it. As such, net-positive resiliency impacts are shown to be achieved by:

1. Assisted habitat migration (retreat)
2. Preservation of ecological services (retreat)
3. Temporary relocation (retreat)
4. Living with water (accommodate)
5. Wave attenuation (accommodate)
6. Densification (accommodate)

Aside from their research-supported efficacy, additional benefits include the ability to be utilized in tandem with other strategies – customizable to a specific site – and, similarly, the ability for these strategies in tandem with other sites in order to affect cumulative change at a larger reach- or basin-wide scale.

Of these, approaches 1, 2, 4, and 6 are particularly applicable to resiliency-based ecosystem attributes of:

- habitat connectivity,
- habitat variability,
- refugia access,
- opening of new habitat,
- and restoration of riparian processes.

These strategies can be applied to Seaport Landing's development and merged to form a more resilient site design. As shown by existing practices targeting living shorelines, stream restoration, and urban water management, outreach and education practices that engage local social and economic processes at multiple scales are essential to further resilience. The existing levee and floodwall system provides a crucial element of social and economic protection to South Aberdeen, and is likely to remain. As such, this piece of infrastructure can be utilized within Seaport Landing's site design, providing flood redundancy and minimizing the degree to which GHHSA's site needs to be integrated with other flood protection measures in the area.

Sea level rise infrastructure: Considering the source

Protect, retreat, and accommodate strategies bear similarities to environmental management approaches of the Army Corps of Engineers, Northwest Indian Fisheries Commission, and the Dutch DeltaWorks program. Each of these organization's role within managing aquatic ecosystems can be traced back to specific events and attitudes. In moving forward with an informed place-based approach to sea level rise adaptation, it is necessary to understand where how adaptations originated.

In order to mitigate sea level rise, "protect" strategies place barriers between ecosystems, whether marine/estuarine divides or aquatic/terrestrial. While these structures could be designed or operated to allow passage of some marine elements part of the time (such as at Oosterschelde), it is uncertain how this will impact links across ecosystems of Grays Harbor estuary. This separation-based anthropocentric design approach is representative of the United States Army Corps of Engineers (US ACE), known for building and maintaining massive levee-based protection systems across the country. The Dutch DeltaWerken (DeltaWorks) program relies on control of water as well, but does so in a way which shapes built development patterns and furthers accommodation of flows by "living with water." Representing place-based communities who rely on salmon fisheries and underpinning ecosystem health, the shoreline management approaches of Northwest Indian Fisheries Commission[53] (NWIFC) are likened to "retreat" strategies, as they seek to restore ecological function in order to improve livelihoods.

Protect: US Army Corps of Engineers

The Army Corps of Engineers' origins begin in 1775, though they became the lead federal agency addressing flood control in the early 1900s[54]. This role was largely influenced by the Mississippi River floods of 1927. As the largest riverine flooding event in United States history[55], these floods highlighted the need for larger-scale coordination between levee and flood management entities along the Mississippi River[56]. US ACE has since been responsible for an extensive network of structural water management and navigation projects across the country, managing safety of over 14,000 miles of levees nationally. This portfolio includes 2,000 levees total, averaging to approximately 7 miles long per levee[57].

Aberdeen's 11 miles of shorelines are today developed to protect the city through a combination of levees, bermed railroad tracks, and high-ground industrial sites along shorelines. Built in the 1970s, South Aberdeen's levee system is undergoing certification processes from the Army Corps of Engineers to ensure that it meets today's standards and conditions. Today's South Aberdeen levee recertification and North Shore levee proposal are directly related to recent flooding in the area, which has led to multiple federally-declared disasters (Fig. 3-39).

Month	Year
December	1964
January	1971
January	1972
December	1975
December	1977
December	1979
January	1990
November	1990
November/December	1995
January/February	1996
March	1997
October	2003
January/February	2006
November	2006
December	2007
December/January	2008–2009
January	2009

Fig. 3-39.
Federally-declared disaster events in Aberdeen.
(image: Timberworks Plan)

Accommodate: DeltaWorks

Initiated in 1953 after historic North Sea flooding, the DeltaWorks' goals are simple and geared toward protection of human settlements: 1) "drain areas that flood regularly … and protect them from the water", and 2) "protect the land from getting brackish[58]". Over 2500 acres (1000 ha) of land have been reclaimed from tidelands of the North Sea by the Netherlands' extensive dike (levee) and polder system[59]. Regardless of this focus on protection, the "Dutch approach" brings water into developed areas, albeit in a controlled manner, employing multiple strategies at multiple scales to manage flooding.

Fig. 3-40. The devastating North Sea flood of 1953 led to a national reworking of water management for the Dutch. (image: Eastern Daily Press)

Fig. 3-41. The Dutch polder system allows farming and habitation below sea level through collective water management. These channels are similar in form to Aberdeen's rectalinear drainage system. (image: Zuiderzeemuseum Enkhuizen)

Southern Louisiana — a vast deltascape comparable in many ways to the Netherlands — is currently developing and implementing sea level rise and disaster mitigation strategies which build off of the Dutch realization that at some point they can no longer keep building walls higher[60]. As Jane Wolff[61] points out in "Cultural Landscapes and Dynamic Ecologies", reliance on historic methods of flood control without periodic holistic reevaluation presents risks to life and property. Such was the case during Hurricane Katrina, when New Orleans' 17th Street Canal failed due to weak soil stratum at the base of the flood wall - soil linked to the canal's initial construction in the 1800s. Following this 2005 disaster, residents have embraced the Greater New Orleans Water Urban Water Plan in order to develop decentralized adaptive strategies to mitigate flooding with alternative approaches, moving beyond antiquated infrastructures of levees and pumping stations alone. This is comparable to Aberdeen's turn toward the Timberworks plan, which closer replicates multi-tiered Dutch approaches.

Stemming from collaborative efforts referred to as the "Dutch Dialogues," these planning paths move beyond traditional US ACE-supported levee-and-floodwall-based flood management, and focus on decentralized flood management strategies at the block, district, and city scales. Aberdeen-Hoquiam's Timberworks Master Plan builds off of these Dutch strategies, providing the towns multiple opportunities to integrate water flows into daily life through creek restoration pocket parks, street edge redesign, and pedestrian/bike paths linking public amenities.

Fig. 3-42. The Dutch Dialogues conjured new visions for how New Orleans could live with water, many of which are currently underway. Pictured is the London Canal, redesigned as a detention basin and amenity. (image: Waggonner & Ball Architects)

Retreat: Northwest Indian Fisheries Commission

Though primary productivity was found to be "robust and resilient" behind the barrier enclosing the Netherlands' Oosterschelde estuary[62], the vast ecological, social, and historical differences between this region and Pacific Northwest bring up an interesting point with regard to "protection" strategies. Coastal zones of Europe and the eastern United States have experienced intense industrial, agricultural, and urban land uses for centuries – extensively altering ecosystem dynamics and disconnecting residents from many ways of life engaged with undeveloped lands. Grays Harbor and the Pacific Northwest were not settled by Europeans until the later half of the 1800s, leaving some socio-ecological relationships of pre-European Native American settlements intact.

Through hard-fought and still-active struggles symbolized by the Boldt Decision of 1974 (United States v. Washington), regional Native American Tribes have maintained Treaty Rights with the United States of America which provide them leverage to enact restorative change to aquatic ecosystems in the name of salmon and other traditional fisheries – a resource which tribes co-manage with the state of Washington. This protection and preservation of a way of life is represented by the Northwest Indian Fisheries Commission (NWIFC), a coalition of 20 independent Treaty Tribes from western Washington[63]. The fisheries management of the NWIFC constitutes "protection" as a connective element between ecosystems and traditional place-based livelihoods, rather than a divisive floodwall isolating human settlements from aquatic ecology. It is useful to note the byline to the NWIFC's quarterly magazine: "Protecting natural resources for everyone." This acknowledgment of playing a major role in the welfare of socio-ecological relationships situates the NWIFC and its member tribes as public-interest ecosystem managers just as the Army Corps of Engineers and DeltaWorks consider themselves.

As influential agents working to preserve particular regional lifestyles and economies while shaping property ownership and settlement patterns, the Dutch and US Army Corps' approaches are place-based approaches to environmental management – just not based in a place which reflects Traditional Ecological Knowledge of the Pacific Northwest. As discussed in documents such as the NWIFC's report, "Climate Change and Our Natural Resources ," regional Native American livelihoods are inseparable from water, and have been so for thousands of years. This approach – and difference between European and Native American epistemology – was highlighted by a Makah Elder during the treaty of Neah Bay: "the water is our land.[64]"

In "Water-based ecology: A First Nations' proposal to repair the definition of a forest ecosystem[65]," Blackstock confers with First Nations Elders from southern British Columbia, highlighting how Western science clashes with First Nations' views of water as a foundational living component of the Earth. As water is here seen as a core element of the ecosystem, a reflection of these values onto shoreline environments exhibits integrity of eco-hydrology: lateral connectivity between stream, floodplain, and groundwater. These ecosystem characteristics are all components of "retreat" strategies for sea level rise adaptation, as "tribes are undoing … damage one step at a time" (Billy Frank Jr., former Chairman of the NWIFC[66]). This application of First Nations' water-based ecological understandings supports ecosystem resilience characteristics as described by Timpane-Padgham et al. (2017[67]) and discussed above.

"The taxonomic lens of science has created a chasm between the living and non-living components of our world...

...and water has unfortunately been placed on the non-living side."

Blackstock 2002[68]

Just as the dikes and floodwalls have altered the landscape and the activities which it holds, the place-based nature of traditional Native American lifestyles in communion with water-based ecology has resulted in many transformative ecological changes. In the name of habitat protection, tribal power and vision have led notable reversals of settler-colonialist-derived control over the region's watercourses, as showcased by the Elwha River dam removals, Nisqually River delta levee breaches, and reinsertion of instream large woody debris to affect channel complexity throughout the Skagit River basin. These projects reinstate aquatic agency in the place of regulation, highlighting the distinct place-based-ness of land/water management. As such, sea level rise adaptation which disconnects ecological elements stands to be improved upon by strategies which reflect ecologically-attuned place-based approaches to land and water management.

Fig. 3-43. Elwha River sediment plume after the largest dam removal project in history, made possible through local tribes.

Learning from the past as we enter the future

It is no wonder that when looking for signs of life on other planets, scientists first look for water. It is quite wondrous, however, how modern built environments have developed quite the adversarial relationship with water — exemplified through pressing global concerns over flooding, contamination, water rights, and drought.

Is the Army Corps' approach appropriate to continue in coastal Washington, or perhaps a stark offense to traditional place-based livelihoods? Watson and Adams state that structural protection strategies are "increasingly considered a 'last resort' for mitigation of erosion[69]." As American coastal communities increasingly respect and engage with ecological systems, might present structural measures also be seen as a "last resort" for addressing inundation? It is unlikely that the flood protection measures of 2050 will be those of 1950, redux. Sea level rise adaptation will both impact and reflect social dynamics of the community, since settlement patterns, economics, and overall activities are so often shaped by our relationships with aquatic ecology.

Fig. 3-44. 17th Street Canal breach, New Orleans, 2005. Resilience requires a move away from fracture-critical infrastructure. (image: nola.com)

Just as new approaches to water management were born from flood events of 1927, 1953, and 2005, renewed socio-ecological relationships are being shaped today through ecologically-restorative actions in response to ongoing degradation of aquatic ecologies as exemplified by the work of the NWIFC and others. This focus on human relationships with water rather than protection from water is more appropriate for adaptation to sea level rise, an event that occurs on a decadal time scale rather than as an instantaneous momentous event. In comparing the DeltaWorks to the US Army Corps' approach, one Dutch designer remarked,

"You treat water like a drowning person. We treat it like a long distance swimmer.[70]"

By viewing sea level rise and flooding, through a "long-distance" time scale, isolated flood events become part of a larger process. This approach dictates an alternative set of strategies than currently in place by Army Corps-centric approaches. Processes situated in place can be reflected in infrastructures, and doing so can support a diversity of place-based lifestyles. The place-based relationships found in the Pacific Northwest and exemplified by the Northwest Indian Fisheries Commission's member tribes reframe "living with water" as "living with aquatic ecology", and provide a base point for placing designed estuarine intervention within a localized socio-eco-physiographic framework. The following chapter discusses concepts of place as they fit within this framework.

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chapter 4

Sea level rise and place

Theories of “place” highlight historic shoreline changes at Seaport Landing, providing a framework for design intervention.

a. “How do you define place?”

If sea level rise adaptations and ensuing site design are to reflect place-based relationships as in the mission of Seaport Landing, we must build off of Chapter 3’s analysis of sea level rise adaptation and resilience strategies to develop a deeper understanding of “place” applied to Grays Harbor estuary. The following literature review and historical analysis points to the importance of sediment transport to the estuary’s existence, while the past century has witnessed large-scale modification of these sediment-built shorelines by industrial processes.

Through this chapter, I find that place-based design interventions in Grays Harbor estuary must engage with substrates and shifting shorelines in order to further sea level rise resilience. Place-based design for sea level rise resilience at Seaport Landing will reconnect and rehabilitate heavily altered shorelines in a manner which embraces morphological and economic change over time, addressing multiple generations of people as well as experiences formed via a single moment.

When I first visited Seaport Landing in October 2016, I found myself in thoughtful conversation with Christie Barchenger, Director of Science Education for Grays Harbor Historical Seaport Authority (GHHSA). Barchenger described the place-based goals of GHHSA as they related to the site’s past, present, and future: Native American settlement, timber processing, public access, tourism, and wildlife habitat.

Of particular relevance to landscape design at Seaport Landing is GHHSA’s focus on place-based education, which Barchenger envisions happening through science programs, participatory maritime history exhibits, and hands-on restoration projects around Shannon Slough. These activities are linked to marine science and maritime education programs aboard the GHHSA-owned Lady Washington and Hawaiian Chieftain tall ships (Fig. 4-1).

In 1788, the original Lady Washington rounded Cape Horn to become the first American vessel to reach the Pacific Coast of North America. This kicked off a number of events locally - many rooted in racism and extraction — before the Lady Washington went on to open trade routes between Asia and the Americas[1]. The present state of the world still bears the imprints of these routes as we seek local place meanings unbleached by globalization, settlement safe from climate change, and ecosystems untrammeled by industry. If the Lady Washington represents Grays Harbor estuary and the shorelines of the lower Chehalis River, it represents a limited narrative of the region beginning with European colonization. This perspective into place seemingly precludes the perspectives of Native Americans and other narratives which are foundational to this region’s socio-ecological relationships.

Fig. 4-1. GHHSA’s tall ships are an anachronism, opening the door to reflect a diversity of place-meanings and relationships. (image: GHHSA)

GHHSA's place-based education efforts are also associated with the Grays Harbor Stream Team, an ecological restoration program based out of Seaport Landing. Focusing on stewardship, the Stream Team links residents of Grays Harbor County to local volunteer-based habitat restoration efforts. According to the Center for Place-Based Learning and Community Engagement (a partnership between the National Park Service and Shelburne Farms of Vermont), "place-based education immerses students in local heritage, cultures, landscapes, opportunities and experiences … place-based education emphasizes learning through participation in service projects for the local school and/or community[2]."

As we parted ways, Barchenger asked a simple question which resonated throughout this project's development: **"How do you define place?[3]"** Through this layered query, Barchenger challenged me to develop a landscape analysis and design response which looked to the past, present, and future while reconsidering the role of the landscape architecture profession towards individual sites which are also inextricably linked to larger ecosystems. As resilience involves maintaining elements of identity amidst disturbance, an understanding of "place" is particularly relevant for communicating and enacting sustainable adaptive sea level rise strategies.

i. Place as process

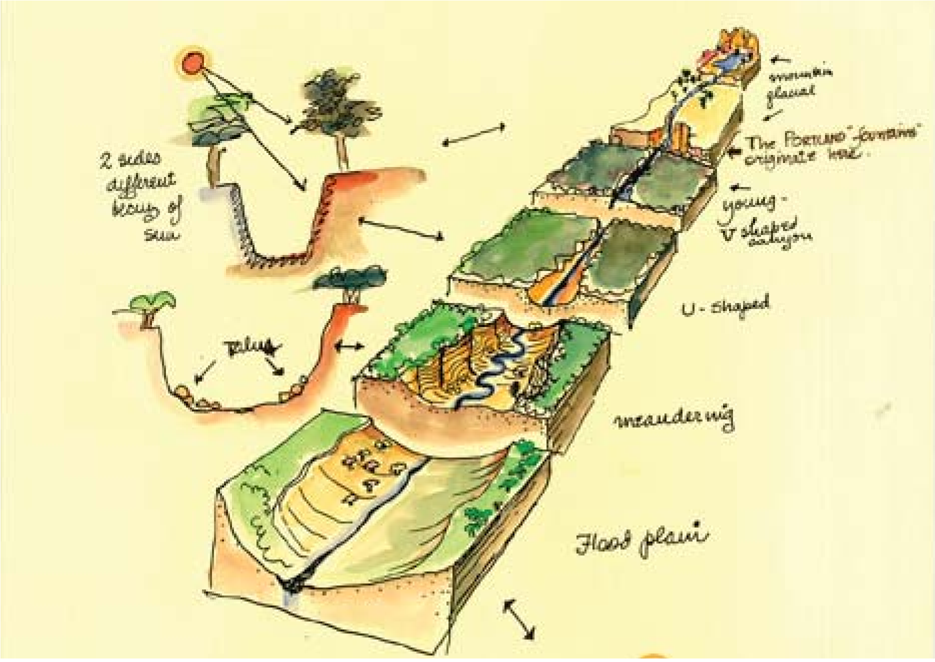
Concepts of "place" have been discussed widely in landscape architecture and allied fields concerned with socio-ecological relationships. Much of this literature focuses on place defined by social, economic, and environmental processes — a trifecta of factors which coincides with the concerns of resilience practice as put forward by Walker and Salt[4]. David Greenwood connects place-meaning to sea level rise adaptation as he argues that the study of place is of utmost importance for "understanding how humans and other species adapt to ecological and cultural changes[5]".

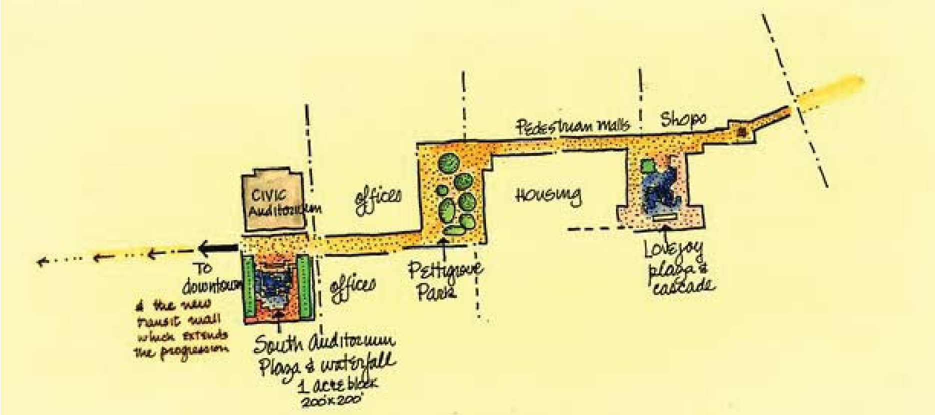
"Place" is a muddy term which can describe many scales: a chair, a house, a neighborhood, an estuary, and much more beyond and between. Views of place are subjective, representing the variety of people who interact with a setting. In "A Critical Theory of Place-Conscious Education[6]," David Greenwood finds "place" to reflect diverse experiences of local ecological and cultural dynamics, particularly in contrast to the "placelessness" of globalization.

The links between place, globalization, and aquatic dynamics are further discussed in Blackstock's "Water-based ecology: A First Nations' proposal to repair the definition of a forest ecosystem[7]." Here, attention to aquatic ecology is a focal point for asserting Traditional Ecological Knowledge and ways of life rooted in place, counter to a globalized capitalism. Blackstock and First Nations Elders argue that European-derived scientific concepts of ecosystems are flawed due to the underappreciation of water. Here we see interpretations of place vary by culture, as exemplified by Chapter 3's connection of sea level rise adaptation strategies to specific place-based worldviews as exemplified by the Dutch, US Army Corps of Engineers, and the Northwest Indian Fisheries Commission.

Fig. 4-2. Place-based processes lead to sustainable ecosystem succession.

In discussing place-based education Robert Michael Pyle (2008[8]) adds to this, asserting that studies of place will not be successful without "reinstating the pursuit of natural history as an everyday act." Landscape architectural design can apply here, communicating natural history as "process made visible," as described by Lawrence Halprin in "Nature into Landscape into Art[9]" (Figs. 4-3, 4-4).





A "process made visible" approach can keep ecological processes intact and living rather than transforming them into relatively static sculpture, however naturalistic, beautiful, and interactive they may appear to humans. At a shoreline setting such as Seaport Landing, this can begin to reinstate the agency of aquatic ecosystems as put forward by Blackstock.

"Living with water" (Chapter 3) approaches often forgo the sculptural aesthetics of nature-inspired design, and work to highlight processes through functional water management relevant to human settlement. This approach engages site participants in a manner which links hydrologic connectivity to positive site-based activities supported by said connectivity (Fig. 4-5).

Figs. 4-3, 4-4. Halprin's studies of channel form (left, top; image: Landscapevoice.com) influence his "Open Space Sequence" park designs in Portland (left, bottom; image: Halprin Landscape Conservancy).

Fig. 4-5 (below). "Living with water" exposes stormwater infiltration to youth as it reduces flooding and park subsidence in New Orleans.

Aberdeen and Hoquiam's Timberworks Resiliency and Restoration Master Plan proposes various strategies for incorporating the water cycle into daily life, though little of this approach exists today in Aberdeen. Franklin Field is a sunken baseball diamond which serves as a detention basin during flood events, though it has little ecological value. Though in a peripheral location, local ecologically-linked water management is perhaps most visible at Aberdeen's North Maple Street detention pond, between West 1st and West 2nd Streets along the railroad tracks. Here, an informal public trail passes by a fenced-off cattail-dominated marsh, juxtaposed with the hidden subsurface drainage found elsewhere in town (Fig. 4-6).

Fig. 4-6 (below). Cattail (Typha latifolia) forms a near-monoculture in an Aberdeen detention basin, hidden between backyard fences and railroad tracks.

Figs. 4-7, 4-8 (right). A hardened shoreline becomes a living shoreline, exposing processes one residence at a time. (images: Green Shores for Homes; design: Paul Broadhurst).

"Retreat" strategies take this "process made visible" approach a step further, as rehabilitation of ecological service provision (and associated lessening of the human-built footprint) is a primary goal. This can occur at multiple nested scales, as seen through ecological restoration and preservation efforts in the Pacific Northwest. At the site scale, Washington Sea Grant's "Green Shores for Homes" works to restore shoreline ecological functions in a manner which encourages daily interaction with living systems, removing bulkheads in favor of beaches and vegetation (Figs. 4-7, 4-8). These small-scale interventions add up to have larger effect as shorelines begin to erode and accrete while woody debris and vegetation communities improve habitat.

The estuarine restorations at Johns River Wildlife Area (Grays Harbor) and Billy Frank Jr. Nisqually National Wildlife Refuge (Puget Sound) are two examples of many regional "retreat" strategies which make process visible. Each project exhibits a reconnection of tidal regimes to previously-protected floodplains through levee breaches accessible to the public. Boardwalks and a visitors' center encourage engagement with cyclical flooding at the Nisqually River delta (Fig 4-9).

While the Johns River site is less accessible to the public (requiring a boat or hike), this site bears specific relation to Seaport Landing and can be used as a reference site for restoration work along local post-industrial shorelines. Located in south Grays Harbor, the main levee breach at Johns River reconnects tides to a former Markham Lumber Company site. Similar plant communities exist here, and vegetative succession can be analyzed as a precedent for restoration actions at Seaport Landing. Interestingly, much of this site has been covered by tall fescue grass (Festuca arundinacea), an invasive species that provides little forage and habitat value for birds[10]. This is observable by the lack of avian usage of the site, while surrounding areas flourish with a variety of bird species. Sea level rise will likely alter this community makeup. Here and at the Nisqually River delta we see exposed natural history processes of tidal regimes and vegetative succession, though the rural locations of these sites mean they are not necessarily observable in a daily manner as advocated by Pyle.

As a precedent for Seaport Landing's sawmill redevelopment, the Markham Lumber Company site along Johns River is place-based through its reconnection with tidal regimes and ensuing ecological dynamics, but is also an example of "decolonization and reinhabitation[11]" of spaces previously geared toward extraction and globalization. This reinhabitation can be further geared toward place concepts by focusing on local economics through an "ethic of cultivation," as put forward by J.K. Gibson-Graham (joint penname of economic geographers Katherine Gibson and Julie Graham) in "An Ethics of the Local[12]."

Gibson-Graham points out that ideas of self-sufficiency are counter to place-based thinking: we are inextricably connected to each other and to the environments within which we dwell. A local place-based economy reflects this complex diversity of connections, as reflected by the ecological relationships put forward by the Northwest Indian Fisheries Commission in Chapter 3. Incubating diverse place-based economic relationships encourages different place-based social phenomena as well, as localized economy becomes a "product of our performance and creativity[13]" rather than an abstract exterior driver controlling and limiting how we go through our days.

Fig. 4-9. Tidal and flood regimes are restored to the Nisqually River delta, as dikes are replaced with a setback levee.

So how do existing relationships with place play into this? Discussion so far has been concerned with the ecological processes of place. According to Dramstad et al (1996[14]), landscape ecology principles "are solid background colors on the professional's palette." The question remains: what provides the detail beyond this foundation, relatable to the general populace? This points to the social component of place. In "Design as if people mattered[15]," Clare Cooper-Marcus responds that the "real experience of place" happens "at the scale of the front porch, where the children play, and can be seen by their parents", highlighting intergenerational relationships and comfort zones at the intersection of public and private space. This description uses setting to describe activity: form informs process. Cooper-Marcus encourages valuation of "undesigned" interstitial spaces such as those found on the batture side of South Aberdeen's levee (Fig. 4-10), as they provide growing moments for youth away from adult supervision — noting landscape architects are often skeptical of such spots in fear of crime.

A similar point is made by Randy Hester (2006[16]) in his discussion of "sacred spaces" as related to the NC coastal town of Manteo. He takes this personal-scale place attachment and expands it outward to identify cultural place attachments otherwise overlooked by designers. Understanding community valuation of spaces can reframe how redevelopment takes shape, as evidenced by recent online public petitions for tourist-centric redesigns to retain historic facades of downtown Aberdeen (Harber 2016[17]).

In this digital age, access to community-generated place meaning is accessible not only through surveys and conversation as Hester undertook. Shirtcliff (2015[18]) posits that social media can provide publicly accessible expressions of young people adapting environments for positive outcomes which would not be evident through typical research methods, as adolescents may be regularly "designed out or boxed in" with typical public space (Fig. 4-11). As applied to Aberdeen, this view of atypical public space (e.g. peripheral zones such as abandoned shorelines) clarifies simultaneous use of abandoned shorelines by both youth and homeless encampments: as mentioned by Cooper-Marcus[19], these sites offer an out-of-the-way "wild" location where societal oversight does not exist, instilling greater freedom and agency to experiment. Whether these moments wind up on Youtube or other social media relates to social capital attributed to these spaces and the desire to engage in the process of sharing an experience. Multitude of processes exist within the use of shorelines by homeless encampments as well, and both could be considered forms of place-reinforcing "dwelling" as described by landscape architect Anne Whiston-Spirn[20].

Fig. 4-10. Post-industrial shorelines of Grays Harbor, utilized by youth and adults alike. (image: Aberdeen Daily World)

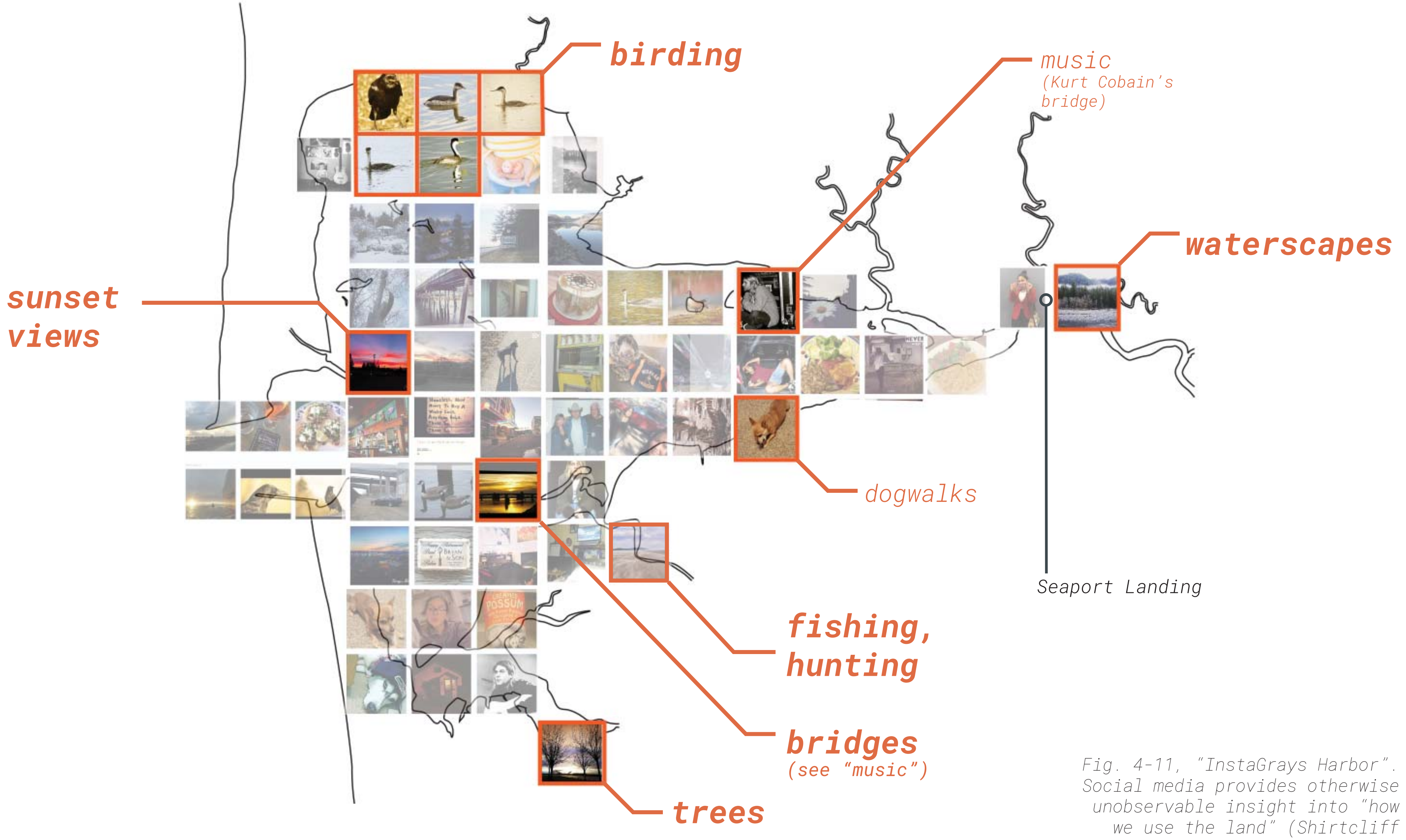


Fig. 4-11, "InstaGrays Harbor". Social media provides otherwise unobservable insight into "how we use the land" (Shirtcliff 2015). Prominent themes from Instagram, Youtube, and other media can inform successful and flexible site design for ***how people use shorelines****.* *(images: Instagram)*

Are all processes relevant to place? I would argue that yes, all processes have potential to define place, but so many processes happen, will happen, and have happened that these phenomena need to exist at a large scale (physical, temporal, or otherwise) in order to make a lasting impression through multiple generations. While present-day place meanings along the shores of Grays Harbor are extremely applicable for any intervention in this area, I see these as a litmus of larger place concepts in this region and therefore a small component of "place" as proposed in this thesis. "Place" extends beyond the present: subjective interpretations of place are formed by place meanings prior. Place-meaning as put forward by the Northwest Indian Fisheries Commission[21] is relevant here, as place is defined by multi-generational relationships with the ecological dynamics which define a region rather than a single parcel or property which has been abstracted from ecological context.

The work of influential landscape architect and theorist Ian McHarg can build upon this view of place. He describes social, environmental, and economic systems as a response to underlying physiographic characteristics of the landscape, created through physically-and temporally-massive geologic processes. Based on the morphology of the natural world as evidence, "form follows most fitting[22]."

McHarg's later discussion of the "inventory of values" is interesting and applicable, as it ascribes cultural valuation to pieces of past existences that last into the present (or otherwise longer than other elements). This brings to mind the buried infrastructures and histories that inform our current settlements, as if we could metaphorically sweep away recent development to appreciate what led to its existence (e.g. decimated Native American villages, unused dike-like railroads through marshes which spurred inland development). As shown in Chapter 3, "Sea level rise adaptation and resilience," built development and associated alterations to landforms reflect cultural priorities. On this note, McHarg's emphasis on physiographic provinces as form-defining elements starts to point to another more-recently created physiography which both reflects and shapes processes: land-fills and other anthropic landforms that are now a ubiquitous foundation for our built existence.

But how do we move into the present and onward to the future with this information? McHarg[23] asserts that the urban form is a human-made adaptation of forms created by natural processes. This implies that natural processes have ceased under the industrialized human's footprint, frozen in time only to be altered by human agency. Pyle's "reinstatement" of place-based understanding of the world through engagement with natural history runs parallel to Greenwood's emphasis on "decolonization and reinhabitation", harkening back to some previous point in time and begging the question of "what is to be removed?" and "what history is to be engaged with?" Gibson-Graham[24] responds that a place-based "ethics of the local" works to incubate local economy and place-based ways of life which have direct connection to ecosystem processes.

What of a design approach which acknowledges, welcomes, and reinstates these natural processes? This can be seen in the "retreat" and "accommodate" responses to sea level rise, discussed in Chapter 3 and applied to Seaport Landing in Chapter 5. To find these processes, the next step is to relate place to time, framing a temporal focal scale through which to view the history of greater Seaport Landing and develop a place-responsive site design.

ii. Place in time

By approaching place-meaning as process, we associate place with time. The flux of place over time - rather than a static existence – has underpinnings within Einstein's theories of relativity and concept of spacetime[25] as a 4-dimensional model of existence rather than typical 3-dimensional spatial model. Astrophysicist Neil deGrasse Tyson describes how place and time are inextricable:

"You've never been at a place, unless it was at a time.

Nor have you ever noticed a time, unless you were at a place.

So the two are forever intertwined.

And one cannot think of one without the other, without manipulating them both to achieve your goals." [26]

Tyson elsewhere describes our relationship to place as a set of 4-dimensional axes: we can move around within and manipulate spatial axes (typically x, y, and z axes), while time functions as a separate confining axis which we cannot move throughout or manipulate[27] other than through subjective memory and perception. As time shifts separate of human agency, spaces shift as well – affected by human agency.

Place meaning represents human reflection on place in time, with an emphasis on this change, as put forward by Harry Heft in "Affordances and Perception of the Landscape: An Inquiry into Environmental Perception and Aesthetics."[28] Heft describes a blindfolded individual and an object. By placing this stationary object in their hand, the individual can gather an idea for a slim one-dimensional selection of its physical characteristics. Manipulation of this object in-hand and exploration of its details provides a more accurate understanding of the object. "Actions participate in perceiving in fundamental way (Heft 15)." Understanding the foundations of place meaning by analyzing various sites in time is analogous to identification through Heft's manipulation of perception. By sifting through variable time with the x, y, and z dimensions of place as constants, process is highlighted: place is static and perhaps nonexistent without multiple points of reference in time. Figure 4-12 portrays this concept in an extremely simplified manner.

Heft's description of manipulating an object for better perspective is directly relatable to Chritophe Girot's work to understand topology, in which he employs point cloud modeling to better understand substrates[29]. This is accomplished Structure From Motion photomanipulation, a process which generates extremely accurate three-dimensional models by merging various perspectives of on an object just as Heft describes. While Heft is concerned with the physicality of an object, Girot's approach to topology through Structure From Motion-derived point clouds produces a detailed document of a place's physicality in time. Shareware computing programs such as CloudCompare can then analyze this data, discerning change over time.

Time is a particularly relevant medium for landscape architects, ecologists, and geologists – fields which study the dynamics of society, ecosystems, and landforms over time. Today's socio-bio-geo-chemical processes will be heavily disturbed by sea level rise, as tomorrow's cycles may morph beyond our expectations.

"As climate changes, we want to have an accurate understanding of the past. This allows us to manage for forests that are resilient to the changes we're expecting in the future," states Carrie Levine, a University of California-Berkeley ecologist[30]. Levine's work involves guiding conifer forest restoration in the Sierra Nevada range in preparation for climate change-related disturbance. Past conditions inform present action towards a resilient future.

Where do we begin to intervene within these changes, and how does this reflect diverse place-meanings? In "The City: Process and Form[31]," Ian McHarg clarifies: "The search for identity must begin at the beginning."

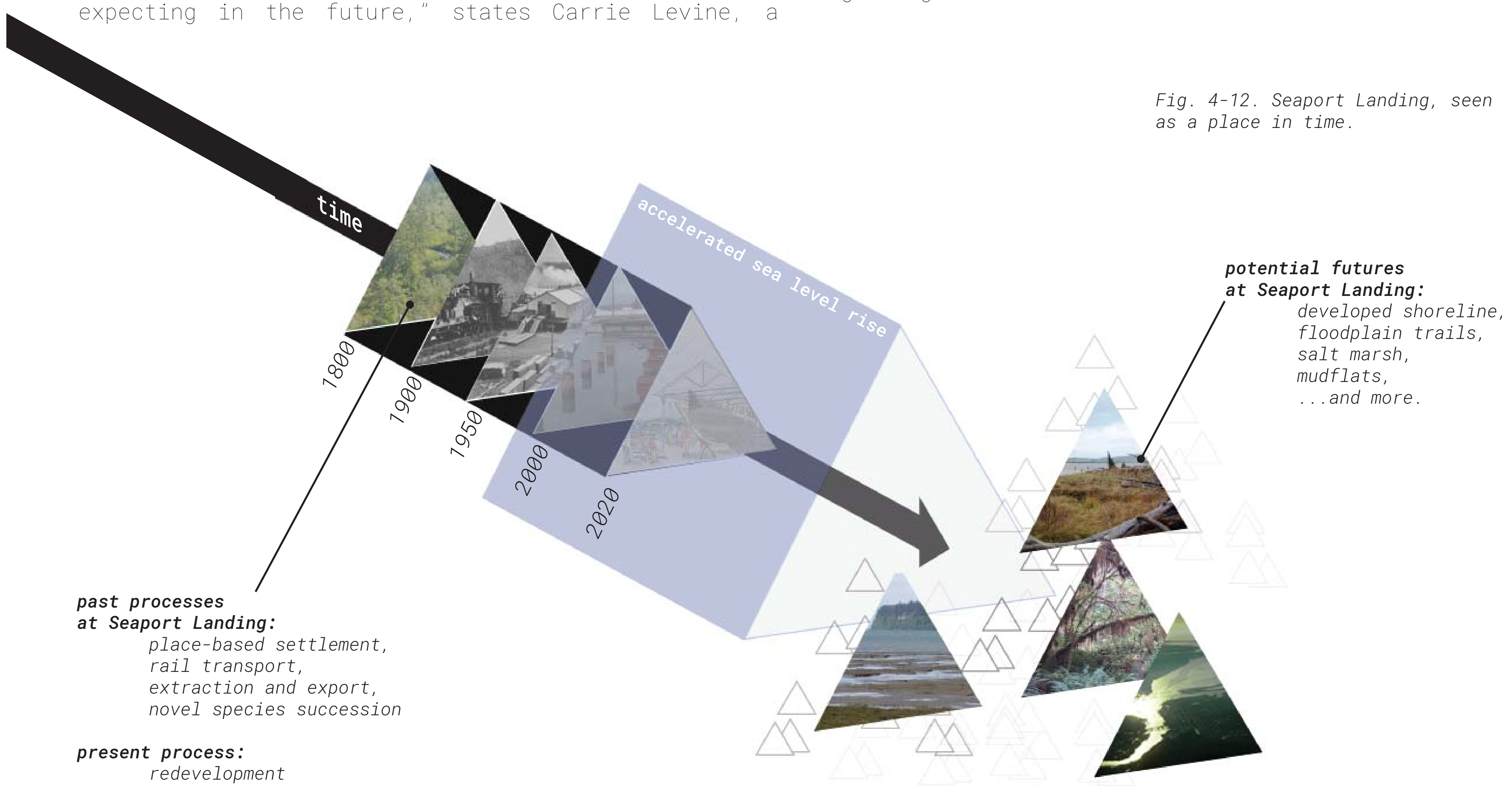


Fig. 4-12. Seaport Landing, seen as a place in time.

iii. Scaling place and time

McHarg asserts that this "beginning" of a place is geology. Geological history and phenomena are reflected in the processes of "climate, physiography, soils, plants and animals that constitute the history of the place and the basis of its intrinsic identity.[32]" In the formative 1960's book "Fluvial Processes in Geomorphology[33]," Luna Leopold — child of ecologist Aldo Leopold — reframed ecological thinking by defining the watershed or drainage basin as the basic ecological unit. This shaped the way science thought about environmental fields and ecosystem management, greatly impacting how humans shaped the modern world. This is particularly relevant in the Washington, where watershed-based Water Resource Inventory Areas (WRIAs) play a large role in development and environmental management of entire drainage basins.

Leopold considered the drainage basin to be the basic physical unit for considering how landscapes were formed — a parallel notion to McHarg's connection between geology and "place". Temporally, biotic factors such as vegetation or human development were considered insignificant in evolution of soils and landform over the past millennia (127[34]). The present geologic era of the Anthropocene, however, points to the extent to which humans have impacted the current surface and atmospheric conditions of the Earth. As Leopold's focus on watersheds was published in 1964, the concept of the Anthropocene had not yet been coined (that would come in 2000, through the work of atmospheric chemist Paul Crutzen[35]). Anthropic influences have yet to be applied widely to drainage basin-based ecology, even though humans occupy 90% of the Earth's terrestrial surface (10% developed + 80% accessible by roads[36]).

As humans living individualized lives through separate minds, we cannot help but view physiographic change at a scale that we can comprehend and see change within. In strategizing and prioritizing ecological restoration efforts, Beechie and colleagues[37] break Leopold's drainage basin into habitat (site), reach, and watershed/basin scales. These nested scales allow ecological phenomena and restoration work to be linked across scales and respond to multi-scalar events. Slow meaningful processes at these tangible scales include vegetative succession and surface changes to landforms: meandering of river channels, alluvial sediment deposition, calving of glaciers, or conversion of forests to forestry or settlement. These slow processes are the foundation for place.

In order to better approach seemingly unreachable phenomena of climate change, I propose a basic temporal unit for considering how place attachments to landscape are formed, which takes into account and contextualizes large-scale human impacts occuring within the Anthropocene - generally beginning with the Industrial Revolution and globalization[38]. This time scale — as described below in "Lost Littorals?" — is a subset of a larger glacial period, or the time between relative glacial maxima. This attention to temporal eras as related to climate and hydrology is appropriate for situating the Anthropocene in a lineage which allows for it to be approached through design intervention, as it reflects the maximum known extent of impact that humans have had to this date. While the past several hundred years of massive rapid change are hard to respond to through environmental design, this scale frames anthropogenic ecological disturbance as a multigenerational occurrence to be approached through slow processes, and as such enables a decolonizing and reinhabitating of place as advocated by Greenwood[39]. These slow processes can be linked to succession of infrastructure and shorelines in social, economic, and environmental terms.

The attention to "slow processes" as decolonizing agents can be likened to the local-centric "slow food" movement, which advocates a place-based food sovereignty via direct participation and local economic incubation in food cycles. Other even slower processes of note are found in geology, decolonizing purely due to their massive scale: conscious human attempts to affect these global processes are largely unrealized, leaving our relationship to geology to be predominantly reaction-driven. Sea level rise — though driven by human activity — occurs on this geologic scale. Response to sea level rise can employ geologic processes.

Though sea level rise models are based upon low-resolution global "top-down" approaches[40], adaptation to sea level rise can be informed by local attitudes, guided by customary approaches to water and shorelines. In the Pacific Northwest, adaptation to sea level rise is informed particularly by approaches representing the Dutch, Army Corps of Engineers, and Northwest Indian Fisheries Commission.

This diversity of approaches — particularly the presences of Native American plae-based livelihoods - has forced regional development away from a linear industrialized trajectory, tying to historic ecosystems and diverse non-European tradition through restoration, rehabilitation, and preservation of environments enacted through Treaty Rights. Here we see the productive and functional ecological impacts of honoring a diversity of attitudes to land-use, reflecting a diversity of places in time lived by a multitude of generations. Observance of Tribal Treaty Rights — and of Native cultures' considerations regardless of Eurocentric treaty obligations — is a place-based action. Simultaneously, the processes addressed by Tribal Treaty Rights are based upon multi-generational interactions between humans and other biota (salmon, particularly). This exemplifies place-based concepts of multi-generational interaction, engagement with natural history, and connection with aquatic ecology as put forward by Cooper-Marcus, Pyle, and Blackstock (informed by First Nations Elders), respectively.

A focus on processes can inform understandings of place. However, Halprins' focus on process lacks grounding in place, evidenced by his focus on Sierra Nevada landforms for his design at Portland's Keller Fountain Park[41], located in the dramatically different physiography of the Cascade Range. Similarly, McHarg's focus on geology as an underpinning for place focuses little on the processes of this condition, giving more attention to the specific elements of the present tense. How can process-based change over time integrate with McHarg's layering of site conditions?

Blackley (1982[42]) incorporates time with landscape, describing forest succession in the foothills of North Carolina, South Carolina, and Georgia. This analysis of place-based succession is done in a tripartite manner analogous to the social-environmental-economic framework of "place" as described above, with an emphasis on process. Blackley describes succession as biotic community, its geologically-influenced environment, and their development over time.

This informs a process-based place meaning, as it emphasizes that ecological conditions are relative to processes over time. ____ discusses the evolution of port cities' shorelines, classifying their development into specific yet variable phases comparable to the seral states of ecological succession.

Here we connect development and economy, as management of place over time. Management of environments influences succession of environments, giving weight to analysis of historical ecology and the economic processes which shaped this ecology. By looking at landform changes over time, we tap into trajectories of place that can inform place-based design.

b. Lost littorals? Process at Seaport Landing

Through the above analysis, I have explained place as a localized concept which is built on environmental processes. These environmental processes develop over multigenerational time scales and inform local social and economic dynamics in a manner which — when acknowledged as a local rather than global phenomenon — can connect ecosystems and people.

In Grays Harbor, place is determined by the relationships between land and water: sediment flows, tidal regimes, flood cycles, and riparian function. These processes built this place, and are inextricable from historic sea level changes. Since the timber-driven industrialization of local shorelines, humans have inserted themselves into these processes to a large degree by filling, armoring, and otherwise altering shorelines. As local place-meanings are built off of these socio-ecological relationships, historic activity across and along shorelines symbolized at Seaport Landing provide a direction for place-based design intervention. The following historical narrative finds that landform changes shoreline morphological change is a continual formative process for the greater Seaport Landing area.

The estuary's shorelines historically hosted Native American settlements, and these waters remain an ecologically important site for fishing operations. Building off of opportunistic location at the confluence of Grays Harbor and the Chehalis River, Aberdeen functioned as an epicenter of the Pacific Northwest's logging industry through the 20th century, prompting the filling of miles of shoreline mudflats for development of industrial sites. As much industry has left Aberdeen, flood-prone communities are now separated from Grays Harbor by underutilized industrial sites.

Fig. 4-13. Tidelands at Seaport Landing's pocket beach, comprised of rubble and novel vegetation communities.

i. Making Grays Harbor

Sea level rise is a long-lasting global phenomenon, impacting various localities differently even though it occurs at a scale seemingly untouchable through local action. As an element of a grander climate change, sea level rise is a localized, place-based occurrence at the same time that it is a global-scale intangible thing. Climate change affects the entire planet, yet any individual is unable to personally affect it due to its immense geographic and temporal scales. Philosopher Timothy Morton describes such multi-scalar phenomena as "hyperobjects"[43], all-affecting elements symbolizing the Anthropocene. But what would Wendell Berry say, he who advised that global thinking is only done through "simplifications too extreme and oppressive to merit the name of thought"? If sea level rise is a global phenomenon, local response has opportunity to take cues from a broad history of environmental place-shaping so as to minimize loss of identity. In other words, resilience is supported by attention to historical underpinnings of place which predate the "placelessness[44]" of globalization.

The most recent episodes of sea level rise and accompanying habitat shifts began approximately 19,000 years before the present as the most recent glacial maximum began to recede. Meltwaters and massive floods caused periodic jumps in ocean elevation, as the sea level then was approximately 120m (393ft) lower than at present[45]. During this time, glacial outwash from the receding Puget Lobe of the Vashon Stade drained south to the Pacific Ocean along the path of the present-day Chehalis River. This flow of meltwater carried massive amounts of glacial gravel to Grays Harbor, passing through the "Chehalis Gap" at the Black Hills near present-day Olympia, between the Olympic Mountains (to the north) and the Willapa Hills (to the south). Glacial sediments were transported to the unglaciated Grays Harbor area, contributing to the floodplains of the lower Chehalis River [46] (Fig. 4-15).

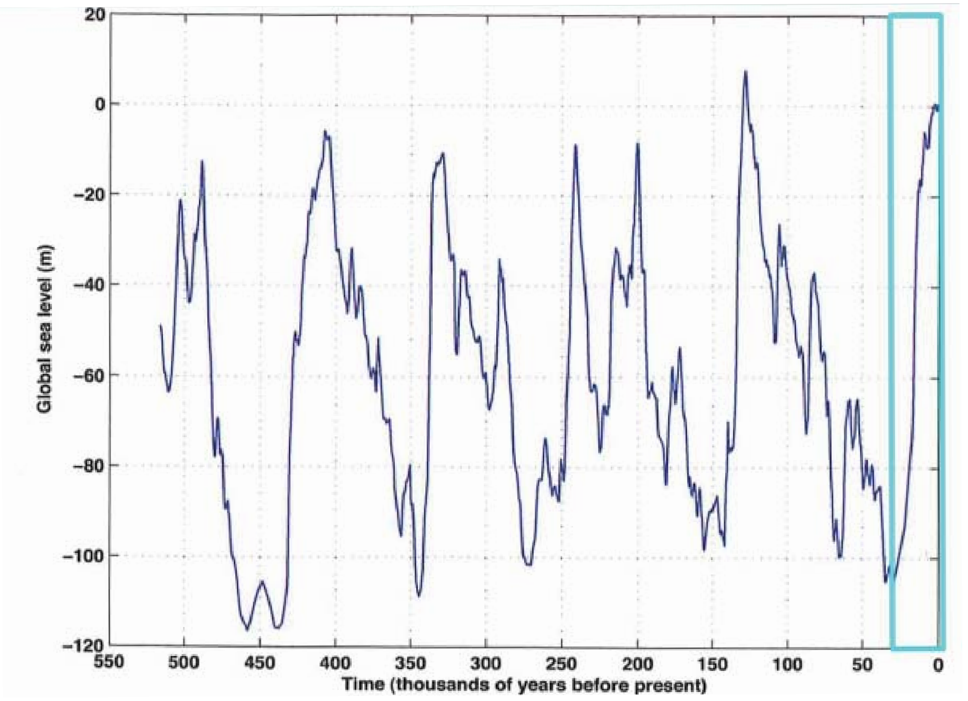


Fig. 4-14. Sea level has ebbed and flowed over millenia, though written records only exist for the most recent phase of rising tides (image: Ducks Unlimited)

lower Chehalis River valley, floodplains formed by glacio-fluvial sediment movement:

Fraser glaciation
+
Chehalis Gap outflow
+
Chehalis River

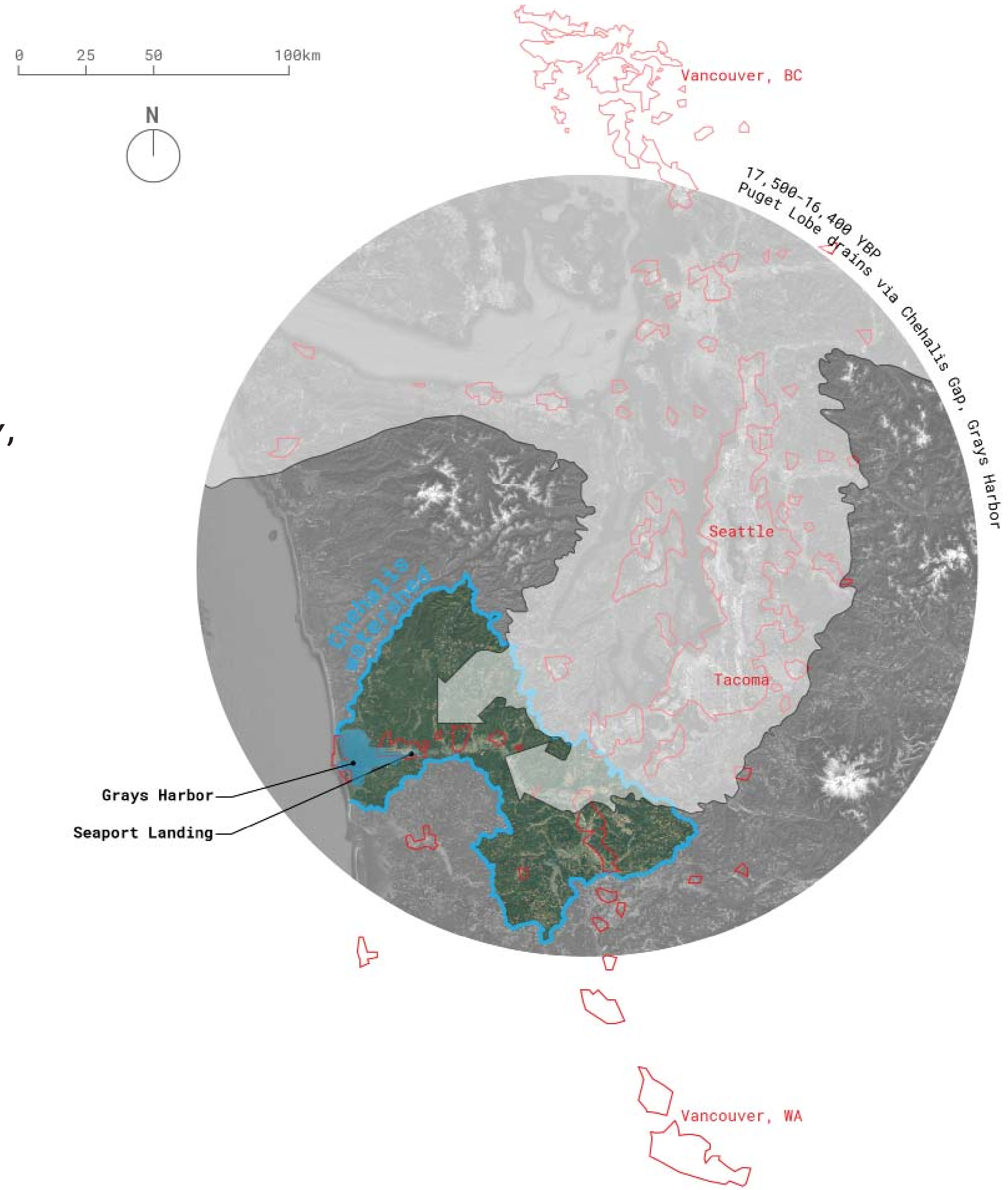


Fig. 4-15. Glacial melt brought upland sediments to Grays Harbor as sea level rose to create this drowned river valley estuary.

As glacial melt reached a sort of equilibrium around 6,000 YBP, sea levels came to their general present elevation[47]. This latest large rise in sea level pushed marine waters up and into coastal freshwater river valleys world-wide, forming drowned river valley estuaries such as Grays Harbor[48]. Sea level rise led to deposition of material atop the sand, silt, and gravel of the ancestral Chehalis River, hosting tidal marshes for approximately 1,000 years. Later episodes of sea level rise converted these marshes to mudflats, depositing sand and mud[49] atop which the sinuous channels of today's Chehalis River surge plain ebb and flow[50]. As sea level crept upward into the Chehalis River valley, habitats were inundated, vegetation was killed by salt water inundation, and wetland ecosystems migrated upland toward satisfactory environments – relatively where they are today.

The bar-built embayment that we now call Grays Harbor was once open to the ocean. Sediments from the Columbia River are brought north from the Columbia River by littoral drift, replenishing the outer beaches and dunes of Grays Harbor[51] (Fig. 4-16). This sediment transport merged with material-laden flows of the lower Chehalis River as fresh water and salt water mixed in the estuary. As these waters mixed, they slowed and sediment dropped from the water column - creating mudflats, bars, islands, and other landforms.

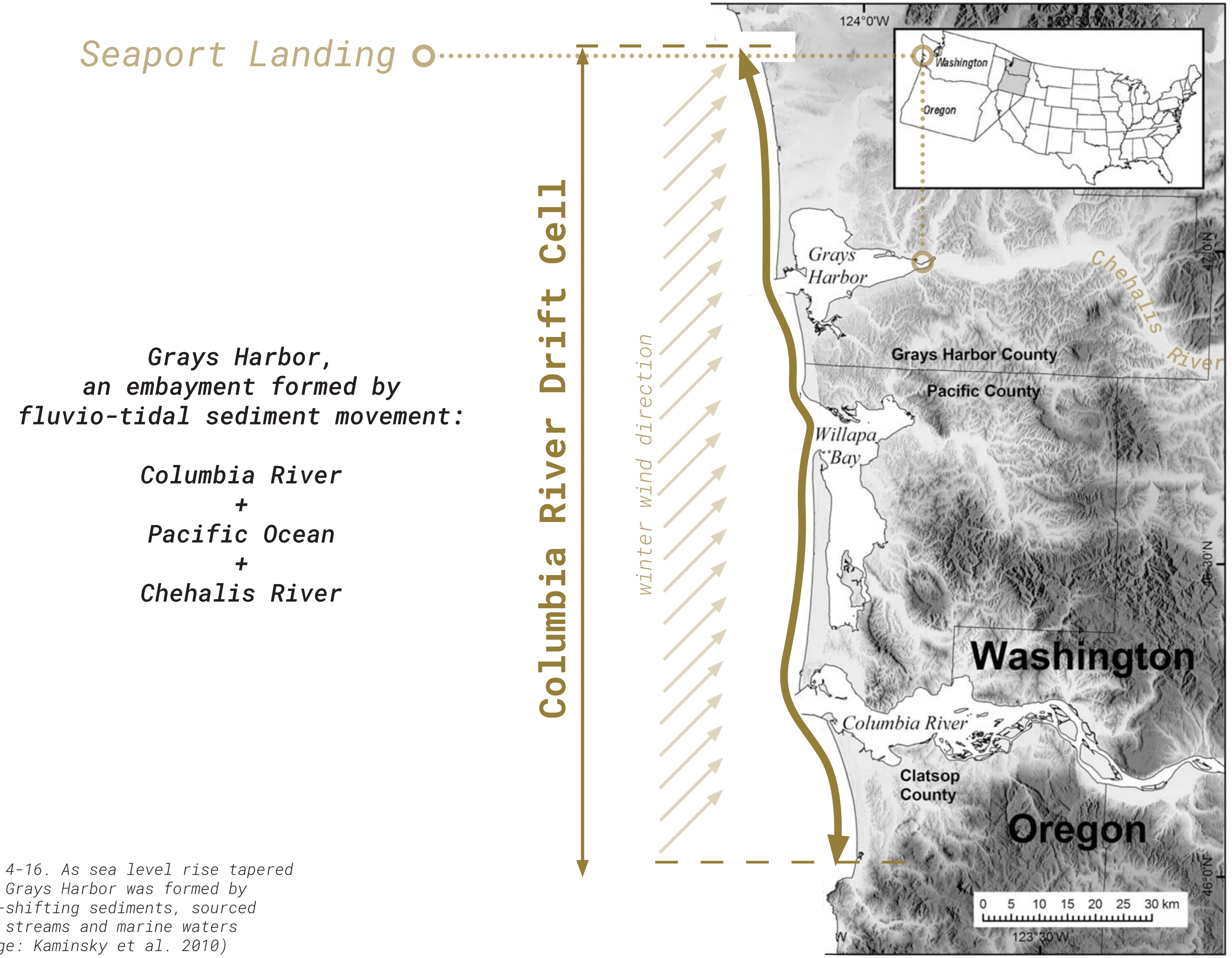


Fig. 4-16. As sea level rise tapered off, Grays Harbor was formed by ever-shifting sediments, sourced from streams and marine waters (image: Kaminsky et al. 2010)

During times of lowered sea level — approximately 18,000 years ago, most recently[52] - the Bering land bridge allowed humans and various other biota to cross between continents. Some of these migrating peoples' descendants eventually came to settle present-day Grays Harbor. Pre-European lifestyles here exhibited close connections to the water, with shellfish and salmon as major food sources. The dense forests of the area provided wood supply which fueled extremely skilled woodworking[53]. Among other uses, local western red cedar trees (*Thuja plicata*) were the primary component for longhouse construction, which reflected deep connections with water through an open doorway facing the water to collect salmon and other bounty[54].

While European smallpox took a devastating toll on these settlements[55], descendants of these lower Chehalis River and Grays Harbor Native Americans are members of today's Quinault Indian Nation, Confederated Tribes of the Chehalis, and the Shoalwater Bay Tribe[56]. As discussed by Billy Frank Jr. of the Northwest Indian Fisheries Commission[57], lifestyles then and now are place-based, relying upon and interlinked with ecological dynamics, locality, and seasonal cycles.

Prior to the arrival of Europeans, industrialized forestry, and dense settlement, the environment of inner Grays Harbor was markedly different than today. Shorelines were unarmored, floodplains were connected to stream channels, and dense old-growth riparian forest stands of spruce and cedar could be found throughout the lower Chehalis River's shorelines. Botanist William Dunlop Brackenridge traveled down the lower Chehalis River to Grays Harbor in 1842, documenting much vegetation. His vegetation documentation[58] - combined with that from David Douglas' 1832 trip[59] - informs Figure 4-17. The lands which now hold Hoquiam and Aberdeen were described as a mix of dense forests with near-impenetrable undergrowth, steep-banked tideland with broad mudflats, swampy forests just inland of shores, and meadowlands.

As we once again encounter rapid sea level rise today, this phenomena is viewed as a disaster. Of particular concern in Grays Harbor is the loss of estuarine habitat for shorebirds and salmonids, as well as the impact that these habitat shifts will have upon humans. As sea level rise has risen for thousands of years, ecosystems have adapted by moving upland[60]. Intact and connected wildlands allowed for this migration to occur, in contrast with today's coastal squeeze due to hardened and developed shorelines.

Fig. 4-17, Shorelines before globalization. Settlements of the Lower Chehalis people along Grays Harbor when Europeans arrived, mapped onto an approximation of the historical shorelines and land cover. Seaport Landing sits adjacent to a village documented in 1841 by botanist William Dunlop Brackenridge. Names at top and bottom represent villages along north and south shores of Grays Harbor, respectively. Hokamits was a village displaced by present-day Hoquiam. (data: Brackenridge journals, 1842; Douglas journals, 1825; Hodge 1912)

ii. Globalizing Grays Harbor

Fig. 4-18 (below, opposite page). Railroads, timber production, and alterations to lower Chehalis River riparian zone. (images: Newreels of CD Anderson, Youtube; Washington DNR; data: Aberdeen History Museum)

Greenwood's contextualization of "place" as both counter to and within an atmosphere of globalization (above, "How do you define place?") connects strongly to Aberdeen, as local shorelines have been almost entirely developed for globalized industrial processes – notably timber processing and export. Throughout the 1900s, the shorelines of Aberdeen and Hoquiam were immersed within global trade. Sitka spruce forests fueled boat building, plane manufacturing, and timber processing economies, leading lumber shipments from Grays Harbor to outperform all other global coastal ports in 1927[61]. Globalized resource extraction is symbolized by the vast amount of dredging which has occurred in this muddy bay, as over 11% of tidelands were filled between 1940 and 1976 alone, though dredging operations have ran continuously since 1905[62]. Dredge disposal industrial waste met as sawdust and sandy silts were used to fill in shorelines for further industry. As sea level rise encroaches upon the basin, abandoned and underutilized shoreline sites reflect past landmaking practices, recent economic shifts, and future potential for development. Seaport Landing is one of these sites.

Aberdeen's prevalent industrial shoreline typology has evolved in connection to the entire basin, in contrast with site-by-site parcelized development of the present. These industrial shorelines are characterized filled tidelands, impervious surfacing, and higher elevations relative to the inland town. Initial industrial growth flourished in the late 1800's as the Northern Pacific Railroad came to Aberdeen in 1895[63]. The construction of railroads along shorelines facilitated the movement of logs to sawmills, as well as the deposition of logs into rivers in order to carry them downstream. Shoreline railroad lines functioned as levees, expanding the reach of extractive timber harvest while also disconnecting river channels from floodplains, producing land which could then be settled (Fig. 4-19). The impact of railroads on the region's riparian zones is further explored in Blanton and Marcus' "Transportation infrastructure, river confinement, and impacts on floodplain and channel habitat, Yakima and Chehalis rivers, Washington, U.S.A.[64]", adapted to design goals for Seaport Landing here in Chapter 5. Upstream of Aberdeen, today's Chehalis River Surge Plain Natural Area Preserve remains largely unlogged due to its challenging swampy terrain.

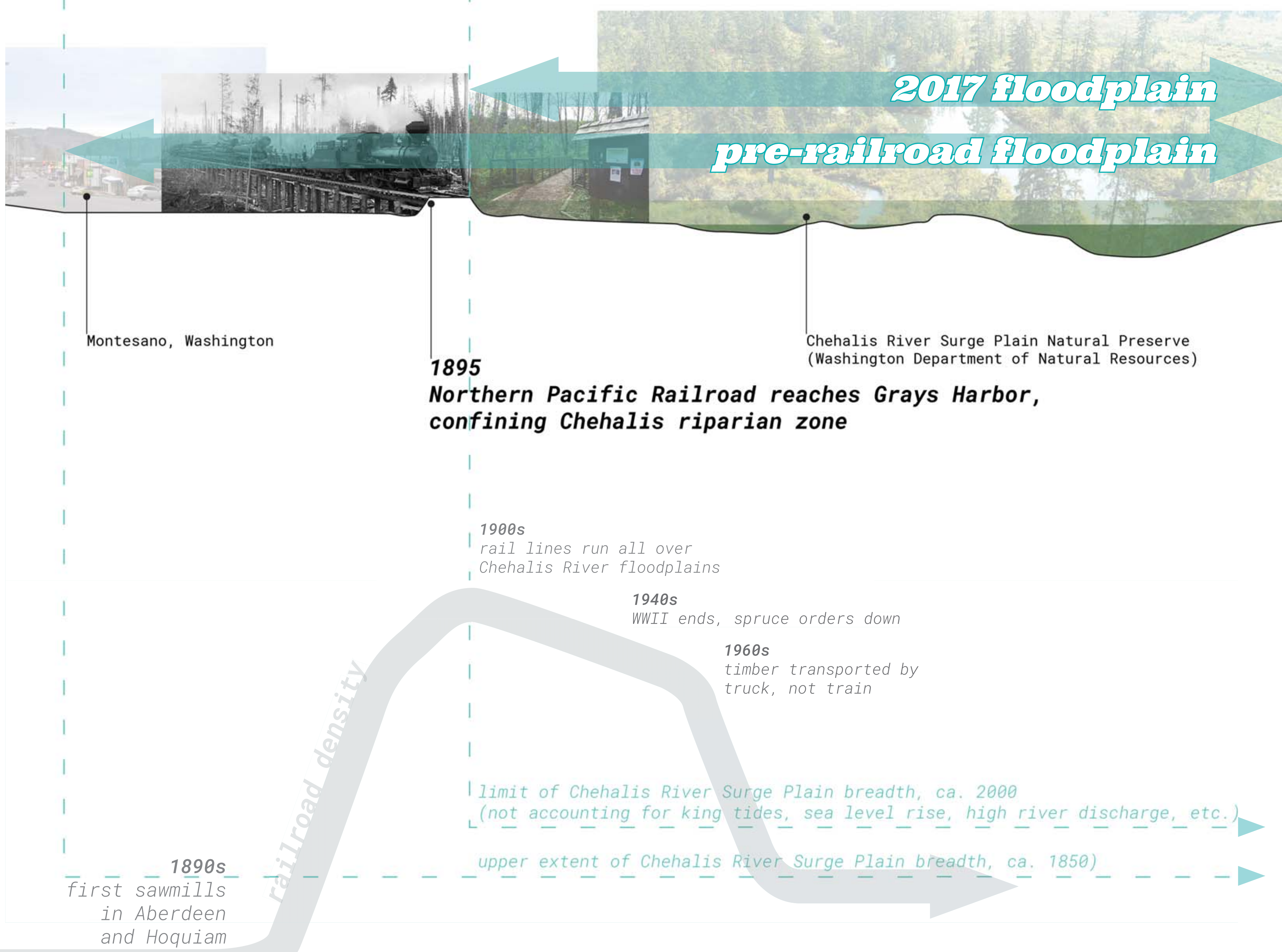
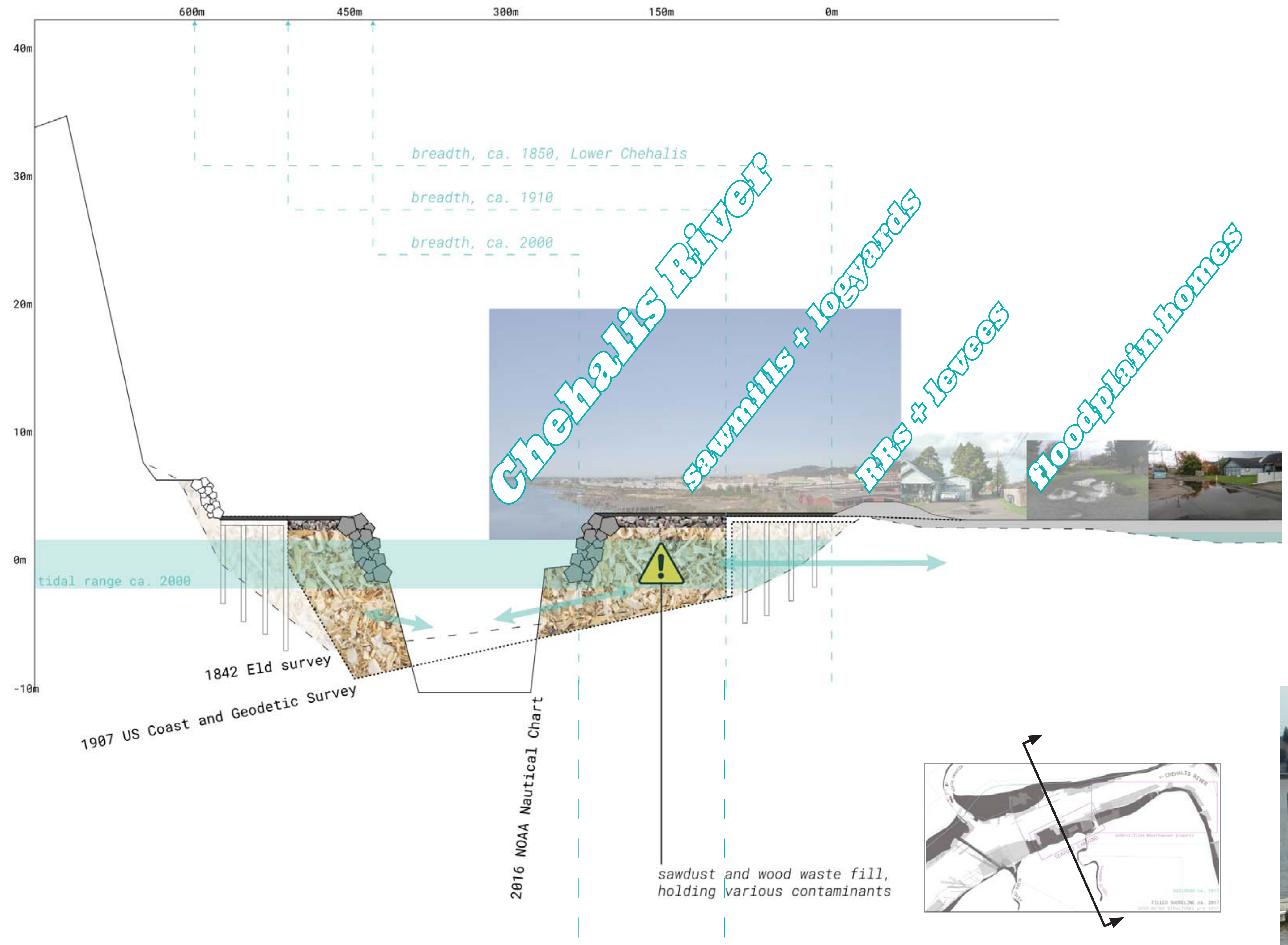


Fig . 4-19. Land use highlights historic mudflats and floodplains of the lower Chehalis River. (background image: Google Earth; data: Sanborn Fire Insurance maps; General Land Ordinance Plat Maps; NOAA)

Ecological processes in the Chehalis River Surge Plain have been restored incrementally through land acquisitions, shoreline restorations, and construction of estuarine sloughs. Figure 4-19 shows how rail and roadway infrastructure confine the river, especially in developed areas. At Seaport Landing, these same corridors delineate the inland edges of industry, as tidelands have been filled to expand industrial lands.



As shoreline sawmills proliferated through Grays Harbor, the footprints of town and mill alike were expanded by the filling of tidal lands. This process was interlinked to industrial waste cycles in a fashion analogous to the alluvial erosion and deposition cycles which previously built these shorelines: Trees harvested (eroded) from higher elevations were brought downstream by rail or raft, where they were processed (deposited) at sawmills. Ensuing wood waste such as bark, sawdust, and scrap was used to fill tidelands and create additional land (accretion).

Railroads, the Shafer Brothers Lumber and Shingle Company, and Weyerhaeuser all built out the land that is present-day Seaport Landing, using various materials available to add to centuries of deposition. Other materials were used for fill as well, including cinders, gravel, sand, and brick - documented in the Army Corps of Engineers' 1975 Feasibility Report on Flood Control[65].. Over the years, toxic chemicals and other contaminants found their way into this subsurface mix (Fig. 4-20).

Fig. 4-20. Land-making and river-shrinking. (data: Sanborn Fire Insurance maps, EMCON, historic photographs)

Fig. 4-21 (below). Social shorelines: mudflats, docks, and diners in South Bend, WA.

Contrasting with the drainage-based land reclamation projects of Holland and England's Fens, this ***landmaking*** (Seasholes[66]) practice actively covered waterscapes with land, erasing all evident historical context. This created functional space through movement and manipulation of substrate — alongside practices of land reclamation, filling, and cutting — and could be seen as a vernacular form of the then-nascent Landscape Architecture profession. An 1890 visitor to Hoquiam remarked that the town was built on "a low flat filled with sawdust", which was seen as a desirable action to address the "horrid mud flats" exposed during low tide[67]. Around this same time, a similar approach was used by Frederick Law Olmsted at Boston's Back Bay Fens, where tidal flats were filled and tidal regimes controlled in order to create a public tidal park devoid of mudflats[68].

Just south of Grays Harbor, the town of South Bend sits along the WIllapa River as it meets Willapa Bay. This location is comparable to Aberdeen's position at the mouth of the Chehalis River. South Bend, however, did not fill and harden tidelands. Today, this shoreline supports public docks, restaurants, parks, and other local amenities which coexist with mudflats to residents' benefit (Fig. 4-21).

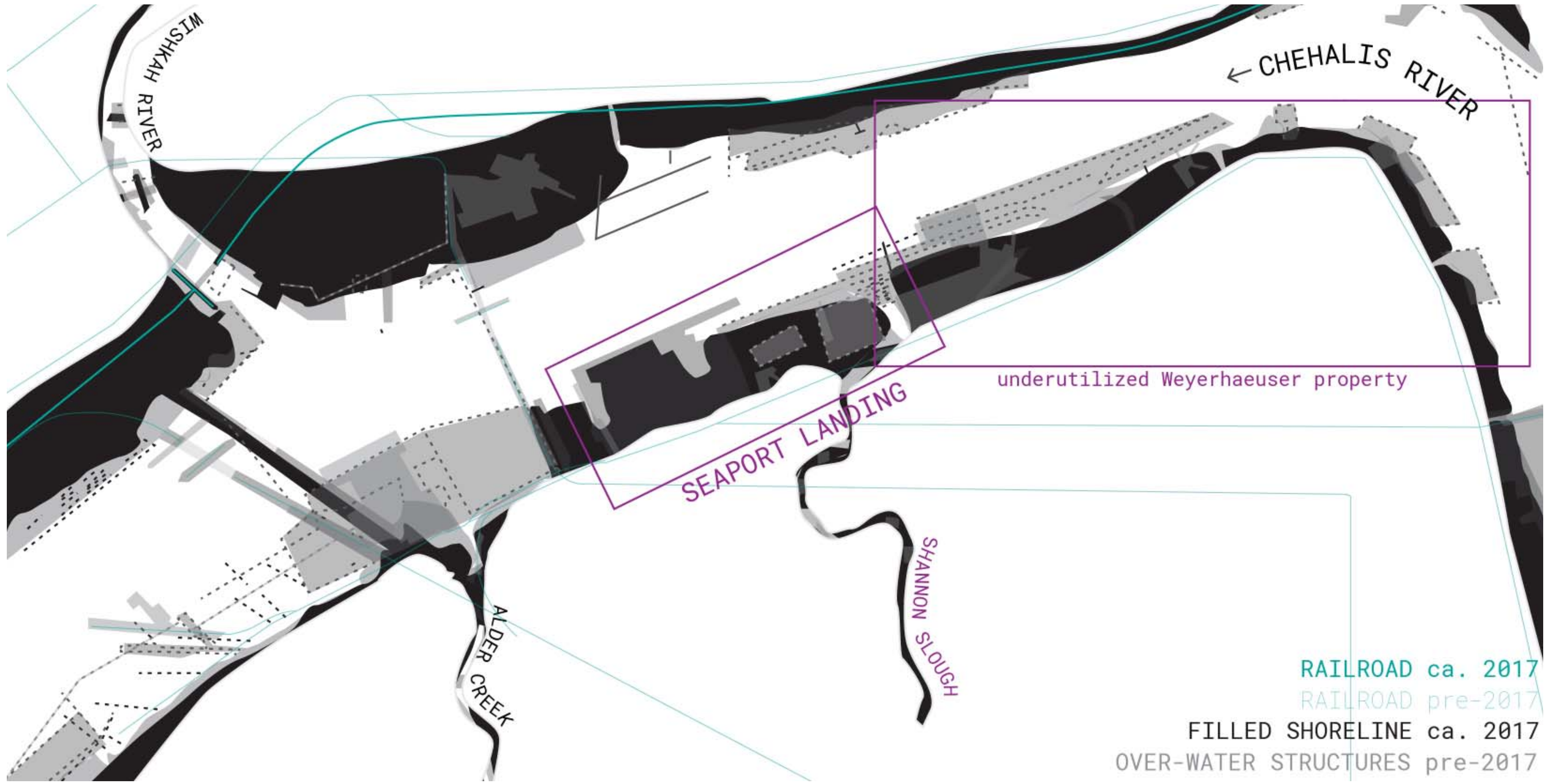


Fig. 4-22. Shifting shorelines of the lower Chehalis River show ever-changing industrial development and a progression away from rail-based material movement. (data: Sanborn Fire Insurance maps, EMCON, historic photographs)

By overlaying historic maps of the Chehalis River reach which encompasses Seaport Landing, we see former railroad paths which hint at pre-industrial shorelines. Comparison to present-day shoreline conditions exposes just how much the Chehalis River has been confined by development and land-making.

In the latter half of the 20th century, this timber-dependent economy began to decline. Causes of this are debatable, with fingers pointed toward industrial restructuring for greater efficiency (and therefore less jobs), effects of long-term over-harvest of timber (paired with more productive forests in Canada, China, and the southeastern United States), and – perhaps most controversially - regulation of timber harvest in order to preserve Northern Spotted Owl habitat. Most telling is the coincidental increase in timber production and 49% unemployment increase during the 1980s, pointing to industrial restructuring as a primary reason for regional economic strife[69].

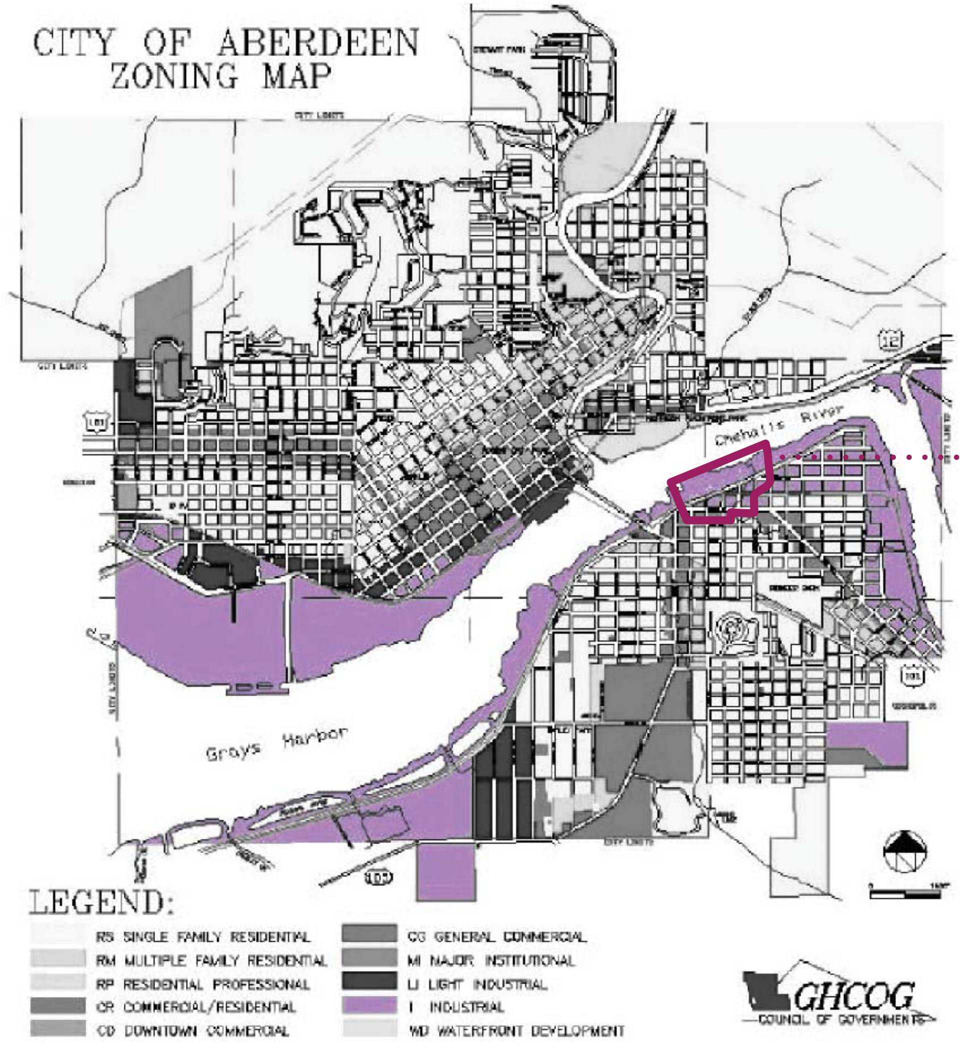
Little discussion, however, is given to changes in the transportation methods during this time. The combined use of waterways and railroads brought industrial connectivity and profits to the shorelines of Aberdeen. In the mid-1960s, logs instead began being brought by truck to Weyerhaeuser's sawmill at present day Seaport Landing. This reflected changes in logging sites' proximities to streams[70], and lessened the need for railroads along the shorelines of Grays Harbor and its tributaries.

These industrial sites are almost all protected by rip-rap with little shoreline vegetation present, disconnecting aquatic-terrestrial connectivity and riparian function. While ecological dynamics of the estuary were sacrificed for industrial development, these shorelines continued to shift through social and economic activity. The 1900s held an abundance of mill openings, closings, fires, booms, and recessions.

Seaport Landing's history as a timber mill goes back to the time just before 1900, when logs were floated downstream to the site and tied up along pilings pending processing. In 1924, the Shafer Brothers Lumber and Shingle Company acquired the property, building a shingle and lathe mill over the tidelands[71]. This was an initial step in landmaking through the deposition of industrial waste.

In 1955, Weyerhaeuser Company acquired the site[72], referring to it as the "Aberdeen Mill and Sorting Yard Site." At this time, the complex included the adjacent upstream property – today still owned by Weyerhaeuser – which was predominantly used as a sorting yard. Seaport Landing held most of the mill facilities. Fig XX shows historic shoreline changes at Seaport Landing. Of particular interest is the landmaking which extended Shannon Slough approximately 350m (1148ft) via a series of channels and culverts. During Weyerhaeuser's 1955-2013 ownership of present-day Seaport Landing, several contaminant releases were documented, most notably a pentachlorophenol (PCP) spill, paint waste disposal in Shannon Slough, and diesel fuel spills[73] (discussed in the next section).

As the economic footprint of the timber industry lessened in the region, shoreline sawmill sites of Aberdeen and Hoquiam were abandoned or converted to other uses. The relevance of these shorelines for commerce remained, and todays zoning layouts reflect the historical deregulated use of shorelines for industry (Fig. 4-23). Aberdeen's industrialized shorelines provide little room for public access to Grays Harbor's waters, and define habitat characteristics here. Of the town's 11 miles of shoreline, industrial land use is only notably broken by a Walmart complex, a Rotary Club pavilion, and a boat launch owned by the Port of Grays Harbor. The Walmart and Rotary Club pavilion lie just across the Chehalis River from Seaport Landing.



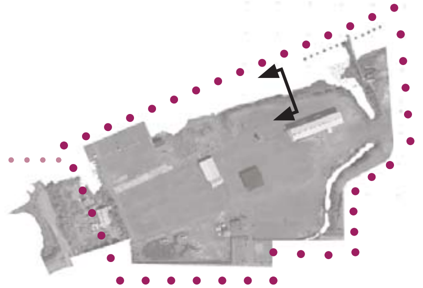
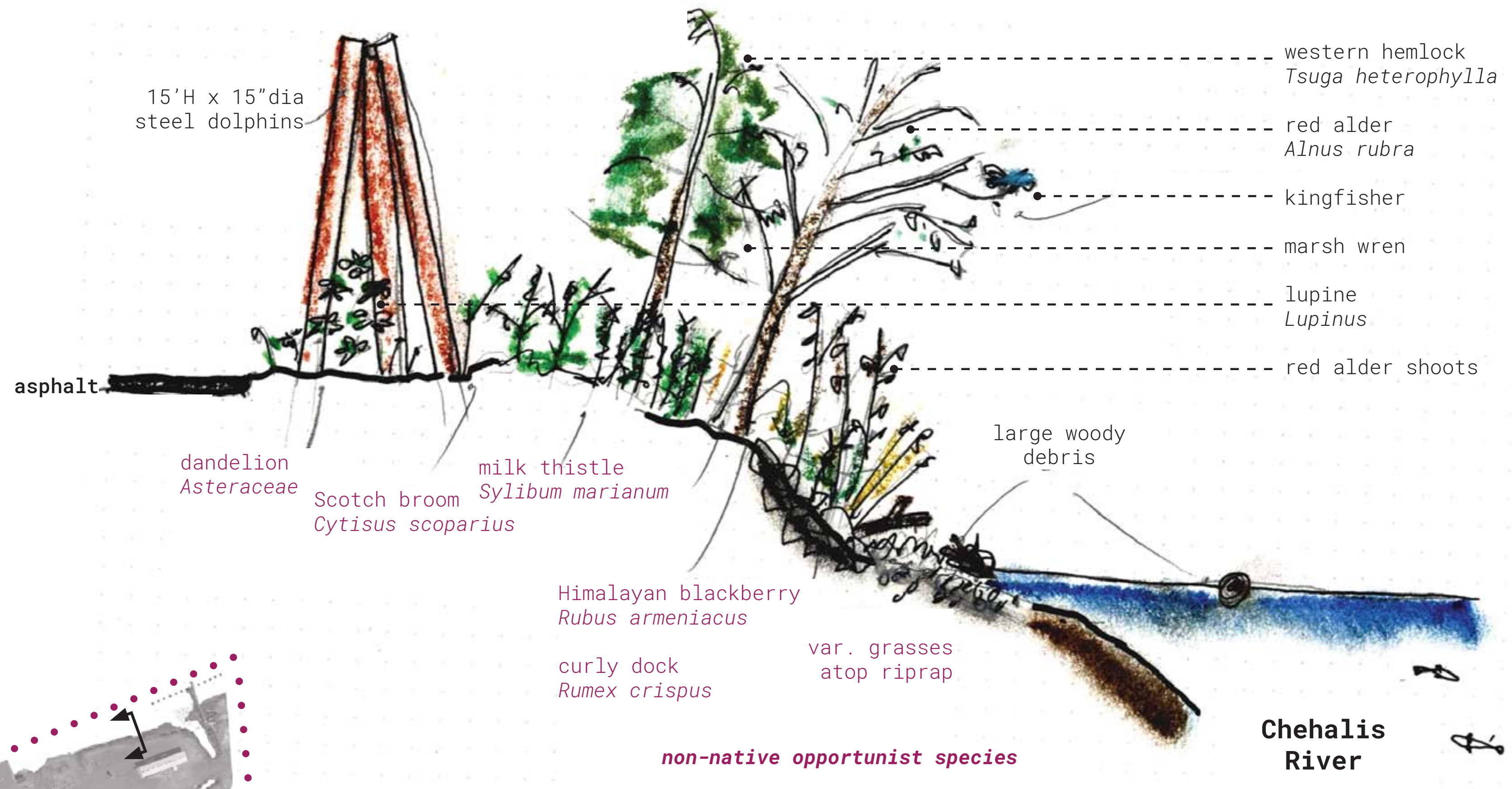


Fig. 4-23. Industrial zoning in Aberdeen is a holdover from earlier deregulated industrial growth along the estuary's shorelines. (image: City of Aberdeen)

Fig. 4-24 (opposite). Typical novel vegetation community of riprapped industrial shorelines along Grays Harbor, a mixture of early seral colonizers and native plantings.



The previously mentioned forest and wetlands on the batture (riverside slope) of the South Aberdeen levee function as public space, however this area was once used for industry as well. The Rotary Club pavilion similarly hosts a beach with little armoring. Vegetation communities along industrialized and developed shorelines neither exhibit historic characteristics nor provide the same habitat value as they once did, made up of novel species assemblages (Fig. 4-24).

Higgs (2016[74]) classifies ecosystems as native, novel, and designed. Designed ecosystems serve human ends and require human input, while novel systems are self-sustaining and do not require anthropic assistance. Miller and Bestelmeyer (2016[75]) add that novel ecosystems have crossed a threshold where "restoration is, at best, unlikely." The substrates of Seaport Landing and other local shorelines are amenable to novel communities with large proportions of invasive species, however inundation from sea level rise provides a disturbance which has potential to open up these settings for alternative futures.

Fig. 4-25. Abandoned and underutilized industrial sites of Aberdeen and Hoquiam, bookended by valuable habitat threatened by sea level rise.

Seaport Landing will be the first major development to alter this shoreline trajectory. Grays harbor Historical Seaport Authority is in a precedent-setting role, with potential for impact at the reach scale, influencing the futures of Aberdeen and Hoquiam's typologically similar shoreline sites (Fig. 4-25).

iii. Plans for Seaport Landing

Fig. 4-26. Seaport Landing's Spar Shop at the mouth of Shannon Slough. (image: GHHSA)

Grays Harbor Historical Seaport Authority plans to redevelop a former Weyerhaeuser sawmill built atop filled tidelands as "Seaport Landing." While the present ongoing work at Seaport Landing is geared toward "place-based education," it does so through a focus on social and economic systems rather than environmental processes. Initial work targets contaminated substrates, but the project's nascent design does not acknowledge the importance of sediment transport and deposition to the history of the site and the inner Grays Harbor estuary.

In 2013, the Grays Harbor Historical Seaport Authority (GHHSA) purchased a former Weyerhaeuser sawmill located along the lower Chehalis River as it merges with Grays Harbor estuary in Aberdeen, Washington. Based on community input, GHHSA is developing the site into a mixed-use facility hosting boatbuilding, place-based science and maritime education, and a public waterfront[76]. GHHSA's mission is "to provide educational, vocational, recreational, and ambassadorial activities and experiences that promote and preserve the maritime history of Grays Harbor and the Pacific Northwest while serving the needs of its community."[77]

GHHSA seeks to "create a vibrant, mixed-use, working waterfront that will embrace and reflect the rich history and character of Grays Harbor and the Olympic Peninsula. The site will blend diverse businesses with arts, heritage, recreation, and dynamic education opportunities that will engage the community and attract visitors. Furthermore, South Waterfront redevelopment will serve as the homeport for the Lady Washington and Hawaiian Chieftain (historic tall ships representing early exploration of the Washington coast), and will provide public waterfront access and public boating facilities.[78]" Flood-gated and ecologically degraded Shannon Slough flows through Seaport Landing, while the inland edge of the site holds a flood wall which protects South Aberdeen. Shannon Slough is the target of planned interpretive trails.

This supplements the organization's existing programming, which focuses around maritime history. The Lady Washington and Hawaiian Chieftain annually travel the California, Oregon, Washington, and British Columbia coast[79], hosting dockside tours, daytime sails, and longer excursions. These trips emphasize wooden boat operations and maintenance with a budding focus on maritime science education geared towards school groups[80].

This is a particularly significant development proposal for Aberdeen's 11 miles of shoreline, as Seaport Landing would host the first public waterfront park, first public moorage, first public fishing pier, and first public landing for canoes or kayaks in Aberdeen[81]. Much industry has left the region, leaving high-unemployment-laden flood-prone communities separated from Grays Harbor by abandoned industrial sites. Seaport Landing would be the first chink in this industrial armor, connecting residents to the lower Chehalis River.

Seaport Landing can provide more than public amenities: GHHSA hopes for the site to provide new options for the local economy through maritime-focused woodworking and tapping into the tourist economy. While Aberdeen is made up of approximately 16,000 people, around 5,000,000 tourists pass through the area annually – many on Highway 101 to the Olympic National Park.

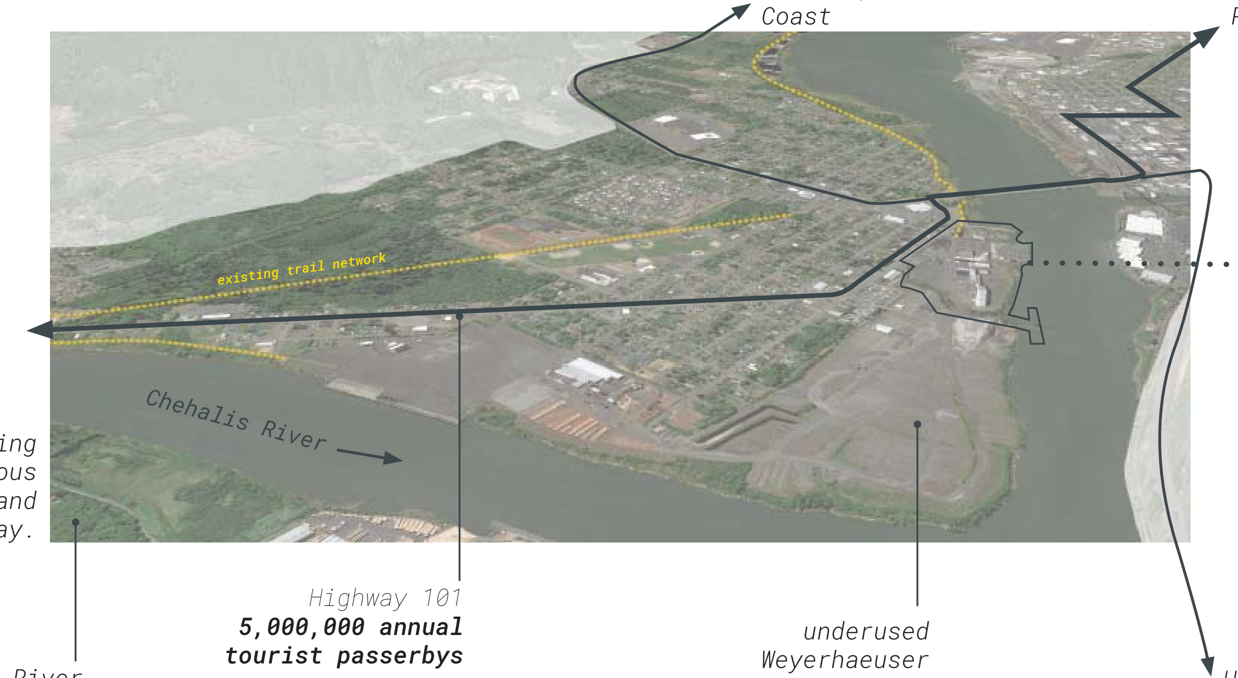
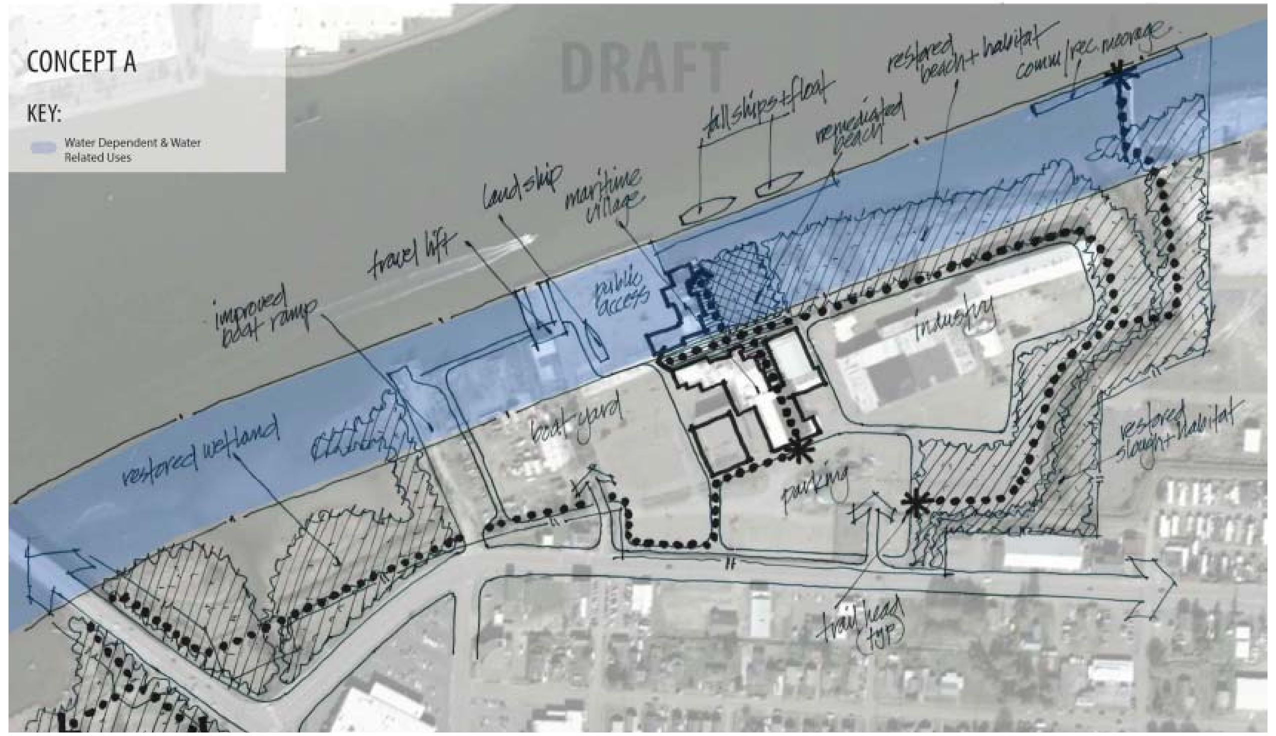


Fig. 4-27. Seaport Landing sits at an advantageous location, between river and highway.

Much of Seaport Landing is built upon filled tidelands, largely made up of contaminated wood waste. As the largest brownfield-to-public land use conversion in Washington Department of Ecology history[82], current activity at Seaport Landing involves assessing the degree of contamination in the site's substrates. Beyond this step, little acknowledgement of the site's narrative is evident.

Seaport Landing's plans are promising as they target social, economic, and environmental dynamics through a multifaceted working waterfront. Shoreline redevelopment plans at Seaport Landing have already acknowledged opportunity to improve habitat, noting planned restoration work along the beach and Shannon Slough. However, these "restoration" plans only slightly improve riparian habitat according to metrics discussed in Chapter 3, and do little to alter the channelized condition of Shannon Slough (Figs. 4-28, 4-29).

Sea level rise is not factored into existing plans for Seaport Landing. This has potential to impact the site adversely through structural damage, loss of functionality, and destruction of planned habitat restoration along Shannon Slough in the long run. A place-based design has opportunity to further engage human and non-human populations alike through sea level rise resilience, embracing the site's histories of landform change in order to provide future habitat and productive public space.



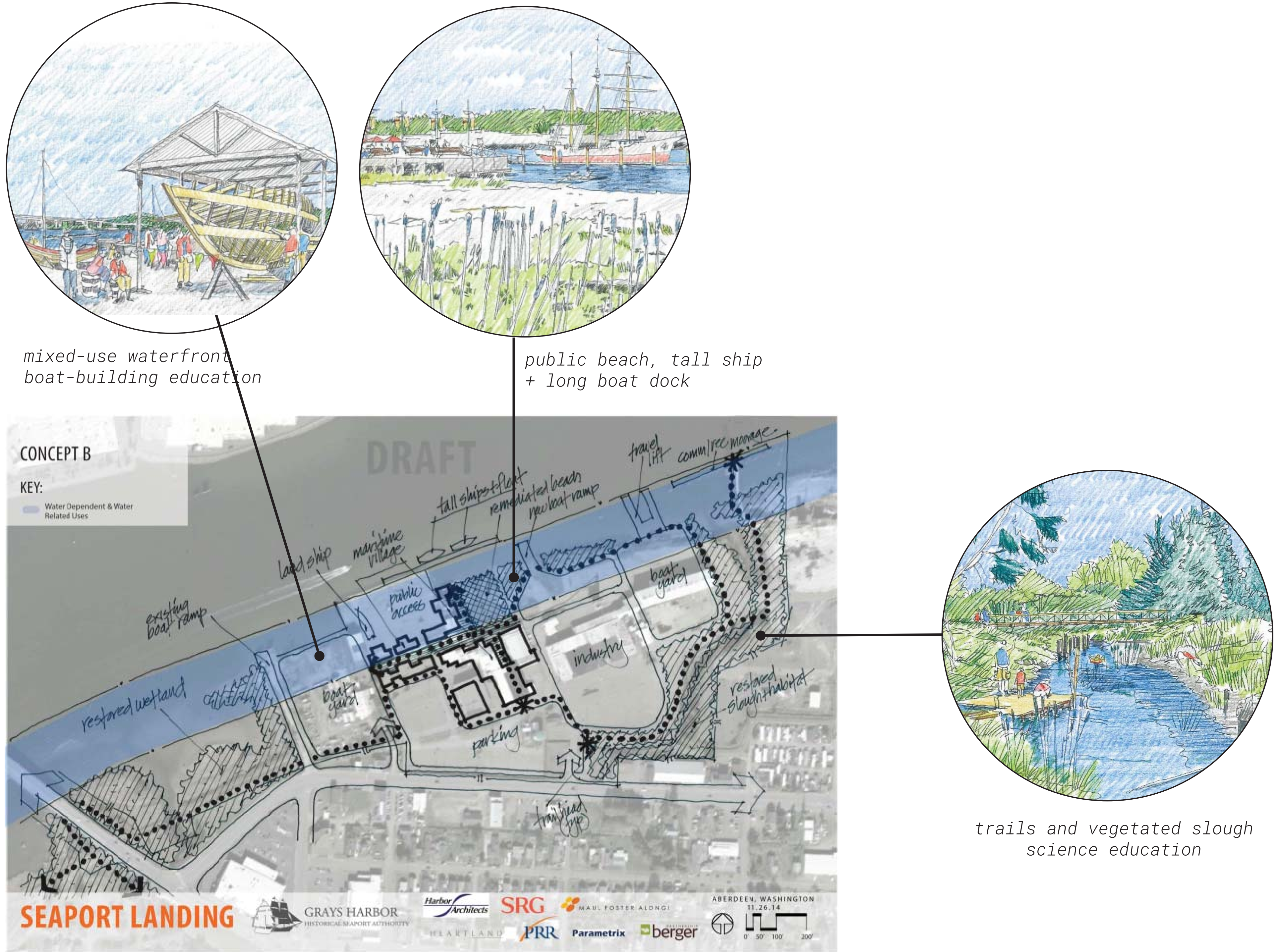


Fig. 4-28, 4-29. Early design schemes for Seaport Landing begin to reconnect the site with aquatic ecosystems, without digging below the surface. (images: GHHSA)

iv: Processes at Seaport Landing

Aquatic ecology and landform changes are fundamental elements of place. These processes are also pressing environmental planning considerations at Seaport Landing, embodied onsite through shoreline conditions, drainage, and sediment management.

1. Shorelines

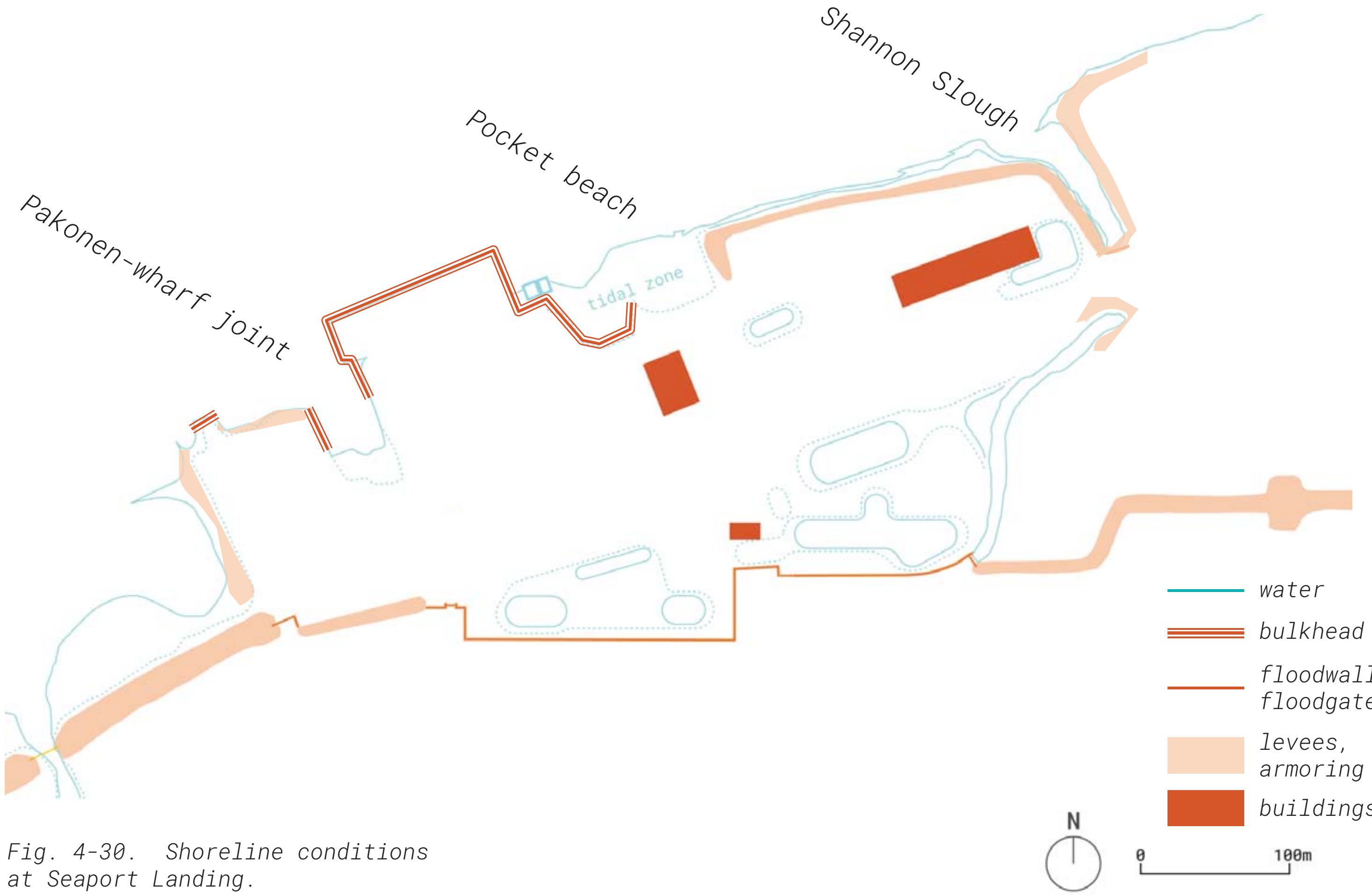
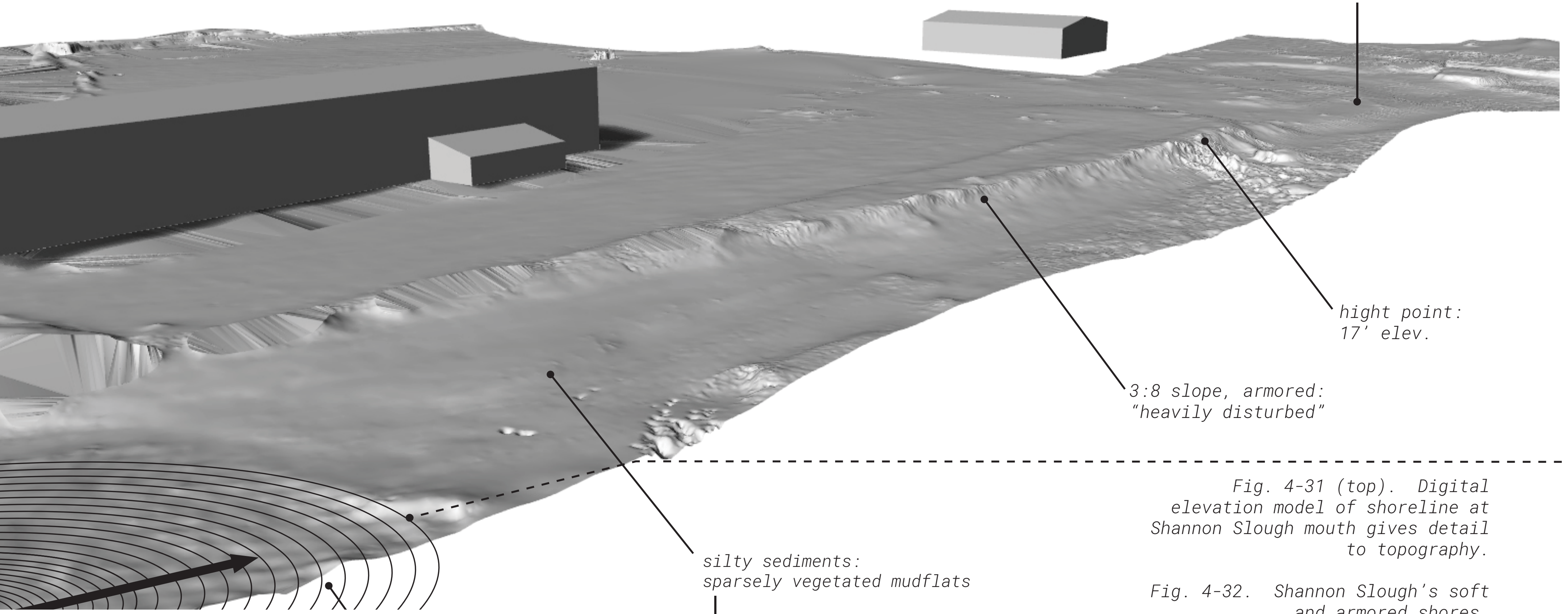


Fig. 4-30. Shoreline conditions at Seaport Landing.

Shannon Slough



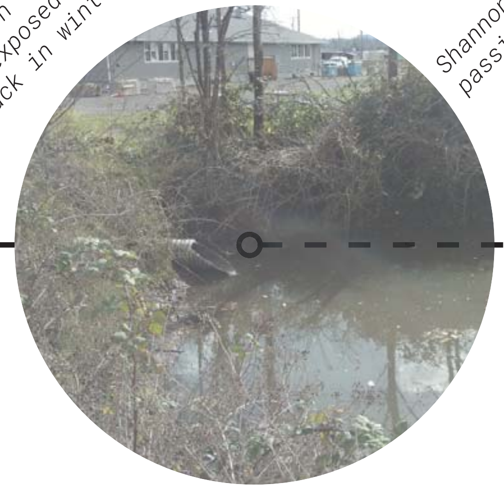


Fig. 4-31 (top). Digital elevation model of shoreline at Shannon Slough mouth gives detail to topography.

Fig. 4-32. Shannon Slough's soft and armored shores.

Starting at the upstream edge of Seaport Landing, Shannon Slough and the adjacent shoreline are armored with rip-rap (Fig. 4-31). While this holds the shoreline in place at a steep grade, the mouth of Shannon Slough exhibits active accretion as water slows and deposits sediments around pilings (Fig. 4-32). Across Shannon Slough from this accretion point is a small tidal flat, presumably a relic of former industrial use.

Pocket beach

Just downstream we find a pocket beach, once home to the "Big Mill" which was built out over tidelands. These waters were filled with wood waste over the last century to depths of up to 19 ft, some of which was excavated by Weyerhaeuser following a pentachlorophenol (PCP) spill. Recent analysis by Maul Foster and Alongi Environmental Engineering and Consulting[83] has found additional contaminants here, such as polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and heavy metals.

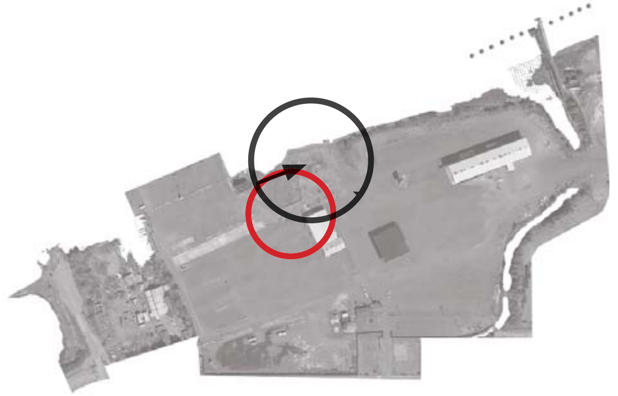
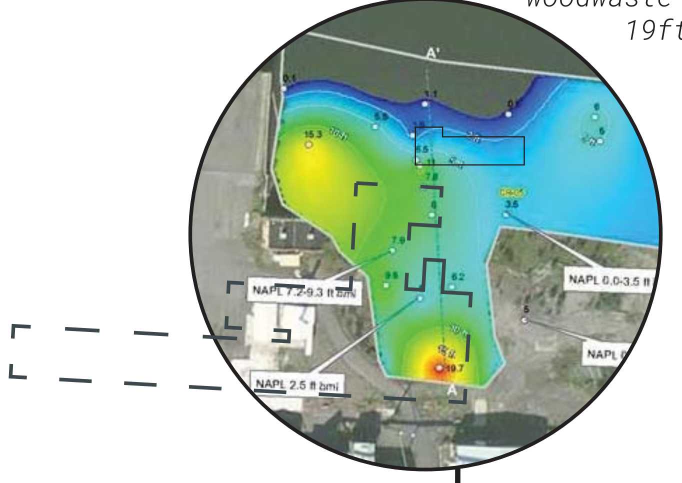


Fig. 4-33.
The pocket beach is the former site of "Big Mill", with woodwaste deposited over 19ft (5.8 m) deep.



Pokonen boatyard - wharf joint

The downstream edge of Seaport Landing holds an approximately 55,000 square foot wharf, which sits atop pilings and fill. The outer face of the wharf along the Chehalis River is intact with a hard vertical edge casting deep shade into the water, while the downstream edge perpendicular to the shore is decaying. It appears that sediment is accreting at this location. This edge of the wharf borders the former Pakonen Boatyard, which holds a shoreline made up of a mixed rip-rap and wooden armoring system, as well as a decaying boat launch.

The riverward edge of the wharf is the current Outer Harbor line, which is the waterward edge of Seaport Landing's aquatic lands lease with the Washington Department of Natural Resources. GHHSA plans to build a floating dock along this edge, which would require an extension of the Outer Harbor line into the river. Such an amendment would in essence continue the landmaking processes of the 20th century, further constricting the Chehalis River's breadth and inhibiting ecological integrity.

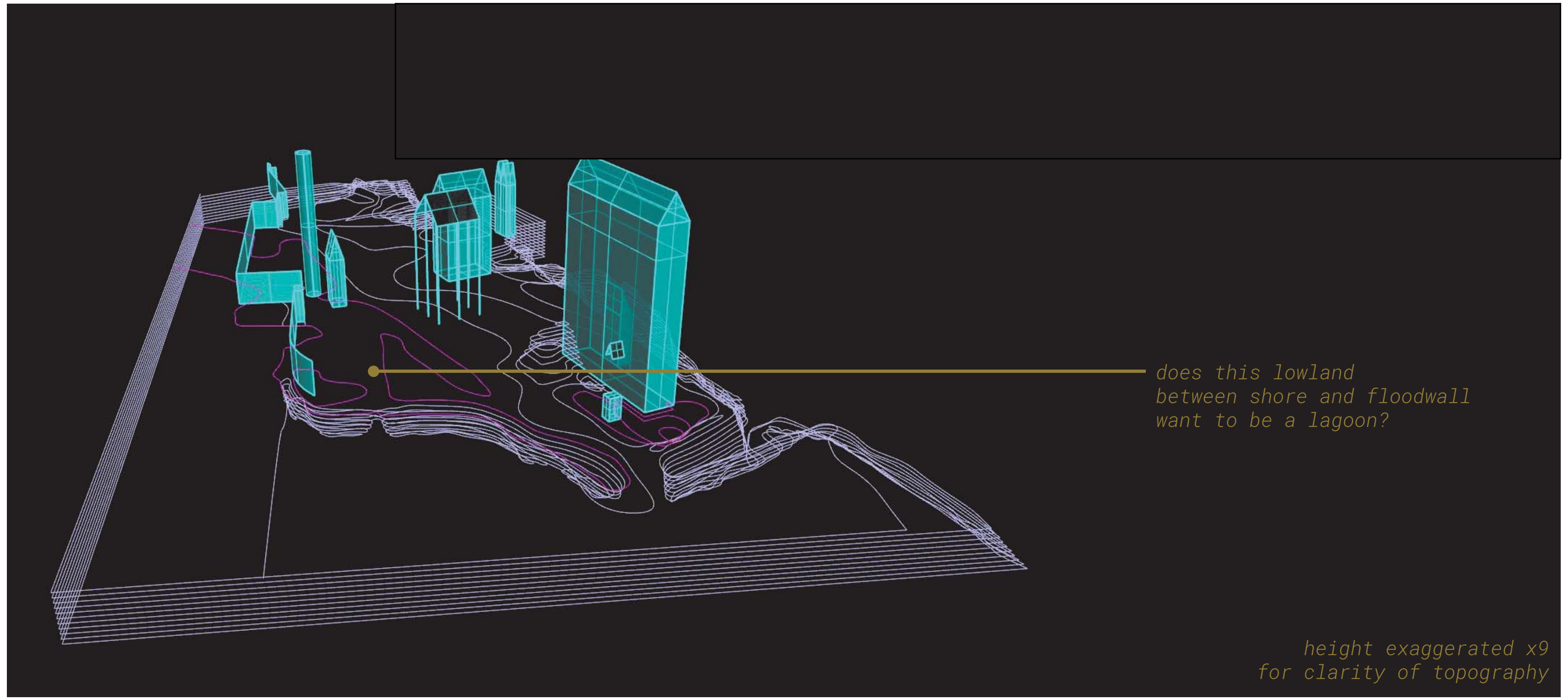
2. Drainage

Seaport Landing exhibits pooling and flooding during high tides and precipitation events. Figure 4-34 maps these locations, noting that the primary puddling area matches with past railroad lines. This inland area matches with the former mouth of Shannon Slough. It is likely that this location was already higher ground than the northern part of the site, and may have received different fill material. This could lead to subsidence of the former river ridges, as soils are not replinsihed by flooding.

N

0 100m

Fig. 4-34. Map of pooling based on field observations, overlayed onto historic railroads onsite.



An exaggerated contour model built from drone photographs processed with Structure From Motion software (Fig. 4-35) confirms the low-lying nature of the inland portion of Seaport Landing, highlighting the potential for connectivity across the site from the historic mouth of Shannon Slough (today's tide gate at the floodwall) to the wharf decay at the Pakonen Boatyard.

Fig. 4-35. The same pooling on-site, highlighted via an exagerrated digital elevation model, made with Structure From Motion photographs.

This information leads us to trace surface drainage across Seaport Landing, resulting in eight drainage micro-basins or sub-basins on the riverside of the South Aberdeen levee. These roughly match with the piped drainage system on-site. By dividing these drainage basins up in a way that corresponds with the above three dynamic shoreline zones, the site is broken into contiguous pieces which can be addressed in distinct ways pertaining to their specific elevations, draiange patterns, and other characteristics.

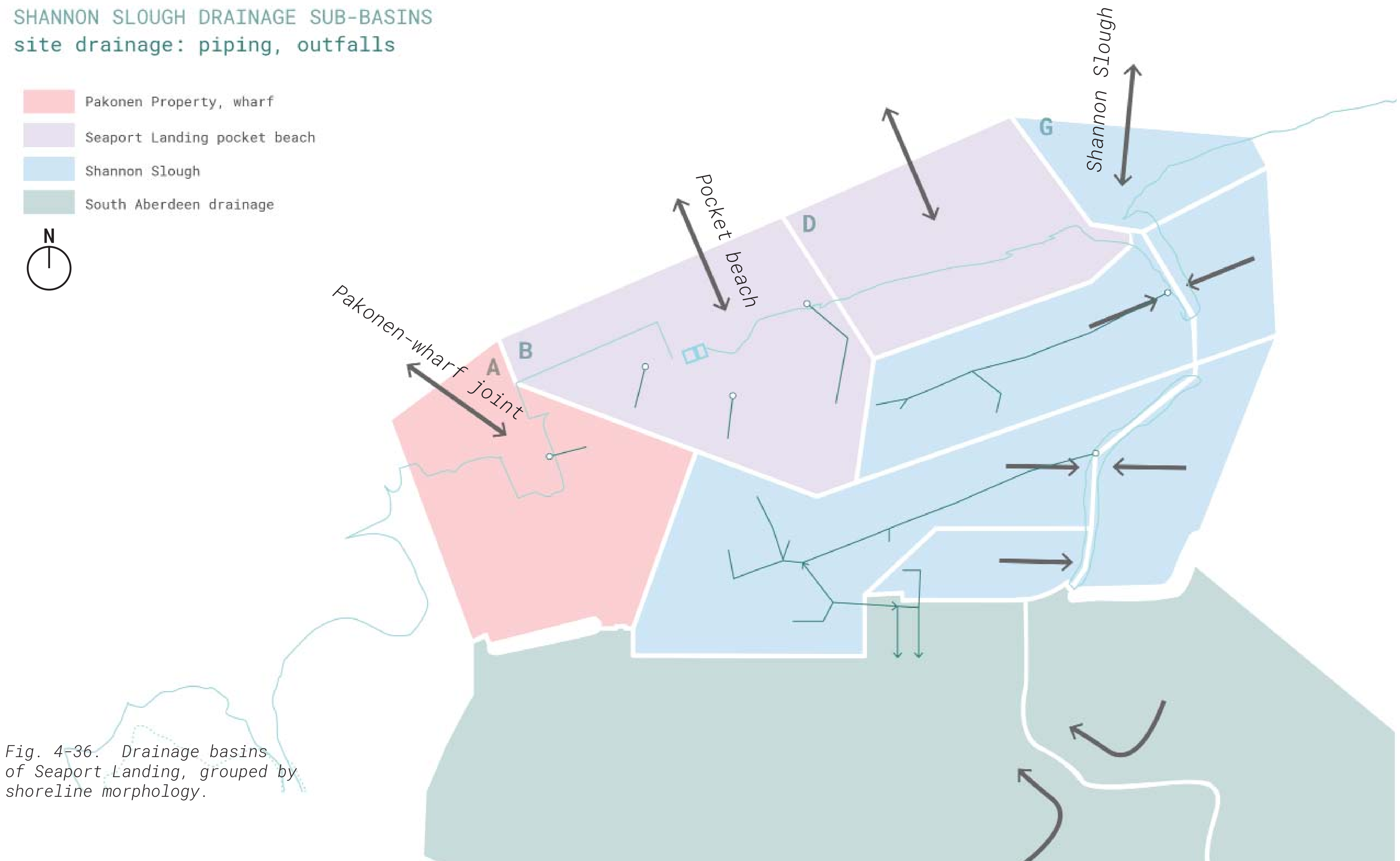
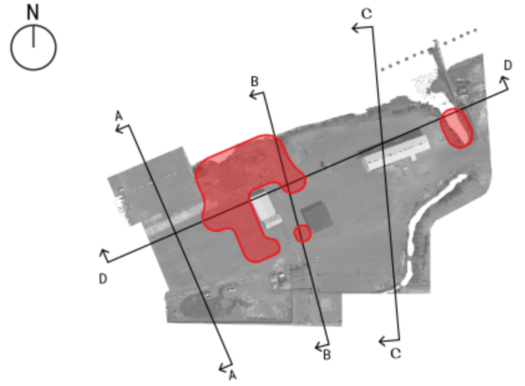


Fig. 4-36. Drainage basins of Seaport Landing, grouped by shoreline morphology.

3. Substrate

Current work at Seaport Landing is looking into the degree of contamination on site. Fig. XX shows zones of concentrated contaminant. It should be noted that the general mix of substrate on-site is assumed to be contaminated with PAHs in dispersed locations and also exhibits low dissolved oxygen and compacted conditions.



Events	Tidal Elevation ca. 2017 NAVD	Tidal Elevation +1m SLR ca. 2100
500-year High Tide	4.3 m (14.1 ft)	5.3 m (17.4 ft)
100-year High Tide	4.0 m (13.2 ft)	5.0 m (16.5 ft)
Mean Higher High Water (MHHW)	**2.6 m (8.5 ft)**	**3.6 m (11.8 ft)**
Mean Lower Low Water (MLLW)	-0.5 m (-1.6 ft)	0.5 m (1.6 ft)

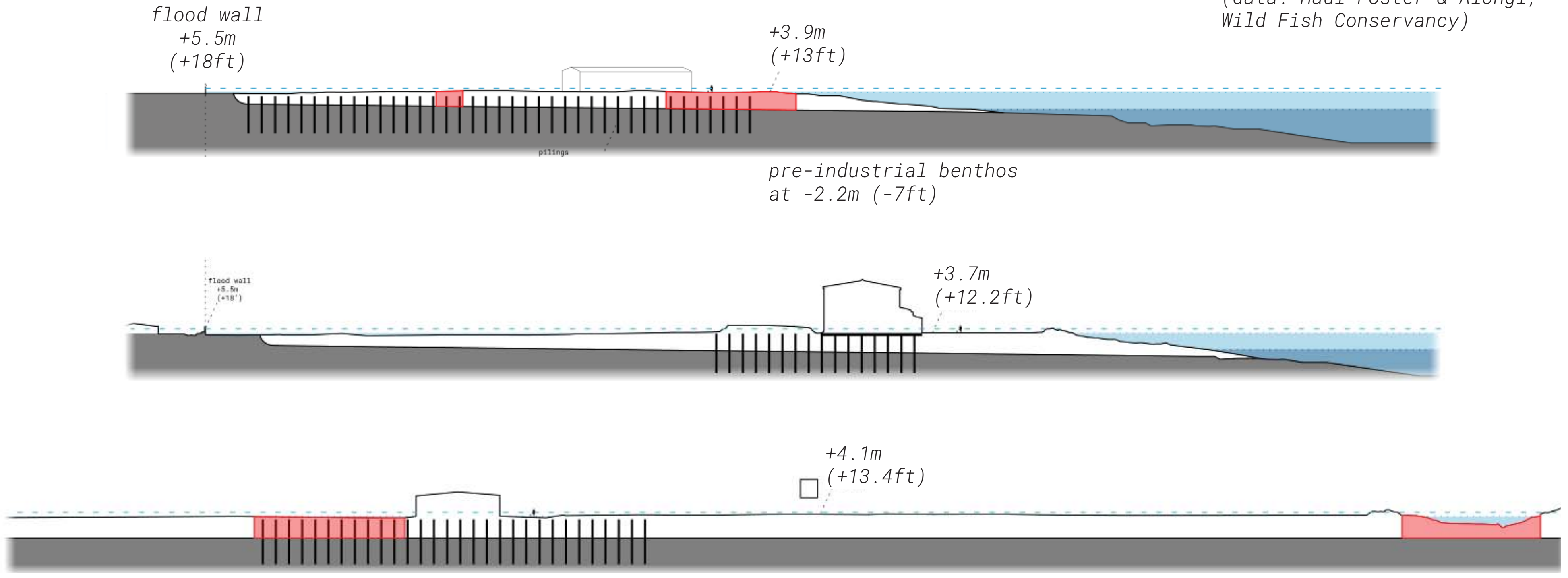


Fig. 4-37. Location of organic contaminants. High tides today are already higher than much of Seaport Landing, and could disperse contaminants into the water. (data: Maul Foster & Alongi, Wild Fish Conservancy)

Typical Seaport Landing substrate stratigraphy is shown in Figure 4-38. Peter Del Tridici - former senior research scientist at Harvard's Arnold Arboretum – likens industrial development to glaciation, as imported and compacted soils create a raw, compacted, and unvegetated landscape awaiting transformation, comparable to glacial till (2015[84]).

Existing vegetation onsite differs drastically from historic plant communities, but there is potential to remediate and amend these substrates for successful colonization by native plant communities migrating upland from sea level rise. As tides reach further inland, mudflats and marshes convert to open water, tidal surge plain swamps convert to tidal marshes, and underutilized industrial shorelines can be converted to surge plain swamp. Through this process, Seaport Landing "provides nature a right-of-way[85]" as advocated by Ducks Unlimited.

One the first goals of site development is to remediate and amend sediments. Substrate remediation and soil replenishment are applicable to all of the following approaches – whether the site is planted as a forest (protect), rehabilitated as off-channel intertidal scrub-shrub habitat (accomodate), or colonized by migrating tidal swamp habitat (retreat). Before any plants can take root to improve soils, however, the impermeable asphalt surfacing which covers the site must me removed.

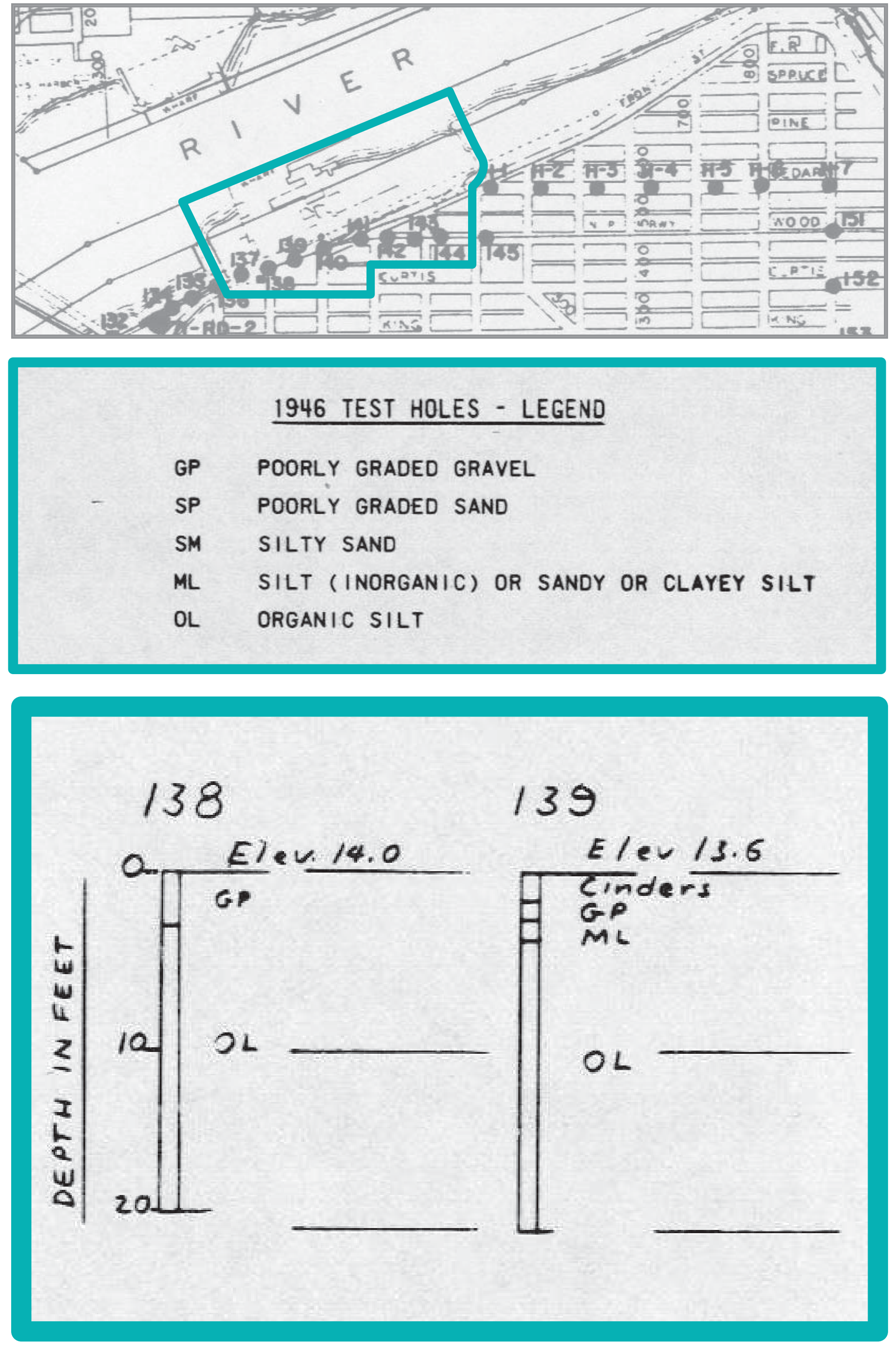


Fig. 4-38. Sediment cores from the inland edge of Seaport Landing tell of a past riverbank: gravel, sand, inorganic silt, and organic silt. In 2016, Maul Foster & Alongi found a similar stratigraphy closer to the river, though with more woodwaste (image: US Army Corps of Engineers 1975)

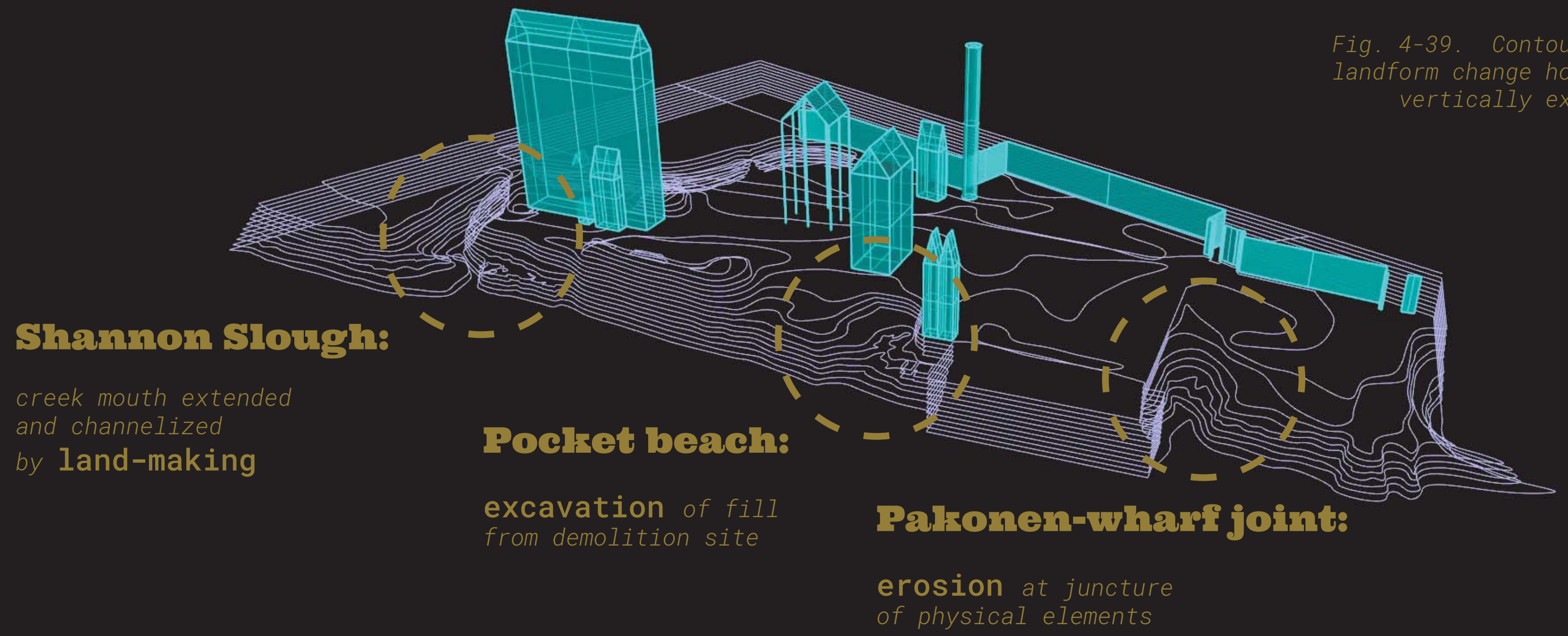
c. Conclusion

Just upland of either side of the lower Chehalis River, abrupt ridges confine the floodplain – known as the Montesano Formation. These hills were formed during the Miocene epoch approximately 23-5 million years ago, when humanity's evolutionary trajectory began diverging from that of the great apes. In this epoch the bone structure of our hominid ancestors' hands came to grasp objects and create tools[86]. This access to tools is a historic force behind today's world, driving globalization and bringing us to the present-tense Anthropocene.

Lower-elevation sediments of the Chehalis River's floodplain relate to a more recent era. Since the height of the most recent glacial maximum, humans have used their Miocene-derived abilities to experiment with tools, employ the landscape for human benefit, and connect across the globe. Global systems shifted.

The nascent stages of the Anthropocene are replete with impactful interventions into the landscape, effective due to their decentralized implementation (e.g. shoreline armoring, CO_2 emissions), realized through widespread access to sophisticated tools. Place-based sea level rise adaptation is a local response to global processes, informed by historical processes which shape local landforms and ways of life. Place-based design at Seaport Landing can forgo some of the tools which carve up our shorelines, embracing formative processes of landscape change in order to design **with** sea level rise.

Fig. 4-39. Contour model of landform change hotspots, 9x vertically exagerrated.



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Shoreline futures at Seaport Landing

A vision of Seaport Landing incubating economies and ecosystems.

chapter 5

Fig. 5-1. Greater Seaport Landing with planned demolitions and existing site elements of interest. (base image: Google Earth)

a. Adaptation scenarios

Chapters 2 and 3 discuss strategies for sea level rise adaptation, finding that resilience is interrelated with place-based social, economic, and environmental processes. Chapter 4 discusses place concepts as applied to historical and ongoing processes of Seaport Landing and the surrounding estuarine environment, finding place-based relevance in the site's shoreline, drainage, and substrate. The following design vision for Seaport Landing merges these analyses, proposing a process-based sea level rise resilience strategy. This vision for Seaport Landing is designed around processes of erosion, deposition, and aquatic-terrestrial connectivity which are foundational to local existence and wetland migration in response to sea level rise.

I describe three potential adaptation scenarios (protect, accommodate, and retreat) for the year 2100, giving attention to place-based shoreline processes in each. I then synthesize them into my preferred vision for developing Seaport Landing, which has components of each scenario. This design targets reach-scale processes in order to incubate resilience by retreating from industrialized shorelines in order to make room for habitat migration. Future sea level rise adaptation scenarios each respond to some or all of the following ecosystem resilience characteristics as put forward by Timpane-Padgham, Beechie, and Klinger (2017[1]) and described in Chapter 3:

- habitat connectivity
- habitat variability
- refugia access
- opening of new habitat
- restoration of riparian processes

"Scenario i: Protect" envisions Seaport Landing responding to sea level rise through protective strategies, harkening back to Chapter 3. This is enacted primarily by constructing a levee around the perimeter of the site. This berm would separate site activity from rising tides and could also host buildings elevated above sea level.

"Protect" uses structures to combat sea level rise inundation, favoring defense of urbanized development over protection of ecological processes. This is comparable to a site-scale rendition of the Army Corps of Engineers' approach to flooding. This method seeks to mitigate the effect of fluvio-tidal regimes on the site in order to expand or maintain human-centric environments along shorelines.

Goals of "protect" are:

1. Environmental: prevent pollution from entering waterways via runoff and contamination, maximize riparian buffer width (restoration of riparian function)

2. Social: create a public shoreline and maritime forest park atop levees

3. Economic: promote and preserve woodworking economy

Current plans for remediating Seaport Landing's contamination are focused on capping pentachlorophenol (PCP) in the pocket beach area[2]. A levee adds fill on top of this cap, further isolating contaminants from the Chehalis River.

"Protect" does not entail much further land-making or wetland reclamation, but this approach continues floodplain disconnection at Seaport Landing. A setback levee can protect Seaport Landing while allowing a limited amount of riparian vegetation to exist upland of the high tide line. While the site is not functional as a floodplain, the levee's crown and batture provide area for trees and other riparian vegetation to grow. These plants will shade the water below, reduce in-stream temperatures, and provide dappled light for juvenile salmonid refuge. As sea level rises, this narrow band of vegetation will be inundated and contribute some wood and allochthonous nutrients to the estuary.

While lateral aquatic-terrestrial dynamics can be improved in this manner, the site's riparian zone is still limited due to the high-gradient slope of the levee. Typical levees in Aberdeen are sloped at a ratio of 1:2[3] (rise:run), far steeper than natural shorelines. A setback levee at Seaport Landing can be built with much lower gradient, though still likely limiting upland wetland migration. Longitudinal riparian connectivity is slightly increased since the site presently has very little vegetation along the shoreline. If adjacent shorelines are replanted as well at sufficient width, longitudinal riparian connectivity could be increased greatly.

Levees inhibit aquatic-terrestrial connectivity and present fracture-critical design approaches to sea level rise. While levees are ecologically disruptive, the realities of investment in Seaport Landing highlight the need for protection of existing structures for which raising or removing (see "accommodate" and "retreat", respectively) may be cost-prohibitive.

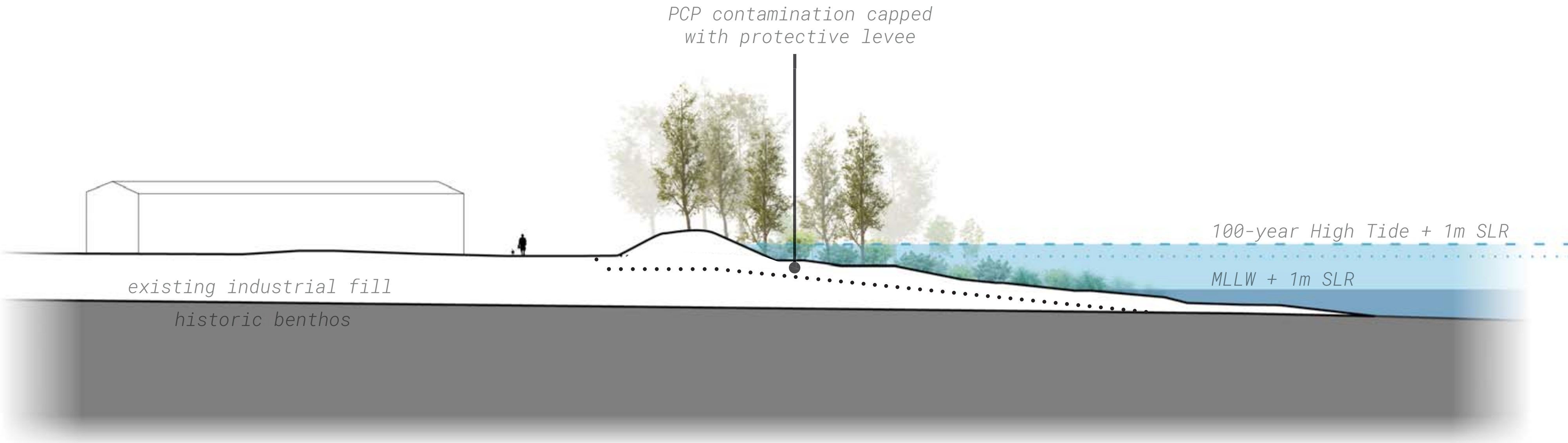


Fig. 5-2. Section A (for location see site plan on following page).

Building levees to separate Seaport Landing from surrounding waterways creates an opportunity to rework drainage onsite. Levees interrupt the downhill flow of stormwater runoff to the Chehalis River and Shannon Slough. Runoff can be instead directed to a series of treatment wetlands which cleanse the water of pollutants before it reaches aquatic ecosystems (Fig. 5-3). This adds small amounts of habitat onsite, while also providing attractive native plantings within the levee. The upstream end of Shannon Slough can be widened to hold stormwater runoff from South Aberdeen, once again filtering out contaminants before this water reaches the Chehalis River.

A levee around Seaport Landing would provide noticeable topographic fluctuation, with higher relief than most of South Aberdeen. Here, spaces at upper heights provide trails and vantage points of the Chehalis River and Seaport Landing, while flat locations inside of the levee are used for programming as currently planned by Grays Harbor Historical Seaport Authority (GHHSA).

"Protect" would primarily benefit woodworking programs at Seaport Landing, as this activity requires large amounts of exterior space for material storage and maneuvering. Of particular concern here is the need to deliver 130-foot long logs to the Spar Shop via truck, as described by GHHSA Site Manager and master woodworker Scott Rubey[4]. The radius required for this delivery forms a central focal point for the site's layout. Inside of this roundabout is a detention basin which provides a final degree of filtration before runoff is released to Shannon Slough and the Chehalis River.

Woodworking education can incubate local economic ventures, and through this can support particular local cultural expressions and ways of living as described by Gibson-Graham[5]. Seaport Landing's site was most recently part of a large-scale extractive operation, though many local residents were involved in woodworking for residential and maritime ends[6]. GHHSA's Spar Shop lathes logs for wooden boats, using industrial-scale machinery for maritime education through programs aboard the Lady Washington and Hawaiian Chieftan tall ships.

Woodworking education also can connect to local Native American lives and histories, as exemplified by Shoalwater Bay Tribe members' successes reviving traditional woodworking in nearby Tokeland. These efforts have led to greater interest in the Lower Chehalis language[7], incubating new life for long-oppressed cultural traditions. GHHSA and Seaport Landing can assist these efforts through partnerships and programming, enabled by protecting Seaport Landing with a levee.

While a levee-based site design for Seaport Landing may limit shoreline ecological functions, this strategy can help to further local economies and place-based livelihoods supported by GHHSA's mission. In doing so, the site's program engages with place through woodworking education. This bridges cultural and economic divides as it respects and provides space for traditional, maritime, and industrial craft side-by-side.

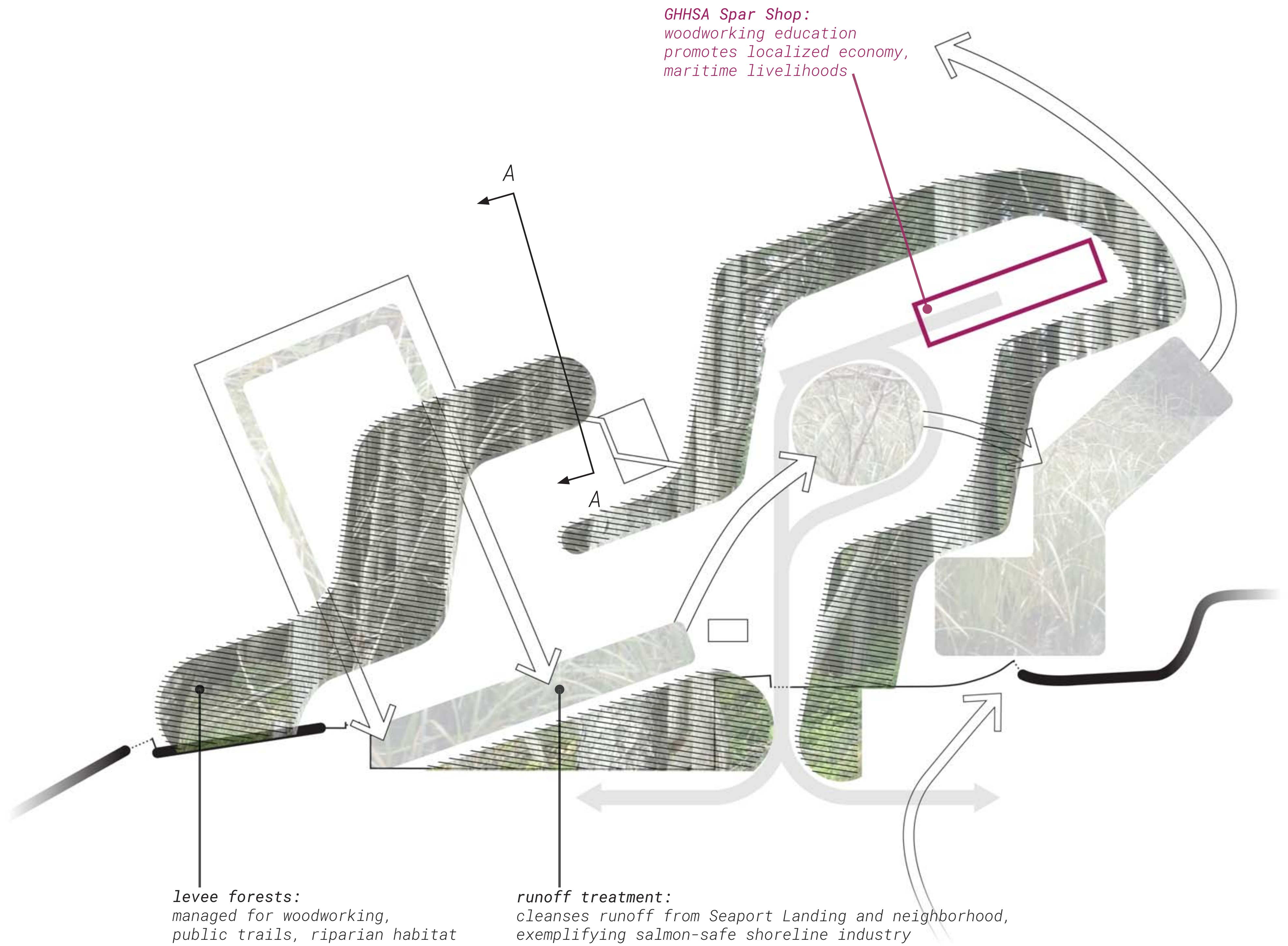


Fig. 5-3. Conceptual diagram of Seaport Landing protected by levees, highlighting emphasis on woodworking education and stormwater management.

"Scenario ii: Accommodate" envisions Seaport Landing responding to sea level rise by integrating site development with increased tidal elevations, exposing the public to forward-thinking adaptation so as to increase local adoption of low-impact sea level rise adaptation.

This approach takes advantage of Seaport Landing's status as a groundbreaking shoreline development in the region, seeking to reframe public attitudes toward tidelands and flood management. The former will incubate appreciation of littoral zones and hasten efforts toward habitat-based climate change resilience in Grays Harbor estuary, while the latter will promote sustainable climate change adaptation for residences and businesses.

Design goals of "accommodate" are:

1. Environmental: accommodate sea level rise by providing off-channel habitat (refugia access, opening of new habitat, habitat variability).

2. Social: encourage adoption of "living with water" strategies in Aberdeen through on-site programming which exposes locals to adaptive precedence

3. Economic: incubate local businesses through a diversity of building sizes, tourist visits, and public events

"Accommodate" adapts to sea level rise by developing Seaport Landing to allow periodic inundation. This is comparable to the Dutch "living with water" approach. Since greater Aberdeen and Seaport Landing face similar threats from sea level rise, this exemplary design strategy can further voluntary sea level rise adaptation by local entities. Accommodation of sea level rise is most visibly enacted by designing structures to withstand inundation at ground level. Existing structures are re-sheathed, re-wired, and otherwise modified to accept inundation. New structures are elevated or constructed in a modular and movable manner similar to "tiny homes".

Modular and movable buildings are necessarily smaller than the existing structures as Seaport Landing, so this approach favors small business. Smaller structures have lower overhead costs and can invite less-established tenants. This diversifies the economic activity at Seaport Landing, creating a vibrant social space which caters to a variety of needs.

Whereas "protect" strengthens local economy and culture through woodworking education, "accommodate" does so by providing space for self-expression and economic sovereignty. Additionally, the "accommodate" scenario allows Seaport Landing to function as a floodplain during high-water events, with trails throughout. This emphasis on vegetated areas creates zones of intimacy and ensuing feelings of investment toward Seaport Landing.

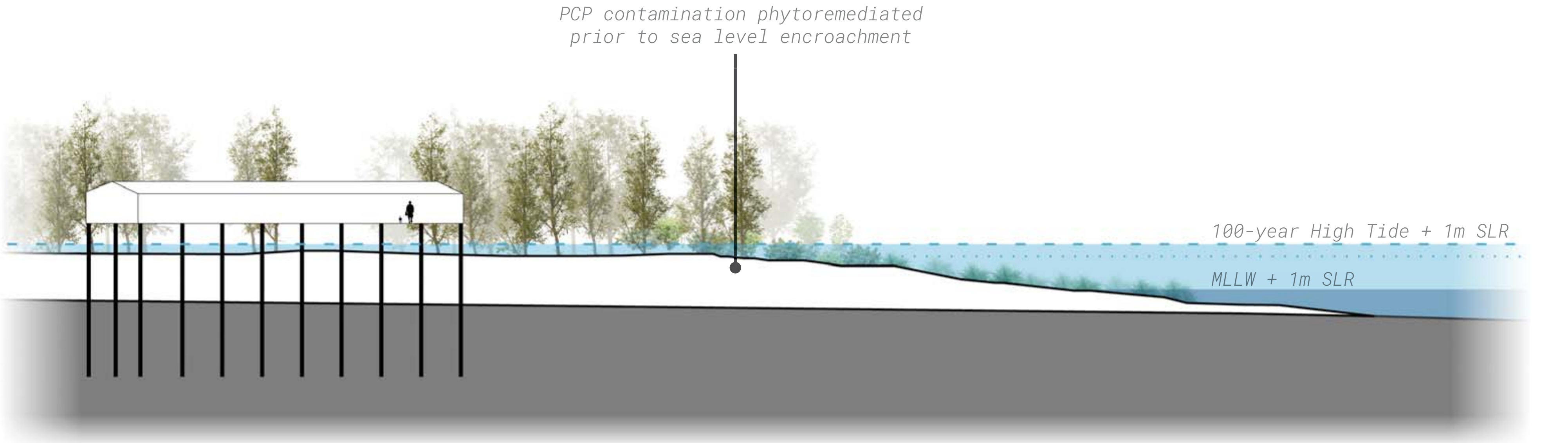


Fig. 5-4. Section B (for location see site plan on following page).

This mix of large and small structures onsite creates an engaging environment for recreation, commerce, and more – focused around riparian ecology and maritime activities. Seaport Landing becomes a "Fishers' Village," providing lodging, entertainment, natural areas, shopping, and trade.

Small-scale lodging alongside tidal channels is encompassed by trees, providing private settings for relaxation. Others may prefer larger-scale accommodations as currently planned for the site by Coastal Community Action Program. Commercial space supplements lodging and can cater to boating maintenance, fishing, or tourism. Simultaneously, commercial spaces can project maritime activity inland by functioning as seafood markets, kayak outfitters, or the like.

When tourists and locals alike come to Seaport Landing, they are exposed to "accommodate" strategies through buildings as well as terrain. Efficient drainage strategies are required for Seaport Landing to return to normal programming after periodic tidal inundation. Just as above-ground structures can influence public sea level rise adaptation, drainage at Seaport Landing builds off of local vernacular drainage systems in order to invite public acceptance of new water management methods.

Today, linear sod-covered drainage channels run between residential and commercial properties of Aberdeen, in the place of past tidal channels. Basins vegetated with cattail (Typha), red alder (Alnus rubra), black cottonwood (Populus trichocarpa), and willows (Salix spp.) detain urban runoff before it flows into the estuary. At Seaport Landing, these species can phytoremediate contaminants on-site while typical drainage channels can become tidal inlets, highlighting historical landforms.

As described by Asah et al.[8], an understanding of provisioning and cultural services provided by ecosystems – such as stormwater management and recreation – strengthens place attachment. Developing flood management and habitat restoration designs which build off of rather than replace existing culturally-ingrained infrastructure can lead to adoption beyond the site, affecting resilience at the reach scale.

Seaport Landing's site design allows inundation of public spaces, encouraging social interface with water as tidal inlets and restored beaches become areas for play. New raised and small-scale moveable structures allow small businesses to aggregate on-site, incubating synergistic economic relationships and resource-sharing.

"Accommodate" restores some habitat through creation of tidal channels, though human activity onsite is likely to occur to a degree which keeps much wildlife away: the goal of this design is to expose the public to ecologically-attuned design in order to influence behavior toward a more regenerative future.

"Accommodate" leverages Seaport Landing's status as a groundbreaking public waterfront development in order to inform ecologically-attuned public adaptation to sea level rise through education, engagement, and exemplary design. This has great potential for furthering economic initiatives of Grays Harbor Historical Seaport Authority as well. Of particular relevance here is the ability for new structures to be unphased by sea level rise and for Seaport Landing to become a tool for incubating larger awareness of sea level rise adaptation.

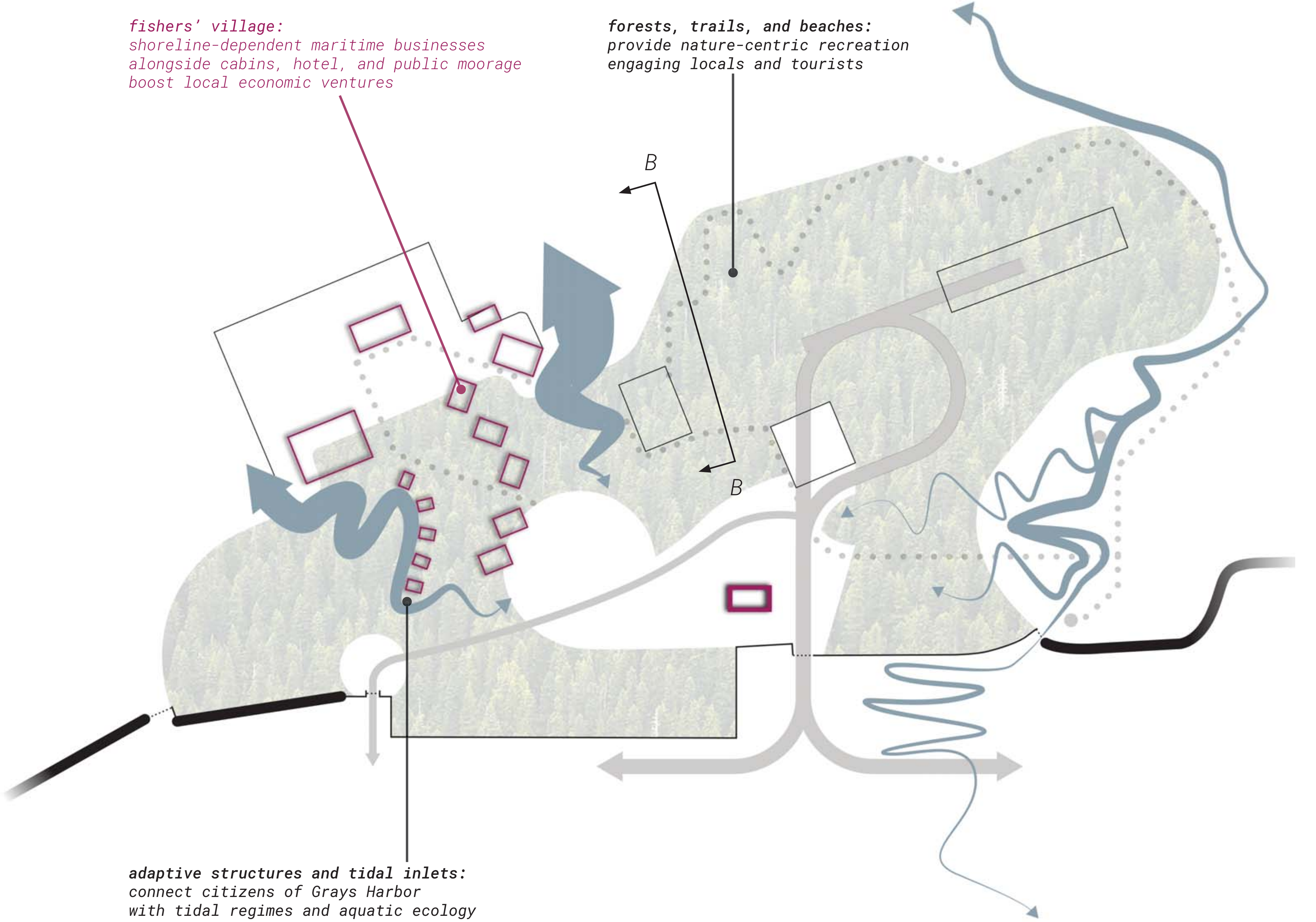
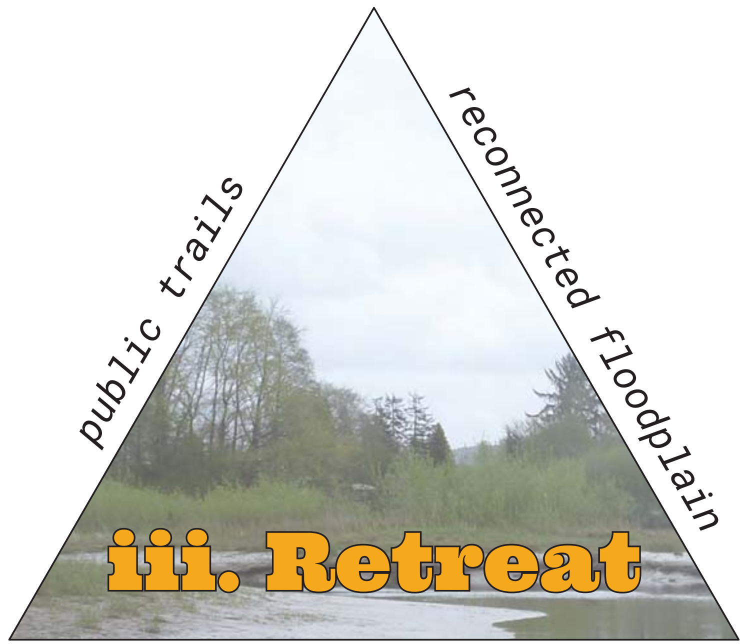


Fig. 5-5. Conceptual diagram of Seaport Landing with a variety of building sizes framed around tidal inlets, creating a "Fishers' Village"



"Scenario iii: Retreat" sees Seaport Landing responding to sea level rise by opening the site for assisted habitat migration. This is enacted by a phased removal of impermeable surfaces as the site transitions from an environmental education center to off-channel tidal swamp — anticipating the loss of lower Chehalis River surge plain habitat.

Under the "Retreat" scenario, Seaport Landing will become tidal channels, islands, and bars hosting a species makeup similar to the Chehalis River surge plain. Site design reinstates tidal regime, removing contaminated sediment while allowing natural sedimentation and erosion to shape the landscape. Human activity on-site is limited to hiking, birdwatching, botanizing, education, and other trail-based activities.

Goals of retreat are exemplified by processes:

1. Environmental: restore riparian function, create off-channel tidal habitat (habitat connectivity, habitat variability, refugia access, opening of new habitat, restoration of riparian processes)

2. Social: environmental education through restoration activities, public wildland trails

3. Economic: incubation of restoration economy through partnerships and educational programming

Retreat applies process-based restoration techniques to Seaport Landing, emphasizing ecological rehabilitation in order to provide habitat on-site. Impermeable surfaces such as riprap and asphalt are removed, while contaminants are excavated and disposed of. On-site planting begins immediately with plants that both uptake contaminants and fix nutrients. Willows (Salix spp.), alders (Alnus rubra), cottonwoods (Populus trichocarpa), and lupines (Lupinus spp.) all fit this description and are found locally — several already exist on-site.

Riprap is selectively removed in order to assist rooting along the shoreline, minimizing mass erosion of substrates which could negatively affect water quality. The shorelines of Seaport Landing have been artificially steepened, so once all rip rap has been removed, the tides and currents of the Chehalis River will sculpt the site. As the waters regrade the shoreline, vegetation and small woody debris will fall in along with eroded substrate.

Primary access to Seaport Landing after retreat-based restoration would be via boardwalk. Here, birders can see a variety of species at the edge of Aberdeen, inserting Seaport Landing between the Chehalis River Surge Plain Natural Area Preserve and Grays Harbor National Wildlife Refuge, creating an Aberdeen-Hoquiam birding network.

While a goal of full retreat is extremely ecologically relevant and may bring tourist income to peripheral economies of greater Aberdeen, it disregards the need for Grays Harbor Historical Seaport Authority to recoup investment made in acquiring and remediating the site. As such retreat is perhaps best approached as a long-term goal or a strategy to be employed in conjunction with other measures.

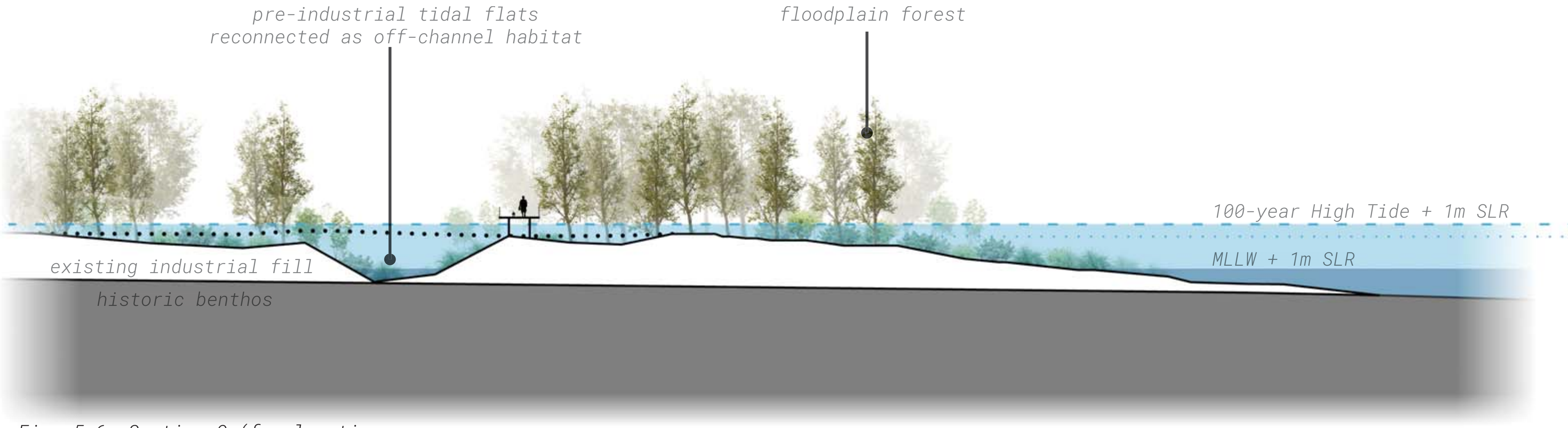


Fig. 5-6. Section C (for location see site plan on following page).

Retreat from Seaport Landing can be done in a way that creates valuable habitat for species of concern. First, GHHSA can neutralize contaminants onsite through excavation. Second, remaining sediments and soils can be remediated and amended through plantings, composting, and mycelium in order to host a variety of native plants and other species. This action prepares substrates for future inundation and non-toxic fluvial transport elsewhere.

Just as sediments will erode and travel throughout Grays Harbor, the Seaport Landing shoreline will accrete material. This is already evident at the mouth of Shannon Slough, where fine sediments pile up around cedar pilings. Sediment accretion and erosion can guide strategic site retreat, as inland areas (likely close to the Science Education building) will house the core of Seaport Landing's activity while peripheral shorelines give way to mudflats and tidelands. This is convenient for place-based science education programs at Seaport Landing, as young learners can experience landform changes firsthand onsite and apply this knowledge to shoreline restorations elsewhere in Grays Harbor.

Aquatic-terrestrial connections at Seaport Landing were first disrupted by railroad infrastructure. This is comparable to many industrial shorelines of Grays Harbor. Understanding the effects of transportation infrastructure upon floodplain and channel habitat can inform goals toward retreat-based ecological rehabilitation of Seaport Landing. This is described by Blanton and Marcus (2013[9]). These goals for restoration elements focus on aquatic habitat and aquatic-terrestrial connectivity:

Channel (Chehalis River shoreline):

- Width of wetted channel area
- Bar and island area
- Large wood count (>10cm dia.)

Riparian area (uplands, Shannon Slough):

- Off-channel refugia: ponds, alcoves
- Channel complexity: length of side channels
- Land cover change: less "developed" area
- Riparian zone width
- Riparian forest area
- Forested banks ("riparian gallery forest")

These goals provide specific details to target within the ecosystem resilience traits put forward by Timpane-Padgham and colleagues (2017[10]): habitat connectivity, habitat variability, refugia access, opening of new habitat, restoration of riparian processes. As portions of Seaport Landing are restored and reconnected with the Chehalis River, the above characteristics can inform adaptive management based on actual sea level rise and vegetation performance.

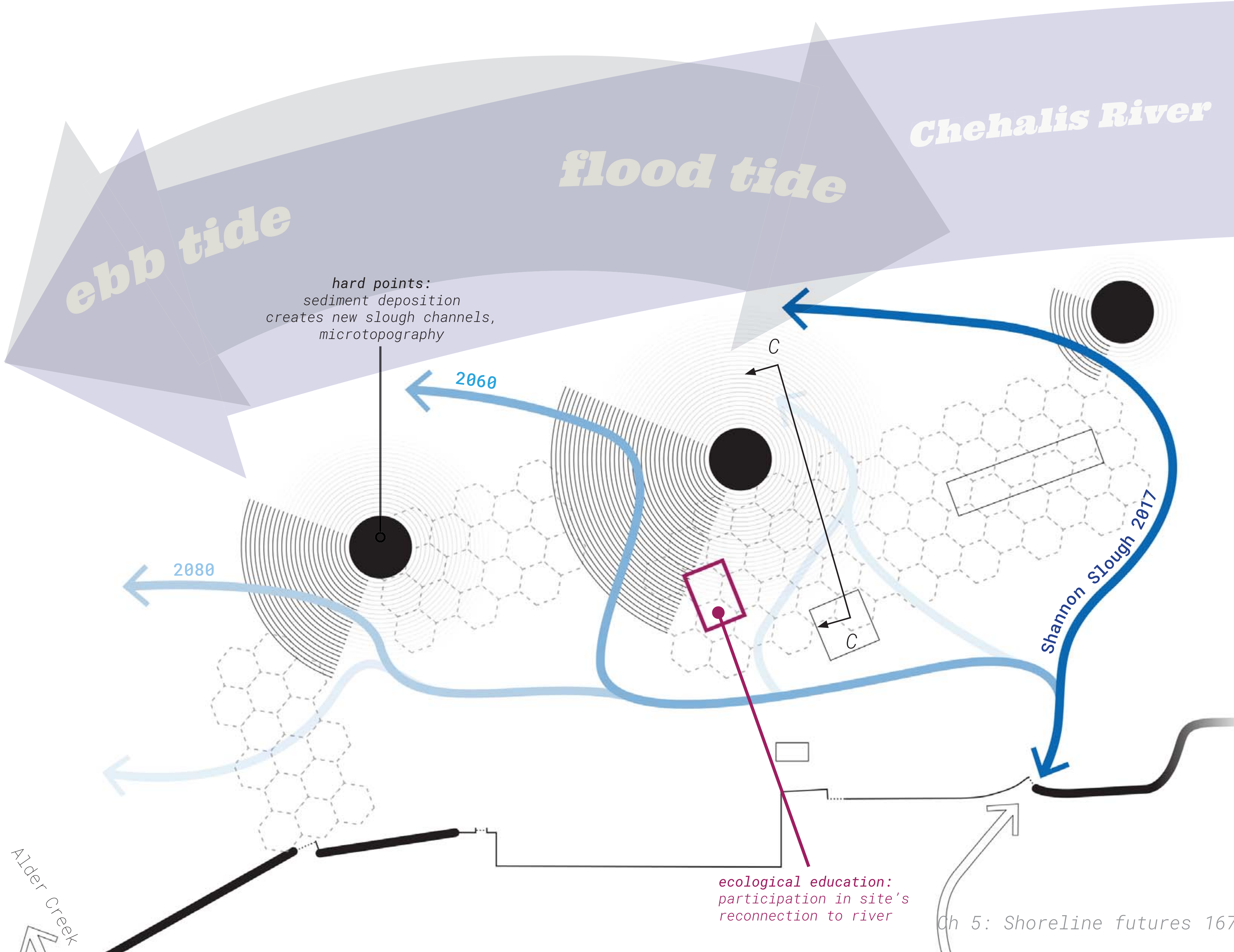


Fig. 5-7. "Retreat" reapproaches past landmaking and impervious surfaces in a manner to encourage upland habitat migration in the face of sea level rise.

b. Design vision: Seaport Landing 2030

In reflection, each strategy represents a variety of costs and benefits. In developing a Seaport Landing-based response to sea level rise in Grays Harbor, a combination of approaches appears to be most efficacious. The details of each approach – protect, retreat, and accommodate – form a kit of loose parts to be utilized dependent upon complex future scenarios.

My preferred design for Seaport Landing merges protect, retreat, and accommodate strategies in order to create a thriving economic and social hub based around shoreline ecosystems. This proposal is not just a site design for Seaport Landing, but a catalyst for sea level rise adaptation, approaching Grays Harbor's underutilized industrial shorelines as future intertidal habitat. This approach engages with landmaking practices of the past, removing shoreline armoring and preparing substrates for riparian habitats of the future. Seaport Landing is reconnected to other sites, creating a self-supporting network of tidal zones instead of fragmented parcels without regard for ecological connectivity.

Of particular interest here is the ability to test restoration of filled tidelands at Seaport Landing while still maintaining social and economic function. This would entail exporting the "retreat" strategy to other similar sites while using Seaport Landing as a hub for restoration work – hyping the idea to the public through exposure and economic engagement ("accommodate"). This process-based approach furthers the goals of the Grays Harbor Stream Team, Spar Shop, and Grays Harbor Historical Seaport Authority.

The site remains a popular public access point to the Chehalis River, though with a larger mission of ecological resilience to sea level rise – placing Grays Harbor Historical Seaport Authority as a "Mission Entrepreneurial Entity", or mission-driven organization that is also able to generate revenue, as described by David Smith at the Affordable Housing Institute (2008[11]). This relies upon utilizing all three adaptation strategies on-site in order to further ecological resilience at the reach scale.

Section 4's "Processes in Place" highlighted three dynamic shoreline conditions at Seaport Landing. These three points could be used as points of educational engagement for locals and tourists alike on site. Each feature is connected to an integral part of the site's recent industrial history (Fig. 5-8). By allowing these features to be remediated and exposed to forces of sea level rise, erosion, and deposition, the environmental aspects of Seaport Landing begin to be "decolonized and reinhabited" (Greenwood 2013[12]) in a manner which reconnects to place-based emphasis on aquatic ecology (Blackstock 2002[13]) in a manner reflective of the geomorphic processes which built the shorelines of inner Grays Harbor estuary – the same processes which were replicated by industrial landmaking as development built out into the Chehalis River to the detriment of supportive ecological cycles.

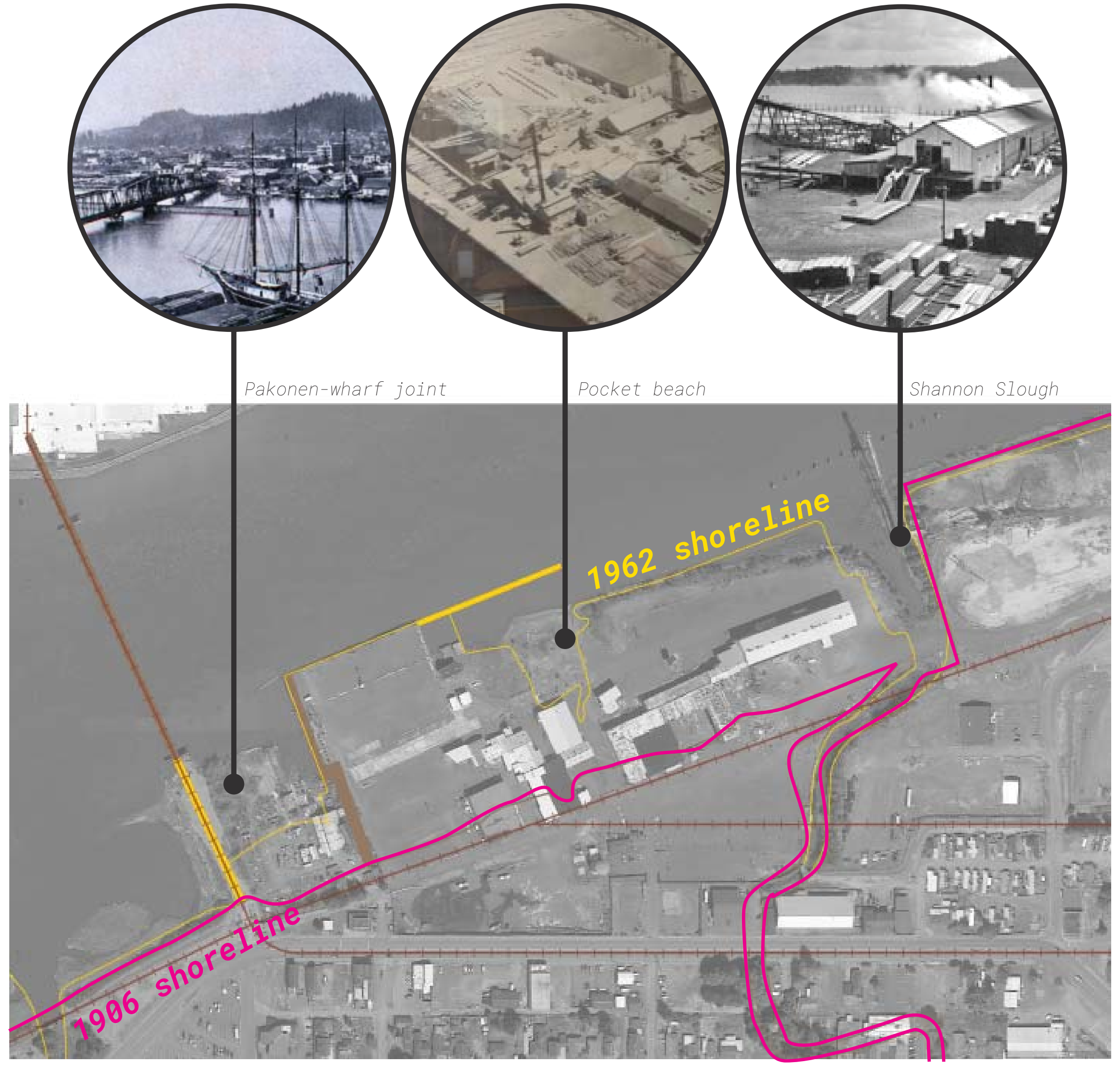


Fig. 5-8. Dynamic shorelines at Seaport Landing and previous industrial use (from left to right): Pakonen boatyard, pocket beach, and Shannon Slough. (images: HistoryLink, GHHSA, Google Earth, 1906 and 1962 Sanborn Fire Insurance maps)

Fig. 5-9. Tidal inlets form peninsulas for specific site programs.

Fig. 5-10. Vantage 1 (called out on opposite page). View looking down tidal inlet created at Seaport Landing's pocket beach. The inlet anchors the site, surrounded by local businesses, a maritime village, and GHHSA's Science Education Center.

Fig. 5-11. Dynamic shorelines become inlets, utilizing the "retreat" strategy to frame "protected" areas.

Design at Seaport Landing restores ecosystem function where possible, but some areas will be dedicated to human use in order to further larger-scale restoration elsewhere. Here, manipulation of landforms through analogs of erosion and deposition processes increases real estate available for riparian processes while protecting site elements crucial for GHHSA's mission (Fig. 5-9). New structures are designed to "accommodate" rising tides.

Seaport Landing's existing structures (Science Education Center, Spar Shop) are surrounded by a small setback levee (Fig. 5-10), which protects woodworking areas from inundation and provides elevated trails for the public. Willows, cottonwoods, and other riparian species fix nitrogen in low-nutrient fill, and remediate substrates for healthy riparian forest succession.

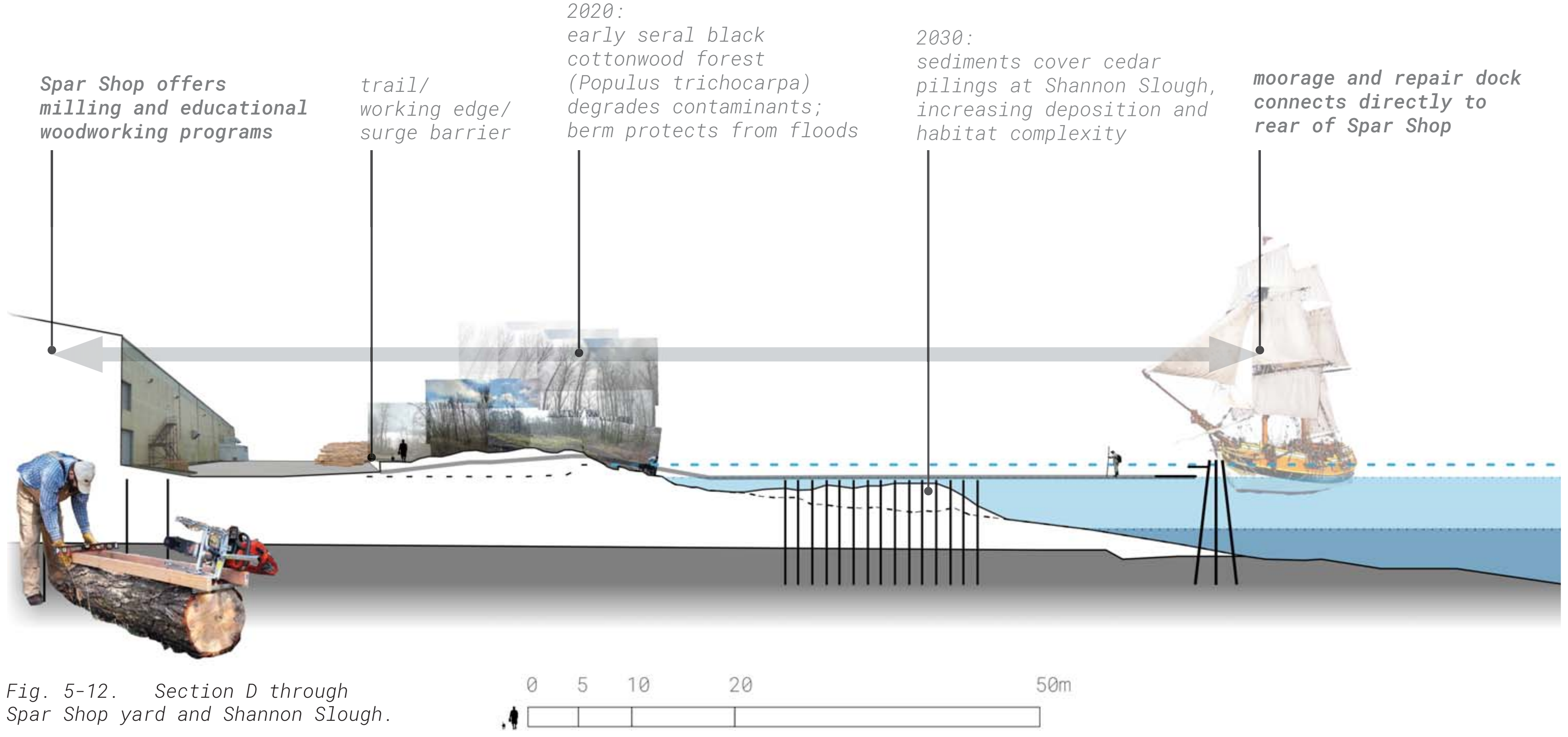


Fig. 5-12. Section D through Spar Shop yard and Shannon Slough.

Today, Seaport Landing is covered almost entirely with asphalt. Fig. 5-13 shows the proposed extent of impermeable surface, providing vegetated areas for play and relaxation while also minimizing flooding from rain events. If sea levels rise to a degree which prohibits use of Seaport Landing, these paved corridors are sparse enough to allow retreat from the shoreline in order for the site to host migrating habitat.

As impermeable surfaces are removed, substrates below are regraded through mechanical and fluvio-tidal action. Mildly contaminated soils are moved upland and phytoremediated against the floodwall, creating an elevated forest trail (Fig. 5-14). This bicycle path connects to existing dead-end paths and provides a vantage point for crossing Highway 101 safely.

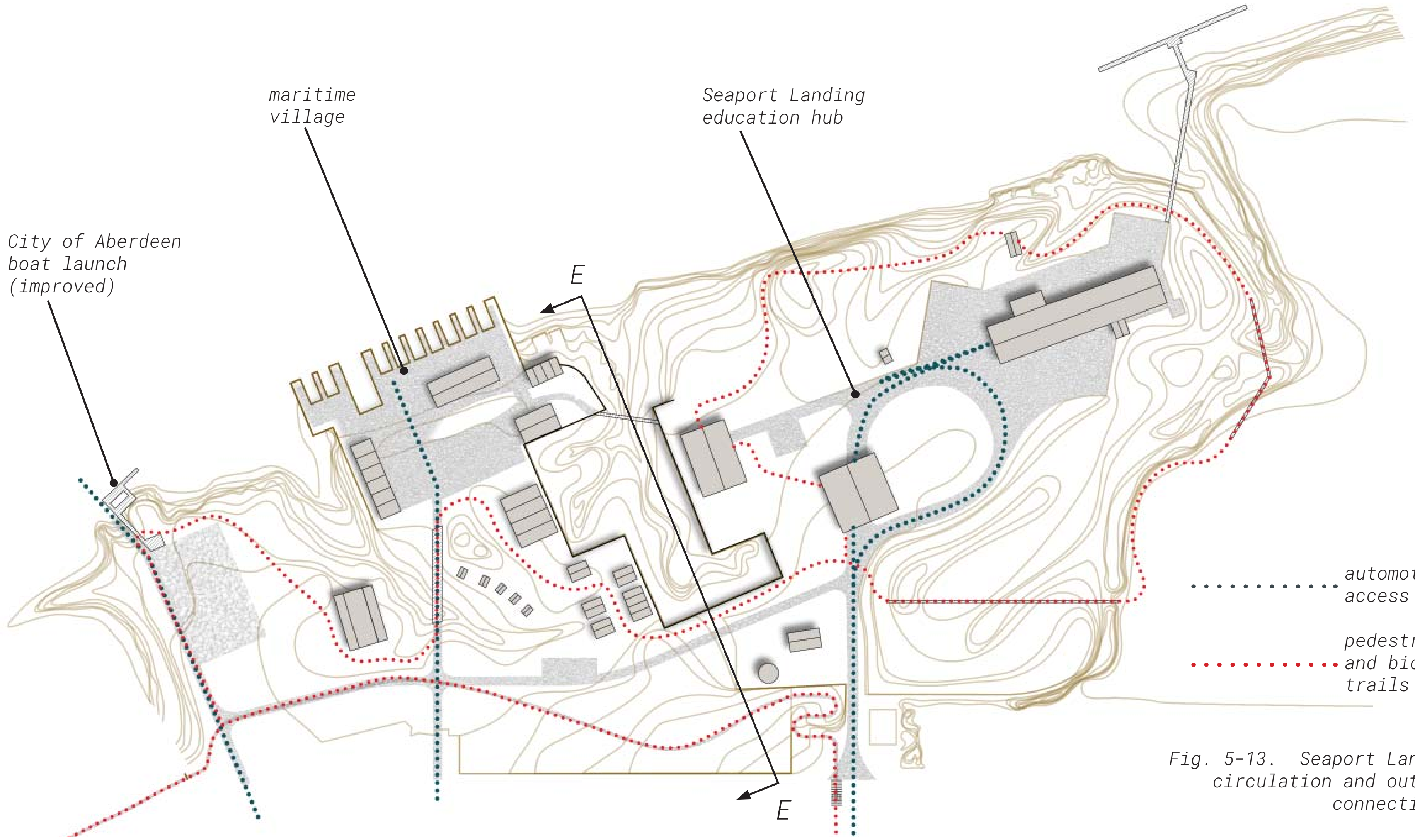


Fig. 5-13. Seaport Landing circulation and outward connectivity

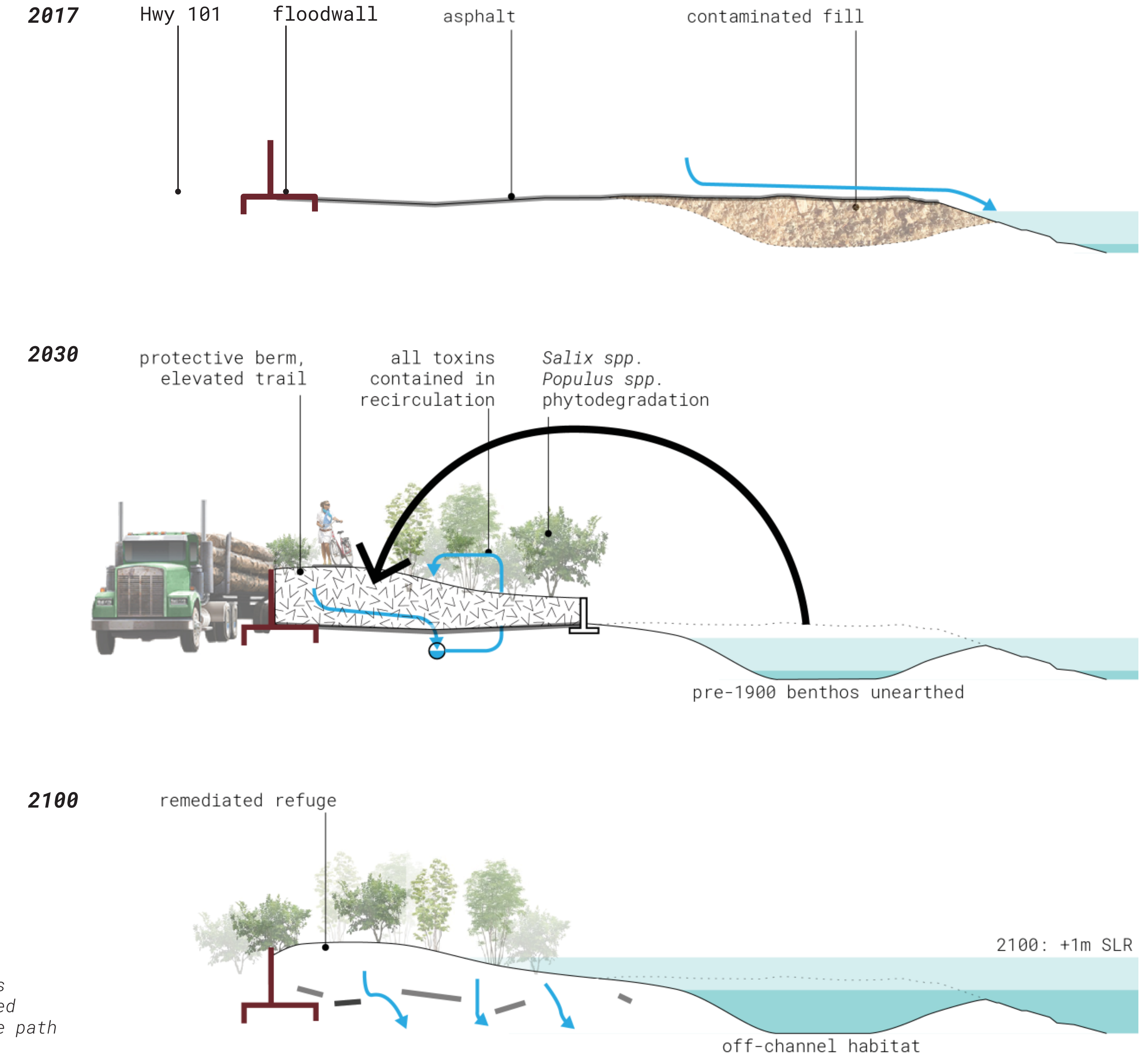


Fig. 5-14. Section E shows contaminated fill remediated and reused as elevated bike path and future upland habitat

c. Resilience: Design at the reach scale

Inner Grays Harbor estuary existed for thousands of years as a productive landscape, with expansive shorelines hosting diverse biotic assemblages that supported Native American societies. European settlement and industrialization divided these shorelines into plots and parcels, though they remained functioning largely as a cohesive unit albeit focused on ecologically unsustainable resource extraction. To move beyond this fragmented approach to terrain, socially engaging site elements at Seaport Landing exemplify connectivity across multiple sites. A place-based design networks with other typologically-similar sites and connects to systems which involve the site yet operate at a larger physical scale.

This emphasis on connectivity engages Shannon Slough, the adjacent underutilized Weyerhaeuser property, and South Aberdeen's bike paths. The Shannon Slough watershed can become a test case for public and infrastructural spaces connected through flood management, driven by Grays Harbor Historical Seaport Authority and Seaport Landing at the mouth of the slough.

Fig. 5-15. Shannon slough watershed has opportunity for a greenway and network of pocket parks. (base maps, Google Earth)

In a similar fashion, the underutilized Weyerhaeuser property just upstream of Seaport Landing provides a prime opportunity to restore habitat and provide public birding trails (Fig. 5-16). This development takes Northwest Indian Fisheries Commission approaches into mind as it builds off of the Wild Fish Conservancy's climate change adaptation plans for Grays Harbor, providing a significant habitat stepping stone for species migrating between the Chehalis River surge plain and outer Grays Harbor estuary.

This adjacent property provides a prime location for testing restoration strategies and inviting the public to understand these processes. Partnerships here may solidify a relationship between Grays Harbor Histoical Seaport Authority, the Wild Fish Conservancy, and others.

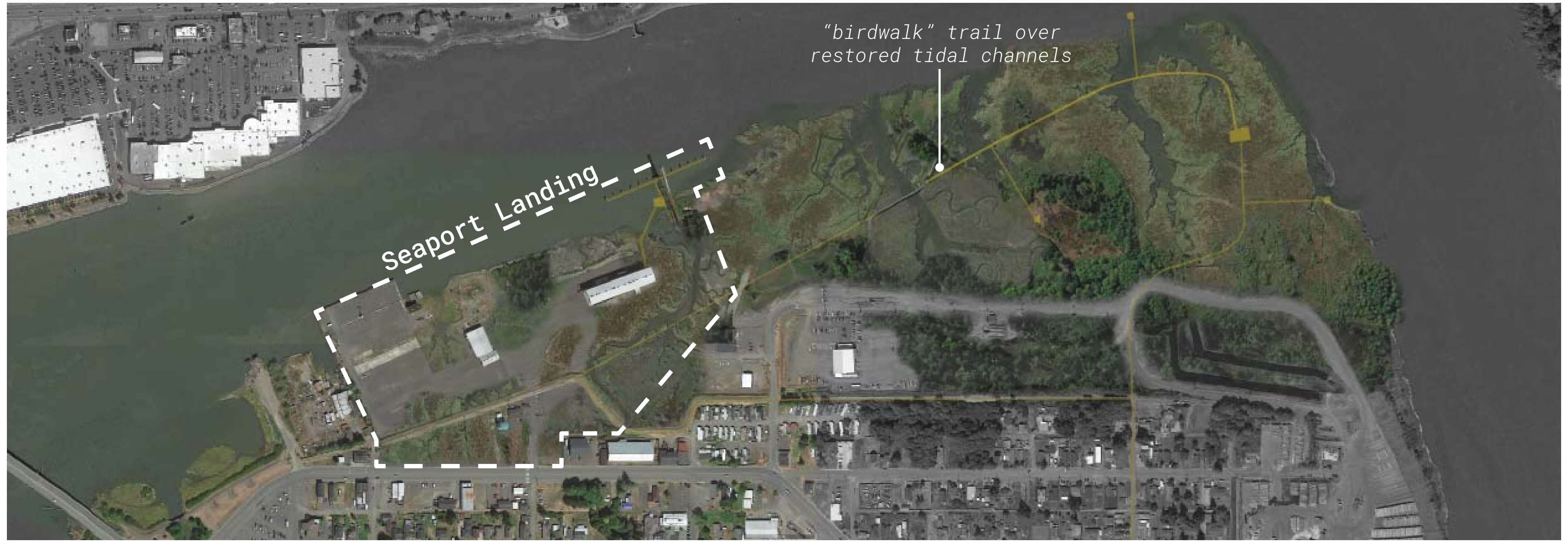


Fig. 5-16. Weyerhaeuser log yard restored and connected to upstream surge plain habitat, leaving present site usage intact. (Base maps: Google Earth)

With the development of these socially and ecologically networked greenways, the entirety of South Aberdeen comes into focus as a surge plain terrace which once was a site of great ecological connectivity. The City of Aberdeen and the Washington Department of Transportation plan to replace the Highway 101 and 105 intersection just downstream from Seaport Landing with a traffic-calming roundabout. This development provides opportunity for a bike path connection. This route would provide greater connectivity to Seaport Landing and through South Aberdeen, creating pedestrian and bicycle paths as analogs to off-channel habitat.

As Grays Harbor fell into economic decline, a gap-toothed land use pattern arose and remains to this day: active port industry is interspersed with abandoned and blighted industrial sites. Current development proposals - such as Seaport Landing – address this shoreline parcel-by-parcel. In response to Walker and Salt's discussion of transformability and multiscalar actions to incubate managed resilience[14] (2012), past shoreline ecologies are referenced by viewing the estuarine reach of the lower Chehalis River as an interdependent network of habitats.

Existing pedestrian paths:
Opportunites for connection

Connections and corridors:
South Aberdeen neighborhoods, commerical areas, and shorelines

Systems and flows:
Walk, bike, drainage, and tsunami refuge

Fig. 5-17. Seaport Landing lies at an advantageous location for connecting South Aberdeen's pedestrian network and shoreline. (base image: Google Earth)

This mosaic of similar typologies is approached singularly at the site scale as well as collectively at the reach scale, adapting Beechie and colleague's spatial approach to process-based restoration[15]. This reflects place as both site-specific and an aggregate of sites forming a larger ecosystem to be restored and strengthened in anticipation of sea level rise.

In dissecting Grays Harbor's coastal futures, the Oregon State University Climate Impacts Research Consortium considers climate and policy as coupled drivers of future coastal scenarios[16]. This binary relationship excludes economic influence as a major environmental determinant in coastal areas. While policy and climate may shape economics, the industrialized shorelines of Aberdeen are a clear example of economics shaping environment.

By incubating economies which work within aquatic ecological thresholds rather than ignoring or isolating them, local place-based industries can take root in a collective manner which adaptively responds to sea level rise in order to further resiliency. A comparable case is described in "The Greater New Orleans Urban Water Plan and the Water Economy," presented by the Urban Conservancy on New Orleans' "All Things Local" radio (2015[17]). There, a growing network of integrated environmental education programs, jobs, environmental design groups, and master-planning visions are working in a "top-down, bottom-up" fashion[18] to address flood resiliency through distributed and socially engaging means.

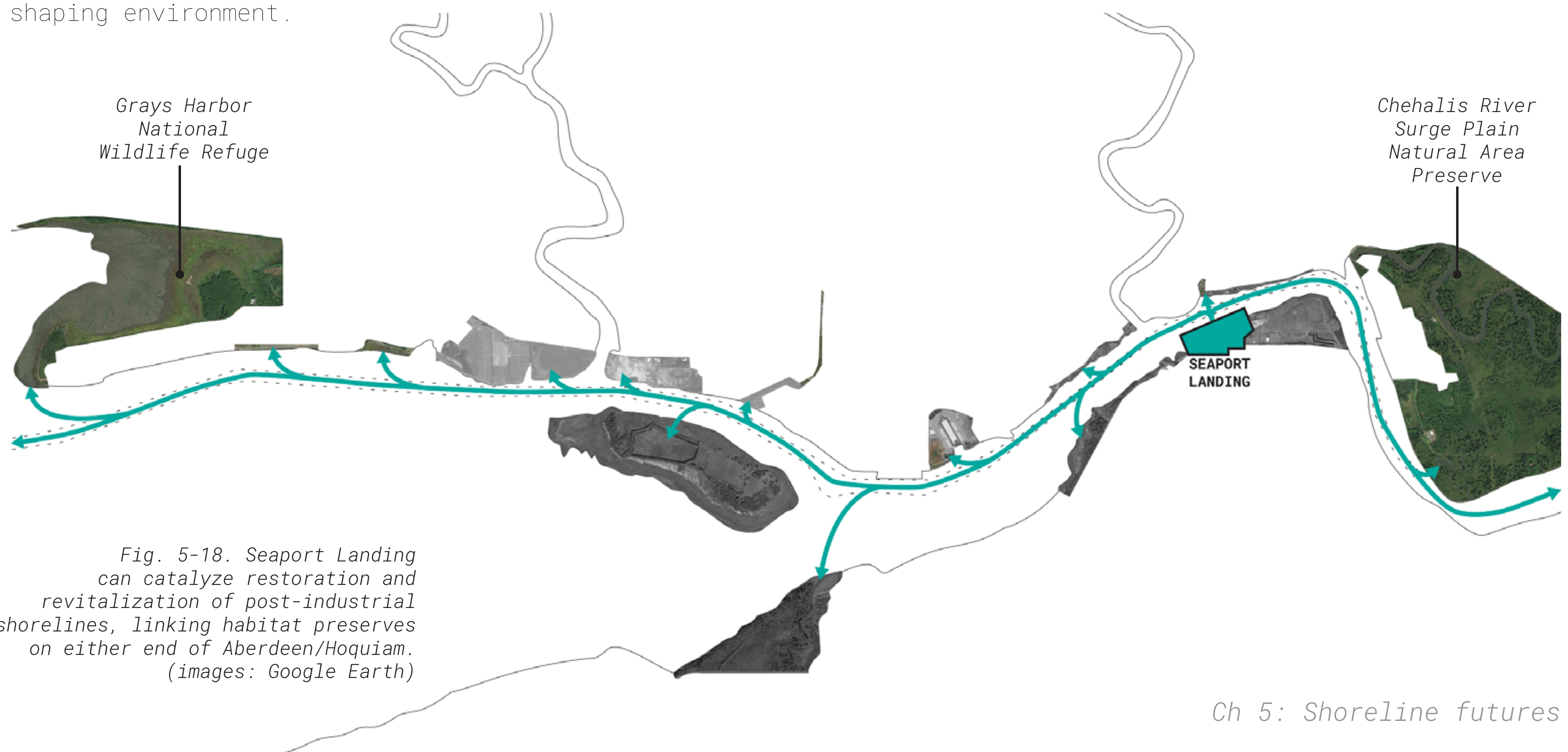


Fig. 5-18. Seaport Landing can catalyze restoration and revitalization of post-industrial shorelines, linking habitat preserves on either end of Aberdeen/Hoquiam. (images: Google Earth)

Grays Harbor Stream Team – through its affiliation with Grays Harbor Historical Society and the Chehalis Basin Partnership – has a wide web of potential organizational advocates and collaborators. These networks may be able to facilitate maximum involvement in a socially-apt and economically viable plan to aid ecological resilience in Grays Harbor estuary through habitat migration.

The 2011-14 breaching of Elwha River dams was a beacon of hope for people relying upon healthy salmon runs, adding momentum to dam removal projects elsewhere as the largest dam removal project in history. As of 2015, over 1,300 dams have been removed from streams in the United States[19], reconnecting longitudinal habitat for aquatic species.

Dispersed yet perhaps equally valuable efforts to reconnect lateral aquatic-terrestrial transition zone habitat (such as floodplains and tidal zones) has received less glamorous attention. Floodplains By Design[20] - a partnership between Washington Department of Ecology, the Nature Conservancy, and the Puget Sound Partnership – promotes and funds floodplain restoration and reconnection, targeting forward-thinking proposals for lateral habitat connectivity and flood management. Aberdeen-Hoquiam's joint Timberworks Resiliency and Restoration Plan applied for funding through Floodplains by Design's 2017-19 cycle, but was denied[21]. This is perhaps due to Timberworks' seeming reliance upon the North Shore Levee - a structural barrier which overshadows the proposed restoration of local creek floodplains. Future proposals which place habitat restoration in the foreground may have better success with funding.

Under the banner of "Our Heritage, Our Future," Grays Harbor Shoreline Master Program has undertaken outreach promoting responsible development which allows natural shoreline processes to occur[22]. Proposed shoreline restoration efforts, however, largely do not concern underutilized industrial lands[23]. Grays Harbor's outer estuary shorelines are predominantly undeveloped, while the inner littorals are almost completely armored with rip-rap for shoreline-dependent industrial uses. By restoring underutilized industrial shorelines, opportunity arises to break down dichotomy between the inner and outer estuary.

These sites can link riparian habitat along the lower Chehalis to the harbor's mudflats to create "stepping stone connectivity" between habitat patches in line with Dramstad and colleagues[24] (Fig 5-18), while also offering opportunity to monitor, evaluate, compare, and experiment with restoration techniques side-by-side.zz

Through partnerships and outreach (Fig. 5-19), the Grays Harbor Stream Team can realize restoration at an impactful scale, using their home base at Seaport Landing to test efficacious shoreline restoration ideas. A scaling-up of restoration programming can begin at Seaport Landing, growing outward to the adjacent Weyerhaeuser property, and eventually on to sites throughout the estuary. By focusing on shoreline sites, the Stream Team will not only be improving ecosystem conditions through "stepping stone" habitat connectivity[25], but will also engage the public with forgotten spaces, revitalizing social and economic elements of Aberdeen.

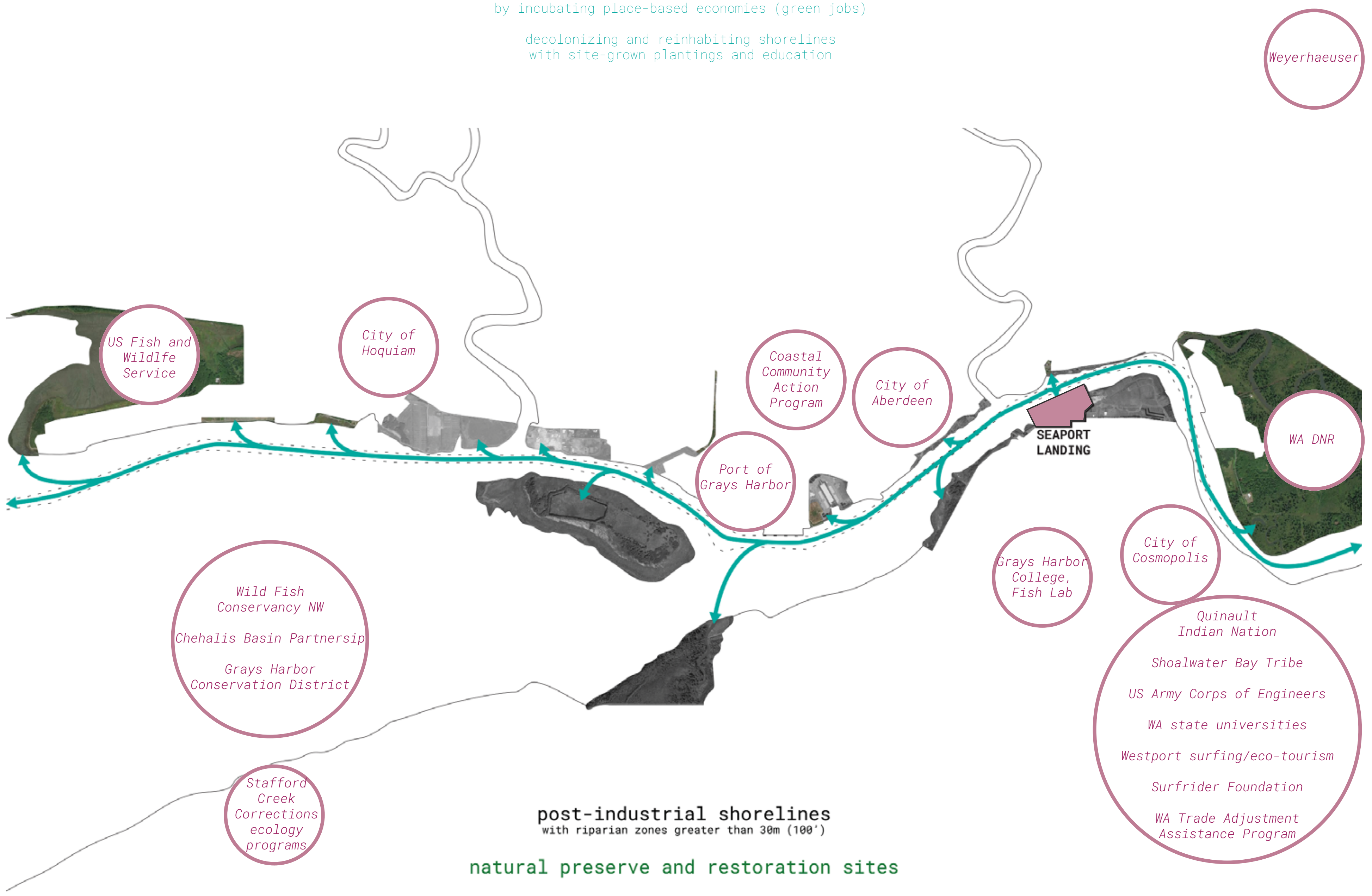
Fig. 5-19 (opposite page). Potential partnerships abound for a shoreline restoration economy.

exploring relationships

exporting habitat

decoolonizing and reinhabiting industry
by incubating place-based economies (green jobs)

decolonizing and reinhabiting shorelines
with site-grown plantings and education



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chapter 6

Reflection

Takeaways from “Shifting Shorelines,” next steps, and a realization that this is just the beginning.

Seaport Landing and the Chehalis River, viewed from the Highway 101 bridge. (image: Wikimedia Commons)

Seaport Landing Goals and Objectives

Through its initial public outreach process GHHSA identified a number of goals and objectives to help guide the design process and ensure that the **Seaport Landing** Master Plan will reflect our vision for the future and serve the needs of our community and its visitors for decades to come.

Goal #1 - Create a quality thematic waterfront destination attraction that will serve the needs of our community and attract both vehicular and boating visitors to our area.

Goal #2 - Design to creatively embrace, reuse and restore working waterfront infrastructure, maximizing public benefit, public access and private investment.

Goal #3 – Collaborate with others to design, develop and incorporate interpretive trails and exhibit opportunities throughout the site that will tell Grays Harbor stories including: boatbuilding, shipping, timber and sawmills, cultural and natural history.

Goal #4 - The Master Plan must accommodate phased development and allow for reprioritization based on changing conditions, resource availability, partner interests and opportunities.

Goal #5 - Site design and Master Plan must address long-term maintenance and lead to sustainable, long-term positive cash flow for GHHSA.

Goal #6 - Establish and maintain consistent and appropriate design esthetics.

Goal #7 - Create a successful development that will serve as a model of "Best Practices," inspiring further creative redevelopment in South Aberdeen and other waterfront areas.

Goal #8 - Engage and involve the youth of our community in the design and redevelopment process at Seaport Landing.

Fig. 6-1. GHHSA's goals for Seaport Landing, realizable through my vision for Seaport Landing (source: "Seaport Landing Project Brief.")

Reflection

My work has produced a document, set of graphics, and a digital elevation model which will all hopefully be useful in the development of Seaport Landing. "Shifting Shorelines" addresses all 8 goals of Seaport Landing's development, as put forward by GHHSA's "Seaport Landing Project Brief" (Fig. 6-1; 2013[1]).

This research, analysis, and design process allowed me to explore overlaps between my interests in infrastructure and historical ecology. I gained a wealth of understandings through this project, with only a fraction of it relayed through the narrative in this thesis. Through in-depth analysis of Seaport Landing and Grays Harbor, I have found a way to incorporate detailed research into forward-thinking design.

I opened up this project by asking…

How does flood infrastructure reflect place?
What does place-based climate change adaptation look like?
How can resilience be incubated at the site scale?

The first question brought me into the realm of multi-disciplinary theory, while the second adapted my findings to a specific place – the lower Chehalis River shoreline at Seaport Landing. I was able to answer the first two questions with the most detail and vigor, as this thesis became much more of a theoretical project than a community-based design as I initially expected it to be.

The last question is relevant for anyone – particularly individuals, NGOs, native plant interest groups, etc. - who have opportunity to develop a site in some manner. In focusing heavily on the landscape analysis portion of the project, I have been able to look into topics, histories, and site conditions that may not be afforded outside of academia. This not only sets up future lines of theoretical inquiry, but also provides an informed base for a robust and clear site design at Seaport Landing. I look forward to stepping away from the concepts to think of human experience on this site, and using the topologic foundation that I have built to create a more in-depth and tactile design.

Reflecting back on Chapter 5's vision for Seaport Landing, I see that this design is place-based but also me-based. While I initially viewed this as problematic and unscientific, I came to realize that place-based processes are relevant because of place-meaning: how a place is internalized by a living thing. What does this place mean to you, to me, to them? This brings up another scale: the proxemic, as put forward by cultural anthropologist Edward T. Hall in "The Dance of Life: The Other Dimension of Time"[2].

Proxemics describe how humans use space and are affected by spatial phenomena, while the related concepts of poly- and mono-chronicity[3] connect these spatial concepts to cultural concepts and ways of life. This place-based culturality of human-used spaces is at the heart of my interest in a typology of socio-aquatic vernacular infrastructures. Further research and design would look deeper into how people use shorelines, and under what circumstances. Further research would be more engaged with people, traditional ways of life, and local vernaculars. Further research would involve much more field work.

My research into Grays Harbor began in the field: wading through waist-high waters surrounded by scraggly alders, boating along the estuary's shores during a frigid January sunrise, and sinking knee-deep in floodplain mud. I connected these endeavors to the local urban landscape by attending public meetings, tracing drainage lines from town to estuary, and learning to fly a drone in order to create a detailed model of Seaport Landing's shoreline. A limited amount of this work made it into this thesis, though these experiences were foundational to my understanding of this embayment.

This work is invaluable for someday developing a detailed site design for Seaport Landing which reflects the nuances of local topology. "Shifting Shorelines" could have been much longer, with narratives and case studies of sediments, vegetation communities, and human activities — segueing from an academic landscape analysis into a realizable set of design documents — but alas, time is limited in a graduate program. Hopefully Grays Harbor Historical Seaport Authority is interested in continuing this dialogue, giving more attention to practical design considerations. For example, would the tidal inlet proposed at the pocket beach (Chapter 5) just become a trash pit?

Perhaps my greatest concern through this research was matching philosophical intent with practice. Throughout this paper, I use the phrase "landform". This is an accepted word to describe morphological characteristics, but it gives preference to terrestrial over aquatic processes. Is an alluvial terrace not more of a "waterform" than "landform"? This line of inquiry would delve into cultural perceptions of tidelands, mudflats, floodplains, and other aquatic-terrestrial transition zones.

This research into the vernacular would be informed by the methods of Mildred Reed Hall in "The Fourth Dimension in Architecture"[4], which explores user participation within designed spaces, and those of Brett Milligan and Alexander Kraus-Polk's "Human Use of Naturalized and Restored Delta Landscapes.[5]" Altogether, this could produce a set of extensive inquiries into the how people engage with shorelines, how this changes over time with sea level rise, and how this trajectory reflects historic ecological processes.

Focus on Grays Harbor — an area outside of major urban centers — was influenced by the limited amount of site-relevant literature available. This meant more reliance upon case studies and research elsewhere, applying these to the estuary. For example, Puget Sound ecosystems were referenced multiple times when research for Washington's central coast was unavailable. As a result of broader reference material, the project took on a broader scope. A tighter focus would be a beneficial next step for refining a design proposal for Seaport Landing, and this work has built a solid foundation for doing so.

Sea level rise adaptation is a form of infrastructure which can strongly reflect place-based processes and ecosystems. However, many water management strategies employed throughout the United States are not supportive of ecological integrity, and as such these one-size-fits-all approaches can unravel place-based livelihoods at the same time as they protect communities from flooding. In the Pacific Northwest, traditional Native American relationships with ecosystems present an ecologically-regenerative place-based approach to shoreline land management which is particularly applicable to sea level rise adaptation. As sea level rise adaptation becomes regular work for landscape architects, traditional ecological knowledge and land management practices of historically-attuned cultures are of utmost relevance for the profession and beyond.

Just as benthic detritus is a building block of estuarine food webs, landforms and the long-running cycles which create them are instrumental in defining socio-ecological relationships. As global climate change and massive landscape alterations continue into the coming century, substrates should be given greater attention. If humans destroy the geomorphologies which gave rise to the resources which we rely upon, is there any going back? These landforms have taken eons to manifest upon the surface of Earth, while human technologies have the ability to wipe away this history in a moment.

Formed by industrial landmaking processes and currently in a state of neglect, the post-industrial shorelines of Grays Harbor are an apt testing ground for this question. Multiple sea level rise adaptation strategies can be mutually reinforcing, and resilience can be incubated for human and ecological systems alike by approaching site design as an outwardly connective intervention into the landscape. In doing so, this proposal begins to play as a mixture between environmental planning, coastal management, and community organizing.

If attention is not given to these place-based understandings of the world, if development does not look below the surface of the land, and if sites remain bounded in design and program, we are doomed to rely upon diminishing natural resources and increasingly fragmented societies.

I initially begain exploration of place-meaning as a way to develop a stronger understanding of grassroots-based design. This investigation has highlighted dynamic processes which are the foundations of place, and can be used to improve livelihoods and ecosystems in a regenerative and inclusive manner. This focus on process deconstructs and expands the field of landscape architecture, incubating resilience. This thesis has helped me to articulate essential guides for my future pracatice. Therefore, tenets for resilient place-based design are:

1. Incorporate traditional, indigenous, vernacular, and otherwise multigenerational place-based understandings into landscape design

2. Integrate geomorphological processes which occur at multiple nested time scales into design, linking human impacts upon the landscape to geological phenomena

3. Merge site design and programming at multiple nested spatial scales, connecting to a wide and diverse resource network in a manner reflecting ecological webs.

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