Concrete Nurse Logs:
Spawning Biodiversity from Ballard's Century-Old Locks

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Abstract

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This thesis embraces the task of biodiversity conservation within the realm of architecture. In the midst of an anthropogenic mass extinction on Earth—the most menacing of the current environmental crises—it advocates for the prioritization of biodiversity conservation in any design project. A bold articulation of the attitude that has engendered mass extinction, the U.S. Army Corps of Engineers-operated Hiram M. Chittenden Locks is emblematic of its early twentieth century origins for its rigid hydrologic control of an entire watershed, severely impacting the pattern and success of migration for several populations of Pacific salmon. As Seattle commemorates the centennial of the opening of one of its most popular yet least understood sites, this thesis re-envisions a complex that continues to fulfill the requirements of human water transportation but with increased biodiversity as a defining goal. The proposed phasing approach looks forward—and backward—centuries and considers the existing historical structures as metaphorical nurse logs that evade obsolescence through their decay.

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I would certainly not be as familiar with the Locks without Susan Connole. I will never forget the fun we had exploring her diligently organized archives room.

U.S. Army Corps of Engineers Seattle District

Several individuals with the USACE have helped me better understand the Locks. Katie McGillvray showed me around the grounds and answered my questions throughout this project. Stephen Munro provided valuable facts about the botanical gardens. Fred Goetz, Jeff Laufle, and Scott Pozarycki took the time to explore various design ideas with me at their office—a meeting that solidified my understanding of the needs of salmon at the Locks.

National Archives at Seattle

Ken House helped track down historical documents that have informed my thesis and understanding of the site. Holding those age-worn journals and drawings in my hands briefly transported me to a time when the Locks was just an idea on paper.

Heron Habitat Helpers

Mike Marsh introduced me to the rookery at Commodore Park where we observed many herons tending their nests. I so enjoyed learning about the herons as he taught me his process for documenting them. It was a treat to observe firsthand Mike's dedication to these interesting birds.

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Rich Deline with the Corps Foundation took the time to give me a unique perspective of the Locks, a conversation which broadened by understanding of the complex. I am thankful for the opportunity to get to know author David Williams as we worked on our respective projects associated with the Locks. I have appreciated words of encouragement from my friend and mentor, architect Josh Distler. I am also incredibly grateful for the chance to discuss my preliminary ideas with architect Bert Gregory during the forming stages of this project.

I thank my dear friends Doug and Lynda for making me a part of their home while I worked on this project.

Most importantly, I thank my family for reminding me that there is indeed a world outside Gould and Architecture Halls, and it is bright.

01

INTRODUCTION

Brief Description of Site and Project

The Hiram M. Chittenden Locks (locally and from here on referred to as *the Ballard Locks* or simply *the Locks*[1]) has more or less operated in the same manner throughout the century in which it has raised and lowered vessels between the levels of saltwater Puget Sound and freshwater Lakes Union and Washington. However, there is more to the complex than its pair of locks. The Ballard Locks is many things to many people. Situated at the mouth of Seattle's human-excavated Lake Washington Ship Canal (from here on referred to as *the Ship Canal* or by its acronym, *LWSC*), it is one of the most popular destinations in Seattle, a gateway to boaters, and a stage where boats are the actors. It is also a heavily traveled pedestrian and bicyclist bridge linking the otherwise disconnected neighborhoods of Magnolia and Ballard. The grounds boast acres of botanical gardens and a number of historical buildings. A fish ladder and subaquatic viewing room anchor the south end of the dam, offering urbanites the opportunity to interact with a species so wild it joins the dark secrets of the briny deep with those of hidden forest streams. Adjacent Commodore Park is home to the largest great blue heron rookery in Seattle. In the spring and summer the Jurassic period echoes in the red alder canopy west of the spillway dam as these modern-day *pterodactyls* assemble in surprising numbers to raise the next generation. Indeed, the Ballard Locks is one of a kind, and cherished by many different demographics.

Even so, the Ballard Locks is ultimately a dam, the result of extensive human engineering that so dramatically altered the ecology of Salmon Bay and the larger watershed that the reference condition is barely discernable. This category of landscape has recently been labeled "novel ecosystems."[2] Through many science consultations I have discovered that the Locks is a rigid wall between water salinity, temperature, and elevation. It precludes the boundless benefits of an estuary and contributes to habitat and biodiversity loss. The decision to excavate the Ship Canal and construct the Locks led to the displacement of human and non-human populations.

Today visiting the fish ladder is an important tradition for city dwellers who might not otherwise interact with wild living Pacific salmon. Interactions with the web of life are important to a child's development[3] and to "ecological literacy."[4] Yet in what might seem a catch-22, the Ballard Locks is itself a threat to salmon—an oftentimes fatal obstacle in the already harrowing journey from natal tributary to open ocean at the start of life, and the reverse journey back to natal tributary before death. Summertime Seattle loves salmon. When the days grow longer and the sun rises higher, people from near and far flock to the Locks to see spawning Pacific salmon, lifeblood of the Pacific Northwest. These salmon funnel into the narrow, 21-step fish ladder they must traverse (unless they pass through the lock chambers or saltwater drain,[5] two of many trials discussed in Chapter Five) to make it to the other side of the dam and on to the rest of their long journeys up the Ship Canal, through Lake Washington, up the Cedar or Sammamish Rivers, and to tributaries beyond. Indeed, the Locks is a physical embodiment of the strained intersection of migrations: human migrations and salmon migrations. As Seattle commemorates the centennial of the opening of the Ballard Locks, this thesis proposes a new fish ladder, or rather "fishway,"[6] at the Locks with biodiversity as its defining goal.

Proposal

The title of this document is admittedly an unusual one. I will only introduce its meaning here, as throughout the document it will evolve as a theme wherein "concrete" is

Figures 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7 (clockwise from top left): For a century this concrete and steel barrier, though cherished by many demographics, has precluded an estuary and the biodiversity inherent in one. This thesis therefore proposes a *decomposition* of the Ballard Locks, metaphorically, in the way nurse logs decay. To introduce this concept, these photographs of the Locks are juxtaposed with seven photographs of nurse logs on the opposite page.

Figures 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 1.14 (clockwise from top left): I took these photographs of nurse logs (and nurse stumps) in the forest where I grew up. The gradient of time and space embodied in a nurse log will develop as a theme throughout the project. These photographs are juxtaposed with seven photographs of the Ballard Locks on the opposite page to introduce the concept.

paired with "nurse logs" to form an oxymoron and conceptual strategy for approaching the Locks (See Figs. 1.1 – 1.14). Made almost entirely of concrete, the Locks complex is a testament to the frequent endeavor in the design professions to resist entropy, the sands of time, with rigidity rather than resilience. Figure 1.15, a "Concrete Progress Sheet" from the time the Locks was being constructed, which includes a plan identifying concrete portions of the design, illustrates this clearly; the plan in Figure 1.15 is essentially a complete plan of the complex, revealing that the complex is almost entirely concrete. Barely changing over the course of a century, the Locks is also metaphorically concrete in its rigidity. Most of the 225,000 cubic yards (6,075,000 cubic feet) of concrete[7] used in the project remains in its original form today, save for the original fish ladder which was re-designed and -constructed in the 1970s, also using concrete.

The narrative of the Locks illustrates recent trends in the design professions. Today, rigid concrete paths are favored over dirt ones. They are more reliable. Buildings too are generally becoming more and more rigid. Even in the profession's noble move toward increased energy efficiency, building envelopes are becoming increasingly impenetrable.[8] Exacerbating this trend, or perhaps a symptom of it, *landscape* and *architecture* are often perceived as two separate bodies. This is an immobilizing distinction that only serves to sever a building from its context, from systems that intersect on site, and from any real potential for tenacity. A redesign of the fish ladder at the Locks, then, offers an opportunity to dig into those issues. Acknowledged or not, the architecture profession currently plays a significant role in decreasing Earth's biological diversity. This thesis anticipates a future in which all designers of the built environment strategically, eagerly, and cohesively prioritize interdependent life on Earth.

Questions and Hypothesis

The central questions explored in this thesis project are the following: What is the architect's role in fostering biodiversity? This question is explored at a site-specific scale. There are several sub-questions implicit in this central question: (a) How might a common goal of increased biodiversity structure a design project? (b) Should architects be held to the same degree of responsibility for understanding biodiversity as landscape architects? (c) Is it appropriate for architects to take on the task of biodiversity conservation in the

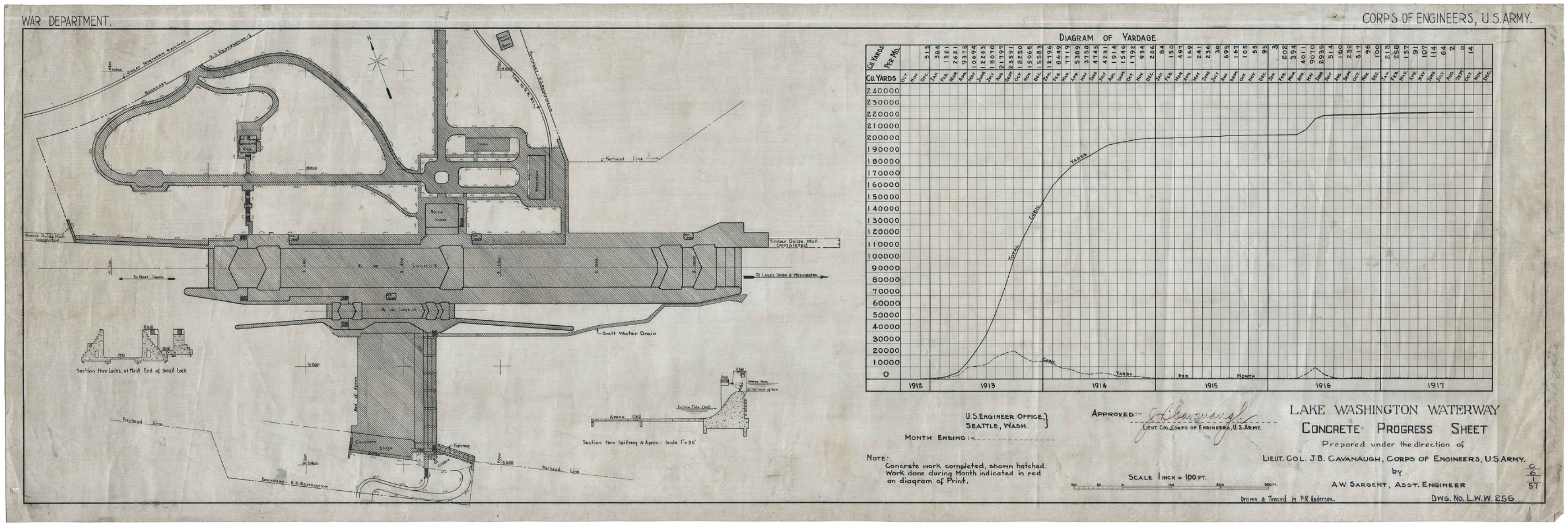

Figure 1.15: This historical "Concrete Progress Sheet" illustrating construction at the Locks from December 1912 through October 1917 gives a sense of the staggering amount of concrete used to construct the Locks complex. This drawing is included here because not only does it illustrate that the complex is composed almost entirely of concrete, but it also introduces the notion that the Locks is conceptually concrete in its rigidity; it has barely changed in a century. The title of this project pairs "concrete" with "nurse logs" in an oxymoron that will develop as a foundational theme throughout this project.
Source: "Lake Washington Waterway Concrete Progress Sheet," Tube 4, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

built environment or does it require a more integrated team? And, perhaps most importantly, (d) How should architects approach projects that center on biodiversity conservation *conceptually*?

I expect to find that it takes an integrated team of practitioners from inside and outside the design field to accomplish a common goal of increased biodiversity in a design project. Architects are responsible for designing to maximize biodiversity, as are landscape architects. Both can only achieve this by consulting scientists and experts from other disciplines, as well as each other, throughout a design project.

Objectives of Thesis Project

The principal objective of this project is to propose a redesign of the Ballard Locks fishway with increased biodiversity as a defining goal. This will be accomplished by (a) clarifying the position that biodiversity conservation should extend into the realm of architecture and that architects have a professional obligation to design for biodiversity, (b) exploring architecture's current relationship with biodiversity, (c) developing a design process and strategy that pursues biodiversity at the Locks, and (d) articulating a conceptual strategy for approaching biodiversity conservation at the Locks. This final step should result in an inclusive conceptual approach which could benefit other anthropocentric landscapes across the globe.

Notes

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[1] Because *the Locks* refers to the complex as a whole (rather than literally the lock chambers), it will be used as a singular noun throughout the document. Accordingly, *locks* (lowercase) will refer to the large and small lock chambers.

[2] Richard J. Hobbs, Eric S. Higgs, and Carol M. Hall, *Novel Ecosystems: Intervening in the New Ecological World Order* (Hoboken: John Wiley & Sons, 2013), 16–20.

[3] Richard Louv, *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*, updated and expanded ed. (Chapel Hill, NC: Algonquin Books of Chapel Hill, 2008), 110.

[4] David W. Orr, *Ecological Literacy: Education and the Transition to a Postmodern World* (Albany: State University of New York Press, 1992), 147.

[5] Mike Cooksey et al., "Synthesis of Salmon Research and Monitoring: Investigations Conducted in the Western Lake Washington Basin" (U.S. Army Corps of Engineers Seattle District, Seattle Public Utilities, King Conservation District, King County/Metro, National Marine Fisheries Service, Washington Department of Fish and Wildlife, 2008): 30.

[6] "Lake Washington Waterway Concrete Progress Sheet," Tube 4, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle. In this drawing (See Fig. 1.15), the fish ladder is labeled "Fishway." *Fishway* will be used interchangeably with *fish ladder* throughout this document. The former is used to describe the design proposal because it is less limiting than the latter.

[7] Friends of the Ballard Locks, "Locks Excavation/Construction Figures" (Seattle, WA).

[8] Carol Williams, *Biodiversity for Low and Zero Carbon Buildings: A Technical Guide for New Build* (London: RIBA Pub., 2010), xiv.

02

ILLUMINATING

[Defining the Problem and Developing a Critical Stance]

> When we have gone they will not know who they are. Supposing themselves to be the purpose of it all, purpose will elude them. Their world will fade into an endless dusk with no whippoorwill to call the owl in the evening and no thrush to make a dawn.
>
> —Paul Shepard, *The Others: How Animals Made Us Human*

Ecoliterate Architects

Biodiversity loss is perhaps the most troubling symptom of the multidimensional environmental crisis currently happening on Earth.[1] In this era of massive biodiversity loss, the web of life that sustains all species, including our own, is threatened. The Code of Ethics and Professional Conduct of the American Institute of Architects (AIA) states that "Members should respect and help conserve their natural and cultural heritage while striving to improve the environment and the quality of life within it."[2] Indeed, because of their involvement in designing the urban realm, where the lowest rates of biodiversity are often found,[3] architects have an obligation to design for increased biodiversity. However, the profession as a whole is failing to meet that Ethical Standard. A profession that is slow to change, architecture's relevancy wanes as it fails to respond to the most significant challenges of this era. That said, in its overall proclivity for integrated practice, the profession is poised to contribute to a biodiverse future through increased dialogue with the sciences.

The Sixth Extinction

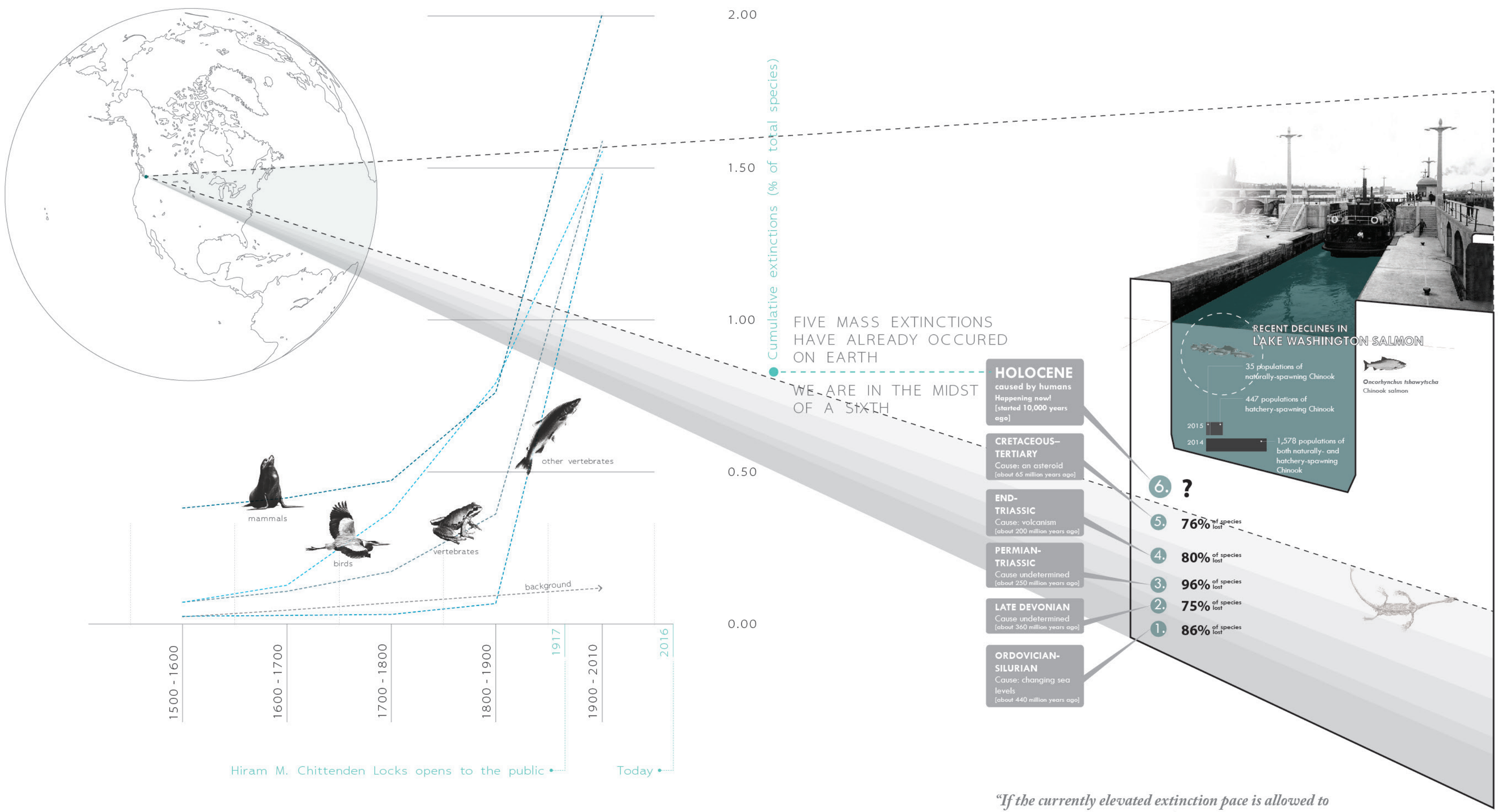
Though critics have regarded scientists' continued warnings of a present-day mass extinction as overstated, a recent study published in *Science Advances*, using conservative figures, confirms that a sixth mass extinction is in progress on Earth.[4] Five mass extinctions preceded the current one, each marked with catastrophe.[5] While the proverbial Cretaceous–Tertiary extinction that ended the dinosaurs was caused by the dust of an asteroid slamming into Earth,[6] the Holocene extinction is anthropogenic, meaning of our species' own making[7] (See Fig. 2.1). The *Science Advances* article offers hope with caution; while there is still a "window of opportunity" for preventing an all-out anthropogenic mass extinction, it is already drawing shut.[8] This is an attitude that is now generally accepted in the scientific community.

Dramatic biodiversity loss—"more than three-quarters of [Earth's] species in a geologically short interval"[9]—is the metric of a mass extinction. After five mass extinctions, or *pulse events*, Earth lives on, swathed again in varied life. A misconception of the sixth mass extinction might be that we need to act now to *save* Earth. However, if this mass extinction is allowed to unfold, down the road Earth will likely diversify itself again, as is the nature of living things. But this will not happen on a human time scale.[10] As one might expect of an anthropogenic mass extinction, its most dramatic markers are found in those places most concentrated with humans—the urban areas—which often have low rates of biodiversity.[11] This is even more dramatic considering the higher non-human population densities typically found in urban areas.[12] Architects, responsible for the physical design of many of these urban sites, have a professional responsibility—to our own species if not the web of life—to design for biodiversity.

Why Biodiversity?

Defining Biodiversity

Biodiversity, or biological diversity, is a measure of the diversity of life within a defined area. The task of Earth's systems is to diversify. This explains *divergent evolution*, which results in *speciation*, or the development of new species in conditions where gene flow is prevented between groups of



> *"If the currently elevated extinction pace is allowed to continue, humans will soon (in as little as three human lifetimes) be deprived of many biodiversity benefits. On human time scales, this loss would be effectively permanent because in the aftermath of past mass extinctions, the living world took hundreds of thousands to millions of years to rediversify."*
>
> —Ceballos et al., "Accelerated Modern Human–Induced Species Losses"

Figure 2.1: exploring the sixth mass extinction at different scales, from the globe to the Locks.

the same species. For example, via speciation, three distinct subspecies of spotted owl have formed along the West Coast: the Northern, California, and Mexican spotted owls. The gradual formation of dialects is another example of the inherent diversification of Earth's systems. These systems organize and diversify to resist the contrasting force of disorganization and simplification, or *entropy*.[13] To resist entropy and maintain itself, a biological entity relies on interactions.[14] These interactions constitute the web of life.

Scales of Biodiversity

Biodiversity often elicits images of the unforgettable *walking dead*, those living species whose fate of extinction has been sealed—the polar bears, the spotted owls. But biodiversity happens at all scales, some undiscernible to humanity. And just because we cannot see them, does not mean they are not going extinct. Entomologist Frank Eugene Lutz's *A Lot of Insects: Entomology in a Suburban Garden*, though published three-quarters of a century ago, remains relevant in its charming demonstration of the overwhelming complexity of insect biodiversity in just one backyard.[15] How can we design for biodiversity if we are not even aware of its ineffable complexity, or do not understand its role in our daily lives? Not only do microbial species inhabit human bodies by the hundred, they also support human health.[16] Biodiversity occurs at all scales, and designing for biodiversity means designing at scales that are not readily discernible.

Mycologist Paul Stamets' work suggests the complexity and mysteriousness of the web of life.[17] He advocates the significance of mycelium, the enigmatic underground networks of a fungus that constitute the largest organisms on Earth, whose branching structures hold uncanny resemblance to the organization of the Universe.[18] Indeed, the web of life is mysterious, vast, and complex, and each "cog and wheel," to use Leopold's vocabulary,[19] has an important role and power whether humanity consciously identifies with it or not. Stamets' work is so captivating because it effortlessly joins our silos of reasoning.[20] Lutz and Stamets' work also illustrates that biodiversity can be measured up or down. Indeed, ecologists have suggested that biodiversity be considered at scales:[21] genes, species, populations, communities, ecosystems, and landscapes.[22] The buildings architects design impact all six scales. Figure 2.2 describes these scales, showing that each scale is not its own entity, but rather that each offers a unique

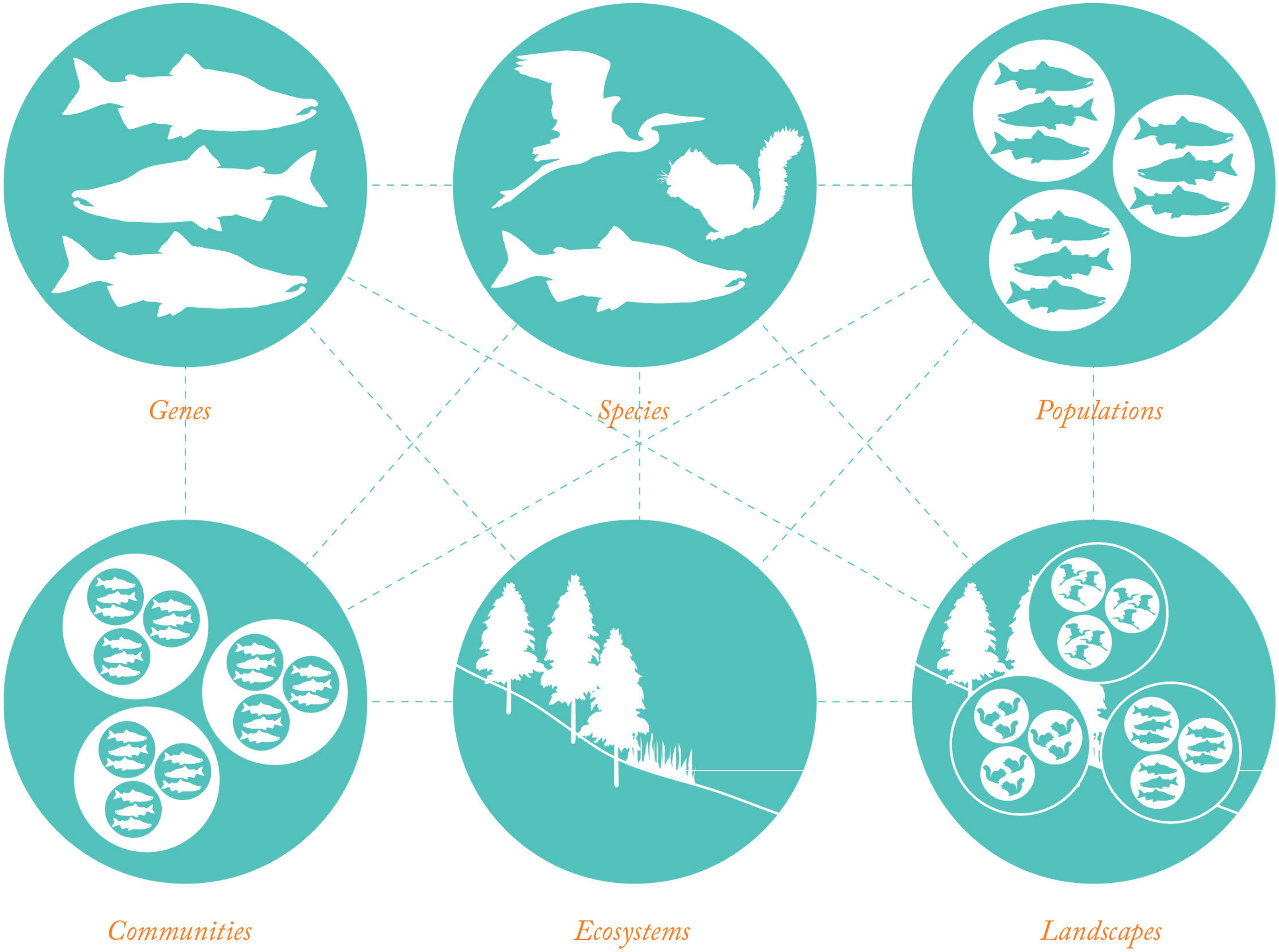


Figure 2.2: Biological diversity can be explored at many interrelated scales.

view into one. If there is more species diversity in an area, there is likely also more ecosystem diversity. It could be said, then, that biodiversity is in fact a diversity of interactions, or relationships.[23]

Biodiversity Is Important, From Different Lenses

Perspectives from many different disciplines agree on the importance of biodiversity for nearly as many reasons. For example, different perspectives from the distinct fields of psychology and biology have come to a shared conclusion: biodiversity improves human health. In his *The Future of Life*, renowned biologist Edward O. Wilson describes each species as "a masterpiece,"[24] an echo of Aldo Leopold's familiar line, "To keep every cog and wheel is the first precaution of intelligent tinkering."[25] Every species has an important role in the web of life. Wilson is responsible for the term *biophilia*, which is, as he describes it, "the innately emotional affiliation of human beings to other living organisms."[26] On the other end of the table, Howard Frumkin, Dean of the University of Washington School of Public Health, believes exposure to what he calls the "natural world" improves human health,[27] referencing experiments such as Roger Ulrich's now notorious nine-year study published over three decades ago which demonstrated patients staying in rooms with windows facing a "natural scene" exhibited various indicators of improved health compared to the same amount of patients staying in rooms with windows opposite a brick wall, including briefer hospital stays following a surgical operation.[28]

This is an example of what Wilson refers to as "consilience," in his so titled book, subtitled *The Unity of Knowledge*, to describe shared conclusions between different disciplines, notably between the humanities and sciences.[29] Never mind the terminology, be it "biophilia"[30] or health benefits via exposure to "a natural scene,"[31] or the "natural world."[32] Here, biology and psychology find themselves at a mutual conclusion: that interaction with the web of life is healthy. It should be obvious, really, that humans are hardwired this way; interactions with the web of life are essential to our persistence as a species.

Threats to Biodiversity

Our species cannot continue into the future without (a) interactions with the web of life, and (b) habitat. Curiously, in diminishing both necessities and consequently driving a mass

Figure 2.3: Biodiversity hotspots are concentrated areas of biodiversity.

extinction on Earth, *Homo sapiens* are acting in a manner contradictory to our species' blueprint. All species have an instinct to persist. Humans are inadvertently modifying the environment in a way that decreases human wellbeing. The Millennium Ecosystem Assessment recognizes the following five "main direct drivers" of biodiversity loss: habitat change, climate change, invasive species, over-exploitation, and pollution.[33] Four of the five—habitat change, climate change, invasive species, and pollution—are especially relevant to the impact of architecture projects. Here, habitat change will be addressed as it is particularly important to this project.

Habitat loss threatens biodiversity. Habitat fragmentation, a result of habitat loss, has been studied for its role in biodiversity loss, a subject biologist Lenore Fahrig suggests is muddled by a lack of distinction between habitat loss and fragmentation.[34] A recent report synthesizing experiments pertaining to habitat fragmentation establishes "that habitat fragmentation reduces biodiversity by 13 to 75% and impairs key ecosystem functions by decreasing biomass and altering nutrient cycles."[35] Thus, habitat connectivity is an important factor in maintaining biodiversity.

Is Ecosystem Health Quantifiable?

There are several metrics used for measuring ecosystem health. Three are mentioned here: ecological lift, indicator species, and ecosystem services. While there is no standard definition for the term *ecological lift*, it has been described "as a net positive change in the biological communities or populations within a targeted area."[36] While increased biodiversity can indicate the occurrence of an ecological lift, more specific indicators exist, such as the success of a species especially sensitive to pollution,[37] or an *indicator species*. Like a canary in a coal mine, the decline of an indicator species can signal an ailing ecosystem. A related term favored in the design field is *ecosystem services*, which The Millennium Ecosystem Assessment defines as "the benefits people obtain from ecosystems."[38] Biodiversity as a concept is useful because it offers a metric, something achievable, that imprecise terms such as *ecology* and *ecosystem* do not provide.

While biological entities rely on interactions to resist entropy, a tactic in resilience, the built environment seems to do so with rigidity. However, urban biodiversity is important (See Fig. 2.3). Ecologist Ingo Kowarik describes the significance of urban biodiversity, writing, "Cities are not dispersed randomly at the global scale, but are often located in biodiversity hotspots."[39] This insight offers a global view of biodiversity and stresses the importance of retaining it in cities. In an essay on "urban sustainability," urban ecologist Marina Alberti and urban planner Lawrence Susskind question how to identify indictors "with clear signals" to measure urban sustainability.[40] While a standard metric for quantifying biodiversity levels has yet to be integrated into the practice of architecture, there are many to choose from.

Integrated Practice

The formula for immobilizing a mass extinction does not lie within one discipline. Experts across disciplines are recognizing the need for consilience to solve our era's obstacles. Marina Alberti and colleagues argue for a "radical change" in how "urban ecology" is approached, reasoning that the current approach is overly-simplified.[41] Because "[u]rbanization is multidimensional and highly variable across time and space,"[42] they advocate greater communication between ecological and social scientists, recognizing that "[i]n their separate domains, neither the natural nor the social sciences can explain how integrated human and ecological systems emerge and evolve, because human and ecological factors work simultaneously at various levels."[43] A change in perspective toward Wilson's "consilience,"[44] described above, will be necessary to foster biodiversity in cities. I believe that Stamets' work, also referenced above, is an example of the consilience that Wilson advocates.[45] Stamets unearths the importance of mushroom mycelium not by thinking within the *box* of mycology, but by using his expertise as a mycologist to make connections outside the profession.

This project supports an emerging paradigm for architecture, aligned with today's context, in which maximizing biodiversity is the central goal from the preliminary stages of a design project. To achieve this, there are many opportunities for architects to take cues from interdisciplinary thinkers such as Wilson and Stamets. Because the built environments we inhabit cannot fit into the discipline of architecture alone, ecologists and biologists ought to be heavily consulted throughout a design project, be it classified as *architecture* or *landscape architecture*.

Notes

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[1] Gerardo Ceballos et al., “Accelerated Modern Human–Induced Species Losses: Entering the Sixth Mass Extinction,” *Science Advances* 1, no. 5 (2015): 3, doi: 10.1126/sciadv.1400253.

[2] The American Institute of Architects, “2012 Code of Ethics and Professional Conduct,” Canon I, E.S. 1.3: “Natural and Cultural Heritage,” Ethics from the Office of General Counsel: 1, http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiap074122.pdf.

[3] Eyal Shochat et al., “Invasion, Competition, and Biodiversity Loss in Urban Ecosystems,” *BioScience* 60, no. 3 (2010): 199, doi: 10.1525/bio.2010.60.3.6.

[4] Ceballos et al., “Accelerated Modern Human–Induced Species Losses,” 3–4.

[5] Elizabeth Kolbert, *The Sixth Extinction: An Unnatural History* (New York: Henry Holt and Company, 2014), 3.

[6] Ibid., 86.

[7] Ibid., 3.

[8] Ceballos et al., “Accelerated Modern Human–Induced Species Losses,” 4.

[9] Anthony D. Barnosky et al., “Has the Earth's Sixth Mass Extinction Already Arrived?” *Nature* 471, no. 7336 (2011): 51, doi: 10.1038/nature09678.

[10] Ceballos et al., “Accelerated Modern Human–Induced Species Losses,” 4.

[11] Shochat et al., “Invasion, Competition, and Biodiversity Loss,” 199.

[12] Ibid.

[13] John Whitfield, “Survival of the Likeliest?” *PLoS Biology* 5, no. 5 (2007): e142, doi: 10.1371/journal.pbio.0050142.

[14] Lee A. Dyer et al., “Diversity of Interactions: A Metric for Studies of Biodiversity,” *Biotropica* 42, no. 3 (2010): 281–82, 286–87, doi: 10.1111/j.1744-7429.2009.00624.x.

[15] Frank Eugene Lutz, *A Lot of Insects: Entomology in a Suburban Garden* (New York: G.P. Putnam's Sons, 1941).

[16] Takahiro Matsuki and Ryuichiro Tanaka, “Function of the Human Gut Microbiota,” in *The Human Microbiota and Microbiome (Advances in Molecular and Cellular Microbiology 25)*, ed. Julian R. Marchesi (Wallingford, Oxfordshire, UK; Boston, MA, USA: CABI, 2014), 130.

[17] Paul Stamets, *Mycelium Running: How Mushrooms Can Help Save the World* (Berkeley, CA: Ten Speed Press, 2005), 7–9.

[18] Paul Stamets, “Mushrooms, Bees, and Saving the World” (presentation, Town Hall Seattle, Seattle, WA, May 4, 2015).

[19] Aldo Leopold and Charles W. Schwartz, *A Sand County Almanac: With Other Essays on Conservation from Round River* (New York: Oxford University Press, 1966), 190.

[20] Stamets, “Mushrooms, Bees.”

[21] Reed F. Noss, “Indicators for Monitoring Biodiversity: A Hierarchical Approach,” *Conservation Biolog*y 4, no. 4 (1990): 358–61, http://www.jstor.org/stable/2385928.

[22] Karen A. Poiani et al., “Biodiversity Conservation at Multiple Scales: Functional Sites, Landscapes, and Networks,” *BioScience* 50, no. 2 (2000): 133, doi: 10.1641/0006-3568(2000)050[0133:bcamsf]2.3.co;2.

[23] Dyer et al., “Diversity of Interactions,” 287.

[24] Edward O. Wilson, *The Future of Life* (New York: Vintage Books, 2003), 131.

[25] Leopold and Schwartz, *A Sand County Almanac*, 190.

[26] Stephen R. Kellert and Edward O. Wilson, *The Biophilia Hypothesis* (Washington, DC: Island Press, 1993), 31.

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[27] Howard Frumkin, “Beyond Toxicity: Human Health and the Natural Environment,” *American Journal of Preventive Medicine* 20, no. 3 (2001): 234.

[28] Roger S. Ulrich, “View through a Window May Influence Recovery from Surgery,” *Science* 224, no. 4647 (1984): 420–21, http://www.jstor.org/stable/1692984.

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[30] Kellert and Wilson, *Biophilia Hypothesis*, 416.

[31] Ulrich, “Window,” 420–21.

[32] Frumkin, “Beyond Toxicity,” 234.

[33] Anantha Kumar Duraiappah and Shahid Naeem, *Ecosystems and Human Well-Being: Biodiversity Synthesis*, Millennium Ecosystem Assessment (Washington, DC: World Resources Institute, 2005), 50.

[34] Lenore Fahrig, “Effects of Habitat Fragmentation on Biodiversity,” *Annual Review of Ecology, Evolution, and Systematics* 34 (2003): 491–92, doi: 10.1146/annurev.ecolsys.34.011802.132419.

[35] Nick M. Haddad et al., abstract, “Habitat Fragmentation and Its Lasting Impact on Earth’s Ecosystems,” *Science Advances* 1, no. 2 (2015): 1.

[36] John R. Craynon, *Environmental Considerations in Energy Production* (Englewood, Colorado: Society for Mining, Metallurgy, and Exploration (SME), 2013), 455.

[37] Ibid.

[38] Millennium Ecosystem Assessment, *Ecosystems and Human Well-being: Synthesis*, Millennium Ecosystem Assessment Series (Washington, DC: Island Press, 2005), v.

[39] Ingo Kowarik, “Novel Urban Ecosystems, Biodiversity, and Conservation,” *Environmental Pollution* 159, no. 8-9 (2011): 1974, doi:10.1016/j.envpol.2011.02.022.

[40] Marina Alberti and Lawrence Susskind, “Managing Urban Sustainability: An Introduction to the Special Issue,” *Environmental Impact Assessment Review* 16, no. 4 (1996): 219, doi:10.1016/S0195-9255(96)00070-4.

[41] Marina Alberti et al., “Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems,” *BioScience* 53, no. 12 (2003): 1176, doi: 10.1641/0006-3568(2003)053[1169:IHIEOA]2.0.CO.

[42] Ibid., 1173.

[43] Ibid., 1174.

[44] Wilson, *Consilience*, 8–9.

[45] Ibid.

03

DECOMPOSING

[Architecture and Biodiversity]

> We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely.
>
> — Edward O. Wilson, *Consilience: The Unity of Knowledge*

A Lack of Tools?

There is very little published that explicitly addresses the role of architecture in biodiversity conservation, an echo of the current trend in both academia and professional practice. Several themes help explain why the architecture profession has yet to address biodiversity loss in full force. Perhaps the most obvious of these themes is that accredited architecture programs—which yield the profession's practitioners—generally do not require students to study concepts related to biodiversity.[1]

The UK Green Building Council (UK-GBC) has identified additional reasons the architecture profession as a whole rarely addresses biodiversity in a meaningful way. A challenge to this trend, the organization set up a Biodiversity Task Group in 2008 to "raise the awareness of biodiversity in delivering a sustainable built environment, and to encourage the construction industry and its clients to incorporate biodiversity into all new and refurbishment schemes."[2] Their 2009 report explains that despite the abundance of information regarding biodiversity and the built environment, it is not "easily accessible" leading to "the perception that biodiversity is a non-essential additional consideration in new developments, imposed by external conservationists, ecologists or government."[3] The team additionally found that in the absence of a shared, standard approach for measuring building construction-related impacts on biodiversity, it is difficult to make strides toward biodiversity conservation within the industry.[4]

An additional explanation for architecture's slowness to assume responsibility for designing for increased biodiversity is simply that the task largely falls on the shoulders of landscape architects. The reasoning in these cases is that landscape architects work with vegetation, and thus habitat. Aggravating the situation, landscape architecture is often diminished to an afterthought in many design strategies, meaning often so too is non-human habitat. In his book *The Fundamentals of Landscape Architecture*, Tim Waterman writes, "Landscape architecture often suffers from the misconception that it is a profession employed to 'shrub it up,' as though the landscape is the parsley garnish to architecture's perfectly formed omelette."[5] Literature reflects this division; there is considerably more material at hand on the role of landscape architects than architects on the subject of biodiversity in the built environment. If vegetation and habitat for non-human species are considered nothing more than building embellishments, then architects often miss opportunities to engage with biologists themselves, and to integrate principles of designing to maximize biodiversity into the building concept. While landscape architecture students in accredited programs are required to take more classes relating to ecology than architecture students, they are generally more aware of overarching concepts than specific principles of the subject. Bridging the worlds of soils, plants, and materials, like architects they are more generalists than specialists. Generalist disciplines thrive on the specificities offered by specialist disciplines. While each profession, landscape architecture and architecture, is vital in its own right, opportunities for real progress toward designs that support biodiversity are not possible without the benefit of consultations from outside specialists.

Opportunities within the Profession

While the architecture profession is currently missing tools to tackle the threat of biodiversity loss in full force, there is an abundance of opportunities to incorporate new tools into existing frameworks within the profession. In recent decades there has been an increasing focus on *sustainable* or *green* architecture, reflecting an eagerness within the profession to address environmental issues. However, very few concepts and organizations associated with this movement cite increased biodiversity or biodiversity conservation as an explicit goal with associated metrics for gauging performance. Several of those concepts and organizations will be considered here.

Biomimicry

The Biomimicry Institute describes designs produced via *biomimicry* as "nature-inspired solutions."[6] Though it has produced inspiring precedents, the concept of biomimicry, or design through emulating "nature," has in some ways inhibited architects' abilities to design actively in an ecosystem. The concept is often touted as forward-looking sustainable practice, while remaining largely unchanged since the architecture community first embraced it decades ago. Critics of the concept argue additionally that the concept reinforces the idea that *Homo sapiens* and the built environment are separate from the web of life. We can only copy "nature" if we are not natural. However, that is not to say biomimicry has not made much progress on this front, or that it is not prepared to continue to address the issues surrounding biodiversity loss. A proponent of biomimicry, architect and author of *Biomimicry in Architecture*,[7] Michael Pawlyn, agrees that architects at times fall short of the task, "dependent on seductive imagery such as spiders' webs" without an authentic underpinning.[8] He suggests a real solution could involve "having a biologist at the design table right from the early stage of a project."[9] This perspective has much promise for addressing biodiversity in the future, and could engender a shift away from nature-as-a-pretext to biodiversity-as-a-goal.

LEED (Leadership in Energy and Environmental Design)

The UK-GBC's Biodiversity Task Group identified several weaknesses of LEED, an initiative of the U.S. Green Building Council, regarding its ability to address biodiversity, including the fact that "[o]nly protected or threatened species are considered in site selection" and that "[t]here is no assessment of site ecology before or after development."[10] A demonstrable if not simplistic illustration of LEED certified buildings failing biodiversity is the many birds that die every year after striking glassy, energy-efficient buildings.[11] Apparently LEED now offers a point for "bird collision deterrence."[12] It should be noted that the UK-GBC identified just as many strengths of the program as they did faults, including that it "[e]ncourages reducing the footprint of the development and [minimizing] the spread of constructions works."[13] LEED is a robust framework positioned to incorporate additional biodiversity-oriented goals. However, this entails more than points for using "bird-friendly" materials,[14] which seems more a feature than a solution—a pitfall of the point system.

Life-Cycle Assessment

In 2010 the AIA put out a "Guide to Building Life Cycle Assessment in Practice" in an attempt to aggregate scattered information about Life Cycle Assessment (LCA) and clarify its principles.[15] The thorough document describes LCA as "a tool that allows architects and other building professionals to understand the energy use and other environmental impacts associated with all life cycle phases of the building: procurement, construction, operation, and decommissioning."[16] The document outlines "impact categories," all of which are connected to biodiversity loss. Issues such as "ecological toxicity"[17] and eutrophication, the latter of which the authors write "results in generally undesirable shifts in the number of species in ecosystems and a reduction in ecological diversity,"[18] candidly address threats to biodiversity.

The Living Building Challenge

Biodiversity is addressed several times in the Living Building Challenge 3.0 document, usually as an abstract goal.[19] Other times biodiversity is addressed more specifically, such as in regard to "limits to growth," the document's first "imperative."[20] For this imperative the document states that the "[o]n-site landscape must be designed so that as it matures and evolves it increasingly emulates the functionality of indigenous ecosystems with regard to density, biodiversity, plant succession, water use, and nutrient needs."[21] While a noble endeavor, there is no explicit explanation for how to achieve or measure this goal of biodiversity. By implicitly recommending imitating the "functionality of indigenous ecosystems" in order to achieve this goal of biodiversity, the document echoes the concept of biomimicry. Additionally, it does not specify if the "on-site landscape" includes the building itself.[22] Because the Living Building Challenge cites biodiversity as a general goal, the program is well-positioned to incorporate it as an explicit goal with specified metrics for gauging performance.

Passive Housing and Carbon-Neutral

These two concepts are similar but not synonymous. The former is based on the concept of energy efficiency, or using as little energy as possible, while the latter is based on the effort to reduce CO_2 emissions via offsets. The goal of the 2030 Challenge is for "All new buildings, developments, and major renovations [to] be carbon-neutral by 2030."[23]

Carol Williams' 2010 *Biodiversity for Low and Zero Carbon Buildings: A Technical Guide for New Build*, a British publication, is a rare instance of literature that explicitly addresses the relationship between architecture and biodiversity. The book addresses this topic straightforwardly in regard to new buildings, from the broader scale of legislation to the specified scale of architectural detail drawings.[24] The 2013 second edition, *Designing for Biodiversity: A Technical Guide for New and Existing Buildings*, with added co-authors Kelly Gunnell and Brian Murphy, widens the scope to include existing buildings in addition to new build.[25] These two editions are particularly relevant to passive housing and carbon-neutral design because they make the case that architecture's increasing focus on designing energy-efficient buildings has resulted in impermeable building envelopes, leaving fewer habitat opportunities for other species.

Opportunities to Engage Outside Perspectives

The aforementioned concepts and organizations associated with the green building movement have made much progress toward sustainability. However, as a whole, they do not address biodiversity explicitly as a goal with quantifiable metrics for achieving and gauging success, and this leaves architects ill-prepared to address it. However, these organizations and others like them are poised to adopt a more biodiversity-centric attitude. There are numerous perspectives outside the realm of architecture that, with increased communication, hold much promise for integration into the field. *Ecological engineering*, for example, is a concept well-suited for inclusion in the architecture sphere. A 2001 article seeking to clarify the field defines it as "the design of sustainable systems, consistent with ecological principles, which integrate human society with its natural environment for the benefit of both."[26] Related, *ecological design* is poised for greater integration with architecture. Headed by John Todd, for decades it has spanned many disciplines, including "technologies for food production, fuel generation, waste conversion, water purification, chemical detoxification, environmental restoration, and ecological innovation in architecture that created bioshelters."[27] Ecological design and engineering are just two examples of disciplines outside the standard building design process that are primed for further engagement by the architecture profession.

The contentious idea of "novel ecosystems," boldly referred to as the "new ecological world order," is relevant to the relationship between architecture and biodiversity because many architects work in "novel ecosystem" contexts. Novel ecosystems have been defined as "systems that differ in composition and/or function from present and past systems as a consequence of changing species distributions, environmental alteration through climate and land use change and shifting values about nature and ecosystems."[28] While biodiversity-depleted ecosystems are certainly not something to strive for, the term offers a way forward for addressing these radically human-altered landscapes. The idea is especially relevant for architects who work in ultra-urban settings.

I believe ecologist Michael Rosenzweig's "reconciliation ecology" concept ties together the fields of ecological engineering and design with the emerging concept of novel ecosystems.[29] It also offers a hand to the design professions. Rosenzweig writes, "Rather than insist on protecting habitat from human use, reconciliation ecology works in and with the human dominated habitats that cover most of the terrestrial surface of the Earth."[30] Though reconciliation ecology came out of the sciences, its core principles reach into the realm of architecture and the other design professions. A generalist profession capable of addressing sweeping challenges through specified metrics, architecture has an important role to play in increasing biodiversity in novel ecosystems. Correspondingly, for architects to achieve maximized biodiversity in their designs, science-borne metrics such as those associated with reconciliation ecology will need to powerfully infiltrate the architecture world.

Notes

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[1] "3+Year Accredited Master of Architecture," *University of Washington, College of Built Environments, Department of Architecture*, http://arch.be.washington.edu/programs-courses/m-arch/3year.

[2] "Biodiversity and the Built Environment," *UK Green Building Council*, http://www.ukgbc.org/campaigns-and-policy/task-groups /biodiversity-and-built-environment.

[3] "Biodiversity and the Built Environment: A Report by the UK-GBC Task Group," *UK Green Building Council*, (March 2009): 9, http://www.ukgbc.org/sites/default/files/Biodiversity%2520and%2520the%2520Built%2520Environment%2520-%2520Full%2520report%2520and%2520appendices.pdf.

[4] "Biodiversity and the Built Environment: A Report by the UK-GBC Task Group," 12.

[5] Tim Waterman, *The Fundamentals of Landscape Architecture* (Lausanne; Worthing: AVA Academia, 2009), 96.

[6] *Biomimicry Institute*, http://biomimicry.org.

[7] Michael Pawlyn, *Biomimicry in Architecture* (London, UK: RIBA Pub., 2011).

[8] Katie Scott, "Biomimicry in Architecture and the Start of the Ecological Age," *Wired.co.uk*, February 22, 2012, http://www.wired.co.uk /news/archive/2012-02/22/biomimicry-in-architecture.

[9] Ibid.

[10] "Biodiversity and the Built Environment: A Report by the UK-GBC Task Group," 28.

[11] Sheryl DeVore, "Migratory Birds Run Afoul of Green Buildings," *Chicago Tribune*, April 13, 2011, http://articles.chicagotribune .com/2011-04-13/news/ct-x-c-fbi-birds-20110413_1_migratory-birds-annette-prince-bird-friendly.

[12] "Bird Collision Deterrence," LEED BD+C: New Construction, v3 - LEED 2009, http://www.usgbc.org/credits/core-shell-existing-buildings-healthcare-new-construction-retail-nc-schools/v2009/pc55.

[13] "Biodiversity and the Built Environment: A Report by the UK-GBC Task Group," 28.

[14] "Bird Collision Deterrence," LEED.

[15] Charlene Bayer et al., "AIA Guide to Building Life Cycle Assessment in Practice" (Washington, DC: The American Institute of Architects, 2010): 9.

[16] Ibid., 10.

[17] Ibid., 55.

[18] Ibid., 54.

[19] "Living Building Challenge 3.0: A Visionary Path to a Regenerative Future," (Seattle, WA: International Living Future Institute, 2014): 3, 7.

[20] "Living Building Challenge 3.0," 24.

[21] Ibid.

[22] Ibid.

[23] "The 2030 Challenge," *Architecture 2030*, http://architecture2030.org/2030_challenges/2030-challenge/.

[24] Carol Williams, *Biodiversity for Low and Zero Carbon Buildings: A Technical Guide for New Build*, (London: RIBA Pub., 2010), xiv.

[25] Kelly Gunnell, Brian Murphy, and Carol Williams, *Designing for Biodiversity: A Technical Guide for New and Existing Buildings*. Second ed. (London: RIBA Pub., 2013).

[26] Scott D. Bergen, Susan M. Bolton, and James L. Fridley, "Design Principles for Ecological Engineering." *Ecological Engineering* 18, no. 2 (2001): 201, doi: http://dx.doi.org/10.1016/S0925-8574(01)00078-7.

[27] John Todd, Erica J.G. Brown, and Erik Wells, "Ecological Design Applied," *Ecological Engineering* 20, no. 5 (2003): 422, doi:10.1016/j.ecoleng.2003.08.004.

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[28] Richard J. Hobbs, Eric S. Higgs, and Carol M. Hall, *Novel Ecosystems: Intervening in the New Ecological World Order* (Hoboken: John Wiley & Sons, 2013), 4.

[29] Michael L. Rosenzweig, "Reconciliation Ecology and the Future of Species Diversity," *Oryx* 37, no. 2 (2003): 194, doi: 10.1017/S0030605303000371.

[30] Ibid.

04 GROUNDING

[The Site]

That was quite a day for the white people at least. The waters just went down, down, until our landing and canoes stood dry and there was no Black River at all. There were pools, of course, and the struggling fish trapped in them. People came from miles around, laughing and hollering and stuffing fish into gunny sacks.
—Joseph Moses, quoted by Coll Thrush in "City of the Changers"[1]

Overview

The Hiram M. Chittenden Locks complex near the mouth of the human-engineered and human-controlled Lake Washington Ship Canal forms a hard barrier in lieu of the soft gradient of an estuary. It exemplifies the issues discussed in the preceding chapters, and offers a palpable opportunity to explore them at an empirical scale. At the Ballard Locks humans have tried to force an anthropocentric landscape, and in so doing have reduced non-human habitat, native biodiversity, and consequently human wellbeing. These reductions emerge in any anthropocentric landscape because humanity is just one component of the composite, intricate, interrelated, endlessly adjusting web of life that shrouds and permeates Earth.

An inflexible wall of concrete and steel,[2] the spillway dam and two locks establish an abrupt transition, not only in water salinity, but also in water temperature and elevation. Figure 4.1 provides a site plan of the complex and surrounding context. When viewed from above, the Locks is unmistakably at odds with the watershed. While Salmon Bay is considered an estuary, it, according to the authors of a synthesis report on the Salmon Bay estuary, "lacks the essential functions of a natural estuary due to urbanization and industrial development, including the construction of the H.M. Chittenden Locks in 1916."[3] Without this wall, a true estuary—the ecologically rich area near the mouth of a waterway where fresh mixes with salt to form brackish water—would form. It is conceptually useful to consider an estuary inherently biodiverse because it is an example of what scientists call an *ecotone*, the coming together of two ecological communities. In the case of an estuary, saline water and freshwater come together to form a brackish ecotone. An ecotone includes species found in both of the communities that comprise it, as well as species unique to the ecotone—far from the reality at today's Salmon Bay. In a dissertation on the impacts of shoreline armoring on nearshore ecotones, Sarah Heerhartz writes, "Regulation of river flows and flood control in the form of dams, dikes, and diversions impacts ecotone structure and functioning by changing the permeability of boundaries and the connectivity between landscape patches."[4] The Locks is an exaggerated symbol of this condition, a hard line on the landscape, a wall between two ecological communities, resisting overlap (See Fig. 4.2).

The Locks complex physically stresses a trait of many ultra-urban sites: there is no reference condition that the landscape can be *restored* to. The Ship Canal was conceived and cut by humans on a brief human time scale compared to that of the retreating ice sheet that excavated Lakes Union and Washington and Puget Sound. The construction of the Ship Canal and Locks quickly altered the direction and speed of water flowing through Lake Washington.[5] It caused a treasured river and thousands of acres of flourishing wetlands to dry up.[6] It established a new watershed.[7] It rerouted migrations. It dispossessed long established populations, human and non-human. It reduced biodiversity.

While dam removal is reviving waterways across the nation, the removal of the locks and spillway dam would further rework an already "highly altered system."[8] The excavations of the Fremont and Montlake Cuts caused the

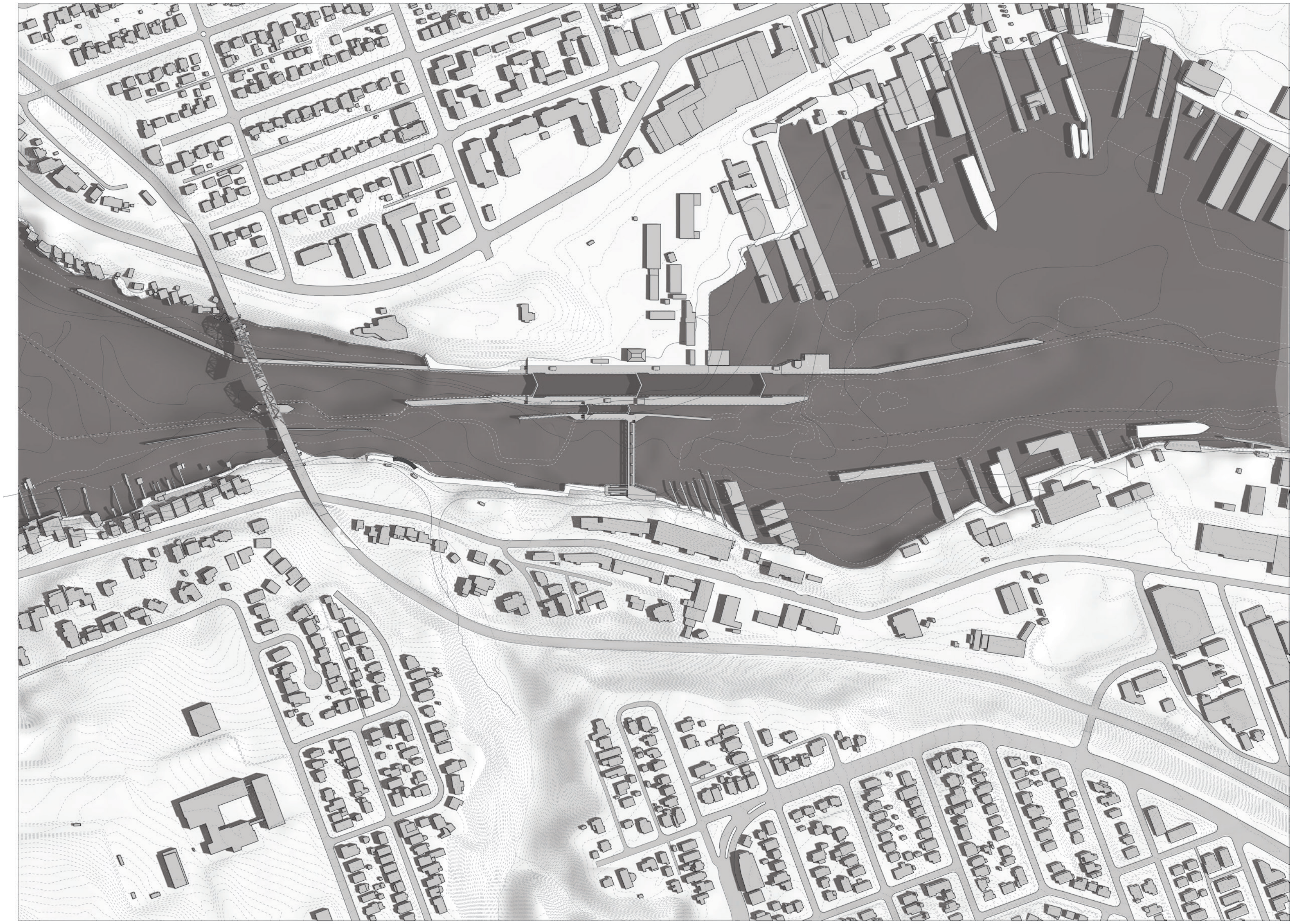


Figure 4.1: This plan of the Locks and context represents historical bathymetry contours with solid lines, current contours and bathymetry contours with dashed lines, and the navigation channel with larger dashed lines.

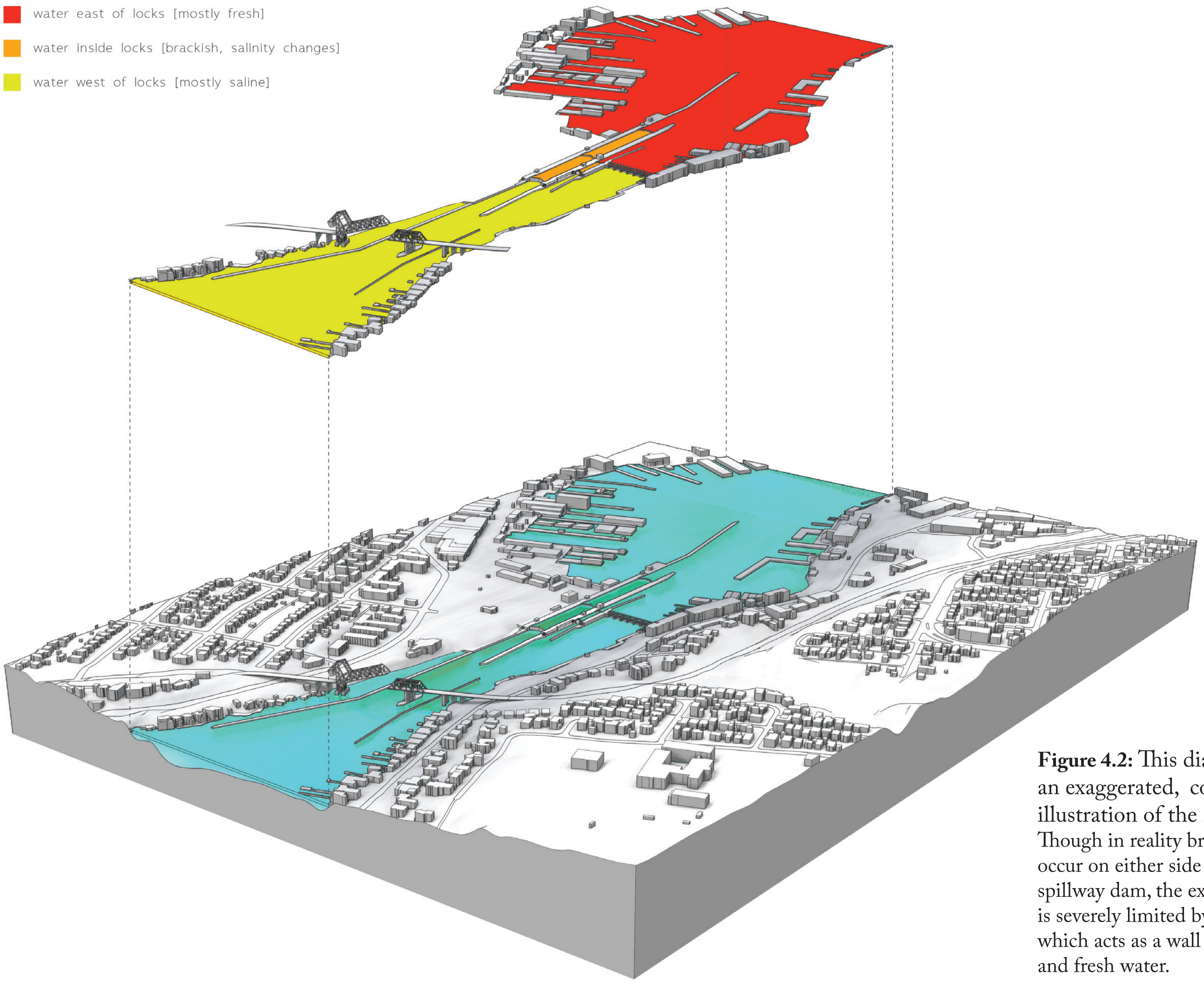


Figure 4.2: This diagram provides an exaggerated, conceptual illustration of the Locks as a wall. Though in reality brackish water does occur on either side of the locks and spillway dam, the extent of mixing is severely limited by the complex, which acts as a wall between saline and fresh water.

water level of Lake Washington to drop 8.8 feet,[9] because they connected three water bodies which previously had three distinct water levels. With no locks and spillway dam to impound it, the now joint water elevation of the canal and Lakes Washington and Union would continue to drop until level with Puget Sound and the whole waterway would become tidal.

Indeed, if the locks and spillway dam were to be removed today, Seattle would experience far-reaching consequences, not the least of which would be possible damages[10] to the longest floating bridges in the world. These things considered, restoration in the traditional sense is not a pragmatic option at the Locks site. Regrettably we cannot go back to the way it was—fill in the Fremont and Montlake Cuts, watch the watershed rediversify in rewind. But we can go forward. Shaping a landscape—a watershed—is an act of iteration; rashly altered places cannot be returned to their former selves (See Fig. 4.3). A city has been built on the severe city planning and engineering choices of the late nineteenth and early twentieth centuries. While we can oppose those choices, we cannot ignore the context that has been shaped by them.

Manipulating Drainage

The Ship Canal

The story of the excavation of the roughly 8.6-mile-long[11] Lake Washington Ship Canal is a story of loss: habitat loss, biodiversity loss, and displacement. The Ship Canal was initially proposed by Seattle pioneer Thomas Mercer in 1854[12] but was not fully realized until more than half a century later, and only after weighing it against six alternate routes[13] to connect Lake Washington with Puget Sound. Incredibly, one of these potential routes, pushed by Eugene Semple who would benefit financially from its realization, was actually planned right through Beacon Hill—an alternative that would entail the excavation of a channel hundreds of feet in depth that seemed to ignore existing topography altogether.[14] Construction of the unlikely plan even began in 1895.[15] Though it was called off in 1904,[16] this plan speaks to Seattle's modern tradition of quickly and dramatically altering the landscape and consequently stormwater drainage.

The route that eventually transpired linked three existing water bodies: Lake Washington, Lake Union, and Salmon Bay.[17] The main projects of the Ship Canal were the

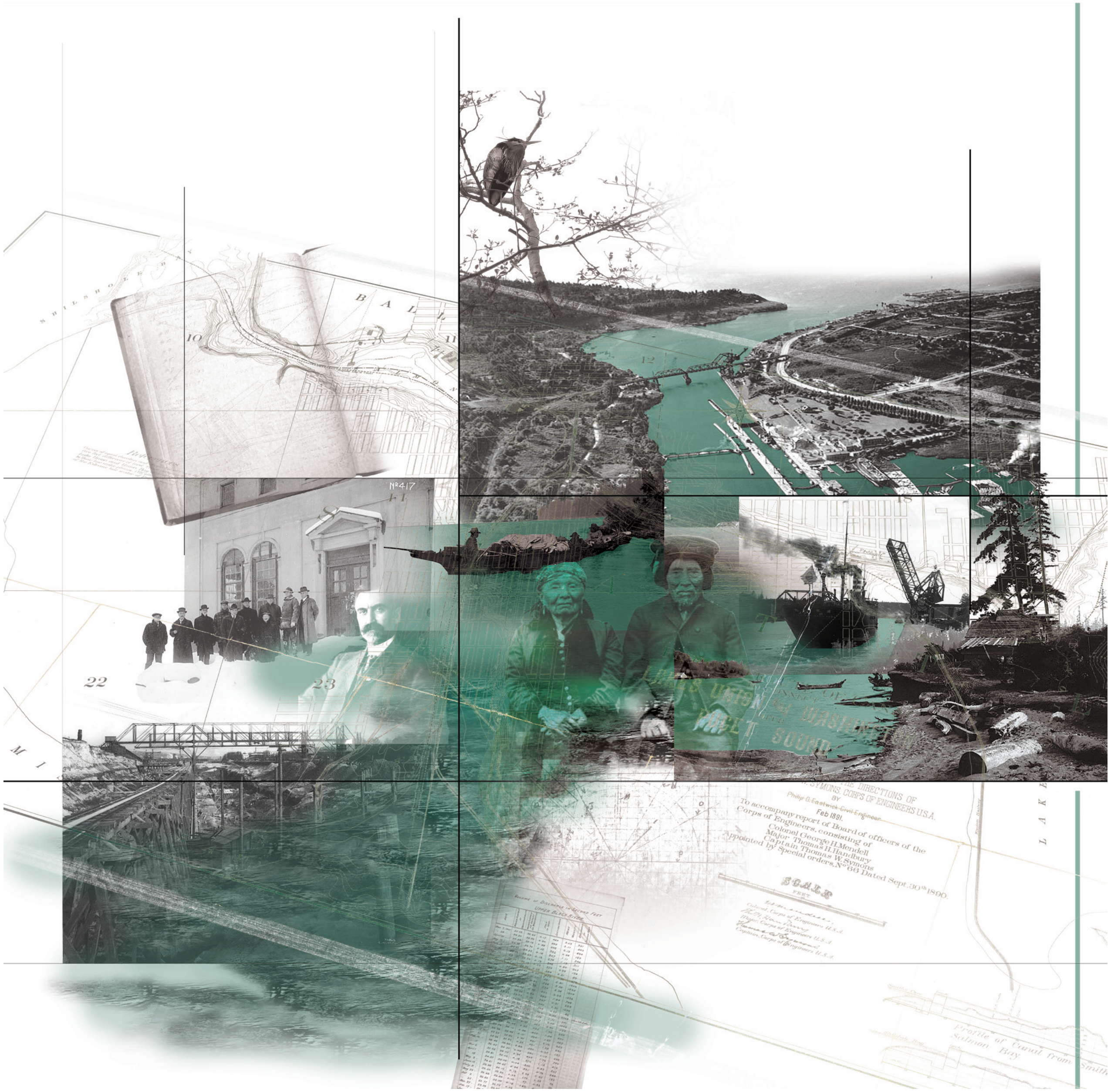


Figure 4.3: Like a palimpsest, this collage conveys a sense of the site's layered history. *Sources of images used in this collage*: National Archives at Seattle, University of Washington Libraries. See Figure Credits, pages 150 and 151, for a detailed list of sources used in this collage.

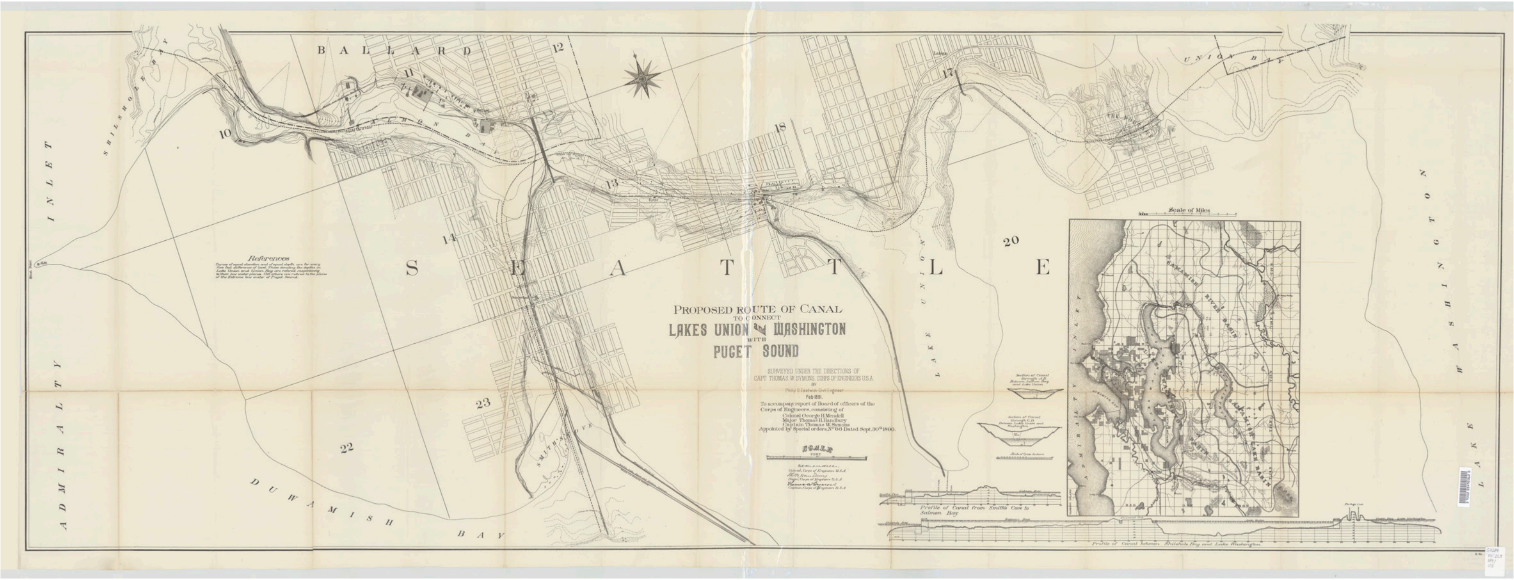


Figure 4.4: Just over a century ago the Ship Canal was just an idea on paper.
Source: Symons, Thomas W., and Philip G. Eastwick. *Proposed Route of Canal to Connect Lakes Union and Washington with Puget Sound (1891)*. Map. Washington, DC: United States Army Corps of Engineers, 1891. University of Washington Libraries Manuscripts, Special Collections, University Archives Division.

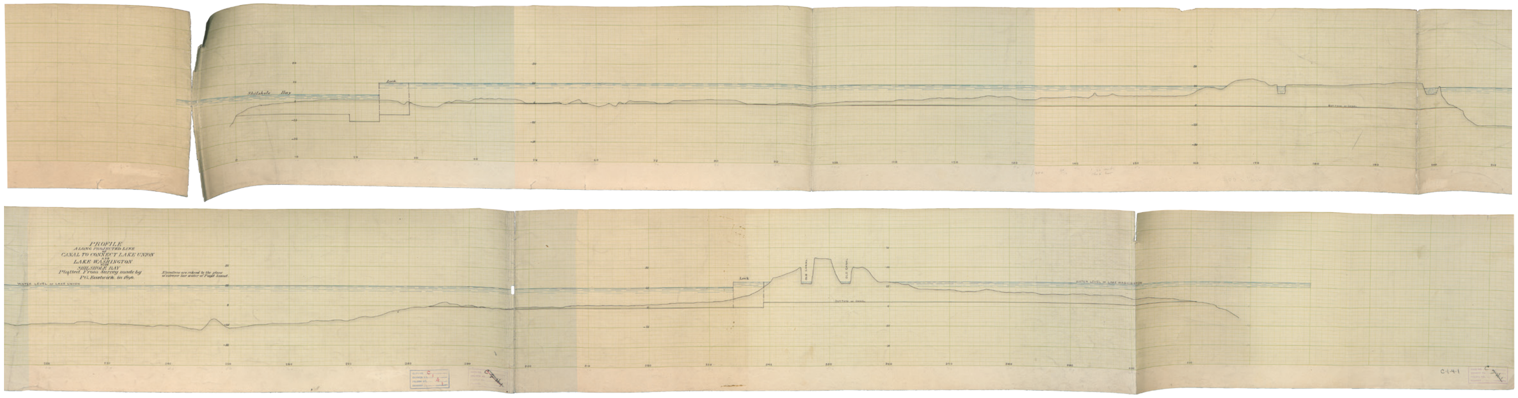


Figure 4.5: This canal elevation has been split in two to fit on the page.
Source: “Profile along Projected Line of Canal to Connect Lake Union and Lake Washington with Shilshole Bay Platted from Survey made by P.G. Eastwick. in 1890,” Tube 3, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

excavations of the Montlake and Fremont Cuts, to the east and west of Lake Union respectively. The former connected Lake Union's Portage Bay and Lake Washington's Union Bay and the latter connected Salmon Bay with Lake Union (See Figs. 4.4, 4.5). For many years in advance of the Ship Canal, Portage Bay and Union Bay were connected by a portage trail and small creek which ran during wet months.[18] It was known by indigenous people as Carry a Canoe, sxWátSadweehL, for this was where they transported their canoes between the lakes.[19] It was here that in 1860 Harvey L. Pike began shoveling a ditch between the two bays.[20]

Such a massive undertaking was supported by various stakeholders, each group having its own set of incentives. All reasons, though, were anthropocentric and many based on industry. Farmers would be able to transport their crops for sale.[21] The canal would serve the transport of logs between Lake Washington and Lake Union and Lake Union and Salmon Bay, where two "small excavations"[22] had already been made for this purpose.[23] A canal to Lake Union was desired to mitigate flooding around Lake Washington associated with heavy rain or snow.[24] The absence of "corrosion, marine-plant growth, and tidal fluctuations" that accompany freshwater moorage led to expectations of industrial growth around Lake Washington,[25] and led the federal government to consider the construction of the canal in the 1860s before the idea was abandoned when the fledgling city could not offer the population and resources a navy port required.[26] But other stakeholders so desired a canal that in the 1880s a group, among them Judge Thomas Burke, paid a company of laborers to channelize Ross Creek, Lake Union's outlet which connected Lake Union and Salmon Bay prior to the Ship Canal, and excavate a canal between Portage and Union Bays.[27] Both projects included locks to maintain Lake Washington's elevation.[28]

The Ballard Locks was completed in 1916 and dedicated in 1917,[29] during World War I. The realization of the canal spoke to the prioritization of rash city planning incentivized by industry at the expense of biodiversity. Though the Ship Canal was navigable at that point, it was not until 1934 that it was officially considered complete.[30] Today, rather than the industrial waterway that the original planners of the canal envisioned, it is used mostly by those seeking recreation[31]—that is, at least the humans who use it. This is illustrated clearly in Figure 4.6, which shows the number and

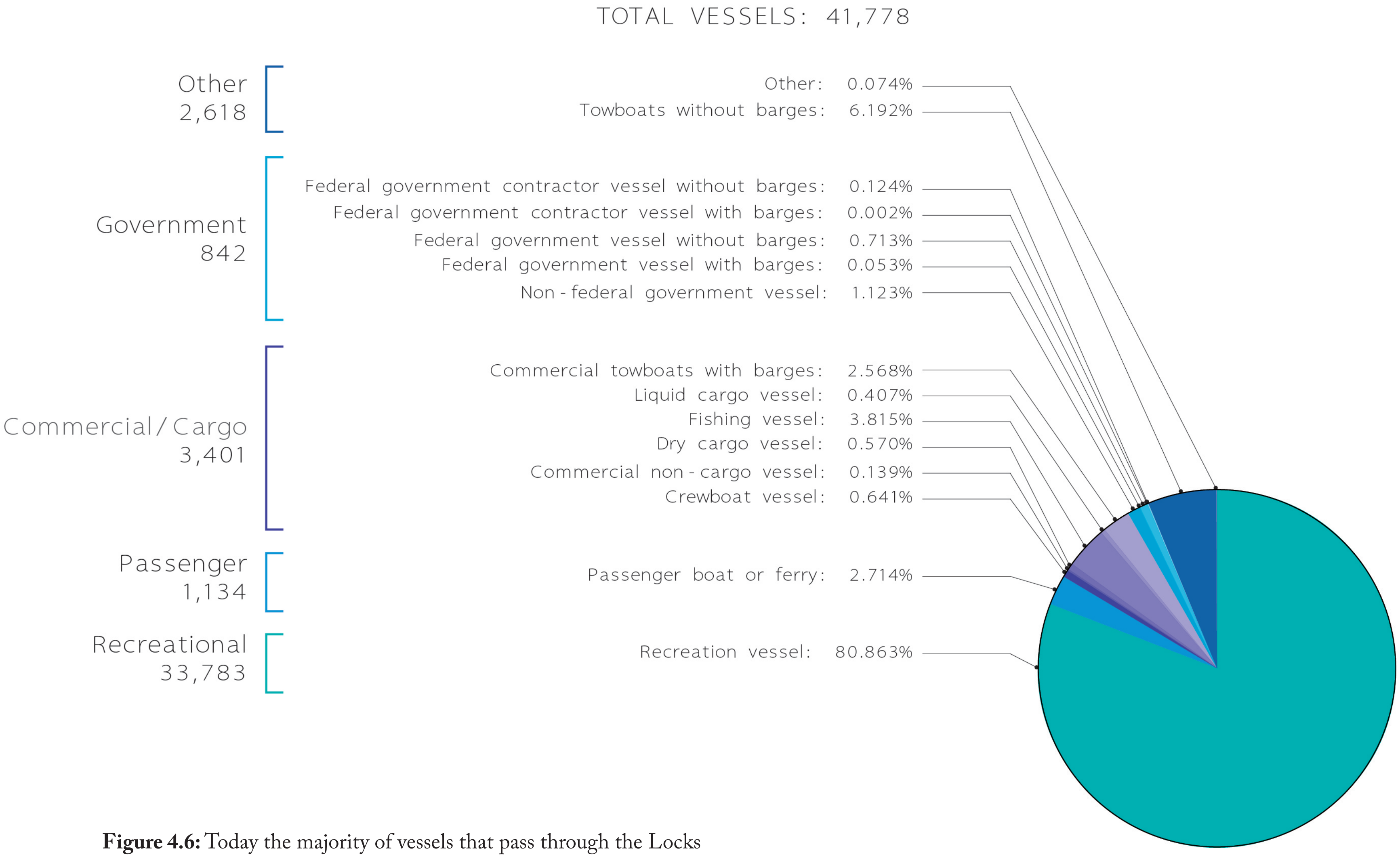


Figure 4.6: Today the majority of vessels that pass through the Locks are for recreation. This is illustrated in this diagram which shows the number and type of vessels that traversed the locks (both locks, both directions) between January 1, 2015 and January 31, 2016.

type of vessels that traversed the Locks between January 1, 2015 and January 31, 2016. Almost 81 percent of the vessels that traversed the Locks during this 13-month span were recreation vessels. Almost three percent were passenger boats or ferries.[32] Human recreation at the expense of biodiversity is illogical, particularly in an era when scientists have confirmed the mass extinction occurring on Earth,[33] and particularly when human recreation and biodiversity are inherently reciprocal. If not obsolete, the Ballard Locks is certainly serving biodiversity loss.

The Larger Watershed

Prior to the excavation of the Ship Canal, Lake Washington[34]—which, along with Lake Union, was carved out by the retreating Vashon Glacier[35] 12,000 years ago—emptied through the Black River at its south end. The Black eventually met with the Cedar, then the White, to become the meandering Duwamish River[36] which still empties into Puget Sound's Elliott Bay, albeit by way of a radically human-altered course.

The excavation of the Ship Canal caused extreme and far-reaching consequences to the landscape. Figure 4.7 illustrates the landscape before and after the Ship Canal, and how these changes dramatically altered migrations for Pacific salmon populations that spawn in the Cedar River. Although Figure 4.7 focuses on Cedar River-spawning salmon, the migration routes of salmon populations that spawn in the tributaries of the Sammamish River, which feeds Lake Washington at its north end and is not depicted in Figure 4.7, were also transformed by the excavation of the Ship Canal. After the Ship Canal had been excavated, it replaced the Black River as Lake Washington's outlet. This transpired in the summer of 1916 when workers dug into an earthen cofferdam separating Portage Bay and the freshly excavated Montlake Cut, allowing Lake Union's waters to rush eastward up to an additional dam at Lake Washington's west shore.[37] In the following months this dam was dismantled, joining the lakes,[38] and causing Lake Washington's elevation to drop 8.8 feet,[39] exposing new waterfront and draining over 4,000 acres of wetland habitat.[40] Lake Washington's water level was now lower than the Black River, which essentially dried up, never to drain the lake again. Instead, water now left the lake at its west shore, through the Montlake Cut and into the Ship Canal. Before that, Lake Union, which has an average depth of 32 feet and a maximum depth of 50 feet,[41] had been fed by ground-

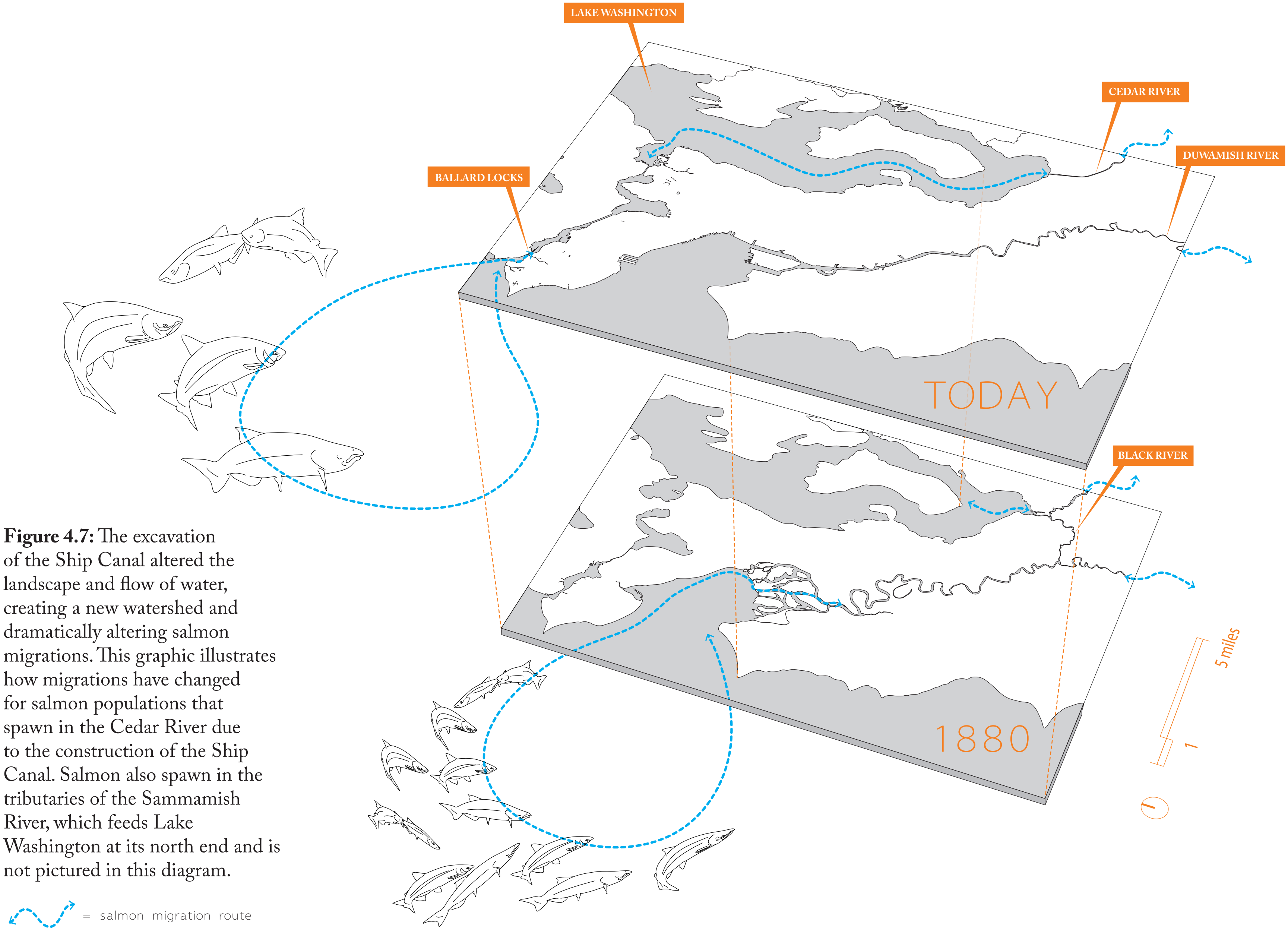


Figure 4.7: The excavation of the Ship Canal altered the landscape and flow of water, creating a new watershed and dramatically altering salmon migrations. This graphic illustrates how migrations have changed for salmon populations that spawn in the Cedar River due to the construction of the Ship Canal. Salmon also spawn in the tributaries of the Sammamish River, which feeds Lake Washington at its north end and is not pictured in this diagram.

and stromwater and “intermittent streams.”[42] Before the excavation of the Ship Canal, the Sammamish River had been the main inflow of Lake Washington. This changed in 1912 when the Cedar River was rerouted away from the Black River and into Lake Washington in advance of the excavation of the Ship Canal. Because of this change, Lake Washington’s water retention time was almost cut in half, meaning water moved through the lake about twice as quickly.[43] From then on both the Cedar and Sammamish Rivers were the main inflows of Lake Washington.[44]

The construction of the Ship Canal and Locks changed the annual fluctuation of Lake Washington’s water level from five to two feet,[45] giving more influence to humans over the lake elevations and later making floating bridges a realistic option in Lake Washington.[46] Today the Montlake Cut is 100 feet wide, both sides armored with a concrete bulkhead.[47] The Fremont Cut, armored with riprap, is straight and “narrow and steep”[48]—all characteristics that cause higher water velocity and reduce nearshore habitat.

Today the water that flows through the Ship Canal into Shilshole Bay is precipitation that fell within the land area that constitutes the Cedar River - Lake Washington Watershed,[49] combined with precipitation from higher connected watersheds such as the Sammamish Watershed, which also feeds Lake Washington.[50] Refer to Figure 4.8 for a depiction of the Lake Union Basin and the larger Cedar River - Lake Washington Watershed that it belongs to, as well as the Sammamish Watershed. Prior to the excavation of the Ship Canal, precipitation that fell within the same boundaries was considered part of Green - Duwamish River Watershed,[51] which now hugs the south border of the Cedar River - Lake Washington Watershed.[52] Figure 4.9 illustrates the branching system of tributaries where salmon spawn in the Cedar River - Lake Washington and Sammamish Watersheds after passing through the Locks.

Before the excavation of the Ship Canal and construction of the Locks, Lakes Union and Washington were separated by a ridge. The two lakes did not connected via surface water[53] nor did they share a water level; Lake Union’s elevation was about nine feet lower than Lake Washington’s.[54] Wet weather sometimes caused Lake Washington’s surface, which was usually 15 to 20 feet above Puget Sound’s high tide, to rise up to six or seven additional feet.[55] Salmon Bay, near what is now the Locks, was an estuary.[56] It was shallow, at

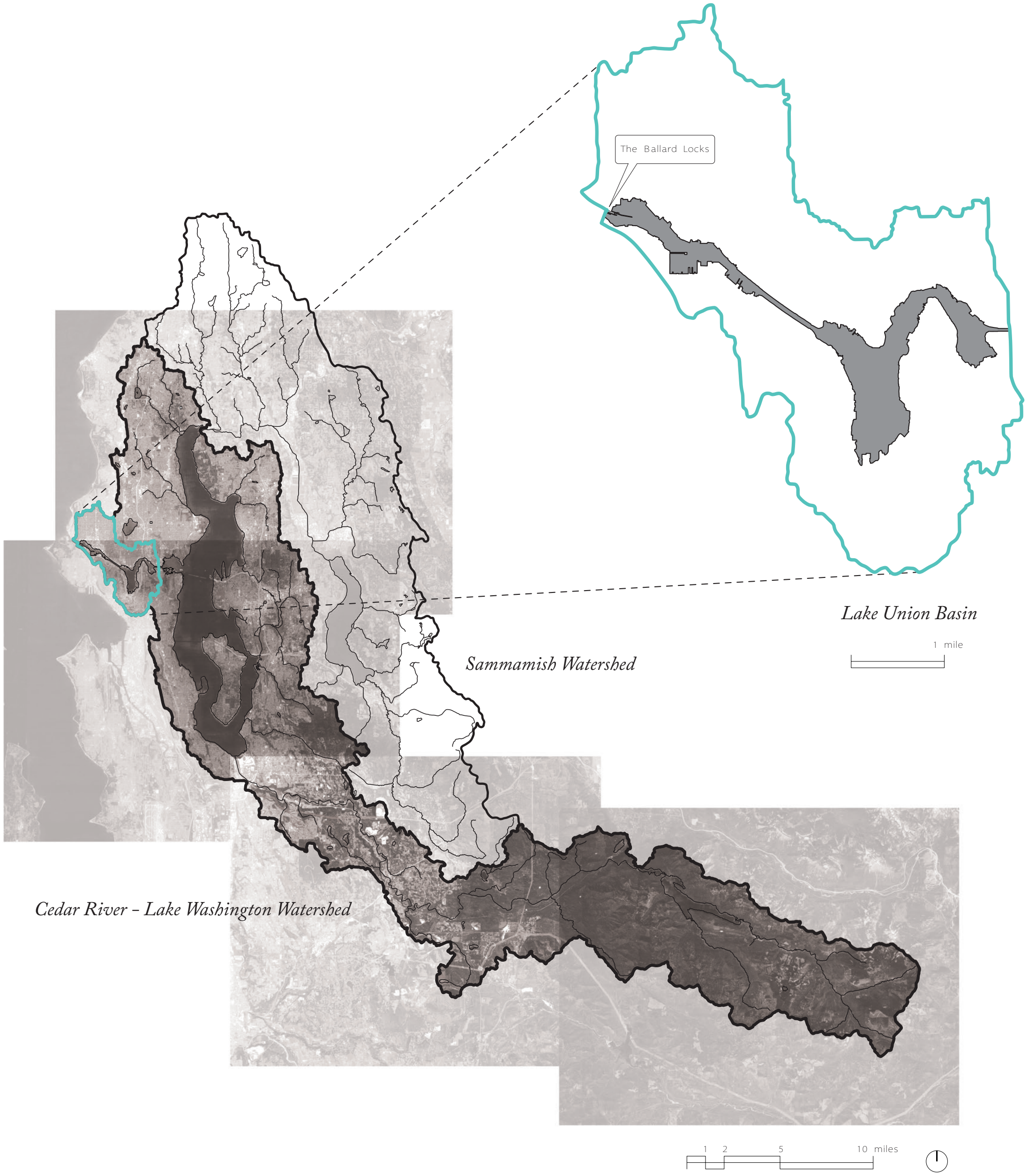


Figure 4.8: This diagram depicts the boundaries of the Cedar River - Lake Washington and Sammamish Watersheds, as well as the Lake Union Basin which is a component of the former. The water that flows through the Ship Canal is runoff from within the boundary of these watersheds (as well as higher connected watersheds).

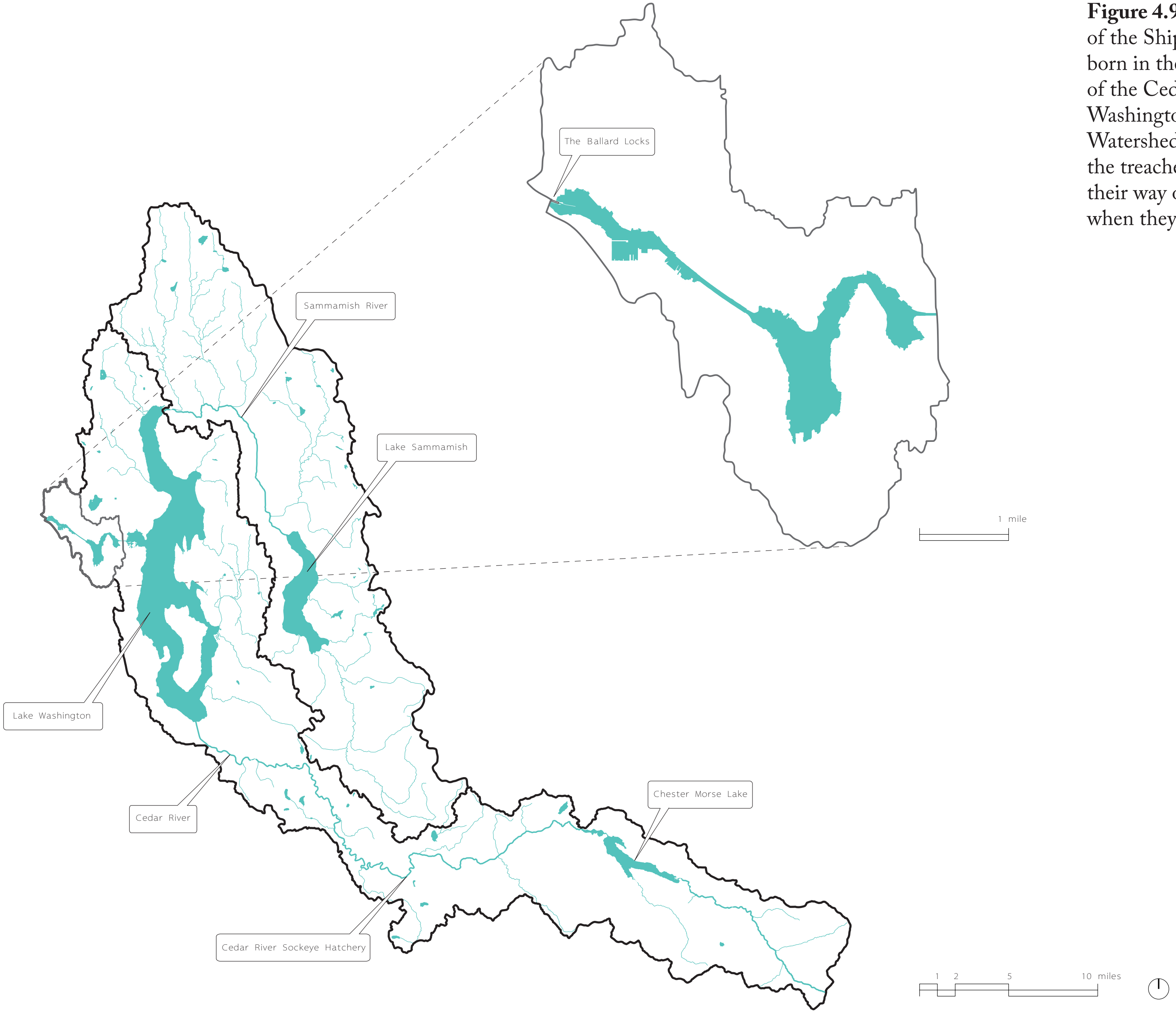


Figure 4.9: Since the excavation of the Ship Canal, all salmon born in the many tributaries of the Cedar River - Lake Washington and Sammamish Watersheds must pass through the treacherous Ballard Locks on their way out to sea, and again when they return to spawn.

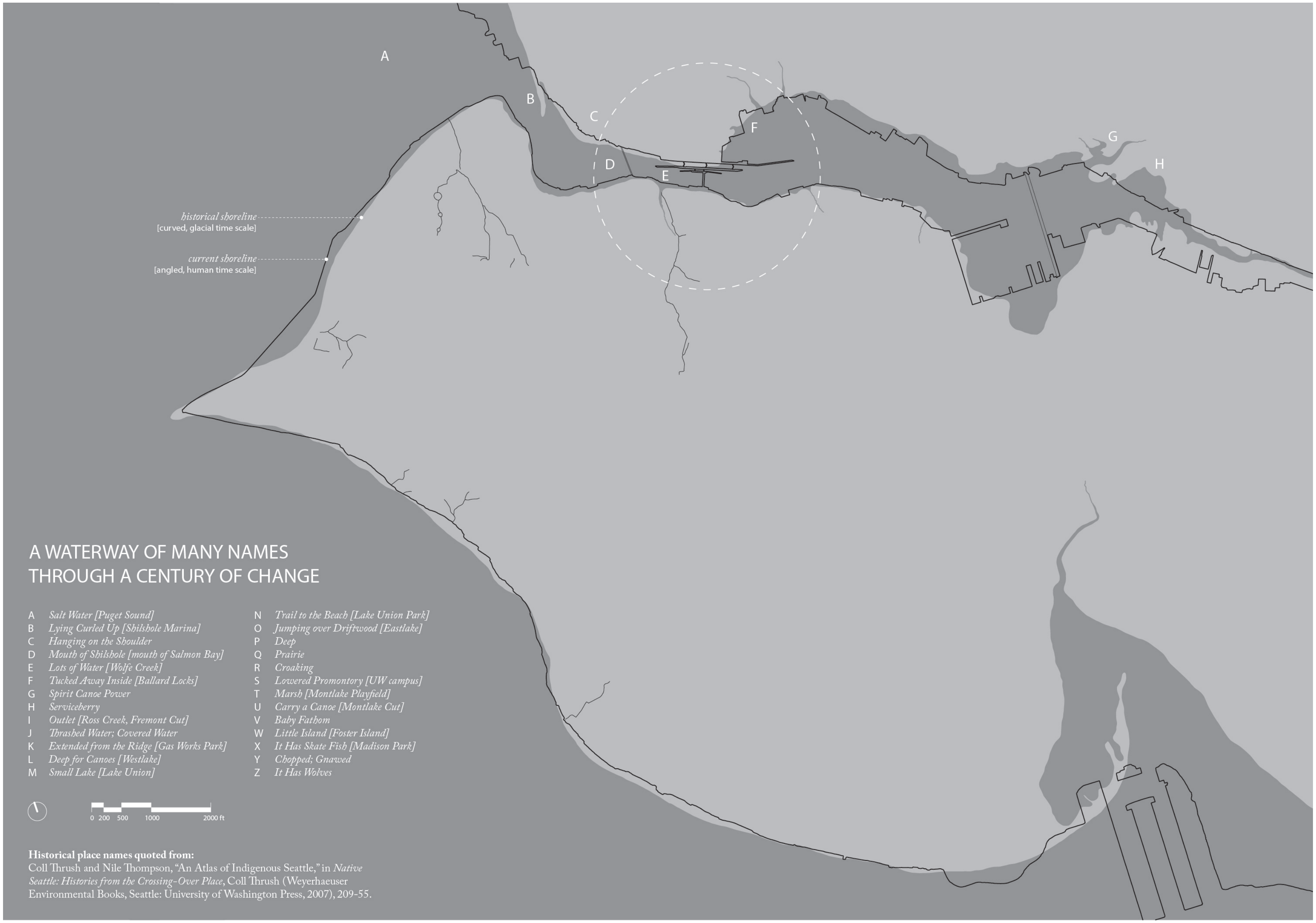
times unnavigable, depending on the tides, which influenced water levels all the way up to Ross Creek, the creek flowing from Lake Union to Salmon Bay, now the Fremont Cut.

Figure 4.10 layers the shoreline of what is now the Lake Washington Ship Canal in 2012 (depicted with a black line) over the pre-European settlement shoreline (depicted with gray swaths for land and water). This historical shoreline is based on the map shown in Figure 4.4, which depicts Lake Union and Union Bay's respective "low water planes" and elsewhere "the plane of the [e]xtreme low water of Puget Sound."[57] While the map in Figure 4.4 is based on a 1891 survey, the map in Figure 4.10 has been adjusted to show no indication of European settlement. Today the tides only influence Shilshole Bay up to the Locks. Figure 4.10 also includes historic place names identified in Thrush and Thompson's "An Atlas of Indigenous Seattle," from Thrush's *Native Seattle: Histories from the Crossing-Over Place*. In Figure 4.10 these names have been combined with present-day place names, illustrating how a sense of place can undergo rapid iterations with a quickly-changing landscape. What is most striking about the two shorelines depicted in Figure 4.10 is the dramatic change that has occurred in little over a century. Also, the modern shoreline is composed mostly of angles, suggesting a hallmark of human engineering on a human time scale, while the historic shoreline is composed mostly of curves, suggesting the slower work of ice sheets.

The Locks Complex

Due to these dramatic changes to the watershed, the Locks complex has become a gateway for salmon and people: for salmon on their way to spawn and boaters traveling upstream, and for ocean-bound juvenile salmon and boaters traveling downstream (See Fig. 4.11). The Ballard Locks, the most active in the nation,[58] represents an antiquated and singular way of thinking. It was championed by a view that meticulously focused on one system to the detriment of other layered systems (See Fig. 4.12). In his book *Northwest Passages*, William Willingham writes that the U.S. Army Corps of Engineers Seattle Engineer Office, established in 1896, "attempted to bring the natural environment under human control."[59] Indeed, unfortunately many early settlers didn't see the importance of an estuary. Chittenden himself once wrote, "Salmon Bay from its present condition as an ugly tidal slough, a large part of which becomes a filthy mud bank at every low tide, will be transformed into a deep freshwater basin destined to be one of the busiest parts of Seattle's harbor."[60] Figure 4.13 provides a sense of what Salmon Bay looked like before the Locks was built. As mentioned earlier, the mouth of Salmon Bay was once shallow and difficult for boats to navigate. Historian Coll Thrush writes, "longtime Ballard families report that prior to the building of the locks, one could wade through the water at the mouth of Salmon Bay at low tide."[61] The saltwater tidal inlet just northeast of the Locks, now mostly freshwater Salmon Bay,[62] was a substantial village, sHulsHóól, which boasted two 60-by-120-foot longhouses and a potlatch house with an even larger floor area. Home to the Shilshoolabsh, the village's name translates to "Tucked Away Inside."[63] Thrush reports that "a dozen indigenous families" still lived at Salmon Bay in the 1850s.[64] During excavation for the Ship Canal in 1913, a large shell midden, a vestige of the once flourishing Tucked Away Inside, was unearthed.[65] Today the area between Puget Sound and the Locks is still considered an "estuarine area."[66] While there is still a "brackish mixing zone" to be found at the site and in the locks chambers, it has been severely shortened by the Locks.[67] Chittenden's vision for the Locks did, to some extent, transpire. However, as stated earlier, today the Ship Canal serves recreation over industry. By comparing the numbers in Figure 4.6 with a historical graph tracking traffic through the Locks soon after it opened (See Fig. 4.15), it can be estimated that the number of boats that use the Locks has less than doubled in about one century (See Fig. 4.14). The hundreds of wrecks that coat the floors of Lakes Union and Washington tell a story of bustling human activity—but not biodiversity.

It was not until 1906 that Hiram M. Chittenden assumed control of the U.S. Army Corps of Engineers (USACE) Seattle District and advocated for the current locks site.[68] At the start of the twentieth century, Thrush explains, indigenous people living in their indigenous places were few and far between, but could still be found in the area. For example, an Indian man, Hwelchteed ("Salmon Bay Charlie"), and his wife Cheethlooleetsa ("Madeline") would sell gathered food in nearby Ballard, across the bay from their cedar plank house.[69] Thrush describes that after Cheethlooleetsa passed away and Hwelchteed thereafter relocated to a reservation, a Duwamish man, Sbeebayoo ("Billy Phillips"), consistent with tradition, burned down Hwelchteed and Cheethlooleetsa's home.[70] By the time the Locks was completed, not a single



Historical place names quoted from:
Coll Thrush and Nile Thompson, "An Atlas of Indigenous Seattle," in *Native Seattle: Histories from the Crossing-Over Place*, Coll Thrush (Weyerhaeuser Environmental Books, Seattle: University of Washington Press, 2007), 209-55.

Figure 4.10: This map layers the current shoreline of what is now the LWSC over the pre-European settlement shoreline.


R
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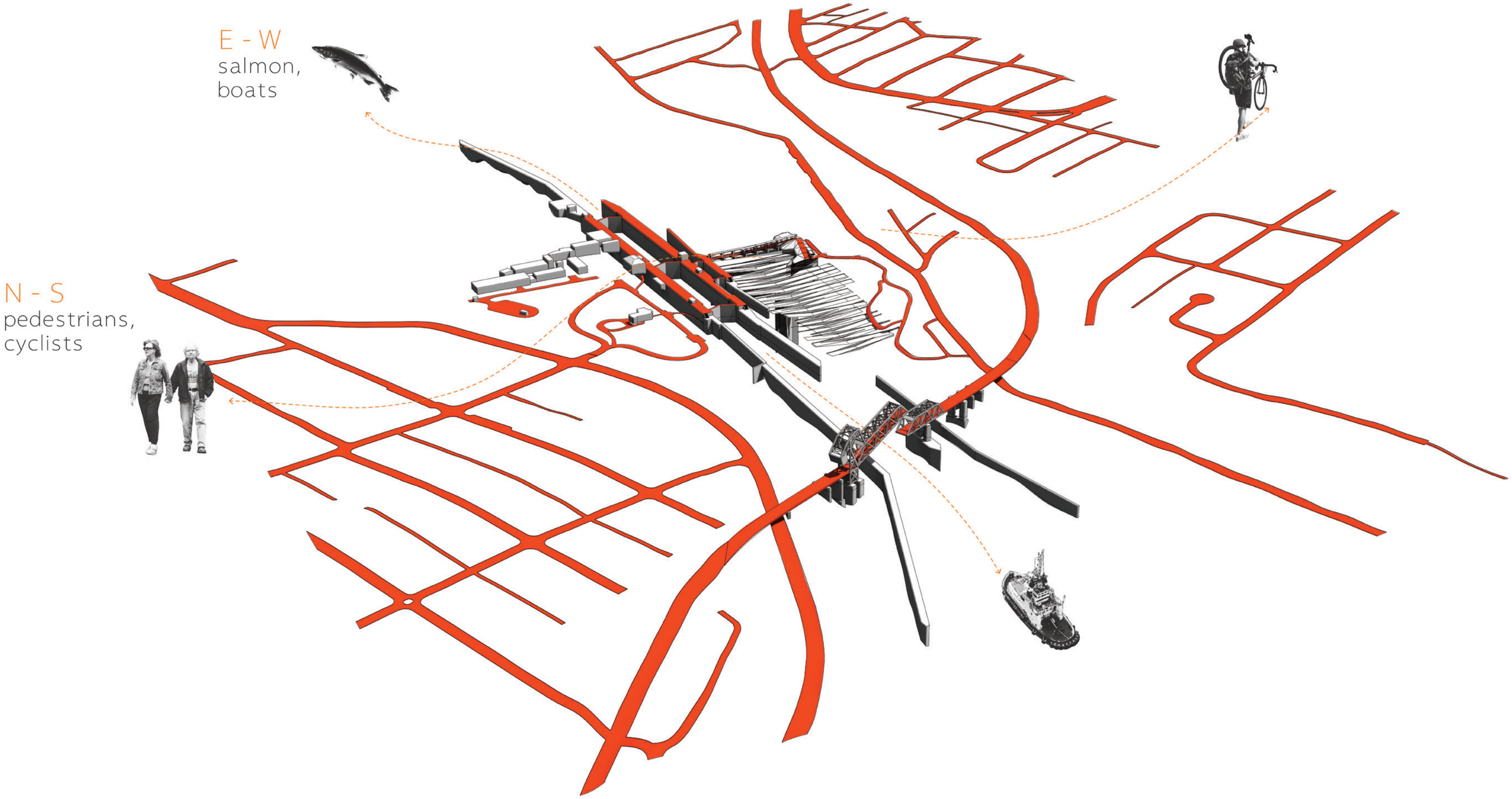


Figure 4.11: While the Locks is an east-west conduit for salmon and watercraft, pedestrians and bicyclists use the complex as a north-south link between Magnolia and Ballard.

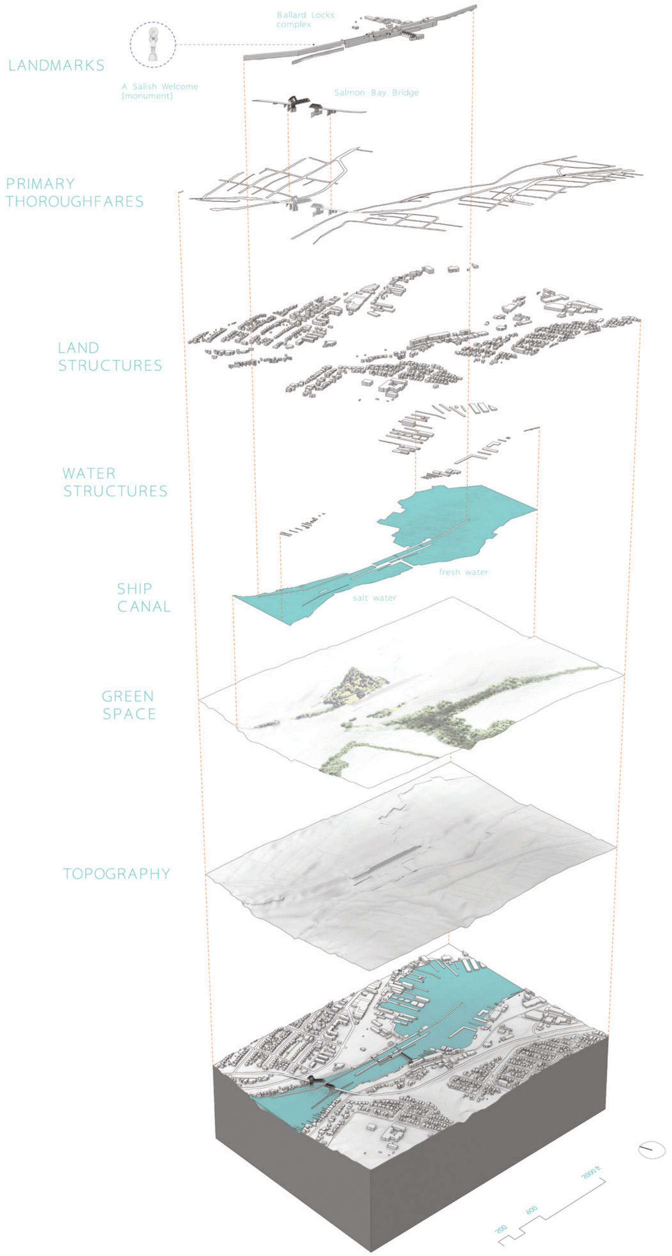


Figure 4.12: site layers pulled apart.

Indian lived near the former village at Salmon Bay.[71] Today the Muckleshoot and Suquamish tribes have fishing rights at the Locks, upstream and downstream of the spillway dam, respectively.[72]

The Locks and the Ship Canal are listed on the National Register of Historic Places. In addition to two locks and a spillway dam, the complex includes a fish ladder and attached subaquatic viewing room, control tower, historical buildings, and gardens. Evidently the complex was planned to be an amenity to the community from the beginning. Though Carl English, a landscape architect who worked for the USACE at the Locks for decades, deserves much credit for the gardens at the complex today, he was not the first to imagine enjoyable gardens at the site.[73] In a letter to Lieutenant Colonel J. B. Cavanaugh, written in 1915, Assistant Engineer Arthur W. Sargent wrote, "If properly laid out, the grounds can be made one of the most attractive spots in Seattle and can be maintained at moderate expense if the services of the permanent lock employees can be utilized for that purpose when not required for the care and operation of the locks."[74] This reveals an early desire for the complex it to be a place for the community in addition to an implement for industry. Figure 4.16 illustrates a plan of the gardens. Today the complex is surrounded by buildings with mostly residential and commercial uses (See Fig. 4.17). By showing land and water structures pulled apart from the rest of the landscape, Figure 4.18 illustrates that Kiwanis Ravine, the railroad corridor, and the Ship Canal are the primary *unbuilt* areas immediately surrounding the Locks. The diagram also provides a sense of the texture of the area via a figure-ground comparison.

The Locks and Spillway Dam

To the west of the Locks there is salt water; to the east, mostly freshwater. These two water elevations have separate ranges in fluctuation. The water elevation west of the Locks is subject to the tides—mean higher high water (MHHW) is roughly 11.3 feet higher than mean lower low water (MLLW)—and to rising sea levels, as it were. In contrast, the water elevation east of the Locks fluctuates about two feet (between 20 and 22 feet above MLLW) per year due to the spillway dam which tightly controls the elevation of the lakes (See Fig. 4.19 for an illustration of these water levels on either side of the spillway dam). When the Ship Canal was being planned, a water level similar to Lake Union's historical

Figure 4.13 (above): historical panorama of Salmon Bay prior to the Ballard Locks.
Source: Photograph courtesy of U.S. Army Corps of Engineers.

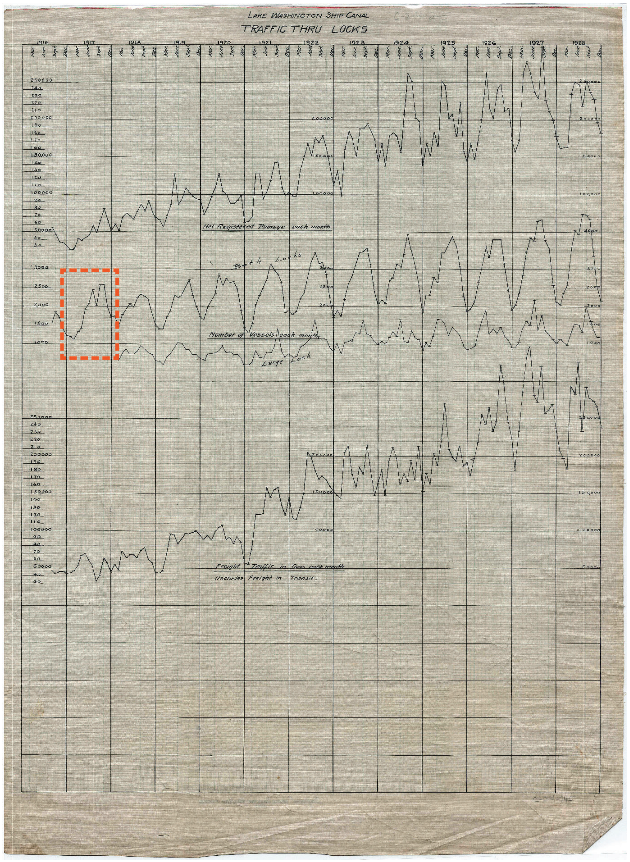


Figure 4.14 (small diagram below, center of page): It is interesting to compare the number of vessels that traversed the Locks (both locks, both directions) between January 1, 2015 and January 31, 2016 (depicted in Figure 4.6) with the number of boats that traversed them in the same time period (13 months) around the time the Locks first opened.

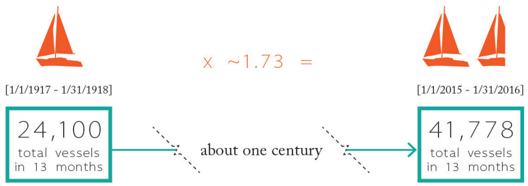


Figure 4.15 (right): According to this historical graph, roughly 24,100 vessels traveled through the locks between January 1, 1917 and January 31, 1918. If we compare this number to the number presented in Figure 4.6 (41,778 vessels), it becomes apparent that the number of boats that use the Locks has less than doubled in about one century.
Source: "Lake Washington Ship Canal Traffic Thru Locks," Tube 6, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

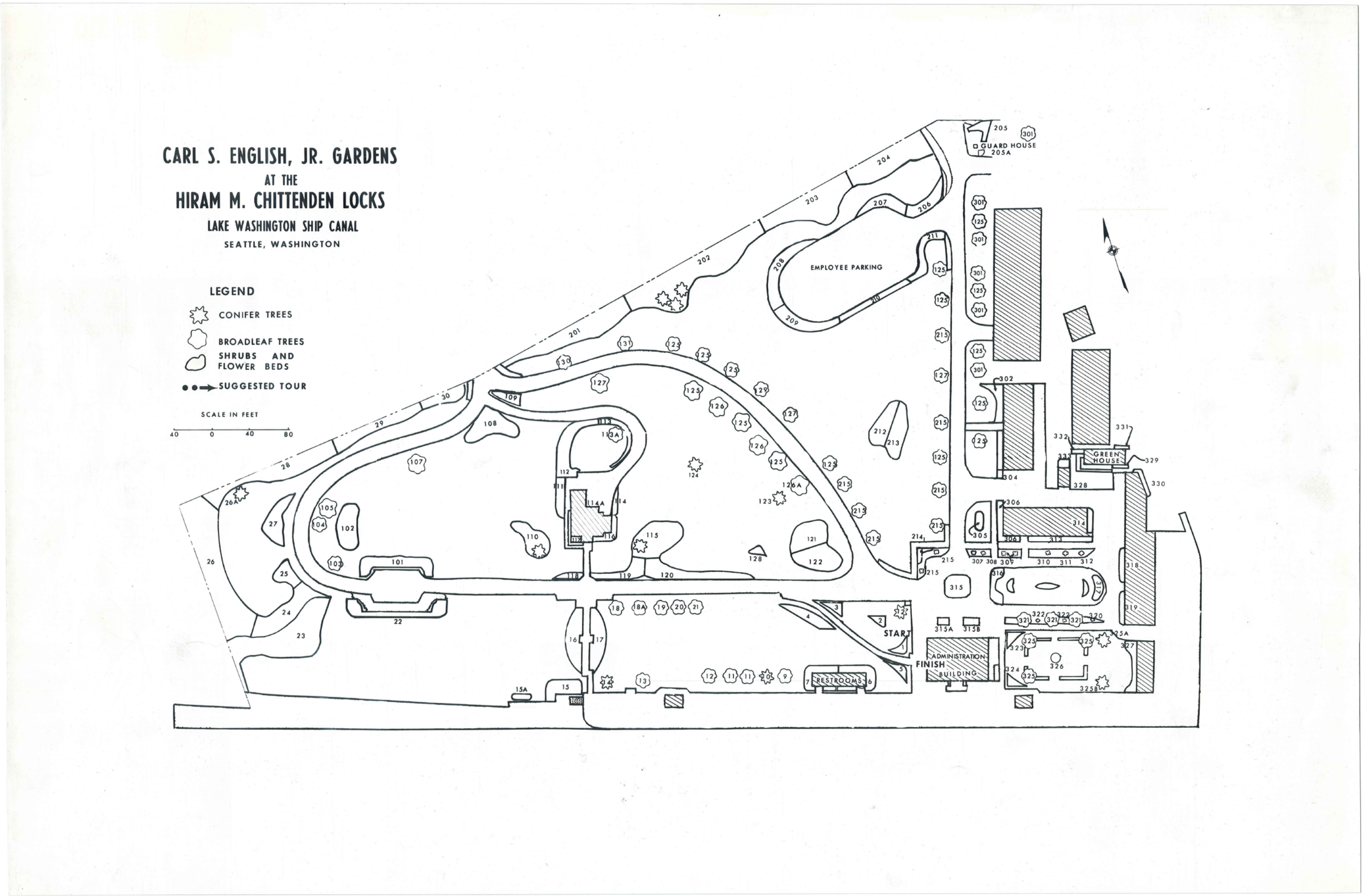


Figure 4.16: historical garden plan.
Source: "Carl S. English, Jr. Gardens at The Hiram M. Chittenden Locks," Tube 5, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

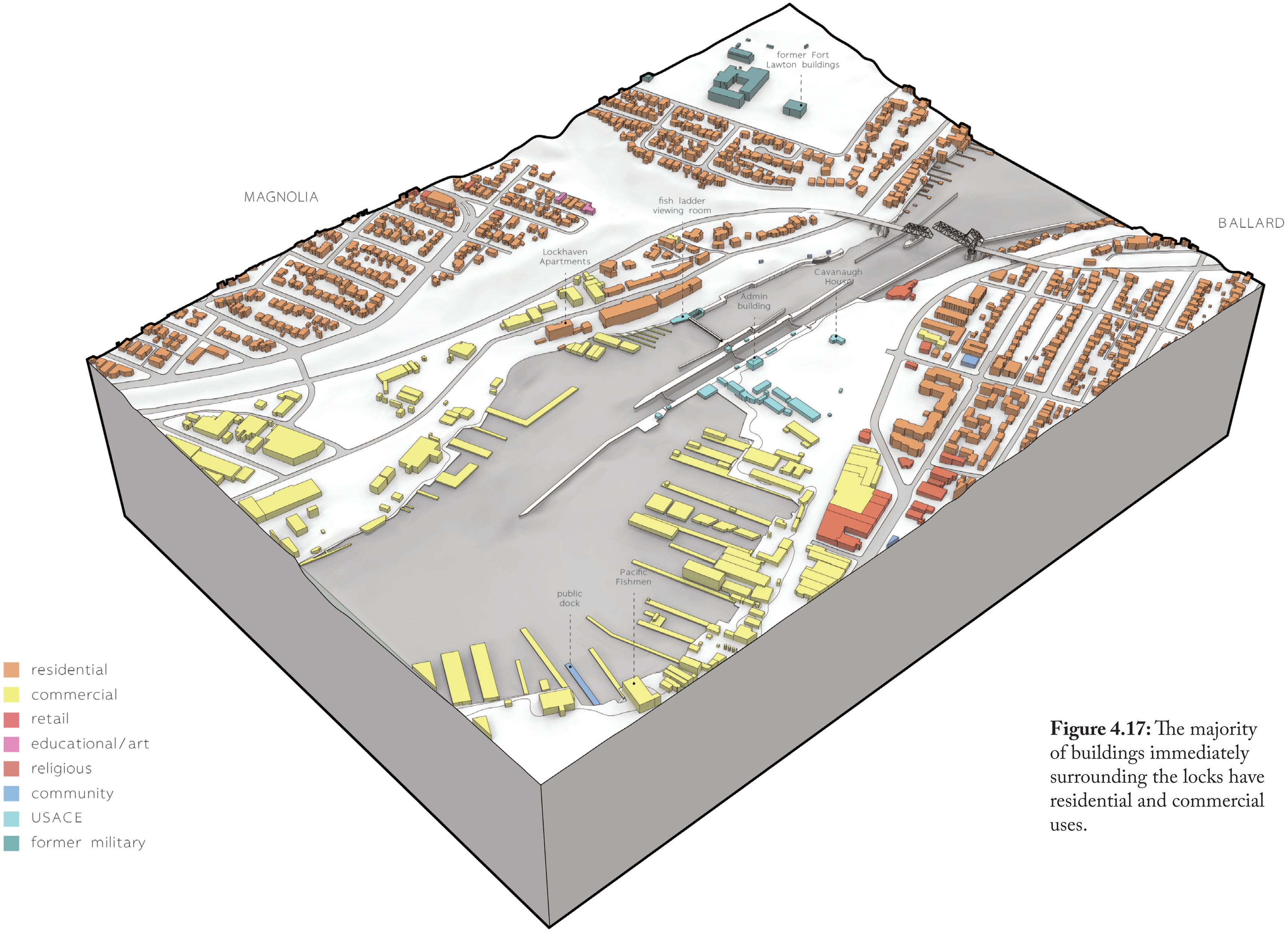


Figure 4.17: The majority of buildings immediately surrounding the locks have residential and commercial uses.

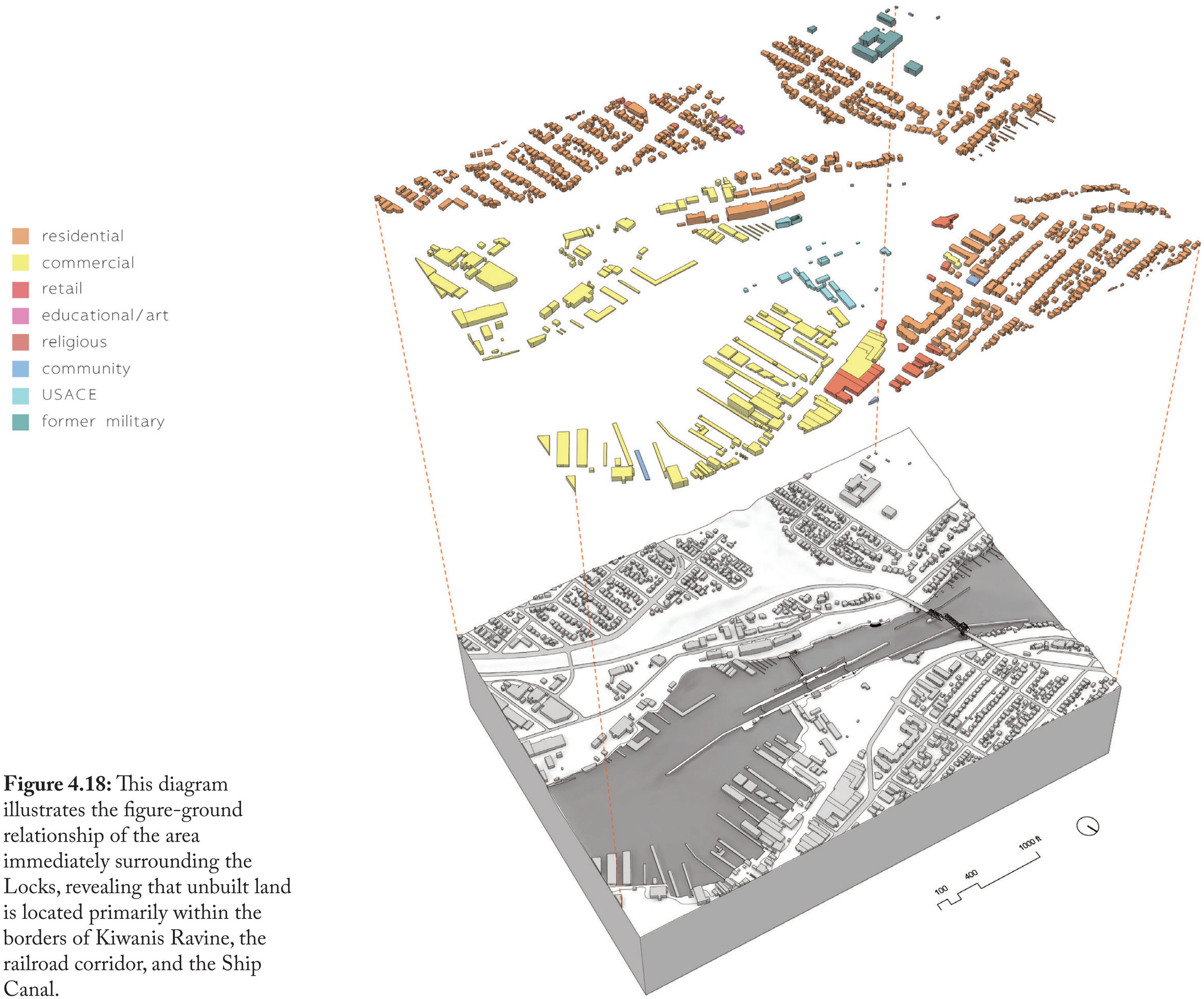


Figure 4.18: This diagram illustrates the figure-ground relationship of the area immediately surrounding the Locks, revealing that unbuilt land is located primarily within the borders of Kiwanis Ravine, the railroad corridor, and the Ship Canal.

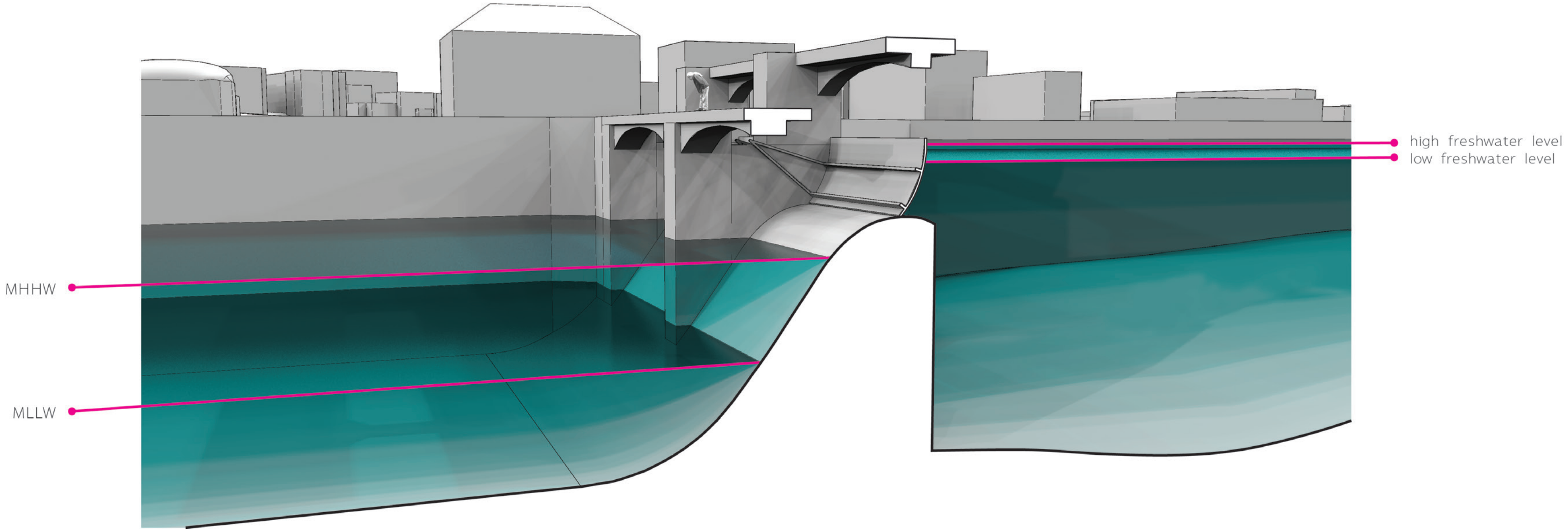


Figure 4.19: Today the lakes' water elevation fluctuates two feet each year. The USACE controls this elevation via the spillway dam. Opposite to historical conditions, the lakes are at their highest in the summer (about 22 feet above MLLW) and lowest in the winter (about 20 feet above MLLW).

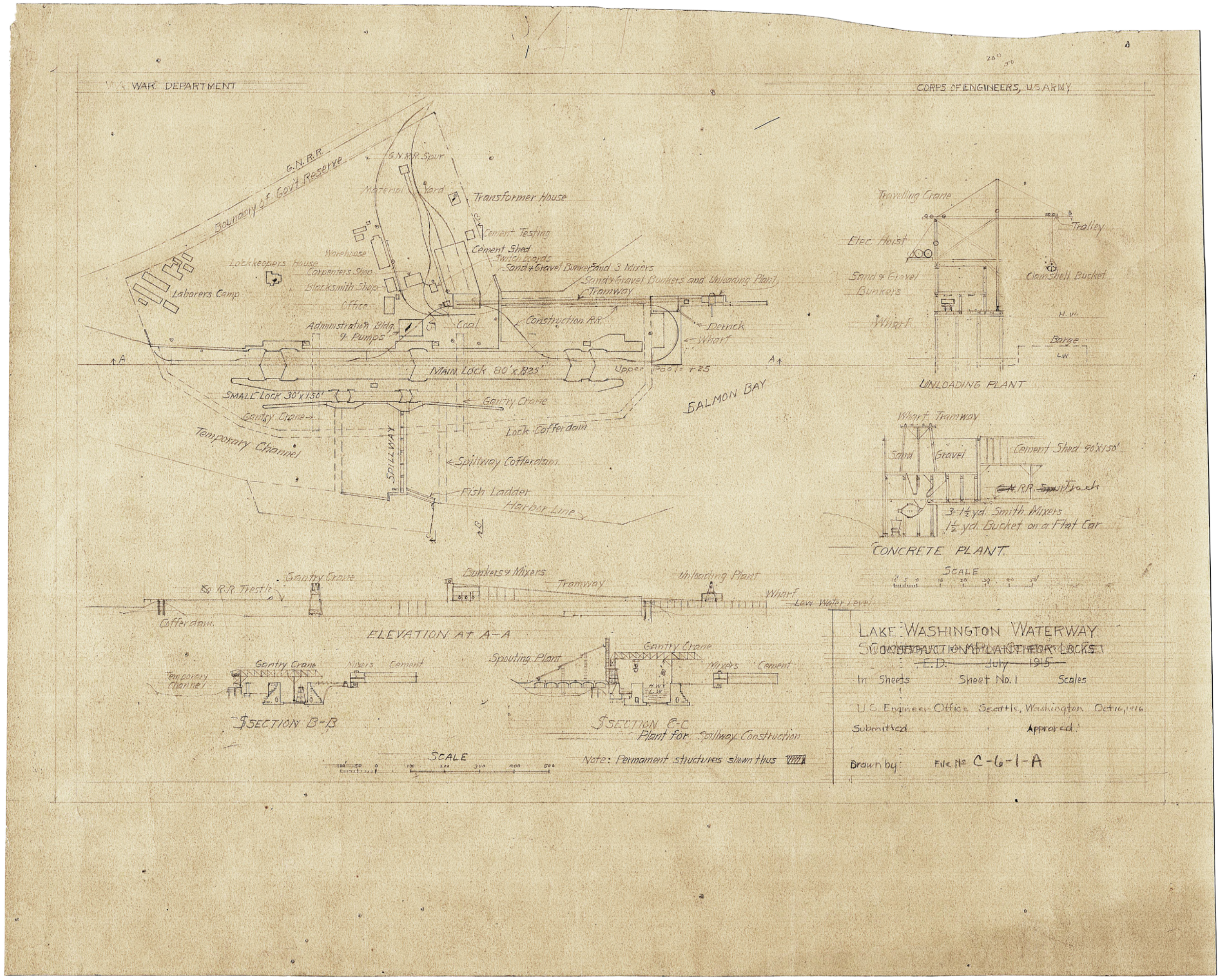
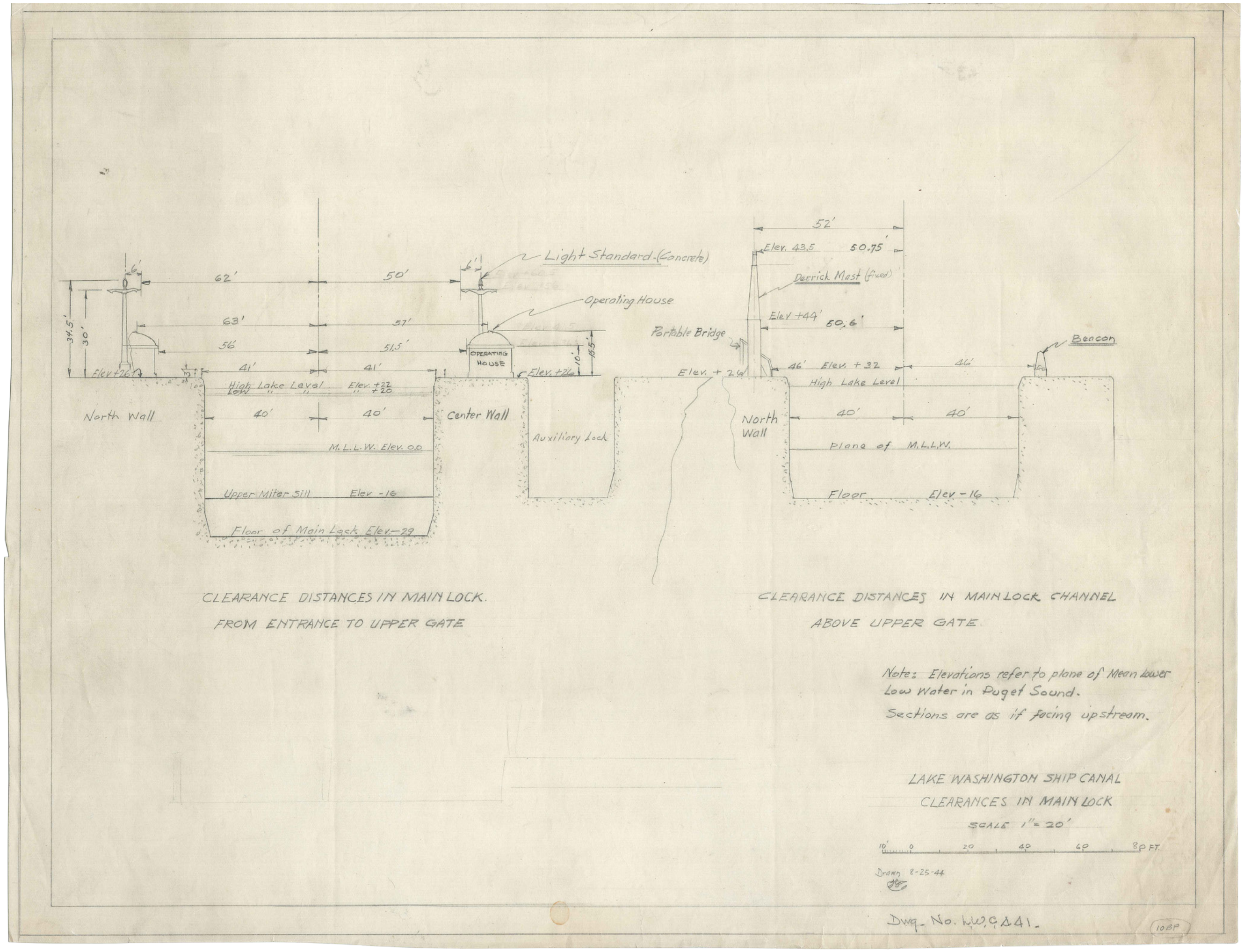


Figure 4.20: historical construction drawings for Locks.
Source: "Lake Washington Waterway Construction Plan for Locks," Tube 6, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.



CLEARANCE DISTANCES IN MAIN LOCK.
FROM ENTRANCE TO UPPER GATE

CLEARANCE DISTANCES IN MAIN LOCK CHANNEL
ABOVE UPPER GATE

Note: Elevations refer to plane of Mean Lower Low Water in Puget Sound.
Sections are as if facing upstream.

LAKE WASHINGTON SHIP CANAL
CLEARANCES IN MAIN LOCK
SCALE 1" = 20'

Figure 4.21: historical sections through locks.
Source: "Lake Washington Ship Canal Clearances in Main Lock," Tube 1, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

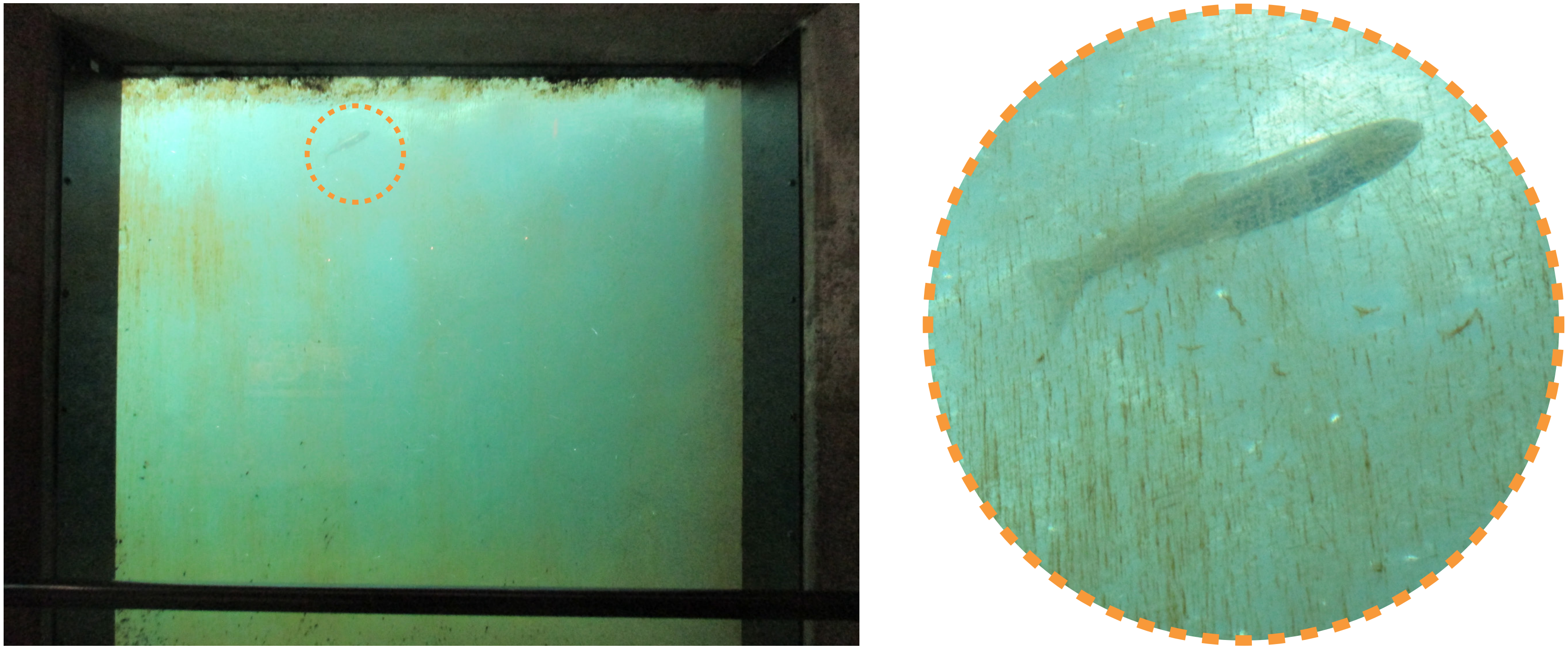


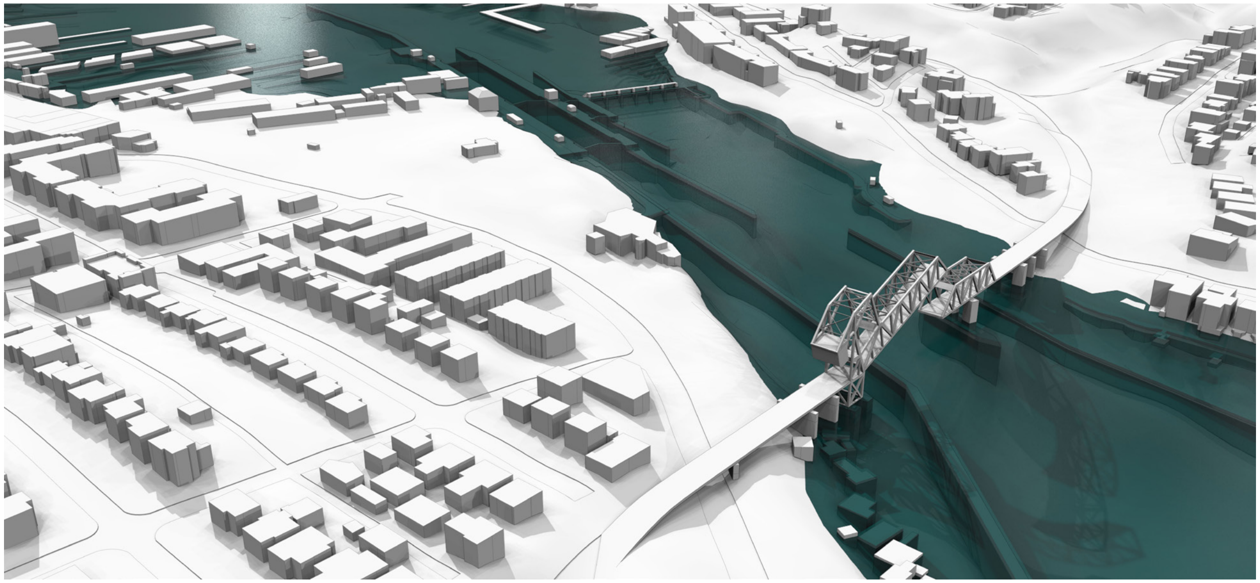
Figure 4.22: This photograph, taken from inside the subaquatic viewing room at the Locks, shows a lone fish in the fish ladder.

elevation was selected, higher than a very high tide, thus avoiding saltwater intrusion.[75] This also meant that Lake Union's shoreline development and water structures would not need to be altered for the new canal.[76] Historically, the lakes' elevations would be higher in the winter and lower in the summer, according to precipitation patterns. However, today the USACE reverses this so that the lakes are higher in the summer and lower in the winter to accommodate the elevated number of vessels that travel through the Locks during warmer months.[77] During a low tide in the summer, when the lakes are at their highest, the Locks could separate a 22-foot change in water elevation.

The locks, essentially water elevators for conveying vessels from the level of Lakes Washington and Union down to the level of Puget Sound, as well as the reverse, function by closing and opening miter gates—three pairs for the large lock and two for the small. The large lock, which is a massive 80 by 825 feet and 50 feet deep, has a set of gates in its center for halving the chamber when a full lockage is not necessary.[78] The small lock is 30 by 150 feet.[79] Historical construction drawings for the Locks are shown in Figure 4.20. Figure 4.21, historical drawings of sections through the locks, illustrates that the lock chambers are not very different from large concrete bathtubs. Culverts in the lock walls controlled by Stoney gate valves drain and fill the lock chambers.[80] With the opening and closing of these gates, some saltwater moves to the east side of the Locks, but, as it is heavier than fresh, much of it sinks into an upstream saltwater basin. South of the lock chambers sits the spillway dam which has six massive Tainter gates for discharging controlled amounts of lake water.

Fishway

The Ballard Locks' current fish ladder was installed in 1976. An attached subaquatic viewing room offers views into one of the ladder's weirs (See Fig. 4.22). It could be said that the fish ladder is as confusing to fish as it is to human visitors.[81] While the mouth of Salmon Bay is now more navigable for boats, it is less so for salmon. Traveling safely through the Locks is a trial for adult salmon headed east on their way to spawn as well as juvenile salmon journeying west to the open ocean—one many don't survive. The following chapter will expand on why the Ballard Locks is a threat to salmon.



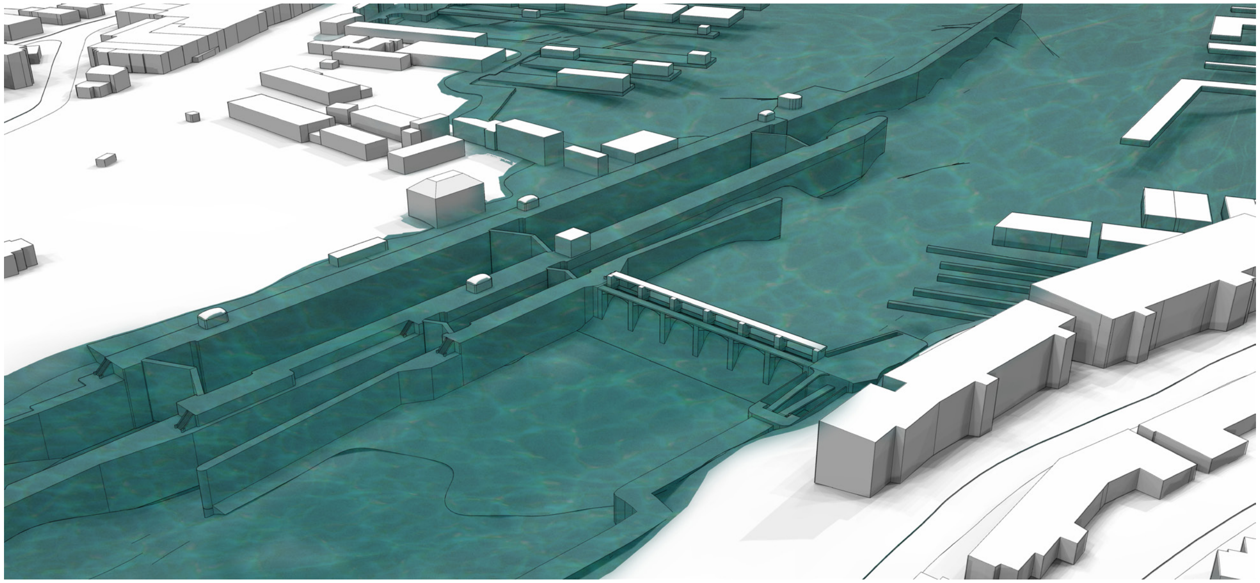


Figure 4.23 (top) and 4.24 (bottom): These illustrations depict how the site might look after sea level rise causes the tide to breach the miter gates.

The fish ladder at the Locks, at the south end of the spillway dam, is an eight-foot-wide concrete chute composed of 21 weirs that makes several 90-degree turns to raise migrating adult salmon on their way to spawn from the level of Puget Sound up to the level of the Ship Canal and lakes. The highest three weirs are adjustable to accommodate the two-foot range of the Ship Canal's elevation. There are also two adjustable slots at the entrance of the fish ladder to accommodate changing tides.[82] Though a trial for the fish that use it, this ladder is a marked improvement from the original, which only had 10 steps.[83]

The Future

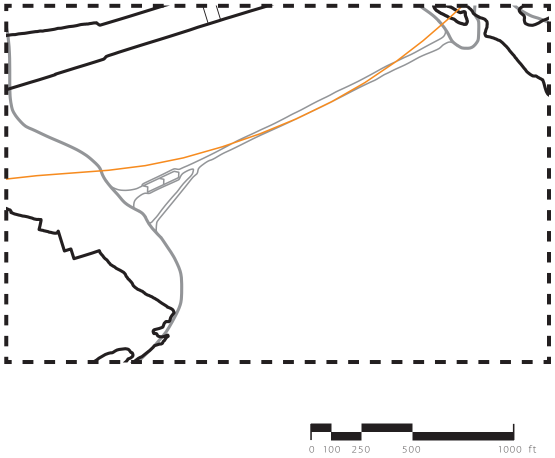
Earthquake Danger

If the Locks were to fail, or be removed entirely, the water elevation of Lakes Union and Washington would not drop as low as the Montlake and Fremont Cut beds, because Puget Sound's elevation sits above them. How far the Ship Canal and Lakes Union and Washington's depths would drop would depend on the tide. The lakes are currently between 10.7 and 8.7 feet above Puget Sound's MHHW and between 22 and 20 feet above its MLLW. So, at a high tide, the canal and lakes' elevation would drop about 10 feet, and at low tide, roughly twice that. Another consideration, is, of course, the mixing of fresh and saline water. While saltwater intrusion does occur to some extent east of the Locks, it is controlled and the lakes, which have always been freshwater, would undergo saltwater intrusion if the Locks failed or was removed.

Climate Change and Sea Level Rise

Scientists expect Seattle to experience more precipitation, warmer temperatures, and a rising sea level due to climate change.[84] As sea levels rise, the difference in elevation between the salt and freshwater sides of the Locks is decreasing. A 2015 GGLO report prepared for The City of Seattle projects a sea level rise of one foot by 2035 and two feet by 2060.[85] By this estimate, a MHHW tide which is currently 9.7 feet below the average level of the lakes (21 feet, with an annual range of 20 to 22 feet above MLLW) could be about 7.7 feet below the level of the lakes by 2060, lessening pressure on the Locks. Until sea levels rise above the level of the Locks, it provides a buffer to Lake Union and Lake Washington against the impacts of sea level rise. Figure 4.23

Figure 4.25 (adjacent and below) and Figure 4.26 (opposite page): The orange line that traces the Ship Canal in Figure 4.25 represents the cutting plane line for the six exaggerated sections depicted in Figure 4.26. Prior to the excavation of the LWSC, Puget Sound, Lake Union, and Lake Washington each had its own water elevation, each fluctuating according to weather, seasons, and/or tides. Today Salmon Bay, the Fremont Cut, Lake Union, the Montlake Cut, and Lake Washington all share one water level, which has a two-foot annual range, up to the Locks. West of the Locks, the water level is tidal. This project anticipates rising sea level, which is depicted in the sections representing future dates.



In 1891 settlers were already starting to mark the watershed. This is evident in the excavation near where the Montlake Cut is positioned today in Figure 4.25. See also the fine gray lines depicting a bridge near today's 15th Ave W bridge in addition to one near what is now the Ship Canal Bridge and the Eastlake Ave E bridge.

Figures 4.25 and 4.26 are meant to be viewed at a larger scale than this 8.5 x 11" page will allow. If viewing digitally, please use your computer's view function to see more detail. Alternatively, the sections in Figure 4.26 are magnified on pages 70 through 75.

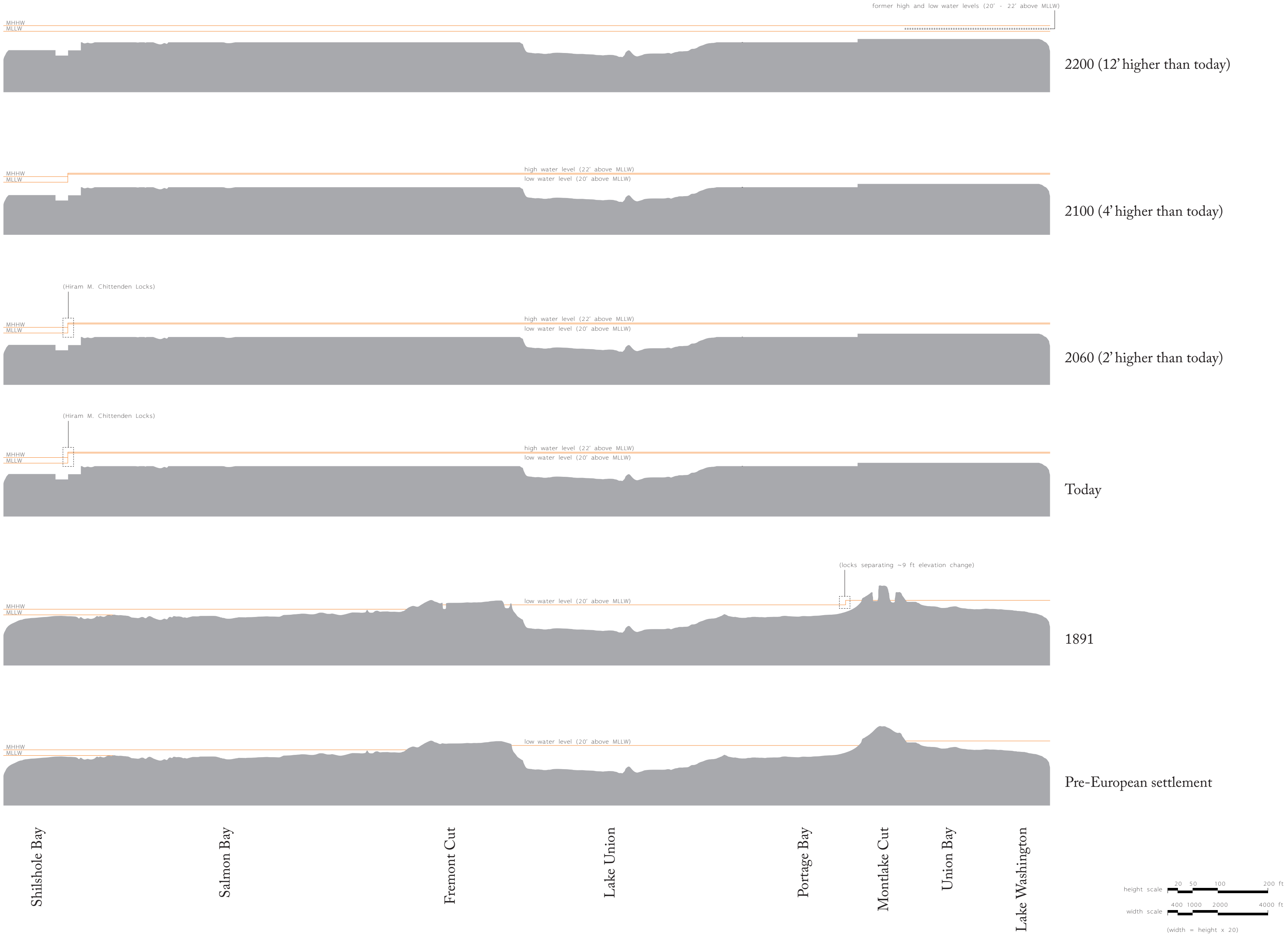
former high and low water levels (20' - 22' above MLLW)
MHHW
MLLW
2200 (12' higher than today)
MHHW
MLLW
high water level (22' above MLLW)
low water level (20' above MLLW)
2100 (4' higher than today)
(Hiram M. Chittenden Locks)
MHHW
MLLW
high water level (22' above MLLW)
low water level (20' above MLLW)
2060 (2' higher than today)
(Hiram M. Chittenden Locks)
MHHW
MLLW
high water level (22' above MLLW)
low water level (20' above MLLW)
Today
(locks separating ~9 ft elevation change)
MHHW
MLLW
low water level (20' above MLLW)
1891
MHHW
MLLW
low water level (20' above MLLW)
Pre-European settlement
Shilshole Bay
Salmon Bay
Fremont Cut
Lake Union
Portage Bay
Montlake Cut
Union Bay
Lake Washington
height scale
20 50 100 200 ft
width scale
400 1000 2000 4000 ft
(width = height x 20)

Figure 4.27: A tug navigates the large lock traveling eastward with a barge of gravel. The Locks complex is funded based on the amount of commercial cargo that passes through the large and small locks.

and 4.24 illustrate what the site might look like after an estimated 17 feet of sea level rise.

However, since the impacts of the recent past will continue to contribute to sea level rise into the distant future, it is prudent to assume that the level of Puget Sound will eventually rise above the level of the lakes. The proposed phasing approach described in Chapter Six looks far into the future at how to best manage the Locks site. Because of this, it accepts rising tides as inevitable. Although it is unknown how quickly sea level will rise, the proposed phasing plan is based on the estimate that by 2100 sea level will have risen four feet, and by 2200, will have risen 12 feet higher than today. Figure 4.26 starts to articulate the forward- and backward-looking phasing plan proposed in Chapter Six through a series of exaggerated sections cut through the Ship Canal. See pages 70 through 75 for magnified views of the sections shown in Figure 4.26. The cutting plane line for the sections in Figure 4.26 is depicted in Figure 4.25.

Maintaining estuary habitat is a prudent tactic for supporting salmon populations given the unknowns associated with sea level rise.[86] Like humans, salmon will experience climate change. Experts expect warmer waters associated with climate change to be responsible for the biggest impacts on Lake Washington salmon.[87]

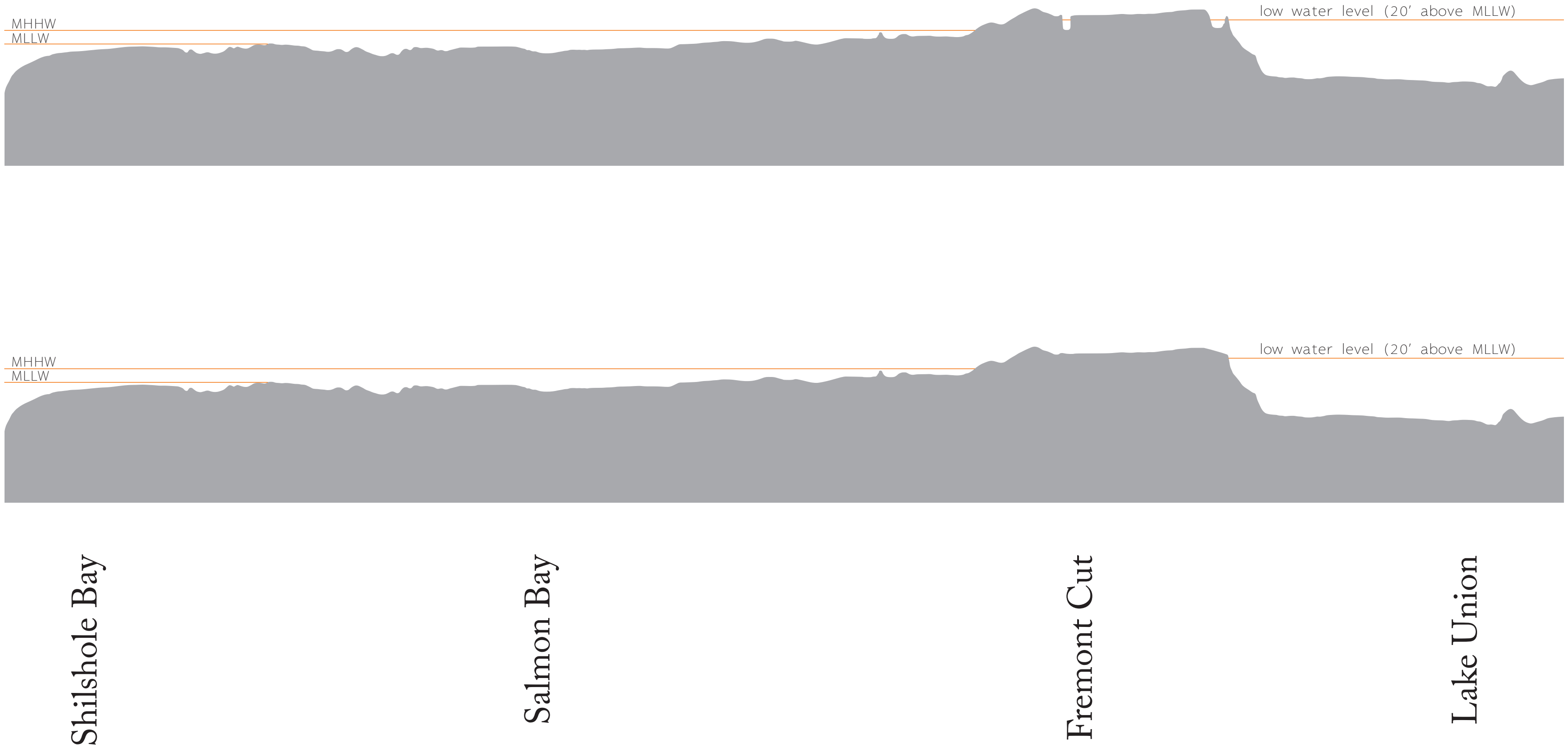
Culture, Community, Education

The Locks are owned and operated by the USACE. A military entity, its mission is to "[d]eliver vital public and military engineering services; partnering in peace and war to strengthen our Nation's security, energize the economy and reduce risks from disasters."[88] It is important to note that its primary mission is not to serve the complex array of non-human species that live in its lakes and waterways across the nation, nor is it to educate the public.[89] However, with "over 12 million acres of land and water located in 43 states, including many significant environmental and cultural resource sites,"[90] the USACE "is the largest Federal provider of outdoor recreation with over 370 million visitors annually."[91] This is obvious in Seattle, where the Ballard Locks is one of the most popular tourist attractions in the city.

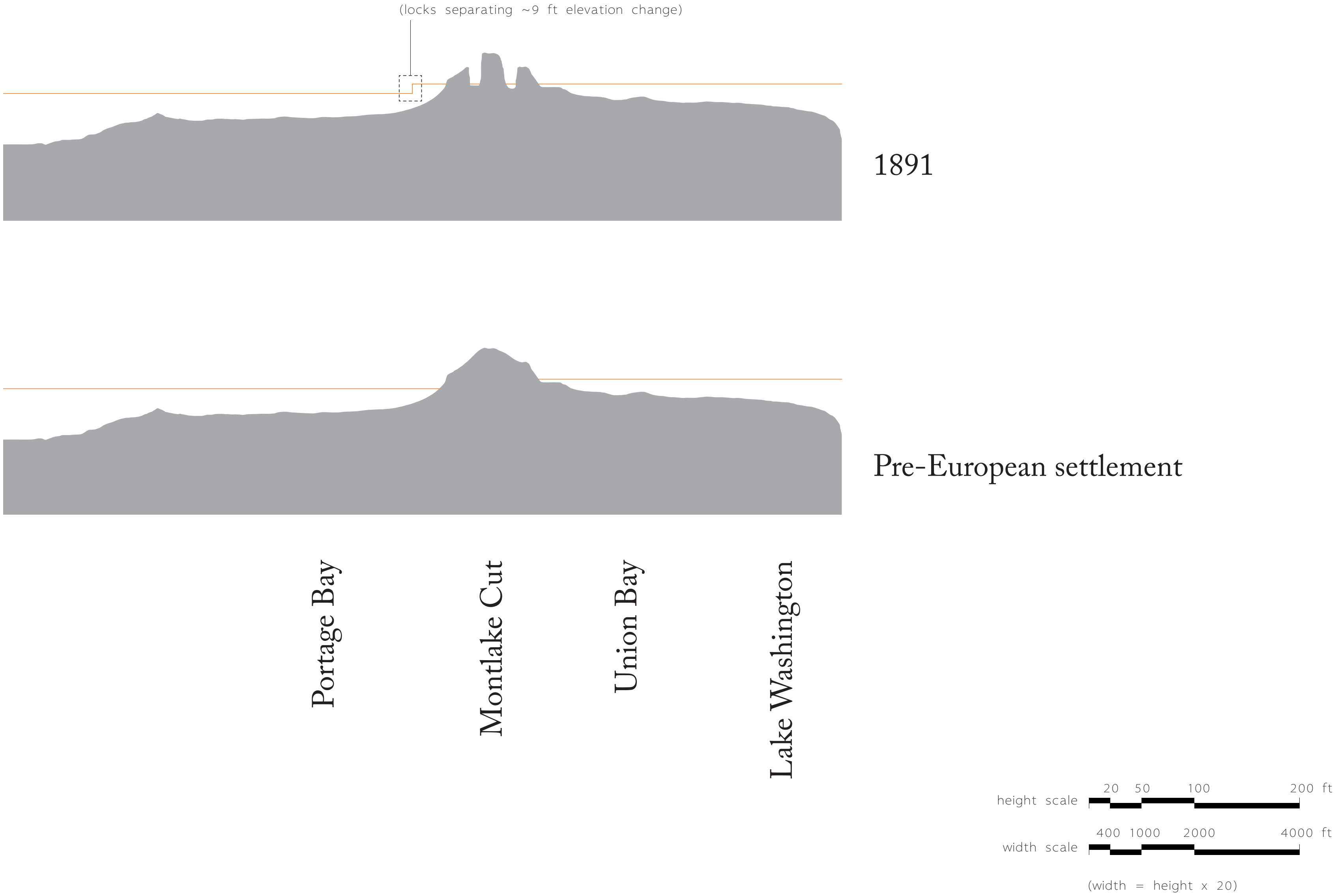
Fortunately, the nonprofit Corps Foundation, a partner of the USACE, was created to counterbalance the USACE's mission. The Corps Foundation's mission, is, conversely, to "[engage] the public to ensure the environmental health and recreational enjoyment of our nation's lakes and waterways administered by the US Army Corps of Engineers."[92]

All facilities at the Locks complex are free of charge; the Locks is sustained by federal funding.[93] However, this funding hinges on the amount of commercial cargo (tonnage)[94] that passes through the Locks, rather than the almost 50,000 vessels that pass through and more than 1.3 million individuals who visit the Locks annually.[95] These federal funds can only be applied toward "operational updates and renovations,"[96] meaning the "visitor education"[97] components of the complex are funded by private donations.[98] Today few boats actually carry commercial cargo through the Locks, meaning the complex is significantly underfunded.[99] Even those cargo boats that unload their cargo before going through the Locks—for example, some of the fishing boats that star on the Discovery Channel's *Deadliest Catch*—don't count towards that tonnage. Figure 4.27 shows a tugboat hauling a barge of gravel through the large lock, an example of commercial cargo. Overall, today the Ballard Locks is vibrant, loved by visitors and locals alike. However, this engaged public is eager to learn and the system is not set up to fully nurture that enthusiasm (See Fig. 4.28).

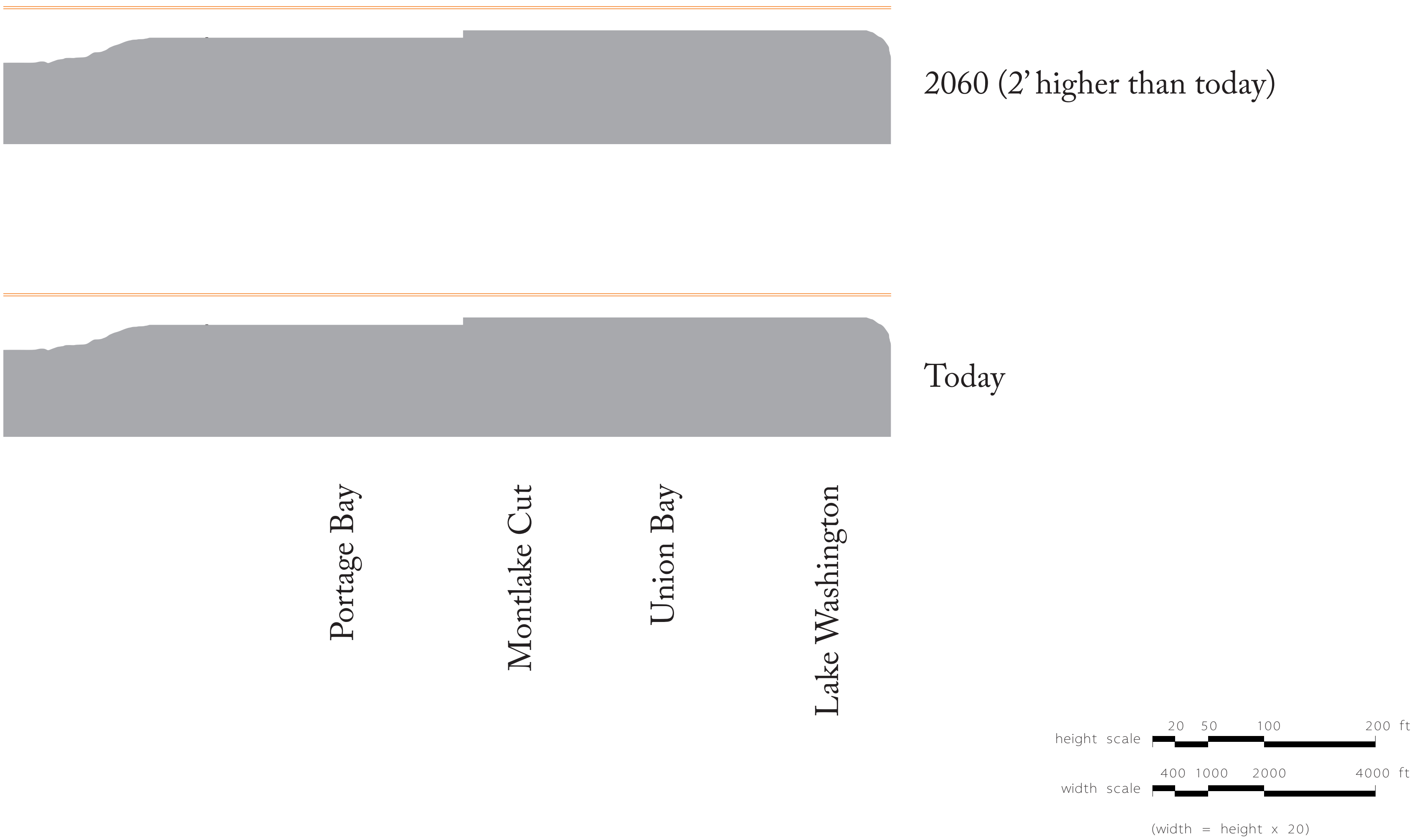
Figure 4.28: This sketch describes the dynamic site by layering many literal and figurative perspectives.

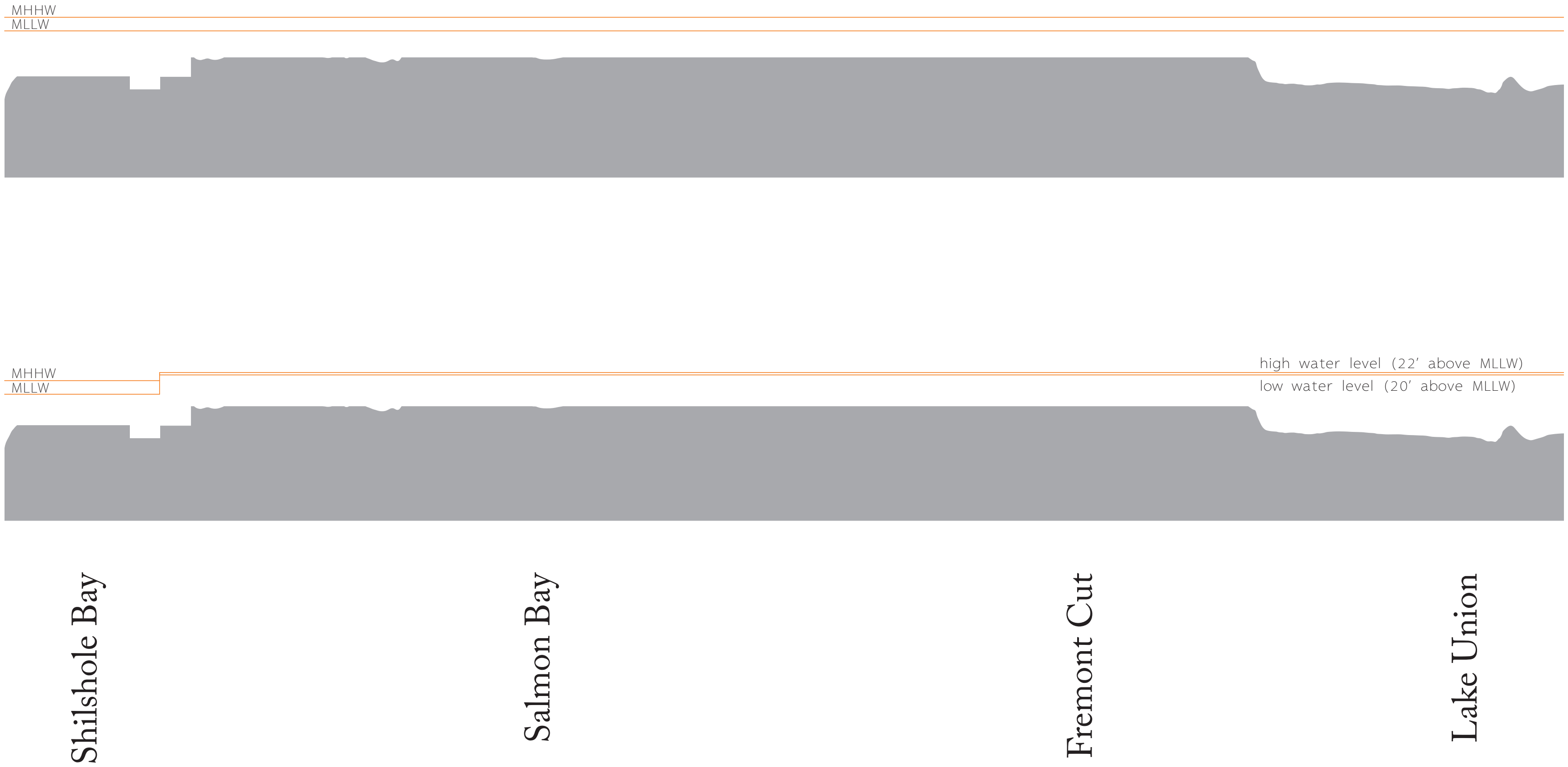


[Magnified view of a portion of Figure 4.26: Sections through Ship Canal, pre-European settlement and 1891.**]**

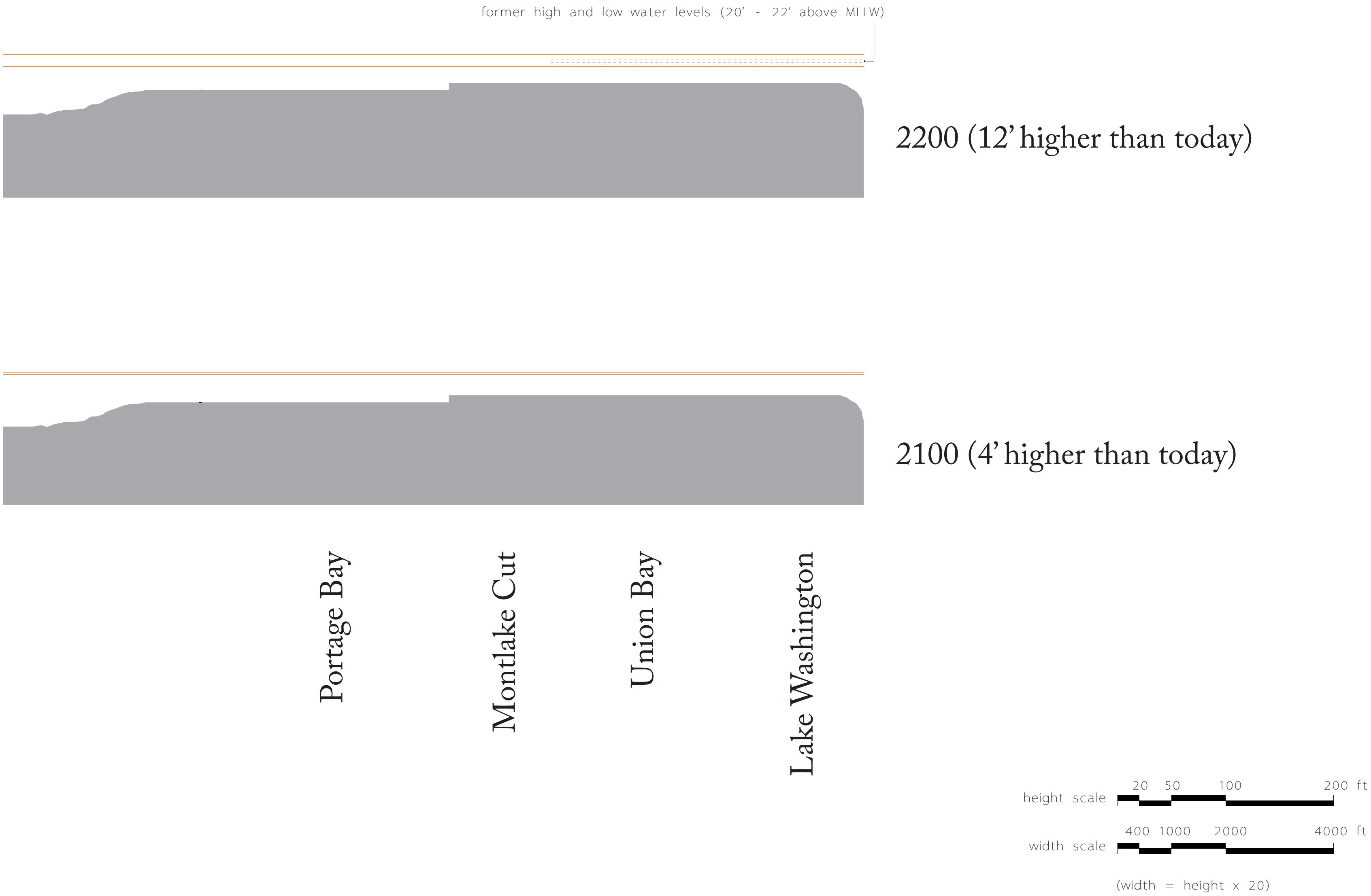

(locks separating ~9 ft elevation change)
1891
Pre-European settlement
Portage Bay
Montlake Cut
Union Bay
Lake Washington
height scale
20
50
100
200 ft
width scale
400
1000
2000
4000 ft
(width = height x 20)

[**Magnified view of a portion of Figure 4.26:** Sections through Ship Canal, today and 2060.]


2060 (2' higher than today)
Today
Portage Bay
Montlake Cut
Union Bay
Lake Washington
height scale
20 50 100 200 ft
width scale
400 1000 2000 4000 ft
(width = height x 20)



[Magnified view of a portion of Figure 4.26: Sections through Ship Canal, 2100 and 2200.**]**


former high and low water levels (20' - 22' above MLLW)
2200 (12' higher than today)
2100 (4' higher than today)
Portage Bay
Montlake Cut
Union Bay
Lake Washington
height scale
20
50
100
200 ft
width scale
400
1000
2000
4000 ft
(width = height x 20)

Notes

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[23] Ibid., 4, 6.

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[27] Ibid.

[28] Ibid.

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05

SATURATING

[Science Consultations]

> The millions of adult salmon are preyed upon, scavenged after death, and decomposed by a wide variety of organisms from bears to gulls, fly maggots, and bacteria. Recent research using stable isotope ratios has demonstrated that these "marine-derived" nutrients in the salmon carcasses are an important contribution to the aquatic and terrestrial ecosystems, affecting the growth and density of bears, growth of juvenile salmonids, productivity of lakes, biofilm and insects in streams, and even the growth of trees in the riparian zone.
>
> —Thomas P. Quinn, *The Behavior and Ecology of Pacific Salmon and Trout*

Method

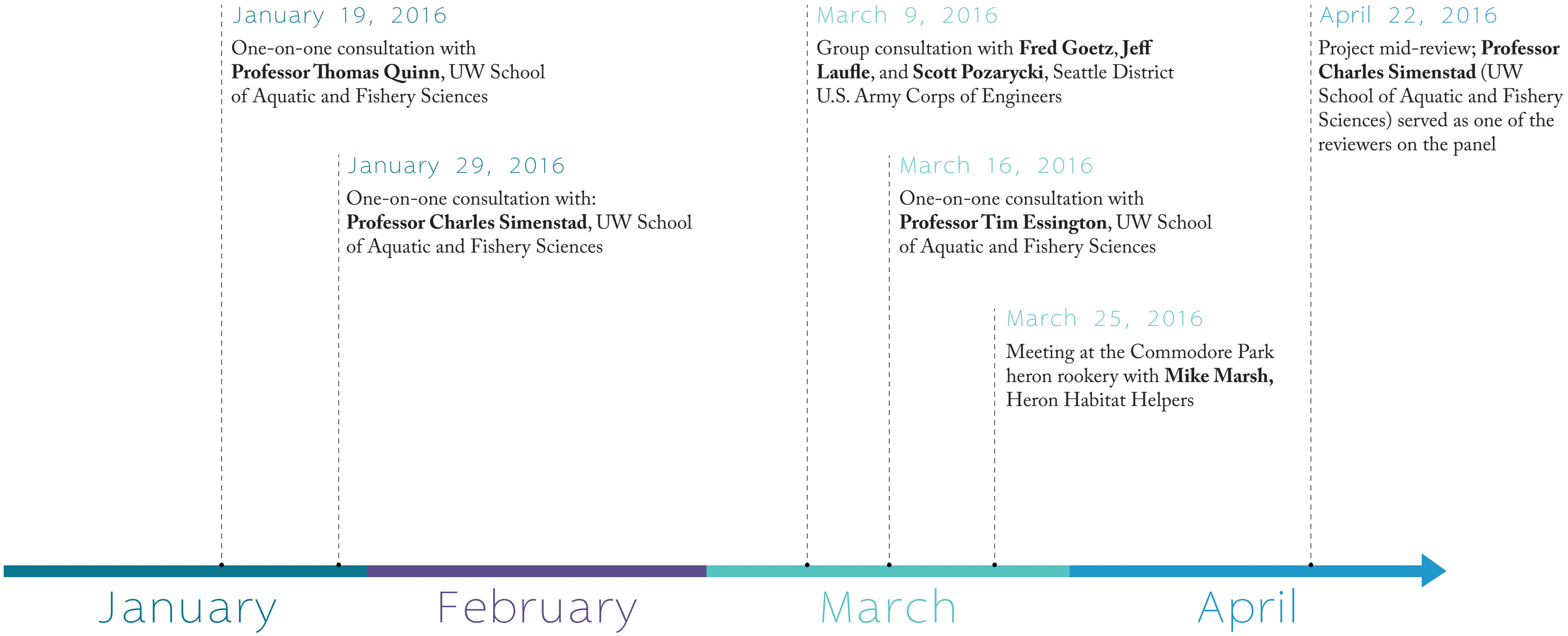
Many people are drawn to the Locks to see the salmon run, when adult Chinook, coho, and sockeye salmon and steelhead trout rush through the concrete fish ladder on their collective pursuits to die in their natal tributaries after delivering the next generation. In this way, the Locks offers valuable opportunities for humans to fulfill *biophilia*, or as Edward O. Wilson defines the title of his 1986 book, "the innate tendency to focus on life and lifelike processes."[1] Yet paradoxically the Locks itself is a threat to those salmon and biodiversity. The Locks is an engineering feat, but a failure of science. It demonstrates why the concepts of biology should be integral to and integrated into every design endeavor to support a biodiverse world. Thus, this thesis supports the integration of science and design. To accomplish this, scientists—particularly biologists—should be consulted throughout any design endeavor, at every stage. In addition, the engagement of a range of scientists from diverse platforms will ensure a more comprehensive understanding of site and the identification of the most urgent problems and opportunities.

Accordingly, to generate a design solution at the Locks that best serves biodiversity, I consulted seven scientists associated with three different organizations: Professors Charles Simenstad, Thomas Quinn, and Tim Essington with the University of Washington School of Aquatic and Fishery Sciences; Fred Goetz, Jeff Laufle, and Scott Pozarycki with the Seattle District USACE; and Mike Marsh with Heron Habitat Helpers (HHH). Refer to Figure 5.1 for a timeline of these consultations. In addition to these consultations, a report synthesizing various salmon studies in Lake Washington and at the Locks, “Synthesis of Salmon Research and Monitoring: Investigations Conducted in the Western Lake Washington Basin,” has been particularly important to my understanding of salmon needs at the Locks and is referenced heavily in this chapter.

The *nurse log* design concept explained in detail in the chapter following this one developed iteratively as I synthesized information about the science of the Locks. Though they are presented as two chapters, the science learning and the design response portions of this process have been essentially connected and have progressed in tandem. Over several months I gradually began to perceive the greatest threat to biodiversity at the Locks as the Locks itself, an awareness that will be clarified in this chapter. Simply put, the Locks contributes to biodiversity loss by constructing an abrupt transition in (a) water salinity, (b) water elevation, and (c) water temperature (See Fig. 5.2).

Why Salmon?

Pacific salmon are nurse logs themselves, their life histories embodying the gradient between saltwater and freshwater that the Locks denies. At the end of life, salmon migrate in groups to the streams and tributaries where they were born. This is a long upstream journey. When they reach their destinations, the males fertilize and females lay and bury eggs in *redds*, nests where the eggs incubate in the gravel.[2] After they die, their decomposing bodies provide important



January 19, 2016
One-on-one consultation with **Professor Thomas Quinn**, UW School of Aquatic and Fishery Sciences

January 29, 2016
One-on-one consultation with: **Professor Charles Simenstad**, UW School of Aquatic and Fishery Sciences

March 9, 2016
Group consultation with **Fred Goetz, Jeff Laufle,** and **Scott Pozarycki**, Seattle District U.S. Army Corps of Engineers

March 16, 2016
One-on-one consultation with **Professor Tim Essington**, UW School of Aquatic and Fishery Sciences

March 25, 2016
Meeting at the Commodore Park heron rookery with **Mike Marsh,** Heron Habitat Helpers

April 22, 2016
Project mid-review; **Professor Charles Simenstad** (UW School of Aquatic and Fishery Sciences) served as one of the reviewers on the panel

Figure 5.1: timeline showing when I consulted scientists for the project.

nutrients to the next generation, as well as to the forest ecosystem. Each salmon run is a batch of nutrients from the ocean delivered to the forest.[3] For this reason, salmon are keystone species,[4] "a predator species which disproportionately influences the food-web structure of its community."[5] After they emerge, these young salmon will eventually make their way out to sea where they will live their lives before returning to their natal streams, repeating the cycle. The salmon's journey spans hundreds of miles, salt- and freshwater; a changing setting and water condition is inherent to salmon biology.

Due to the excavation of the Ship Canal, salmon populations that once accessed the Black and Cedar Rivers via the Duwamish River were forced to either abandon their natal streams to spawn in the Green - Duwamish River Watershed, or locate the new entrance to Lake Washington,[6] Salmon Bay, roughly ten shoreline miles away from the mouth of the Duwamish (Refer back to Fig. 4.7 in the previous chapter). Now salmon born in the Cedar River - Lake Washington and Sammamish Watersheds pass through the Ballard Locks and Ship Canal as smolts on their initial journeys out to sea,[7] and again at the end of their lives when they return to spawn. These altered watersheds, from the Cascades to the Puget Sound lowlands,[8] and the rerouted salmon migrations that negotiate them, are now hydrologically controlled by the Locks. Because of this, design moves executed at the Locks are inherently multi-scaled. In accommodating Pacific salmon at the Locks, the design will concurrently accommodate the entire changed watershed.

While it is obvious that anadromous fish provide food for various forest species, there are other less obvious but vital impacts of their carcasses on forest ecosystems. In a 2001 report authors James Helfield and Robert Naiman attribute faster growing Sitka spruce near spawning salmon streams (compared to Sitka spruce adjacent to streams where salmon do not spawn) to marine-derived nitrogen.[9] A 2011 study by Rachel Field and John Reynolds investigating the significance of residual nutrients from Pacific salmon carcasses for breeding birds in estuary forests found "that salmon have ecological influences on breeding bird populations, probably through the long-term cycling of salmon nutrients through coastal watershed food webs."[10] These studies not only start to reveal the importance of Pacific salmon on different ecosystems, but

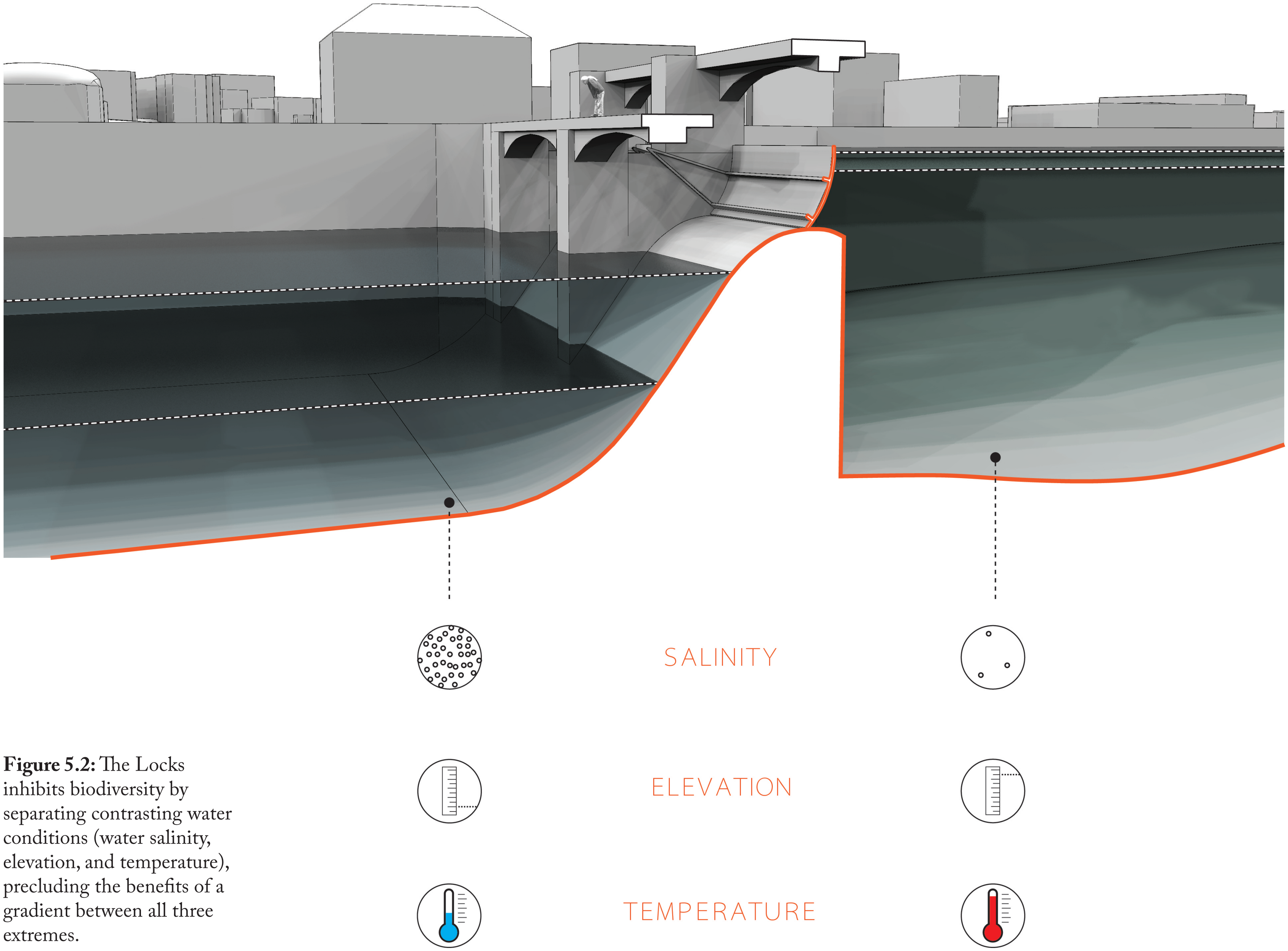


Figure 5.2: The Locks inhibits biodiversity by separating contrasting water conditions (water salinity, elevation, and temperature), precluding the benefits of a gradient between all three extremes.

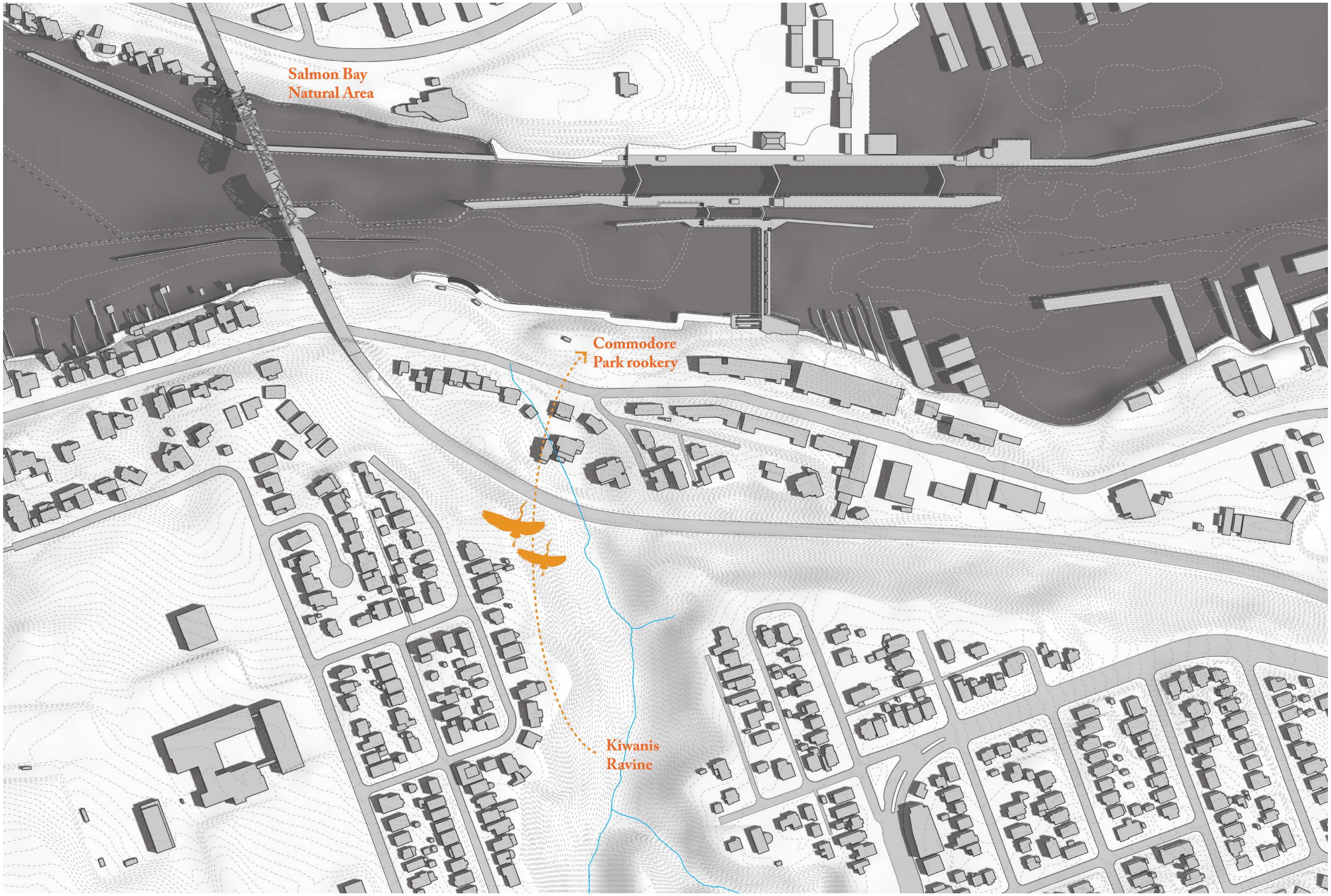
illustrate the impalpable and intricately woven strands between different species that comprise the web of life.

Salmon are “needy.”[11] This is one more reason to focus on them when designing for biodiversity, because a design benefitting salmon will provide many additional benefits to the ecosystem.[12] For example, in designing a “salmon heaven,” sculpins and various invertebrates will likely return to the area.[13] Professor Tim Essington offers a simple image that illustrates the importance of biodiversity: With just one species of mayfly, there is just one period when larvae hatch. However if there are twenty species of mayfly, there is a range of times when larvae hatch, feeding birds for a longer span.[14]

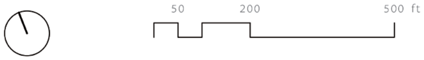
Finally, salmon matter for many reasons outside the realm of science. The Locks illustrates the Pacific salmon’s importance in human culture, recreation, and commerce. The Pacific salmon is symbolic of the Pacific Northwest. Timothy Egan expresses this sentiment in his book *The Good Rain: Across Time and Terrain in the Pacific Northwest*, writing, “The Pacific Northwest is simply this: wherever the salmon can get to. Rivers without salmon have lost the life source of the area.”[15] People love the Locks in no small part due to salmon.

Ship Canal Journeys

The “Synthesis of Salmon Research and Monitoring” report outlines the journeys of juvenile and adult Chinook, coho, and sockeye salmon and steelhead trout that travel through the Locks. Although each species has its own migration schedule, all salmon that spawn in the Cedar River - Lake Washington and Sammamish Watersheds have approximately the same route from Shilshole Bay to Lake Washington, and the reverse. After incubating in the Cedar and Sammamish Rivers, juvenile salmon move to Lake Washington toward the start of the year where they rear in shallow waters. As they develop, they move into deeper water. Months later they enter the Ship Canal, moving westward, until they reach the Locks. Some will never make it to the other side, due to threats outlined below. The ones that do make it through will move on to Shilshole Bay, then Puget Sound, and finally the open ocean where they will reside for years.[16] When it is time to start the migration back to freshwater to spawn, the adult salmon will reenter Puget Sound, then Shilshole Bay, until they again face the treacherous Locks. Those that make it will continue quickly through the Ship Canal, then Lake



Figures 5.3: plan showing Locks and adjacent non-human habitat connections. The current path of Wolfe Creek is highlighted in blue.



Washington, and on to their natal tributaries to spawn.[17] Not all of these salmon are "naturally produced"; some will return to hatcheries.[18] For example, of the Chinook salmon that return to the Cedar River, roughly one-third return to hatcheries.[19] The Issaquah Creek hatchery, for example, released over one million salmon in 2000, and over two million the year before that.[20]

Dangers to Salmon at the Locks: Abrupt Changes in Water Conditions

This section will discuss the dangers to salmon caused by the Locks that most powerfully informed my design concept: simultaneous and abrupt changes in water salinity, temperature, and elevation. My decision to propose an extended new fishway design, described in the next chapter, is in an attempt to address these threats.

Water Salinity

The Locks makes for an abrupt transition between saline and freshwater. *Anadromous fish*, fish that are born in fresh water, live the majority of their lives in saline water, and return to fresh water to spawn, such as salmon, usually experience a gradual transition from fresh to saline water, and the reverse. The Locks creates a physical wall between fresh and saline water, preventing the amount of brackish water that would be found in a true estuary. The mixing that does occur happens primarily via "lockages."[21] The authors of the "Synthesis of Salmon Research and Monitoring" report write that this division caused by the Locks has the effect of "truncating the brackish mixing zone, which is much larger in typical estuaries."[22] A freshwater lens, or freshwater that floats above denser saltwater, serves an important function as young salmon acclimate to saltwater on their journey out to sea. The abbreviated freshwater lens downstream of the Locks could be the source of distress in young salmon, and is a possible reason for the speed at which they move through Salmon Bay on their way out to sea.[23] In order to prevent saltwater intrusion, the salinity concentration of the variable saltwater wedge upstream of the Locks is not permitted to exceed one part per thousand at the University Bridge.[24] This saltwater wedge is crucial to adult salmon due to its cooler temperature and higher dissolved oxygen concentration compared to the rest of the Ship Canal.[25] To control salinity concentrations in the Ship Canal, a large saltwater drain on the east end of the locks sends denser

Figures 5.4, 5.5, 5.6, 5.7, 5.8 (clockwise from top left): photographs I took of the Commodore Park Great Blue Heron Colony on the afternoon I met with Mike Marsh with Heron Habitat Helpers. Mar. 25, 2016.

saltwater through a pipe to the opposite side of the spillway dam. Some of this water is piped to the fish ladder to attract salmon.[26]

Water Temperature

The Ship Canal is incredibly warm, especially the surface water.[27] As mentioned in the previous chapter, climate change will likely result in even warmer waters in Lake Washington and the Ship Canal.[28] Lake Washington's temperature has already started increasing.[29] The warm temperatures in the Ship Canal contribute to less dissolved oxygen. The warmer the water, the less dissolved oxygen. This is compounded by the fact that the warmer the water, the more oxygen fish need.[30] A 2013 study investigating the effects of temperature gradients associated with Snake River, Washington fish ladders on adult Chinook salmon and steelhead found "that ladder temperature gradients can create a migration obstacle that slows adult salmon and steelhead passage at Snake River dams."[31] As with the abrupt change in salinity at the Locks, the drop in temperature from upstream to downstream of the Locks is likely problematic for juvenile salmon.

Water Elevation

The two threats described above, abrupt changes in water temperature and salinity, are exacerbated by a shorter ladder and thus steeper climb. *Unfolded*, the fish ladder would be an estimated 320 feet in length.[32] During the summer when the lakes are at their highest, at MLLW the fish ladder can raise salmon 22 feet. While this is a quick increase in water elevation, it bears mentioning that the current fish ladder is much improved from the original ladder built a century ago, which was an estimated 80 feet[33] and only had 10 steps.[34]

Additional Dangers to Salmon at the Locks

In addition to the sudden change in water salinity, temperature, and elevation that the Locks creates there are additional threats to salmon at the site. The design proposed in the next chapter will also attempt to mitigate these threats.

Lack of Habitat

The entire Ship Canal is lacking suitable habitat for many species. A 2003 study found that 1,551 acres of the Ship Canal's shoreline is shaded by docks, 42.6 percent of which is caused by "large boat marinas."[35] Salmon Bay's scarcity of estuarine habitat provides a possible explanation for why fish move so quickly through it.[36] Much of the shoreline is armored, limiting the shallow water required for juvenile salmon development. Salmon Bay Natural Area, on the south bank, adjacent Salmon Bay Bridge, provides much needed habitat in the bay. However, conditions are so altered in the bay that some juvenile Chinook rear in Lake Washington, "a rare life history strategy for ocean-type Chinook salmon."[37] Increased habitat is one of the most important changes a design can make to the site.[38] It is also important to remember that the excavation of the Ship Canal and subsequent change in salmon migration routes removed thousands of acres of "intertidal wetlands" from those routes.[39]

Predatory Mammals

California sea lions and harbor seals are not themselves threats to salmon populations. After all, salmon are their expected prey. However, conditions at the Locks create a situation where salmon and trout become incredibly easy for the seals and sea lions to catch. When the fish hesitate before entering the fish ladder they are easy targets for these mammals and there are very few places to hide.[40]

Pollution

Contaminants in the Ship Canal are not as big a problem as they are in the Duwamish, for example.[41] Prior to my science consultations, I expected pollution to be the greatest threat to salmon welfare at the Locks. While it is a problem in the Ship Canal, it is actually not as severe a problem as lack of habitat and warm water. However, while pollution is not the most pressing issue in regard to threats to salmon in the Ship Canal, it is still a problem. Seattle Public Utilities and King County are currently working on a project to address the average of "more than 130 times per year at seven outfall locations" combined sewer overflows "send sewage and stormwater into the Ship Canal."[42] The pollutants in stormwater runoff can be incredibly harmful to salmon.[43]

Mechanics of the Locks Complex

Although there are salmon counts at the Locks and at the Cedar River, it is not well-known how many salmon pass through the Locks. Obtaining an accurate count is hindered by the fact that not all salmon use the fish ladder.[44] The authors of the "Synthesis of Salmon Research and Monitoring" report outline different routes salmon take through the Locks. In addition to the fish ladder, adult salmon on their way to spawn also use the large and small locks and the saltwater drain on their journeys upstream.[45] Juvenile salmon headed downstream on their way out to sea also use the large and small locks, the saltwater drain, and additionally the spillway dam and associated smolt flumes to traverse the Locks.[46] These four smolt flumes are retrofits, essentially water slides for juvenile salmon headed downstream. They are positioned in two bays of the spillway dam and were first installed in 2000.[47] Sometimes salmon end up circling through the same or different structures multiple times before moving on to the remainder of their migrations.[48] The USACE has made various efforts to make the Locks safer for salmon.[49] However, these efforts are generally retrofits rather than solutions. For example, the Stoney gate valves suck juvenile salmon into the filling culverts, pummeling their tiny bodies against the walls.[50] The USACE now annually scrapes barnacles from the walls of the filling culvert and uses strobe lights to deter salmon from entering them in an attempt to reduce the amount of smolts that are killed, injured, or "descaled" in the culverts.[51]

Commodore Park, Kiwanis Ravine, and the Great Blue Heron Colony

While salmon have been the focus of the design, many other species play important roles in increasing biodiversity at the Locks. Herons have a dramatic presence on the site, and for that reason deserve special attention in this chapter. The Commodore Park Great Blue Heron Colony consists of dozens of nests in a clump of red alders at Commodore Park, adjacent to and overlooking the Locks.[52] Herons have nested in nearby Kiwanis Ravine since 1982,[53] until May 2013 when bald "eagle predation" caused them to abandon their 86 nests and relocate to Commodore Park, where about seven nests already existed.[54] In the span of two weeks,[55] the Commodore Park rookery quickly grew to 62 "active nests," nests used by herons to incubate eggs.[56] Despite this interruption, about 87 young

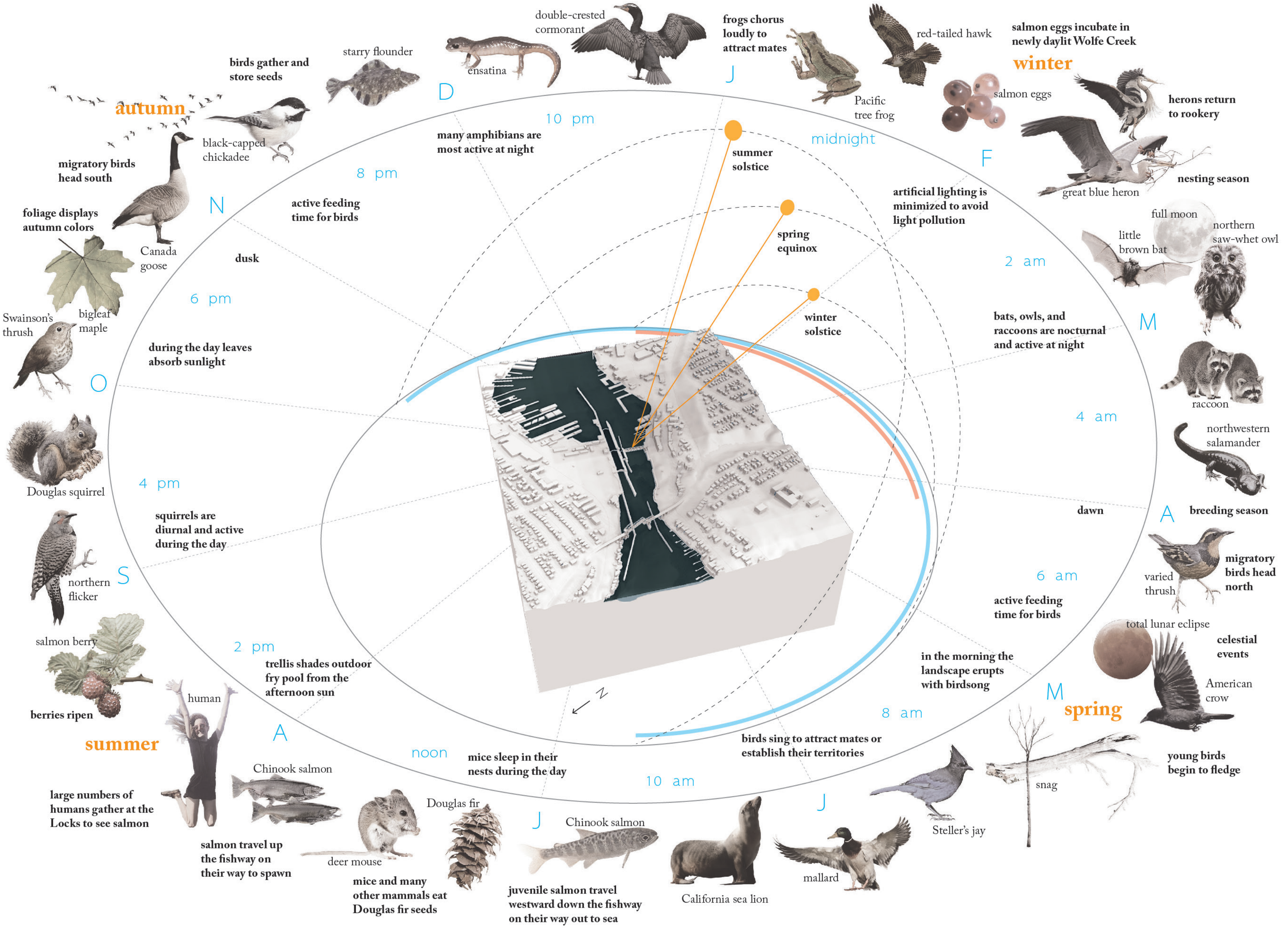

double-crested
cormorant
ensatina
starry flounder
birds gather and
store seeds
autumn
black-capped
chickadee
migratory birds
head south
foliage displays
autumn colors
Canada
goose
Swainson's
thrush
bigleaf
maple
Douglas squirrel
northern
flicker
salmon berry
berries ripen
human
summer
large numbers of
humans gather at the
Locks to see salmon
Chinook salmon
salmon travel up
the fishway on
their way to spawn
deer mouse
mice and many
other mammals eat
Douglas fir seeds
Douglas fir
Chinook salmon
juvenile salmon travel
westward down the fishway
on their way out to sea
California sea lion
mallard
Steller's jay
snag
young birds
begin to fledge
spring
American
crow
celestial
events
total lunar eclipse
varied
thrush
migratory
birds head
north
breeding season
northwestern
salamander
raccoon
little
brown bat
full moon
northern
saw-whet owl
great blue heron
nesting season
herons return
to rookery
salmon eggs
winter
salmon eggs incubate in
newly daylit Wolfe Creek
red-tailed hawk
frogs chorus
loudly to
attract mates
Pacific
tree frog
J
F
M
A
M
J
J
A
S
O
N
D
midnight
2 am
4 am
6 am
8 am
10 am
noon
2 pm
4 pm
6 pm
8 pm
10 pm
summer
solstice
spring
equinox
winter
solstice
artificial lighting is
minimized to avoid
light pollution
bats, owls, and
raccoons are nocturnal
and active at night
dawn
active feeding
time for birds
in the morning the
landscape erupts
with birdsong
birds sing to attract mates or
establish their territories
mice sleep in their
nests during the day
trellis shades outdoor
fry pool from the
afternoon sun
squirrels are
diurnal and active
during the day
during the day leaves
absorb sunlight
dusk
active feeding
time for birds
many amphibians are
most active at night
N

Figure 5.9 (opposite page): This thesis advocates for "program" to include not only human needs, but also biodiversity as a whole. This requires an understanding of the layered systems, large and small, that intersect on site. This attitude is illustrated in this diagram which explores some of the daily and annual systems at the Locks with an emphasis on wildlife biology. This perspective could be expanded to show other systems such as wind patterns and the activities of various insects. **Figure 5.10 (above):** This aerial diagram begins to map larger scale non-human habitat connections.

herons ended up fledging that year, and approximately 105 to 116 the following year.[57]

A creek once connected Kiwanis Ravine to Salmon Bay. In his book *Native Seattle: Histories from the Crossing-Over Place* Thrush explains that before the Locks were constructed, the Coast Salish people referred to this creek, now known as Wolfe Creek, as "Lots of Water," because it "was a reliable source of freshwater in all seasons."[58] The creek still runs through its original ravine in what is now Kiwanis Memorial Preserve Park. Figure 5.3 illustrates the creek's path north of the fork. Fortunately, this part of the ravine, the location of the former heron rookery, has remained vegetated. However, the upper reaches of the creek, south of the ravine, where it splits into an east and west fork, are heavily altered, covered and piped through culverts.[59] Currently salmon are not able to access Wolfe Creek because north of the ravine, instead of running into Salmon Bay as it used to, the creek is now sent into a culvert where it joins the combined sewer system before the King County sewer line, and ends up at the West Point Treatment Plant.[60]

I met with Mike Marsh with HHH at the heron rookery in March 2016, when incubation was beginning for the year (See Figs. 5.4 – 5.8). It is interesting that the herons chose such a loud place to call home, so close to human commotion. Mike Marsh and Deborah Andrews, another member of HHH, suggest in their 2014 report describing that year's heron activity at Commodore Park that this could be due to the fact that the location of the new rookery "was probably part of the herons' flight pattern" and so "the noise of the trains and loudhailers from the Locks were familiar sounds, not new disturbances."[61] However, the report also points out that unfamiliar sounds, specific examples being a drone and a leaf blower, do cause the birds to leave their nests for minutes to hours. Fortunately, HHH spreads awareness so that site visitors are mindful of the impacts of their activities on the herons in the rookery during nesting season.[62]

As a designer, entranced by this vibrant bird village, it is tempting to employ design moves in an attempt to preserve it. But in fact, the birds' droppings are apt to eventually kill the very trees that hold their nests, and then they will move on to somewhere else.[63] An architect's response might be something like, "Let's engineer industrial trees that are *better* than real trees so the herons will never move from this spot!" However, I would argue that humans and herons are better served by real trees.

Discussion

Though this chapter has focused on science, it has not been the writing of a scientist. However, in taking time for this process, the science of the site has become the foundation of my design proposal—a necessary circumstance to achieve the primary goal of designing for biodiversity. And while this research certainly took time, I would not have been able to come up with a design that makes sense without it. For reasons described above I chose to focus this chapter on just a few species: Primarily Chinook, coho, and sockeye salmon, steelhead trout, as well as great blue herons.

Hopefully in designing for these species, their respective networks with other species will encourage biodiversity as a whole. There are innumerable interactions, many imperceptible, at work at the Locks. Figure 5.9 is my attempt to imagine and diagram some of these interactions by considering daily and annual systems at the Locks. Of course, this diagram is limited in its scope. As evidenced by salmon, herons, and humans, species pass through the Locks. It is a landscape in itself, but it is also connected to other landscapes, is a component of larger landscapes, and is comprised of smaller landscapes. For this reason it is important to think about habitat connection opportunities, such as with Discovery Park (See Fig. 5.10). It is easy to get caught up in the specific scope of a scientific report. However, designers are well-poised to locate generalist connections between the information of specialists. As mentioned earlier, throughout the decades, methods for addressing the web of life at the Locks have generally consisted of retrofits. One example, a new fish ladder, also concrete. Another, a fake orca whale installed underwater in the 1990s in an attempt to intimidate sea lions.[64] Examples abound. Each story illustrates the rigidity of the Locks, not just in form—and perhaps a product of its form—but in behavior. Scraping barnacles, for example, is the opposite of the approach proposed in this thesis. Continually combatting one system to benefit another does not make sense in the long term. A resilient strategy would shift the rhetoric toward working with site systems, without the need for constant maintenance.

Notes

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[1] Edward O. Wilson, *Biophilia* (Cambridge, MA; London: Harvard University Press, 1986), 1.

[2] Thomas P. Quinn, *The Behavior and Ecology of Pacific Salmon and Trout* (Vancouver, BC, CAN: UBC Press, 2005), 3–4.

[3] Ibid., 141–42.

[4] Ibid., 138–39.

[5] Audrey Valls, Marta Coll, and Villy Christensen, “Keystone Species: Toward an Operational Concept for Marine Biodiversity Conservation,” *Ecological Monographs* 85, no. 1 (2015): 30, doi:10.1890/14-0306.1.

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[7] “Salmon Bay Estuary Synthesis Report Including Assessment of Proposed Daylighting Wolfe Creek Project: Lake Washington, Cedar, Sammamish Watershed (WRIA 8)” (Prepared for Lake Washington, Cedar, Sammamish Watershed (WRIA 8) Estuary and Nearshore Workgroup. Prepared by Taylor Associates, Inc., Seattle, WA, 2010): 1.

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[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] Timothy Egan, *The Good Rain: Across Time and Terrain in the Pacific Northwest* (1st Vintage Departures ed. Vintage Departures. New York: Vintage Books, 1991), 22.

[16] Cooksey et al., “Synthesis of Salmon Research and Monitoring,” 93–110.

[17] Ibid.

[18] Ibid., 34.

[19] Ibid.

[20] Michele E. Koehler et al., “Diet and Bioenergetics of Lake-Rearing Juvenile Chinook Salmon in Lake Washington,” *Transactions of the American Fisheries Society* 135, no. 6 (2006): 1582, doi: 10.1577/T05-178.1.

[21] Cooksey et al., “Synthesis of Salmon Research and Monitoring,” 31.

[22] Ibid., 22.

[23] “Salmon Bay Estuary Synthesis Report,” 17–18.

[24] Cooksey et al., “Synthesis of Salmon Research and Monitoring,” 22.

[25] Ibid., 32.

[26] Ibid., 25–26.

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[27] Thomas Quinn (professor, University of Washington School of Aquatic and Fishery Sciences) in discussion with the author, January 19, 2016.

[28] Cooksey et al., “Synthesis of Salmon Research and Monitoring,” 104–106.

[29] George B. Arhonditsis et al., “Effects of Climatic Variability on the Thermal Properties of Lake Washington,” *Limnology and Oceanography* 49, no. 1 (2004): 263, doi: 10.4319/lo.2004.49.1.0256.

[30] Thomas Quinn (professor, University of Washington School of Aquatic and Fishery Sciences) in discussion with the author, January 19, 2016.

[31] Christopher C. Caudill et al., “Indirect Effects of Impoundment on Migrating Fish: Temperature Gradients in Fish Ladders Slow Dam Passage by Adult Chinook Salmon and Steelhead,” *PLoS One* 8, no. 12 (2013): 6, doi: http://dx.doi.org.offcampus.lib.washington.edu/10.1371/journal.pone.0085586.

[32] This is a very rough estimate based on historical drawings.

[33] This is a very rough estimate based on historical drawings.

[34] Brett Hansen, “Linking the Lakes: The Lake Washington Ship Canal,” *Civil Engineering* (08857024) 80, no. 10 (2010): 45, *Military & Government Collection*, EBSCOhost.

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[36] “Salmon Bay Estuary Synthesis Report,” 15.

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[39] Cooksey et al., “Synthesis of Salmon Research and Monitoring,” 21.

[40] Priscilla Long, “Herschel and the Steelheads,” *American Scholar*, Jan. 9, 2013, https://theamericanscholar.org/herschel-and-the-steelheads/#.V7OnS5grKSS.

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[42] “Ship Canal Water Quality,” *Seattle.gov*, Seattle Public Utilities, http://www.seattle.gov/util/EnvironmentConservation/Projects/ShipCanalWaterQuality/index.htm.

[43] Nathaniel L. Scholz et al., “Recurrent Die-Offs of Adult Coho Salmon Returning to Spawn in Puget Sound Lowland Urban Streams,” *PLoS ONE* 6, no. 12 (2011): E28013, doi:10.1371/journal.pone.0028013.

[44] Thomas Quinn (professor, University of Washington School of Aquatic and Fishery Sciences) in discussion with the author, January 19, 2016.

[45] Cooksey et al., “Synthesis of Salmon Research and Monitoring,” 30.

[46] Ibid., 29.

[47] Ibid., 27.

[48] Ibid., 28–30.

[49] Ibid., 33.

[50] Christopher Dunagan, “Will Ballard Locks Withstand a Major Earthquake?” *Encyclopedia of Puget Sound* (University of Washington Puget Sound Institute), Feb. 18, 2016, https://www.eopugetsound.org/magazine/ballard-locks.

[51] Cooksey et al., “Synthesis of Salmon Research and Monitoring,” 33.

[52] Mike Marsh and Deborah Andrews, “Commodore Park Great Blue Heron Colony Report, 2014” (*Heron Habitat Helpers*, Seattle, WA, 2014): 2.

[53] Ibid., 3.

[54] Ibid.

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[55] Ibid.

[56] Ibid., 1.

[57] Ibid.

[58] Coll Thrush, *Native Seattle: Histories from the Crossing-Over Place* (Weyerhaeuser Environmental Books. Seattle: University of Washington Press, 2007), 226. Thrush refers to this creek which flows through Kiwanis Ravine as *Kiwanis Creek*. In this thesis and elsewhere it is referred to as *Wolfe Creek*.

[59] "Salmon Bay Estuary Synthesis Report," 3.

[60] Ibid.

[61] Marsh and Andrews, "Commodore Park Great Blue Heron Colony," 9.

[62] Ibid., 9–10.

[63] Mike Marsh (member, Heron Habitat Helpers) in discussion with the author, March 25, 2016.

[64] Timothy Egan, "Getting Faked Out May Be Sea Lions' Last Chance," *The New York Times, Seattle Journal*, Nov. 12, 1996, http://www.nytimes.com/1996/11/12/us/getting-faked-out-may-be-sea-lions-last-chance.html.

06

ECHOING

[Design Response]

Ironically, the professionals who specialize, reading certain parts of landscape more deeply than other parts and shaping them more powerfully, often fail to understand landscape as a continuous whole. Once those who transformed landscapes were generalists: naturalist, humanist, artist, engineer, even priest, all combined. Now pieces of landscape are shaped by those whose narrowness of knowledge, experience, values, and concerns leads them to read and tell only fragments of the story.

—Anne Whiston Spirn, *The Language of Landscape*

Concept

Buildings are landscape components and landscapes themselves. Their roofs are drainage basins contributing to larger watersheds. Buildings are subject to entropy, like everything else. They aren't permanence; they are change. Nothing illustrates this better than buildings that have been around for a while. They embody an authenticity that is lost in the glowing architectural renderings that have become standard sales hooks in the industry. Ruins reveal how the landscape has worked through them: root-choked homes, haunted ghost towns, old air, cracked wood, stories trapped in rooms, shacks engulfed with ferns and rainwater in the middle of nowhere.

Designing a building, a landscape, which intentionally embodies this incremental authenticity is no easy task. How should a design move beyond the easy pitfall of mimicking a biological entity only in its form? What form does a building take that is not just *sustainable* but concedes its position to site processes—a building that willingly decays? These are questions I considered when approaching a redesign of the fishway at the Locks. As outlined in Chapter Four, the locks and spillway dam at Salmon Bay are not only increasingly obsolete, they contribute to biodiversity loss. However, when regarded as metaphorical nurse logs, they avoid both (See Figs. 6.1, 6.2).

As a log decomposes, it provides nutrients and a foundation for new life. The hole in the forest canopy indicating where the tree once stood allows sunlight to reach the soft lime leaves of saplings now growing from its trunk. When the log has finally become detritus, its shape remains in the root structures of the trees that grew from it. Even centuries later, the peculiarly straight line of trees that grew from it marks where it once lay. A nurse log provides a powerful metaphor for the phasing approach offered in this design. However, it is not the only example of this full-circle account. The journey of the salmon, outlined in the previous chapter, reveals that salmon are also nurse logs.

Design

Formulating a strategy that serves biodiversity, the primary goal of the fishway redesign, involved consulting seven scientists (biologists) from three platforms throughout the design process. This development, described in the preceding chapter, led to my understanding of the Locks as a wall between extremes in water temperature, salinity, and elevation, contributing to salmon mortality and biodiversity loss. In lieu of lowering the temperature of the entire Ship Canal, a feat outside the scope of this endeavor, the design itself becomes a gradient, a gradual transition between those three extremes. While it might seem counterintuitive to lengthen the salmon’s already laborious journey upstream, the design proposal attempts to establish the longest possible fishway to form a more gradual gradient from cold to hot, low to high, and saline to fresh. In this way the primary goal of the project, *design for biodiversity*, translates to *design a gradient*. Perhaps unexpectedly, the design uses the Locks complex itself along with sea level rise—tangible threads to the site’s past and

ILLUMINATING

Sunlight streams through a single hole in the forest canopy where a cedar has fallen.

DECOMPOSING

This dappled light moves over the log on the damp forest floor, drawing life from it.

GROUNDING

As it rots, the log is home and a life source to a medley of new growth, including three cedars.

SATURATING

The trees that grow out of the decomposing log echo its former form in their root structures.

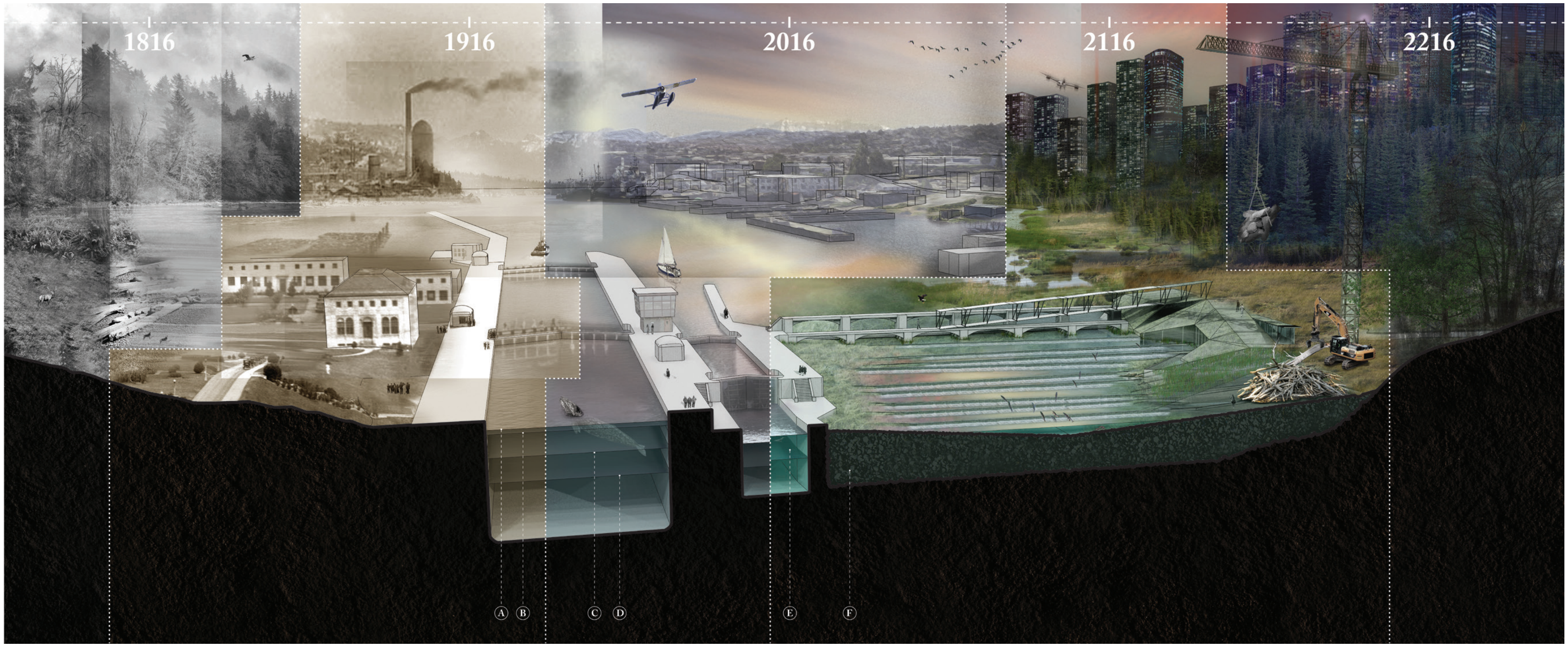
ECHOING

The log has now become the forest floor, a line of trees marking where it once lay.

Figure 6.1 (above): This diagram compliments Figure 6.2, further articulating the design concept by comparing the Lock's succession to the stages of a nurse log's decomposition into the landscape. The concept is focused on the decomposition process rather than a physical imitation of the form of a nurse log.

Figure 6.2 (opposite page): Rather than imposing a design on the landscape, this phasing plan *decomposes* the Locks as if it were a nurse log which, before disappearing into the landscape, would nurture new life from it and leave its mark on that new life. To illustrate this concept, this section-perspective at once depicts the Locks through four centuries—two in the past and two yet to pass. The design itself, a phasing strategy, is a gradient between water temperature, salinity, and elevation. This gradient through space and time is achieved using the Locks themselves and eventually sea level rise. The design represents a shift in perspective: though the Ballard Locks is a damaging barrier, it is also material for a future biodiverse estuary. Likewise, though sea level rise is a consequence of the anthropogenic environmental crisis that is reducing biodiversity, it is used here as a tool for eventually increasing biodiversity by breaching the miter gates and creating an estuary. This way of thinking frees designers to push on with hope rather than bemoan history. It also gives purpose to what otherwise might be viewed as threats.

Note: This section-perspective is intended to be viewed at a large scale. Some detail may be lost when viewed on this document's 11 x 8.5" page. If you are viewing the document digitally, you may use your computer's zoom function to view in more detail.



A. high fresh water elevation (+ 22 ft)
B. low fresh water elevation (+ 20 ft)
C. high salt water elevation (MHHW: + 11.3 ft)
D. low salt water elevation (MLLW: + 0.00 ft)
E. depiction of future sea level rise (precise level unknown)
F. fill for proposed fishway

[Figure 6.2 callouts]

future—to achieve this gradient. Interestingly, these threads are both associated with the environmental crisis of which biodiversity loss is a devastating component, one a contributor to it and the other a consequence of it, respectively. In this way the site's history is not divorced from the design but rather foundational and essential to it. Moreover, the future becomes an important part of the design, even if it is wrought with uncertainty.

To broaden the gradient to inhabit time as well as space, a phasing strategy emerges that looks as far into the future as it looks into the past. The result is both a physical gradient but additionally a gradient of succession through time—a nurse log. To illustrate this point, Figure 6.2 depicts the site through four centuries in one image. Note that the right and left sides of the rendering—the distant past and future—are the most biodiverse, though far from identical. This emphasizes that a goal of biodiversity does not require restoration in the traditional sense. In the case of the Locks, restoration is currently not a realistic option. This section-perspective is paired with a diagram of a nurse log's decomposition (Fig. 6.1) to illustrate parallels between the two. As a metaphorical nurse log, the Locks is freed from obsolescence and the negativity associated with anthropocentric landscapes. Instead, this landscape becomes the key to a biodiverse future, a nurturing estuary, just as threatening sea level rise becomes the very tool that will eventually reestablish an authentic estuary in Salmon Bay.

Process

In an exercise to better understand the site and appreciate the repercussions of various design moves, I modeled three preliminary schematic designs using chipboard and acrylic paint (See Fig. 6.3). Each of the three schematic designs represents a single, severe design perspective. Because the Locks hydrologically controls the Cedar River - Lake Washington Watershed, design moves executed on site have far-reaching implications. Because of this, it was important to visualize these design moves so that their implications could be fully appreciated. The goal of this exercise was thus to make each proposal as unique as possible to initiate a better understanding of the site and a clearer pathway forward. Orange paint was used to represent areas under the water's surface, white paint to represent areas above it.

PROPOSAL 1: HOLD FAST

Primary design move:
Maintain spillway dam and locks + design fishway around them

This strategy represents the extreme decision to leave the Locks complex functioning as it has for the past century, accepting the site as the authority of an entire watershed. Thus, the proposed fishway is designed around the existing complex. **Biodiversity is limited because it is only fostered on the fringes of human water transportation.**

PROPOSAL 2: GRAY AREA

Primary design move:
Maintain locks + replace spillway with extended fishway

This design scheme falls between the extremes of Proposal One and Three in that a portion of the Locks complex remains as it is while the other portion is eroded away. While the locks are maintained for human water transport in this scheme, the spillway dam aggregates sediment to become an extended, brackish fishway. **The design enhances biodiversity in tandem with human water transportation.**

PROPOSAL 3: LET GO

Primary design move:
Remove spillway dam and locks entirely, precluding a defined fishway

This approach, to relinquish all power to flowing water, never mind the consequences to human infrastructure, represents the opposite extreme of Proposal One. **The design encourages biodiversity at the expense of human water transportation.**

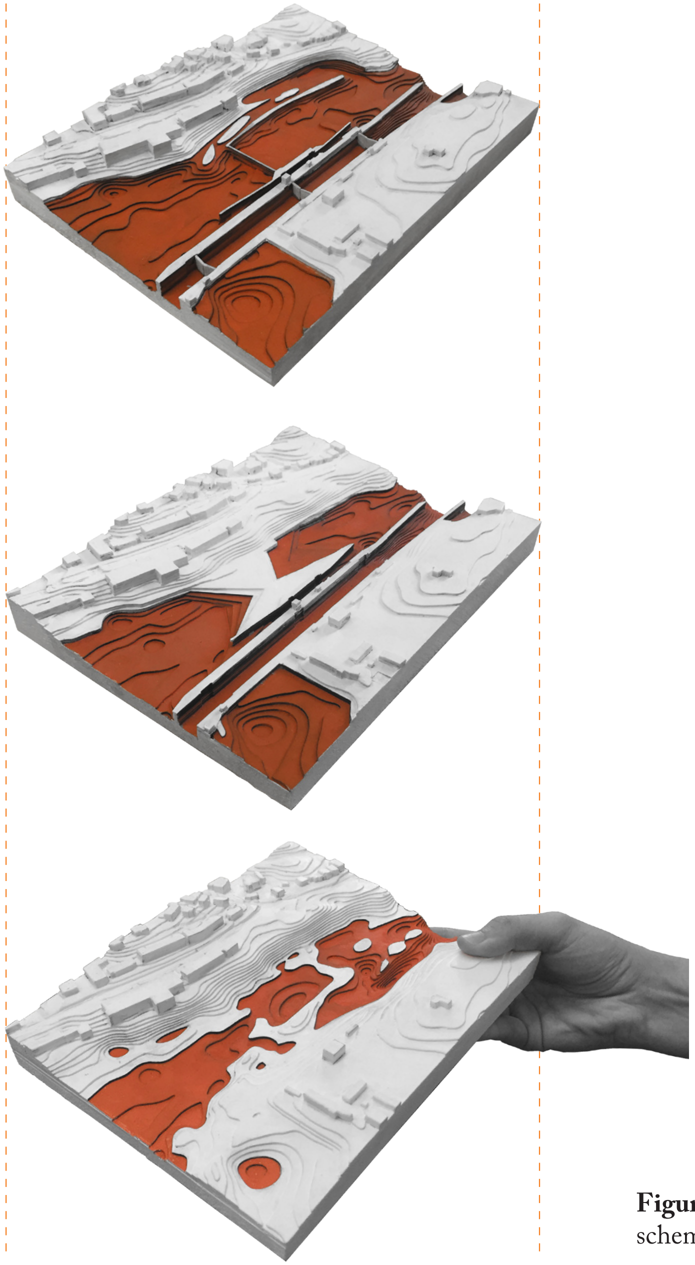


Figure 6.3: preliminary schematic designs.

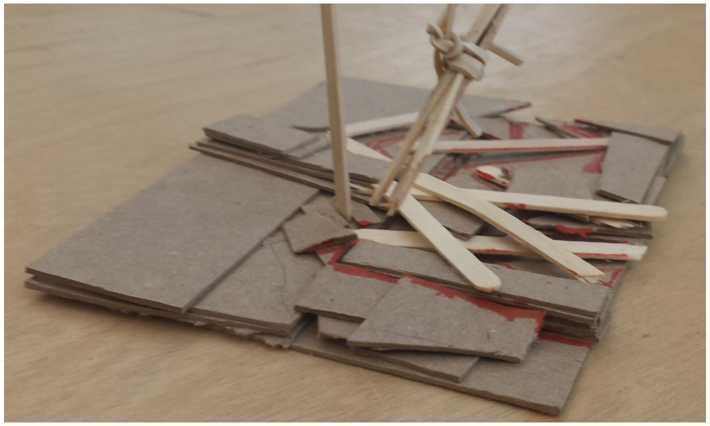


Figure 6.4 (left): a study model exploring ideas related to logjams and river morphology. **Figure 6.5 (below):** An important part of the design process has been building a three-dimensional digital model of the site and surrounding context. This is a screen capture of the model I built using Rhinoceros 3D, a computer modeling software.

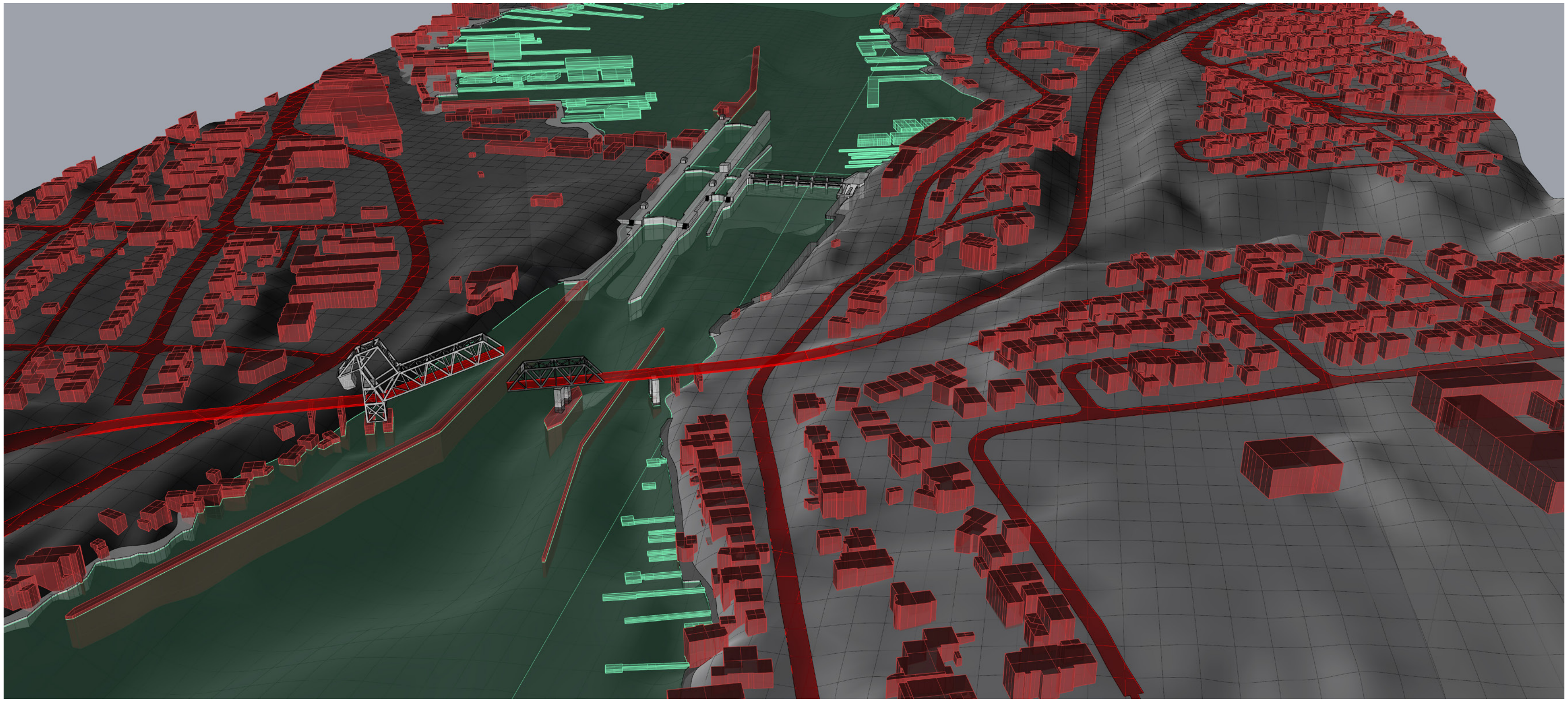


Figure 6.6 (above) and 6.7 (opposite page): photographs of 3 x 2' model depicting site and context. Base: plywood. Topography, bathymetry, buildings: CNC milled foam, painted with gesso. Locks complex and Salmon Bay Bridge: 3D print.

Note: additional photographs of models located in Appendix.

Proposal One is primarily about maintaining the Locks as it has operated for a century. To do this, the new fishway is built around it, limiting biodiversity. This proposal continues to give the site and humans authority over the entire watershed upstream of the Locks. Proposal Three, on the other end of the spectrum, removes both lock chambers and the spillway dam, relinquishing the power of the watershed back to the watershed itself. This option prioritizes biodiversity at the expense of human water transportation. Proposal Two falls somewhere between Proposals One and Three, maintaining both locks, but replacing the spillway dam with an extended fishway.

The most important lesson gleaned from this preliminary design exercise was to incorporate site systems into the phasing plan so that it would not need constant human maintenance to evolve. This involves designing at the watershed scale and using the power of the site—the power of water—as a participant in the evolution of the design.

At first it seemed necessary to propose an entire master plan for the Locks complex. Thus, initial iterations were unfocused and broad, attempting to work out design strategies that included the historical buildings and gardens. However, it eventually became apparent that limiting the scope of the redesign to the fish ladder and viewing room, spillway dam, and Commodore Park would allow for a more productive investigation into architecture's role in biodiversity conservation.

Additional components of the design process included consulting scientists (described in the previous chapter) and building models to better understand the site. Figure 6.4 depicts a small study model assembled during an exploration of log jams and their influence on river morphology. Two ambitious components of the design process were building a detailed digital model of the Locks and surrounding context (See Fig. 6.5) and building a large physical model of the Locks and surrounding context (See Figs. 6.6 and 6.7; see Appendix for additional photographs). Other important components of the design process were consulting individuals who are familiar with the Locks, studying the watershed, researching the history of the site, and becoming familiar with the daily and annual cycles of other species that use the site.

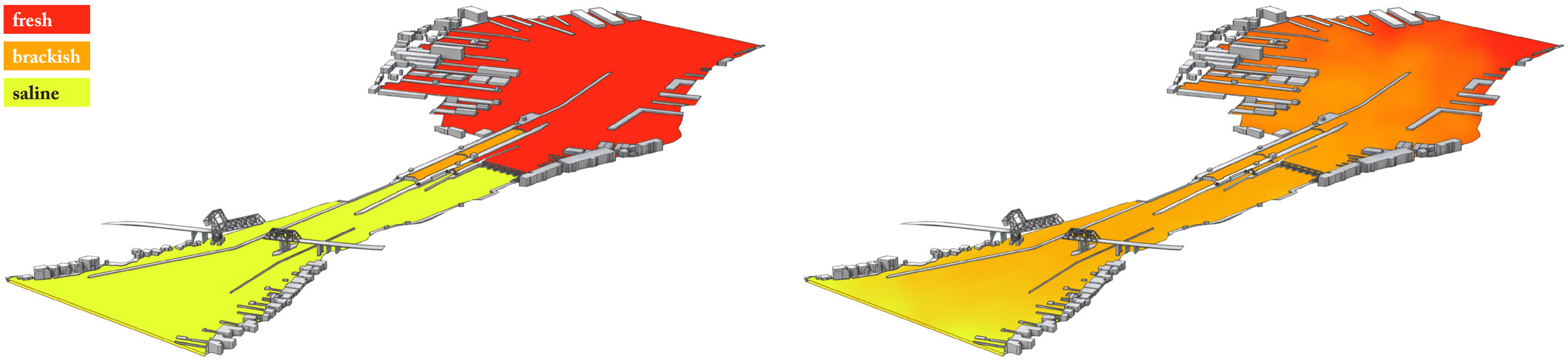
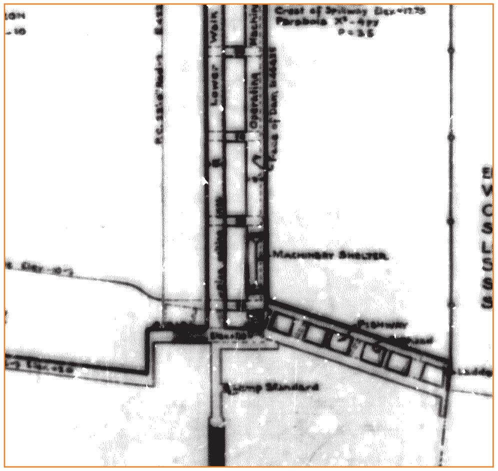
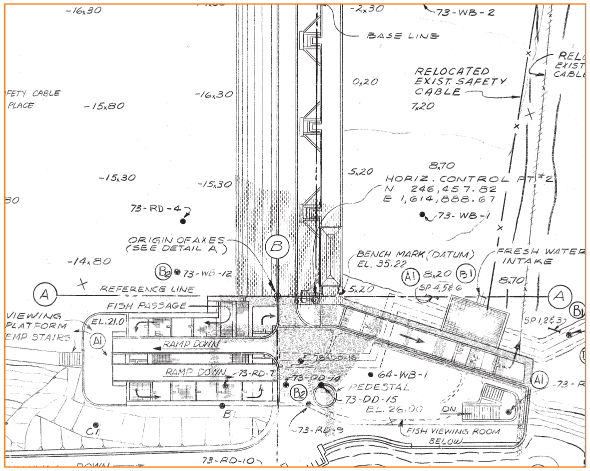


Figure 6.8 (top of page): conceptual diagrams comparing an exaggerated and simplified current condition at Locks (left) with proposed condition (right).
Figure 6.9 (left): Obstacles are opportunities.

The Locks create an abrupt transition between water salinity, temperature, and elevation.	- - - - - - - - - ->	The design establishes the longest possible fishway, extending the gradient between water salinity, temperature, and evelvation.
There is a severe lack of habitat for most species at the Locks and throughout the LWSC.	- - - - - - - - - ->	The design offers habitat without dictating where other species should dwell.
People who visit the Locks are eager to learn, yet the facilites are lacking.	- - - - - - - - - ->	The design provides opportunities for learning.



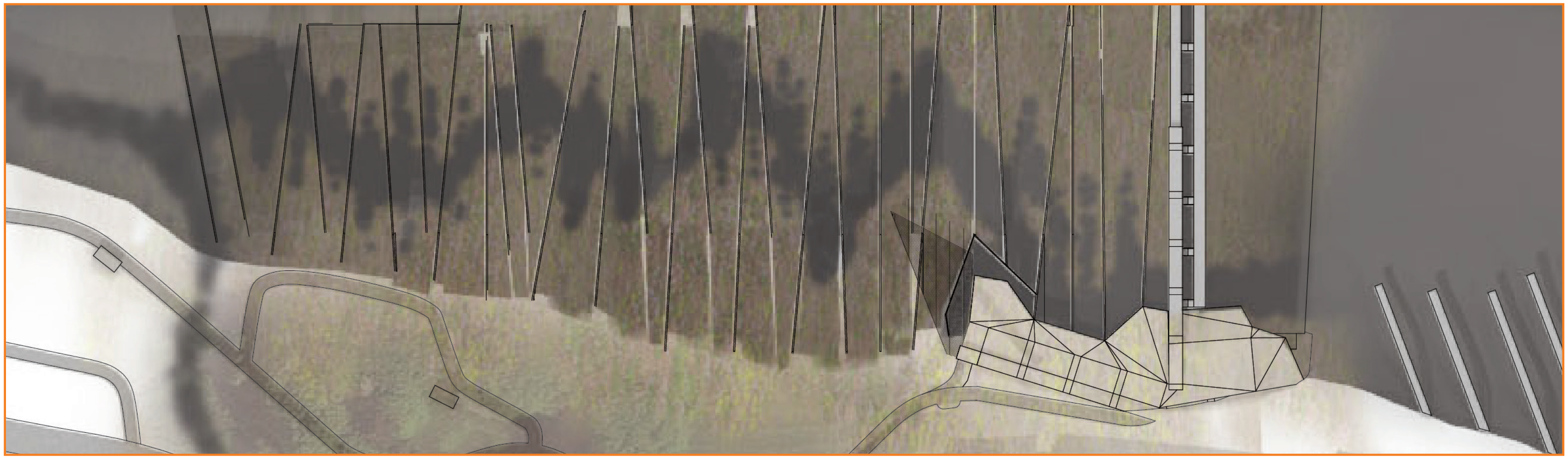
original fish ladder
estimated 80 ft



1970s rehabilitation
estimated 320 ft

Figure 6.10 (top left): original fish ladder built in 1917.
Source: Historical drawing courtesy of U.S. Army Corps of Engineers.
Figure 6.11 (top right): fish ladder rehabilitation, completed in 1976.
Source: Historical drawing courtesy of U.S. Army Corps of Engineers.
Figure 6.12 (below): proposed fishway.

The figures on this page depict the evolution of the Ballard Locks fishway as an increasing gradient.



new fishway proposal
about 900 ft

Phasing Approach

Designers design for an uncertain future. The response to this unknown is often rigidity. The Locks exemplifies this response, having remained largely unchanged throughout the past century. The proposed redesign of the fishway instead attempts to respond with resilience and adaptability through a phasing approach that considers the design as a gradient between water salinity, temperature, and elevation. This gradient also spans centuries before and after present day. In this way, the fundamental design challenge—that the Locks are a wall preventing the mixing of unique water conditions (See Fig. 6.8)—becomes an opportunity. Two additional key design opportunities were identified: (a) there is a severe lack of habitat at the Locks and (b) despite an engaged public, opportunities for learning are limited (See Fig. 6.9). The resulting phasing approach, described below, not only proposes a change in structure, but also a change in operation.

Phase One

The first step of the phasing plan will be to pour a construction crane foundation and erect a construction crane just west of the spillway dam on the canal's south bank. This crane will remain a fixture at the site for decades as the fishway evolves. The crane's first job will be to *decompose* the concrete bulkhead and adjoining concrete pathway along the Commodore Park shoreline. The crane will then haul it into the bay, beginning to reintroduce shallow water habitat. An important design strategy will be to use available materials. Accordingly, recycled concrete from demolition associated with Seattle's current building boom will provide the estimated three million cubic feet of fill that will be required for the new fishway slope. This repurposed concrete will be delivered to the site by truck in stages. For this reason, permanent truck access will be important. Since an additional strategy will be to avoid impervious surfaces on site, this access route will be surfaced with gravel.

After the concrete is crushed into a course aggregate, it will also be transferred into the bay, starting directly under the spillway dam and moving downstream. Eventually a very gradual slope and additional shallows will begin to form. The process of erosion will be reestablished once the bulkhead along Commodore Park has been removed, supporting the formation of beaches downstream. The size of aggregate will vary. Some of the concrete will be crushed to the size of gravel

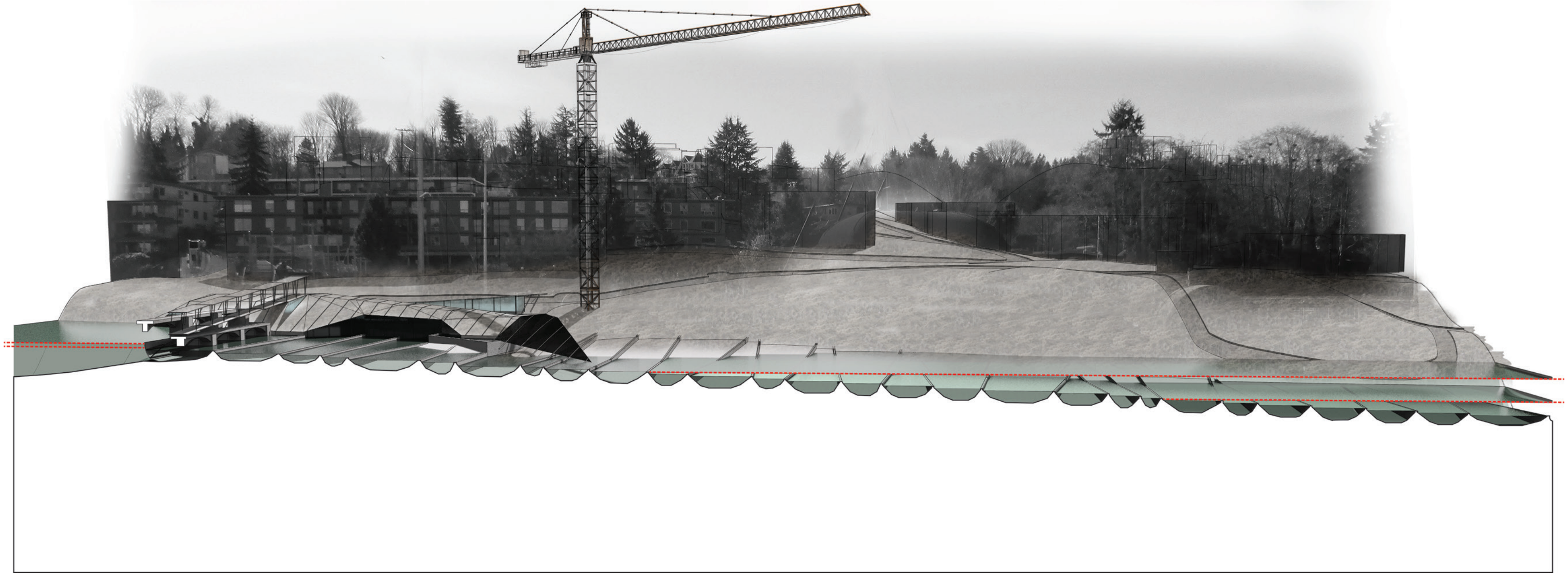


Figure 6.13: longitudinal section-perspective depicting new fishway.

to increase dissolved oxygen. Larger material will reside longer, playing a role in the changing morphology of the new fishway. Both small and large aggregate will be distributed in a pattern that will establish a variety of depths and velocities, including runs/glides, pools, and riffles,[1] with the intent that different depth and velocity combinations will form different habitats. The shallower bay will not only provide a safer journey for adult salmon on their way upstream to spawn, but also vital intertidal habitat for the development of smolts.

Phase Two

The future fishway will slowly evolve as the crane moves material into the bay between the Commodore Park shoreline and the small lock, reaching about 900 feet downstream from the spillway dam, providing additional estuarine habitat for developing juvenile salmon and a more gradual upstream slope for adults. Large weirs spanning the beach at Commodore Park to the outer wall of the small lock will be positioned in a cascading sequence below the spillway dam (See Figs. 6.10 – 6.12). These will be formed using large pieces of anchored concrete and large woody debris (LWD). The result will be approximately 29 large, irregular, gradually sloping *steps* (See Fig. 6.13). In addition to conceptually describing this project, on a literal level logs will be an important design element, providing the same benefits they provide to rivers, such as supplying nutrients to, slowing, and directing water by forming jams. The action of water flowing over the weirs will also increase dissolved oxygen, which is lacking in the Ship Canal due to high temperatures.[2]

During this phase Locks operators will continue to operate the Tainter gates. However, what was once an abrupt drop in water (the spillway) will become a gradual slope that rises to meet the spillway just below its lip. This dramatically decreased slope will slow the freshwater pouring through the Tainter gates. Additionally, the amount of water coming through the Tainter gates could be decreased by piping an amount to Shilshole Bay. To further avoid erosion, the small lock will be used for water discharge, remaining open when large amounts of water need to be released from the lakes. During these events, small vessels will go through the large lock in groups in lieu of using the small lock. The addition of riparian vegetation in the new fishway will also decrease erosion. When water needs to be conserved in the lakes, just one Tainter gate will be opened, only inches, maintaining the

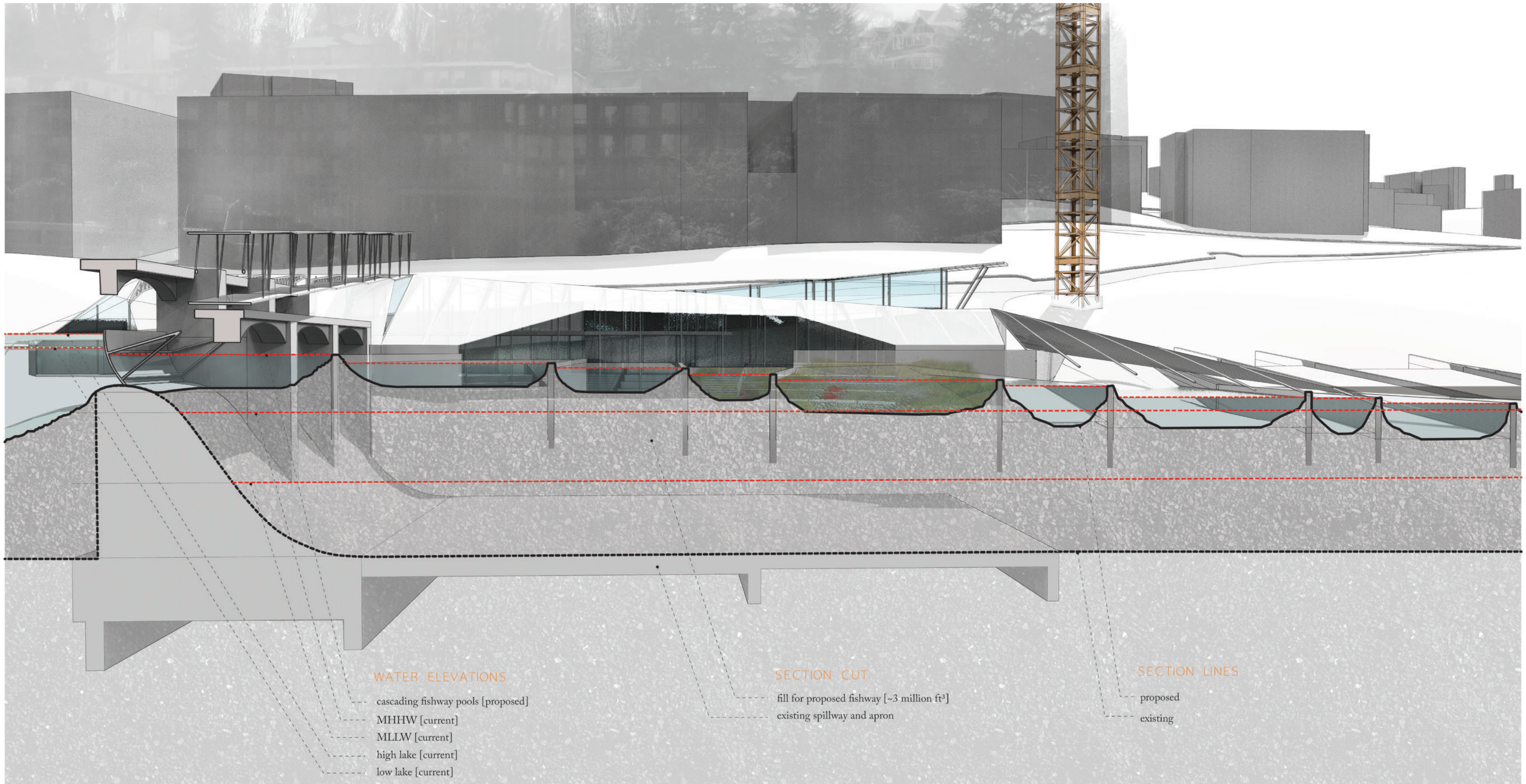


Figure 6.14: section-perspective depicting new fill over spillway.

lake water level within its two-foot range but also allowing the passage of juvenile salmon downstream. During events of minimal water discharge, fresh water will collect in pools between weirs. The lower weirs will contain residual brackish water from previous high tides. The fishway will gradually slope downstream but will also have a cross slope that snakes back and forth through the channel. The water will generally follow this impression, forming an even longer gradient in water temperature, salinity, and elevation.

Though water coming through the gates will have been significantly slowed, it will likely not be possible for adult salmon to pass under the Tainter gates upstream. However, when the gates are shut, the highest weir will establish a pool of water just below the elevation of the lakes (See Fig. 6.14), making it relatively easy for adult salmon to leap over the top of the Tainter gates. Accordingly, at least one gate will always be closed to facilitate the passage of adult salmon upstream. A small earthen cofferdam will protect the entrance to the old fish ladder, so it remains submerged and is not covered with fill, until the new fishway is in place. However, adult salmon may begin using the new fishway even before the old one is demolished. Likewise, juvenile salmon (who already often travel through the spillway dam in the opposite direction) will begin to use the new fishway. Because of this, the smolt flumes currently installed in the last two Tainter gates will be removed.

After this, riparian vegetation will be planted along the Commodore Park shoreline, along the small lock's outer south wall, and in the shallower areas of the fishway to increase habitat for a variety of non-human species. Some vegetation will have likely already *volunteered* at this point and will not be removed; a fundamental goal is to allow the system to regulate itself. The lawn above the fishway will be replaced with native plants such as salal, Oregon grape, western redcedar, and Douglas fir. Through the process of succession, a variety of habitat levels will emerge. This area and Commodore Park will not be actively maintained and will be left unprogrammed save for the delineation of meandering trails. This will encourage space for non-anthropocentric habitat. An additional key strategy will be to leave space for other species while refraining from dictating which species will use it. While it is distressing to hear stories of eagles displacing herons and sea lions devastating salmon runs, the best thing the design can do in these cases is provide quality habitat and

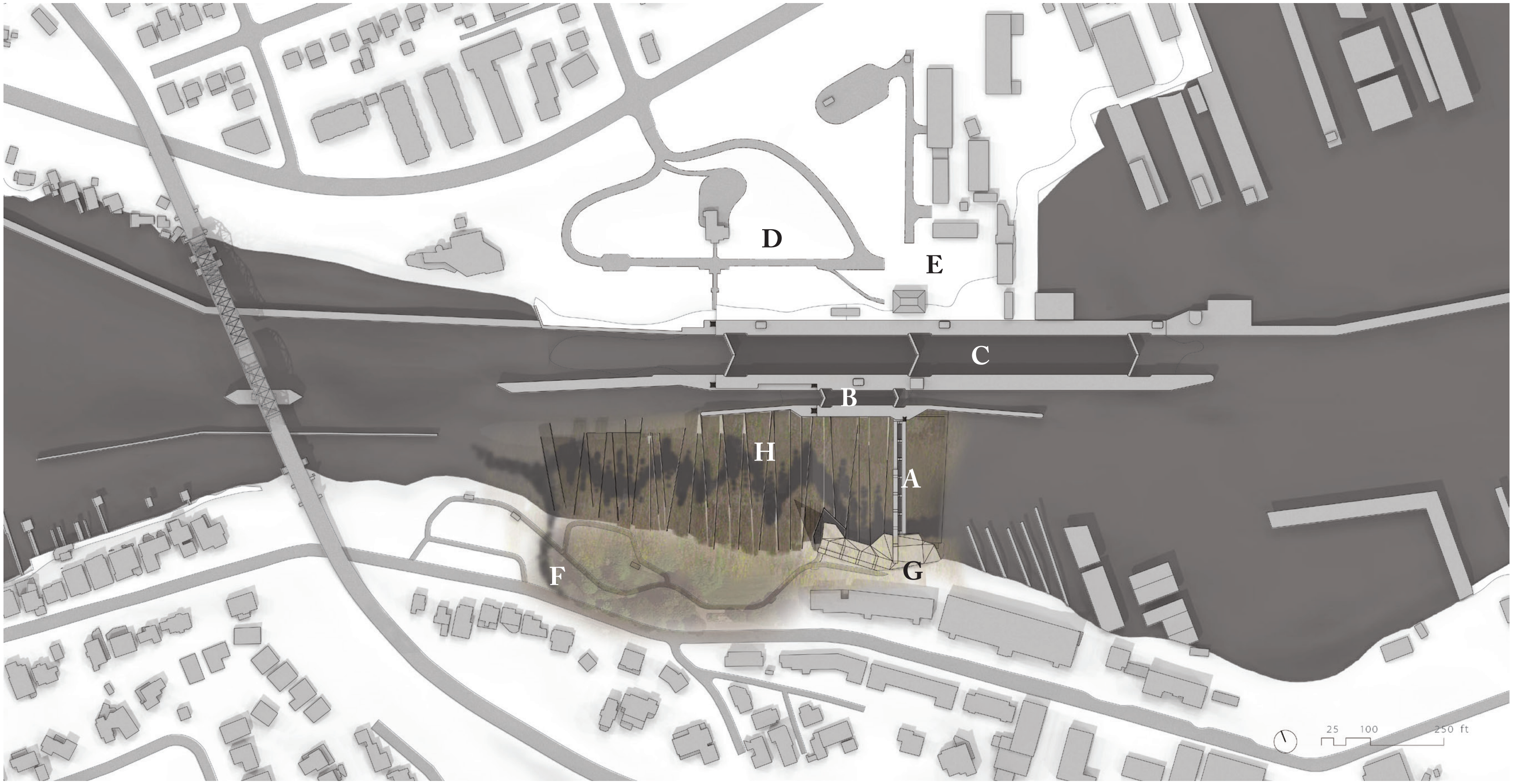


Figure 6.15: plan of proposed design.

EXISTING:
A. spillway dam
B. small lock
C. large lock
D. Carl S. English, Jr., Botanical Gardens
E. historical buildings

PROPOSED:
F. proposed Wolfe Creek daylighting
G. proposed learning center
H. proposed fishway

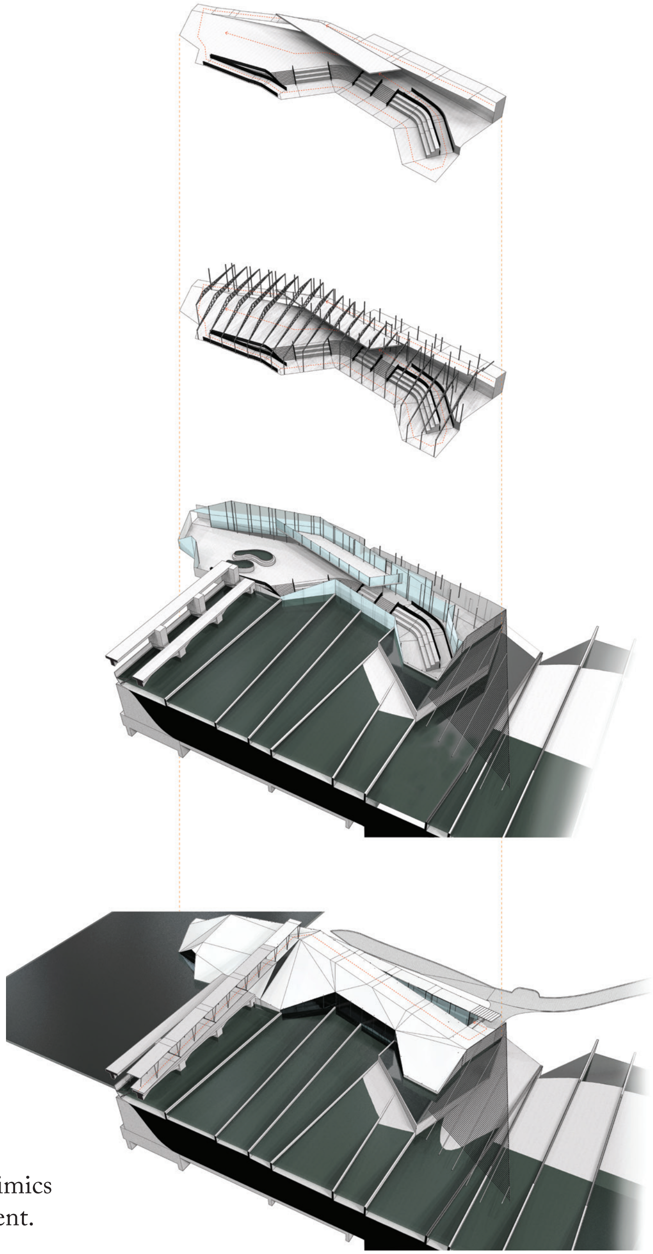


Figure 6.16: building circulation mimics fishway in an indirect sloping gradient.

space. These are interactions constituting the web of life. Rather than intervening, or trying to outsmart the eagles and sea lions, the design will provide valuable habitat. For example, the new fishway will make it much more difficult for sea lions to catch adult salmon on their way to spawn.

Next, Wolfe Creek will be daylit. A meandering, shallow channel will be excavated from the culvert north of Kiwanis Ravine through Commodore Park to the foot of the new fishway, increasing freshwater input. This channel will avoid the red alders supporting the heron rookery and other existing trees (See Fig. 6.15). All construction at Commodore Park will be scheduled outside of heron nesting season. Likewise, all construction activities will comply with the work window to protect aquatic species.

Phase Three

Once the new fishway is constructed, attention will shift to the demolition of the old fishway and viewing room. The crane will be used for this task as well. Concrete will be recycled into the bay, this time on the upstream side of the spillway dam. The spillway will now be mostly buried. Like a nurse log, it will serve as a datum of change while also influencing that change.

An important goal of this proposal is to foster ecoliteracy. Thus, engaging humans with the new fishway will be essential. A new building will be constructed using approximately the same footprint as the previous one. This building will also be embedded in the landscape, its roof a series of accessible and planted ramps connecting Commodore Park with the spillway dam walkway. Interior circulation will also consists of ramps (See Fig. 6.16). These interior and exterior ramps will be reminiscent of the fishway in their indirect, gradual slopes. The planted roof will provide additional habitat, rising out of the hill and blurring the borders between architecture and landscape. The north-facing slopes extending into the fishway will be covered with reed gabions, providing additional habitat for aquatic species. The new facility will be much brighter than its predecessor (See Fig. 6.17), opened up with large windows including two large U-shaped subaquatic window walls, one below and one above the spillway dam.

As mentioned previously, the Locks complex is already one of Seattle’s most popular attractions, with program

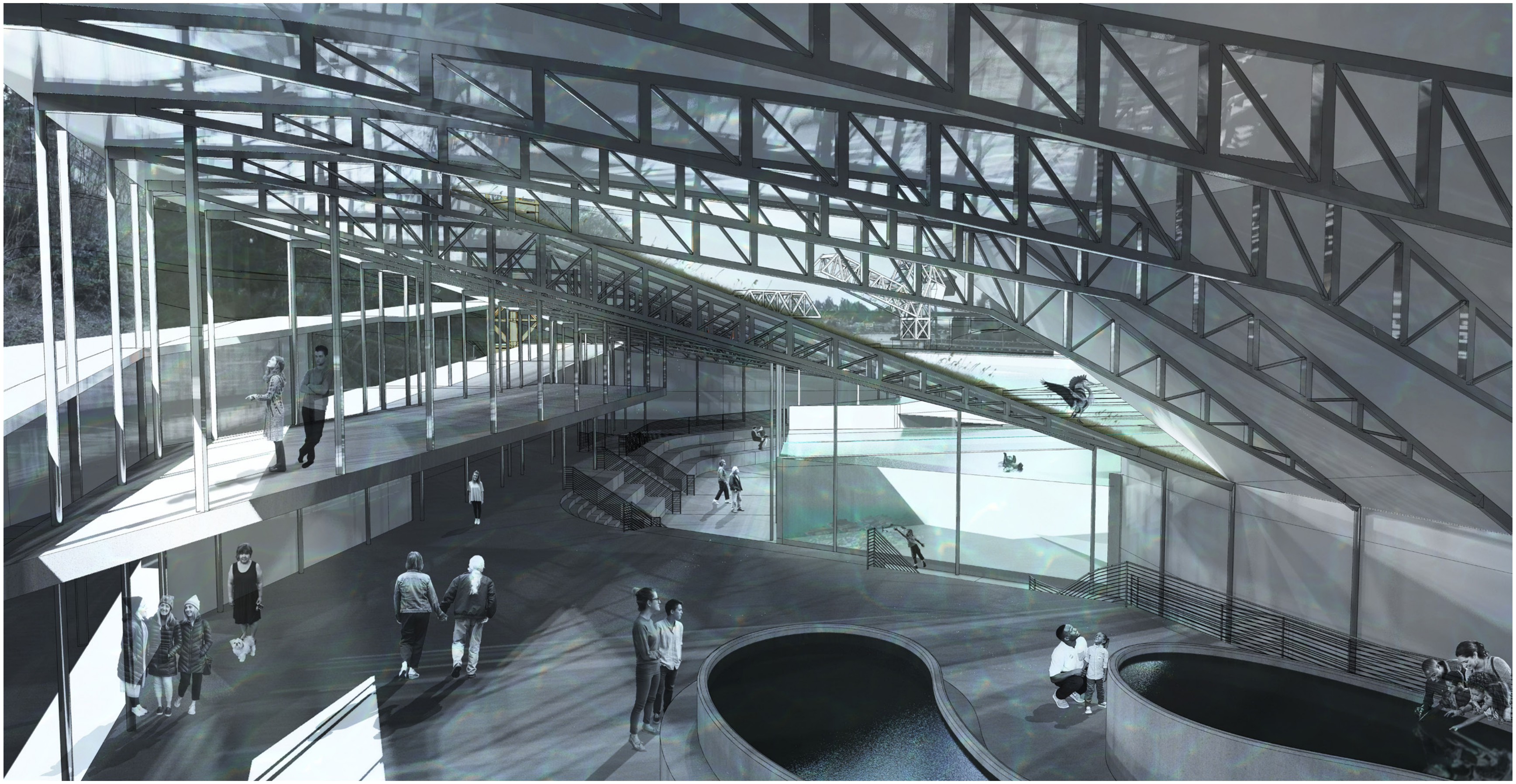
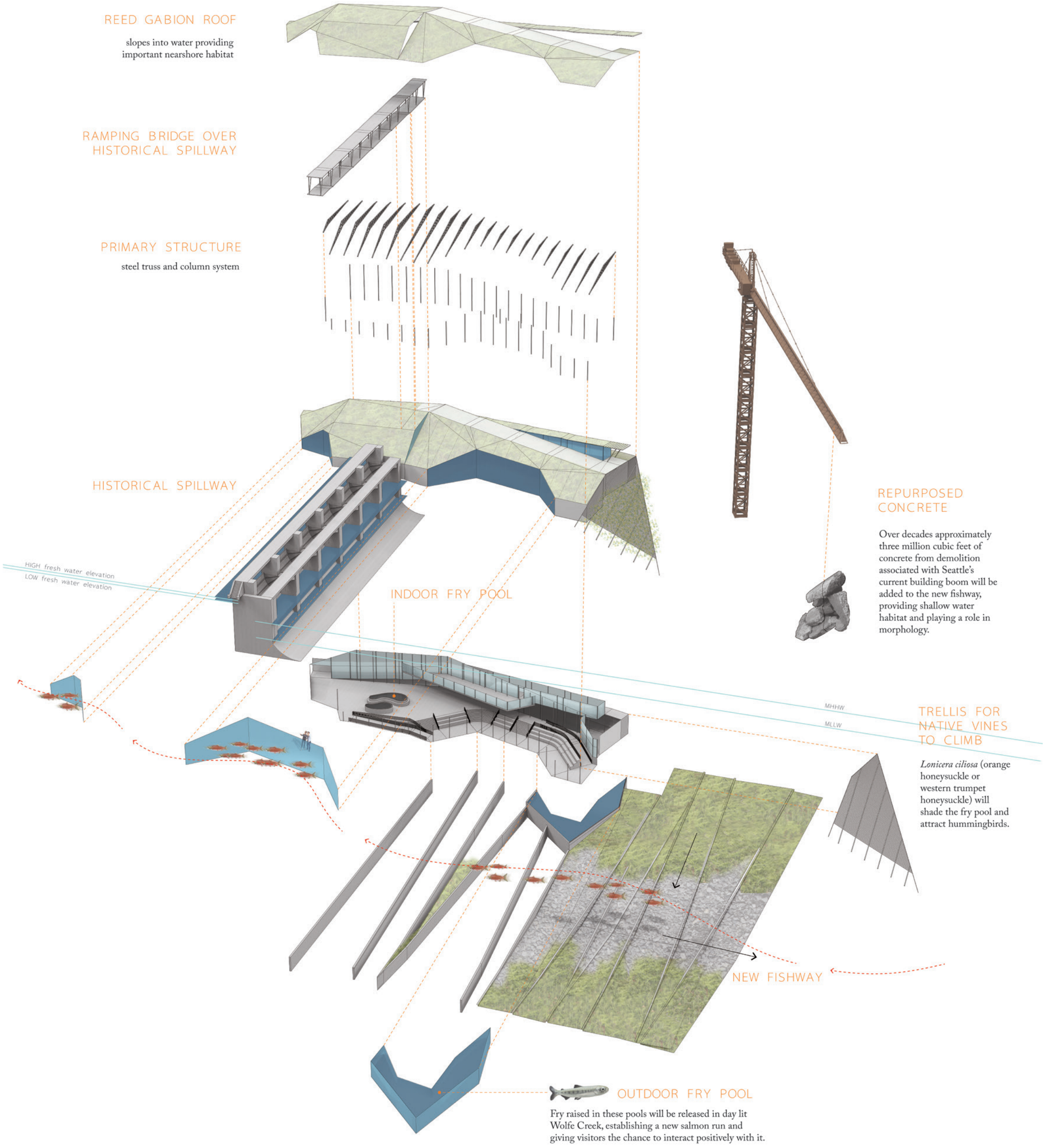


Figure 6.17: interior rendering facing fishway.



slopes into water providing important nearshore habitat

steel truss and column system

Over decades approximately three million cubic feet of concrete from demolition associated with Seattle's current building boom will be added to the new fishway, providing shallow water habitat and playing a role in morphology.

Lonicera ciliosa (orange honeysuckle or western trumpet honeysuckle) will shade the fry pool and attract hummingbirds.

Fry raised in these pools will be released in day lit Wolfe Creek, establishing a new salmon run and giving visitors the chance to interact positively with it.

Figure 6.18: layered design strategy.

elements including guided tours and summer concerts. It will be important for the design to take advantage of this engaged human public. In this spirit, it will build off and amplify these existing programmatic elements. People who currently occupy the site often engage in informal learning and teaching. This is a missed opportunity, as current educational facilities on site are lacking. The new design offers more opportunities for play and learning with programmatic elements that foster hands-on interaction with the web of life. These features include indoor and outdoor rearing pools for raising salmon fry to be released in newly daylit Wolfe Creek, a swimming beach at Commodore Park, classrooms, additional walking trails, and a subaquatic auditorium. These programmatic elements offer opportunities for interaction with free, wild non-human species—a departure from the interactions offered at facilities such as zoos and aquariums (See Fig. 6.18).

A large trellis structure will descend from the hillside above the fishway, partially shading the outdoor fry pool (See Fig. 6.19). Native vines such as western trumpet honeysuckle will be planted so that they eventually cover the trellis, shading the young salmon before they are released into Wolfe Creek and providing habitat for birds (See Fig. 6.20).

Phase Four

This final phase offers a window two centuries into the future. At this point, sea level will have risen an estimated 12 feet, and breached the miter gates, which will be removed and dropped into the deeper parts of the bay to prove habitat opportunities. The steel Tainter gates will also have been removed and cast into the water upstream of the spillway dam, which will have eroded considerably. The whole canal, even Lake Washington, will be tidal. However, the lakes’ elevation will not have significantly increased or decreased from its previous level: MHHW will be just above its previous range, MLLW just below. Boats will still navigate Salmon Bay to access the lakes, even at low tide, due to the deeper waters of the canal route and lock pits coupled with higher tides. Saltwater intrusion will have occurred, but with it a self-sufficient estuary with marshes and tide flats, varied habitat, and biodiversity. The historical buildings on the canal’s north bank will remain, as will the subaquatic structure adjacent to the fishway. The remaining concrete remnants of the Locks, which will be partially submerged, will slowly be demolished in place and added to the fishway which will be deeper under

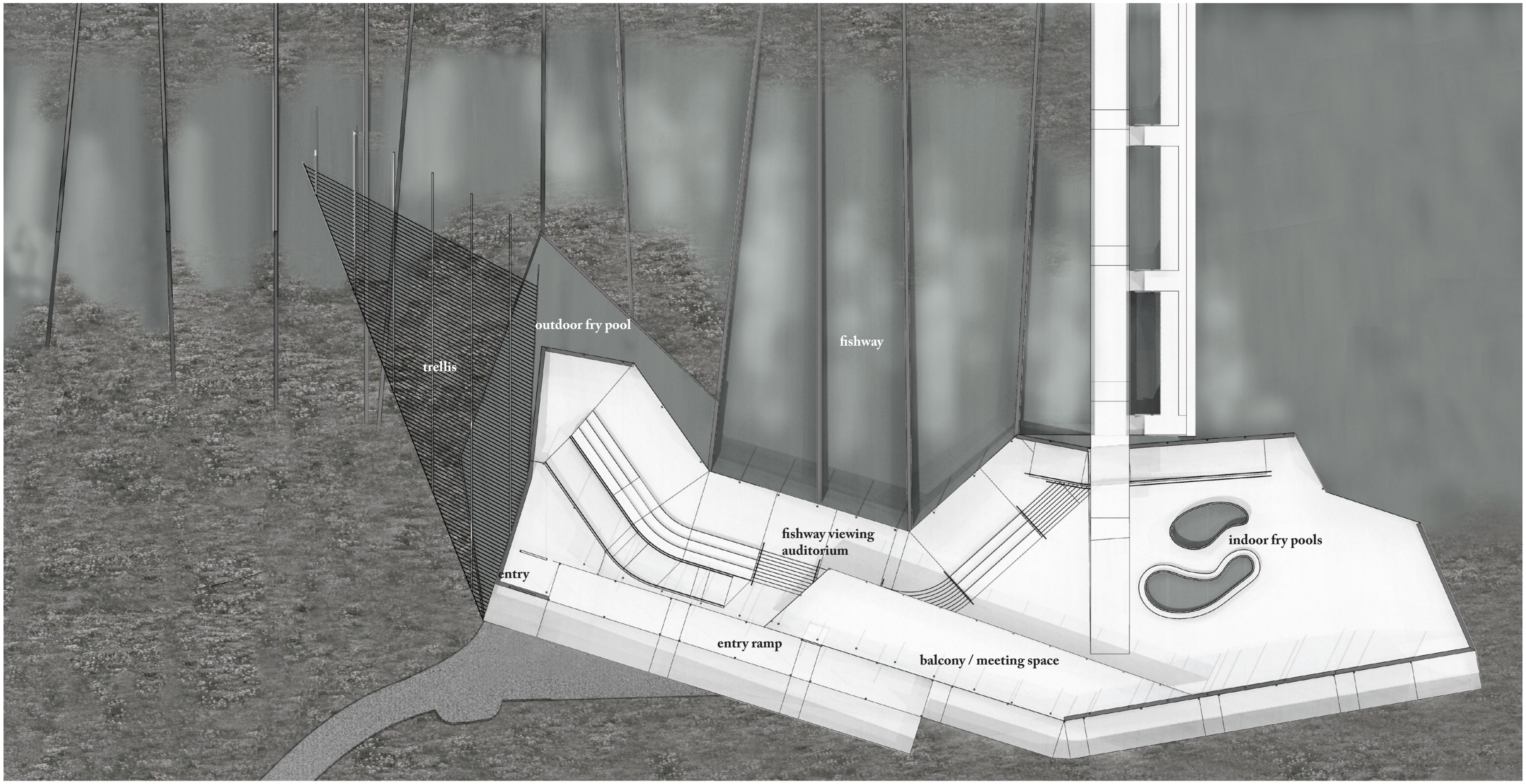
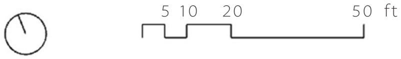


Figure 6.19 (above): floor plan. **Figure 6.20 (following spread):** exterior perspective from Commodore Park facing toward Locks. Phase Three of proposed *decomposition* of Locks.



water than it was when initially constructed. The fishway, now submerged at high tide, will no longer be necessary for adult salmon, but will continue to provide habitat for smolts. Over the centuries, Commodore Park will have developed into a climax forest.

Life at the Locks: A Depiction of Phase Three

It is Valentine's Day and great blue herons are returning to their rookery to court and find mates. On wide wings, lanky legs trailing behind, they fly home to an extensive network of nests that crowd the branches of deciduous red alders throughout Commodore Park. Later, the males will fetch sticks for their partners who will add them to existing nests. The "stick transfer display," often accompanied by "bill clappering,"[3] is one of many elaborate pair-bonding[4] behaviors the herons will carry out as couples. Together these giant birds form the largest great blue heron colony in Seattle. They will stay into the summer to lay and incubate eggs and to raise their young. This site was not selected happenstance; the fish that pass through the Locks provide food for these herons[5] whose bodies reflect their aptitude for hunting aquatic creatures: long legs for wading in deep water,[6] a motionless stance, elongated necks and sharp bills for snapping up prey and swallowing it whole.

The herons are not the only creatures drawn by the fish. "Don't you think they look like pterodactyls?" a child sticks out her chin, peering at her first-grader pal from under a yellow hood. Her friend agrees as they plod along the gravel shore of the fishway with the rest of their afterschool group in a glossy collection of raincoats and rubber boots. This cohort has been diligently monitoring Chinook fry in the rearing pools at the Locks until last month when they hiked through the woods up to Kiwanis Ravine to release the fish in cupfuls into Wolfe Creek. The fish had seemed to disappear when they slid under the water, and the girls now scan the shallows with hopes that the tiny salmon have travelled down to the estuary. They learned that in several years these baby Chinook might return as adults to spawn, establishing a new population. Up the canal other juvenile Chinook, coho, and sockeye salmon and steelhead trout are departing their natal Cedar and Sammamish River tributaries. Eventually they will reach the fishway at the Locks where many will reside for months as their bodies adapt to saltwater.

Notes

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[1] Tim Essington (professor, University of Washington School of Aquatic and Fishery Sciences) in discussion with the author, March 16, 2016.

[2] Thomas Quinn (professor, University of Washington School of Aquatic and Fishery Sciences) in discussion with the author, January 19, 2016.

[3] Laura Erickson and Marie Read, *Into the Nest: Intimate Views of the Courting, Parenting, and Family Lives of Familiar Birds* (Pownal: Storey Publishing, 2015), 36.

[4] “Great Blue Heron,” *The Cornell Lab of Ornithology*, All About Birds, https://www.allaboutbirds.org/guide/Great_Blue_Heron/lifehistory.

[5] “Heron Facts,” *Heron Habitat Helpers*, http://www.heronhelpers.org/heron-facts/.

[6] Ibid.

07

CONCLUSION

Decomposing Anthropocentric Landscapes

At a distant scale, this thesis has been driven by an appreciation *for* human life, and *through* human life for the ever-reacting web of species which unfurls at endless spatial and temporal scales, including and in turn defining humanity. This appreciation translates to concern, because Earth is undergoing massive biodiversity loss due to the actions of humans. The stance that biodiversity conservation should be at the heart of every architectural intervention is a hopeful response to this concern, and is one of the fundamental reasons I am pursing the Master of Architecture - Master of Landscape Architecture concurrent degree, of which this thesis is the final step. The gradient between saltwater and freshwater that this project ultimately proposes at the Locks also provides an apt metaphor for the overlap of these two disciplines. In both cases, overlap yields increased biodiversity.

The Ballard Locks at the mouth of the human-excavated Ship Canal is emblematic of an anthropocentric landscape, or what some might call a novel ecosystem,[1] for many reasons, including its century-long hydrologic control of an entire watershed, severe impact on the pattern and success of migration for several populations of Pacific salmon, and resistance of entropy through rigidity rather than resilience. All of these reasons contribute to biodiversity loss. As with all anthropocentric landscapes, actions to force the landscape to perform for humans have ultimately been self-inflicted in that loss of biodiversity negatively impacts the web as a whole, including humans. A redesign of the fishway at the Locks has therefore offered the opportunity to explore the topic of biodiversity conservation within the realm of architecture at an empirical scale.

The essential nature of nurse logs has been a central theme of this project. The thesis itself has been presented as a nurse log, each key chapter representing a stage of a nurse log's decomposition into the landscape. The final stage of this *decomposition* has been a phasing strategy to support biodiversity at the Locks, aggregating the longest possible gradient between water salinity, temperature, and elevation. This resolution, though specific to its context, offers several lessons on the matter of approaching anthropocentric landscapes and watersheds in general.

The proposed redesign of the fishway at the Locks illustrates that by *decomposing* anthropocentric landscapes, they, along with anthropogenic environmental forces—in this case future sea level rise—can become the very substance that spawns biodiversity. This accomplishes several aims. At a basic level, it finds optimism in what is commonly perceived as a threat. On a conceptual level, it grounds the design in both the site's history as well as its future. In this way, this thesis celebrates a paradigm shift in architecture and landscape architecture from design responses that *impose* to design responses that *decompose*. In the case of the Ballard Locks, this approach resulted in a gradient of water conditions. The design ultimately proposed to achieve this gradient is an initial attempt rather than a complete physical realization of the paradigm explored in this thesis. The glass components of the design especially emphasize that the *building* and *landscape* are not as unified as they could be.

Applying this approach to other anthropocentric landscapes is likely to engender diverse results, because it is fundamentally about a site's character. The proposed fishway at the Locks could be considered an example of "reconciliation ecology,"[2] a term mentioned in Chapter Three, because it supports biodiversity in the urban realm. While this is a term that came out of the sciences, the *nurse log* approach makes it more readily accessible for design practitioners.

This project has illustrated the benefits of consulting scientists throughout a design project. The heart of the fishway redesign proposal was informed by conversations with scientists. These conversations were complimented by processes such as consulting historical documents and individuals who are intimately familiar with the Locks, building detailed models of the site and surrounding context, and researching the watershed. These methods together constructed a deeper understanding of the site that was essential to designing a scheme that prioritizes biodiversity. Throughout this process, I returned to the gradient concept again and again, sometimes from a *science* perspective and sometimes from a *design* perspective. Perhaps it could be described as an example of Wilson's "consilience," mentioned in Chapter Two, the term for the delightful circumstance when perspectives from different fields meet at a mutual conclusion that is sounder than either of the two conclusions alone.[3] It could even be said that the project offers a method for pursing reconciliation ecology by way of consilience—fitting, since both concepts have been foundational to my time at the College of Built Environments.

In the end, this is a conceptual project that emerged out of *blue-sky thinking*, and its success—whether it will, in fact, support biodiversity—can only be surmised in a theoretical sense. In practice, an important component of designing for biodiversity would entail effectiveness monitoring so that the eventual impacts of the design on biodiversity would be well understood. This means scientists should have a continued presence in *decomposing* a design after the plans are finalized and that standard metrics should be formulated for assessing a design's impact on biodiversity. Metrics have been an important part of the *green* architecture movement, so the profession is poised to incorporate a standard set of biodiversity-gauging measures. Biodiversity is a goal that is well-suited for measuring, which sets it apart from related goals such as *sustainability* and *greenspace*.

The pairing of scales, or paces, has been an additional theme explored through this project. Scales are exaggerated at the Locks, where proposed design actions immediately scale up to the high reaches of the Cascades and the watershed as a whole and scale down to the micro-ecologies of Salmon Bay. Not only spatial scales, but temporal scales have been compared: the gradual progression of the tides through daily fluctuations compared to larger-scale sea level rise; a glacier carving out a landscape compared to the more immediate measure of the excavation of a canal by humans. The concentrated focus of a science essay has been compared to broader connections made by an architect or landscape architect. These scales move forward but can be traced backward, and exploring them serves to further contextualize the design so that it at once ripples in and out, up and down, in time and space, disinclined to exist within any imposed borders. Ultimately, this thesis has been about conceptually decomposing one landscape to aggregate with other landscapes a hopeful, biodiverse future. In that spirit, to conclude I offer the following account to focus, personalize, and literally bring home the concept explored through this project and throughout my years at the College of Built Environments.

Figure 7.1 (left), 7.2 (right): On August 15, 2016, I returned to the woods where I grew up to take photos of nurse logs and nurse stumps. Many of those photos are included in Chapter One, juxtaposed with photos of the Ballard Locks to introduce the design concept (Figs. 1.1 through 1.14). I am concluding this project with two additional photographs I took on that day, both of "Fort Trillium" which has changed since I was a child.

Nurse Logs

Days before submitting this project I returned to the woods where I grew up to photograph familiar nurse logs and stumps. As children, my twin sister and I spent more time within the green belt that adjoined our home than we did within the home itself. The woods were our refuge. Consequently, I am deeply familiar with the rhythms of the forest: the evergreen conifers, nettles and ferns; the clearings, the study of decay; the dynamic creek bed, the gentle power of water that shaped it; the routes between things, stamped down by our feet during daylight, by paw and hoof by night; the eruption of birdsong at daybreak; the trillium patch that springs bright white from nowhere, blushes purple, disappears altogether; the persistent Douglas squirrel; charred wood, time-softened notches where loggers wedged springboards, stood, and cut into bark.

On the morning I returned to the woods I immediately noticed changes: new decay, new growth. I was instantly more comfortable, more me. A tree frog began to croak as I pushed through the sword ferns. Summer sun reached through the trunks, placing shifting orange shapes on moss. The branches rustled: a bird, aware of my presence. I reached Fort Trillium quickly, a rot-hollowed nurse stump, the centerpiece to our childhood adventures. It supports a large, arcing maple whose branches grow straight up like trunks themselves. I noticed a yellow rope stiffened on the forest floor, once a swing we had tied to fly out over the creek. Half of the fort is now lying down. One day this stump will disappear into the forest detritus completely. However, the maple’s bending trunk will retain its profile after the stump has gone.

Notes

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[1] Richard J. Hobbs, Eric S. Higgs, and Carol M. Hall, *Novel Ecosystems: Intervening in the New Ecological World Order* (Hoboken: John Wiley & Sons, 2013), 4.

[2] Michael L. Rosenzweig, “Reconciliation Ecology and the Future of Species Diversity,” *Oryx* 37, no. 2 (2003): 194, doi: 10.1017/S0030605303000371.

[3] Edward O. Wilson, *Consilience: The Unity of Knowledge*. 1st ed. (New York: Alfred A. Knopf, 1998), 8–9.

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FIGURE CREDITS

FIGURES 1.1 – 1.14: Photographs taken by author.

FIGURE 1.15: Reproduced at the National Archives at Seattle.

"Lake Washington Waterway Concrete Progress Sheet," Tube 4, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

FIGURE 2.1: Figure created by author using the following sources:

Graph data and quote: Ceballos, Gerardo, Paul R. Ehrlich, Anthony D. Barnosky, Andrés García, Robert M. Pringle, and Todd M. Palmer. "Accelerated Modern Human–Induced Species Losses: Entering the Sixth Mass Extinction." *Science Advances* 1, no. 5 (2015): 1–5. doi: 10.1126/sciadv.1400253.

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FIGURE 2.2: Figure created by author using data from the following source:

Poiani, Karen A., Brian D. Richter, Mark G. Anderson, and Holly E. Richter. "Biodiversity Conservation at Multiple Scales: Functional Sites, Landscapes, and Networks." *BioScience* 50, no. 2 (2000) 133–46. doi: 10.1641/0006-3568(2000)050[0133:bcamsf]2.3.co;2.

FIGURE 2.3: Figure created by author using data from the following source:

"Biodiversity Hotspot Maps." Critical Ecosystem Partnership Fund. http://www.cepf.net/resources/maps/Pages/default.aspx.

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FIGURE 4.3: Collage created by author using reproduced photographs/documents from the following sources:
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Circular engineering drawing on graph paper, bottom center of collage: Book “1” (engineering notes, computations; 1913), Box 6, Lake Washington Ship Canal – Field Books, 1890-1969 (SEA-22), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

Sheet titled “Volume of Discharge in Second Feet Upper Black River,” bottom center of collage: “Volume of Discharge in Second Feet Upper Black River,” Box 45, Lake Washington Ship Canal – Engineering/Construction/Survey Records, 1890-1970 (SEA-27), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

Open book showing drawings and numbers on spread of graph paper, upper left of collage: Book “11” (engineering drawings, computations; 1913), Box 6, Lake Washington Ship Canal – Field Books, 1890-1969 (SEA-22), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

Historical photographs from UW Special Collections’ Digital Collections:

Aerial photograph of Locks, upper right of collage: *Lake Washington Ship Canal, Hiram M. Chittenden Locks aerial view, 1947*. 1947. Seattle Photograph Collection, University of Washington Libraries, Special Collections Division, Seattle, WA. Accessed April 9, 2016. Digital Collections.

Seated woman and man, center of collage: Denny, Orion O. *Duwamish man and woman known as Old Tom and Madeline, Portage Bay, Seattle, Washington, ca. 1904*. Ca. 1904. American Indians of the Pacific Northwest Images, University of Washington Libraries, Special Collections Division, Seattle, WA. Accessed April 9, 2016. Digital Collections.

Portrait of Hiram M. Chittenden, center left of collage: *Hiram M. Chittenden*. Portraits Collection, University of Washington Libraries, Special Collections Division, Seattle, WA. Accessed April 9, 2016. Digital Collections.

Canoe, toward center of collage: *Chudups John and others in a canoe on Lake Union, Seattle, ca. 1885*. Ca. 1885. American Indians of the Pacific Northwest Images, Museum of History and Industry, Seattle, WA. Accessed April 9, 2016. Digital Collections.

A group standing in front of building in snow, center left of collage: *Lake Washington Ship Canal, Hiram M. Chittenden Locks, February 2, 1916*. 1916. Seattle Photograph Collection, University of Washington Libraries, Special Collections Division, Seattle, WA. Accessed April 9, 2016. Digital Collections.

Boat headed toward Salmon Bay Bridge, center right of collage: Curtis, Asahel. *Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, June 16, 1921*. 1921. Asahel Curtis Collection, University of Washington Libraries, Special Collections Division, Seattle, WA. Accessed April 21, 2016. Digital Collections.

Salmon Bay Charlie’s house, center far right of collage: Webster & Stevens. *Salmon Bay Charlie's house at Shilshole with canoe anchored offshore, ca. 1905*. Ca. 1905. American Indians of the Pacific Northwest Images, Museum of History and Industry, Seattle, WA. Accessed April 9, 2016. Digital Collections.

The Locks under construction, bottom left of collage: Curtis, Asahel. *The Lake Washington Ship Canal locks under construction, Seattle, 1913*. 1913. Asahel Curtis Collection, University of Washington Libraries, Special Collections Division, Seattle, WA. Accessed March 22, 2016. Digital Collections.

UW Libraries Map Collection

Map spanning collage: Symons, Thomas W., and Philip G. Eastwick. *Proposed Route of Canal to Connect Lakes Union and Washington with Puget Sound (1891)*. Map. Washington, DC: United States Army Corps of Engineers, 1891. University of Washington Libraries Manuscripts, Special Collections, University Archives Division.

FIGURE 4.4: Map courtesy of UW Libraries Map Collection.

Symons, Thomas W., and Philip G. Eastwick. *Proposed Route of Canal to Connect Lakes Union and Washington with Puget Sound (1891)*. Map. Washington, DC: United States Army Corps of Engineers, 1891. University of Washington Libraries Manuscripts, Special Collections, University Archives Division.

FIGURE 4.5: Reproduced at the National Archives at Seattle.

"Profile along Projected Line of Canal to Connect Lake Union and Lake Washington with Shilshole Bay Platted from Survey made by P.G. Eastwick. in 1890," Tube 3, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

FIGURE 4.6: Figure created by author using data from the following source:

Kathryn McGillvray, e-mail message to author, March 14, 2016.

FIGURE 4.7: Figure created by author.

FIGURES 4.8, 4.9: Figures created by author using data from the following sources:

King County IT Services, GIS, Visual Communications and Web Section. File Name: 1211_2650_CedarLkWashMap.ai skrau. "Lake Washington/Cedar River Watershed." *Lake Union Laboratory/ LULab*, http://lulab.be.washington.edu/omeka/items/show/1015.

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FIGURE 4.10: Figure created by author using data from the following sources:

Present-day shoreline: City of Seattle GIS Data, February 2012.

Historical shoreline: Symons, Thomas W., and Philip G. Eastwick. *Proposed Route of Canal to Connect Lakes Union and Washington with Puget Sound (1891)*. Map. Washington, DC: United States Army Corps of Engineers, 1891. University of Washington Libraries Manuscripts, Special Collections, University Archives Division.

Historical place names: Thrush, Coll, and Nile Thompson. “An Atlas of Indigenous Seattle.” In *Native Seattle: Histories from the Crossing-Over Place*, by Coll Thrush, 209–55. Weyerhaeuser Environmental Books. Seattle: University of Washington Press, 2007.

FIGURES 4.11, 4.12: Figures created by author.

FIGURE 4.13: Photograph courtesy of U.S. Army Corps of Engineers.

FIGURE 4.14: Figure created by author using data from the following sources:

Historical number of vessels: “Lake Washington Ship Canal Traffic Thru Locks,” Tube 6, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

Recent number of vessels: Kathryn McGillvray, e-mail message to author, March 14, 2016.

FIGURE 4.15: Reproduced at the National Archives at Seattle.

Historical graph showing number of boats that traversed the locks between 1916 and 1928: “Lake Washington Ship Canal Traffic Thru Locks,” Tube 6, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

FIGURE 4.16: Reproduced at the National Archives at Seattle.

“Carl S. English, Jr. Gardens at The Hiram M. Chittenden Locks,” Tube 5, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

FIGURES 4.17 – 4.19: Figures created by author.

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“Lake Washington Waterway Construction Plan for Locks,” Tube 6, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

FIGURE 4.21: Reproduced at the National Archives at Seattle.

"Lake Washington Ship Canal Clearances in Main Lock," Tube 1, Lake Washington Ship Canal – Maps and Drawings, 1895-1984 (SEA-31), Seattle District, Records of the U.S. Army Corps of Engineers, National Archives at Seattle.

FIGURE 4.22: Photographs taken by author.

FIGURE 4.23, 4.24: Figures created by author.

FIGURE 4.25: Figure created by author using data from the following sources:

Current shoreline: City of Seattle GIS Data, February 2012.

Historical shoreline and cutting plane line: Symons, Thomas W., and Philip G. Eastwick. *Proposed Route of Canal to Connect Lakes Union and Washington with Puget Sound (1891)*. Map. Washington, DC: United States Army Corps of Engineers, 1891. University of Washington Libraries Manuscripts, Special Collections, University Archives Division.

FIGURE 4.26: Figure created by author using data from the following source:

Symons, Thomas W., and Philip G. Eastwick. *Proposed Route of Canal to Connect Lakes Union and Washington with Puget Sound (1891)*. Map. Washington, DC: United States Army Corps of Engineers, 1891. University of Washington Libraries Manuscripts, Special Collections, University Archives Division.

FIGURE 4.27: Photograph taken by author.

FIGURE 4.28: Sketch created by author.

FIGURES 5.1 – 5.3: Figures created by author.

FIGURE 5.4 – 5.8: Photographs taken by author.

FIGURES 5.9 – 5.10: Figures created by author.

FIGURES 6.1, 6.2: Figures created by author.

FIGURE 6.3: Figure (and models) created by author.

FIGURE 6.4: Photograph/model by author.

FIGURE 6.5: Figure/digital model created by author.

FIGURES 6.6, 6.7: Models and photographs by author.

FIGURES 6.8, 6.9: Figures created by author.

FIGURE 6.10: Historical drawing courtesy of U.S. Army Corps of Engineers.
“Lake Washington Ship Canal Locks & Grounds”

FIGURE 6.11: Historical drawing courtesy of U.S. Army Corps of Engineers.
“Fish Ladder Rehabilitation Area Plan.” File No. C-2-3-139. R.W. Beck and Associates, Analytical and Consulting Engineers. U.S. Army Corps of Engineers.

FIGURES 6.12 – 6.20: Figures created by author.

FIGURES 7.1, 7.2: Photographs taken by author.

FIGURES A.1 – A.7: Physical models created by author.

APPENDIX

[Additional Photographs of Physical Models]

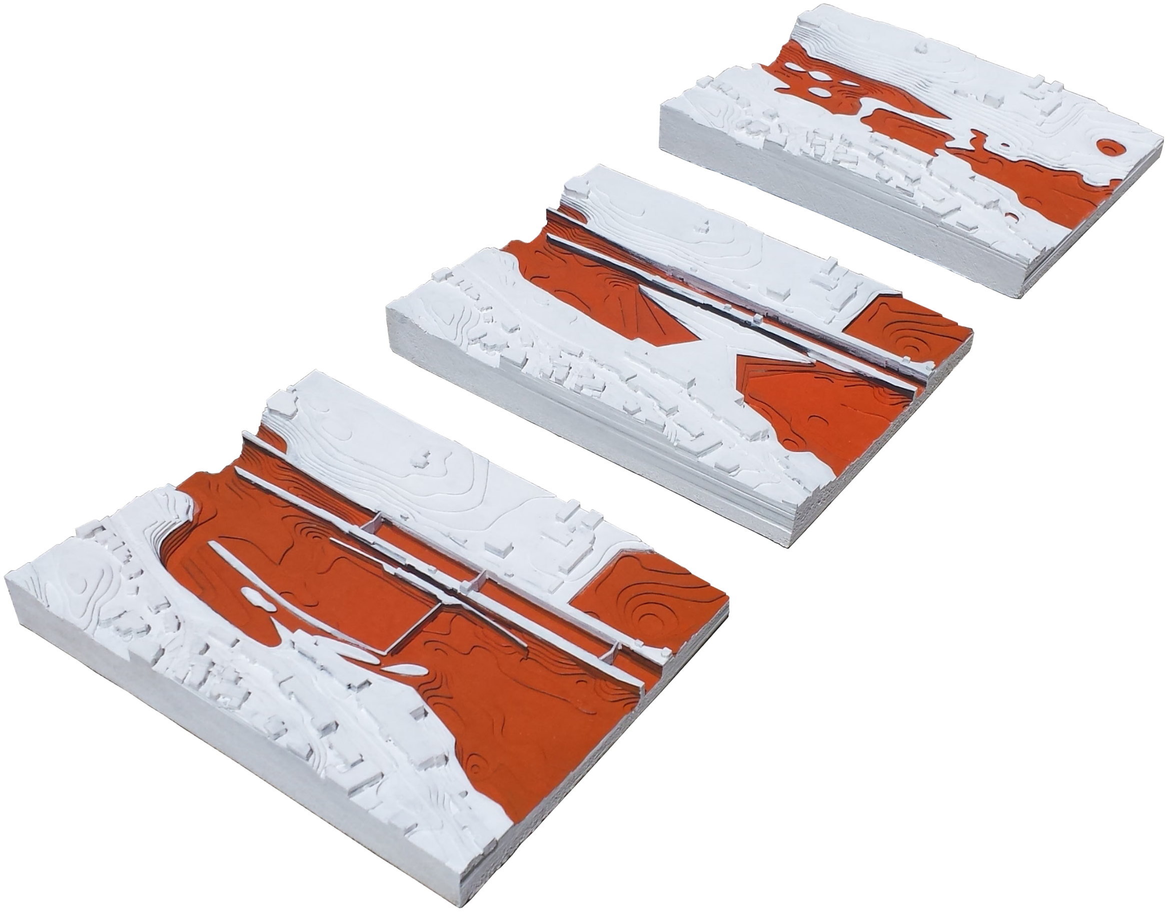


Figure A.1 (left) and A.2 (above right): Three preliminary schematic 9.2 x 7.3” models. Layers of chipboard stacked with tacky glue, painted with acrylic paint.

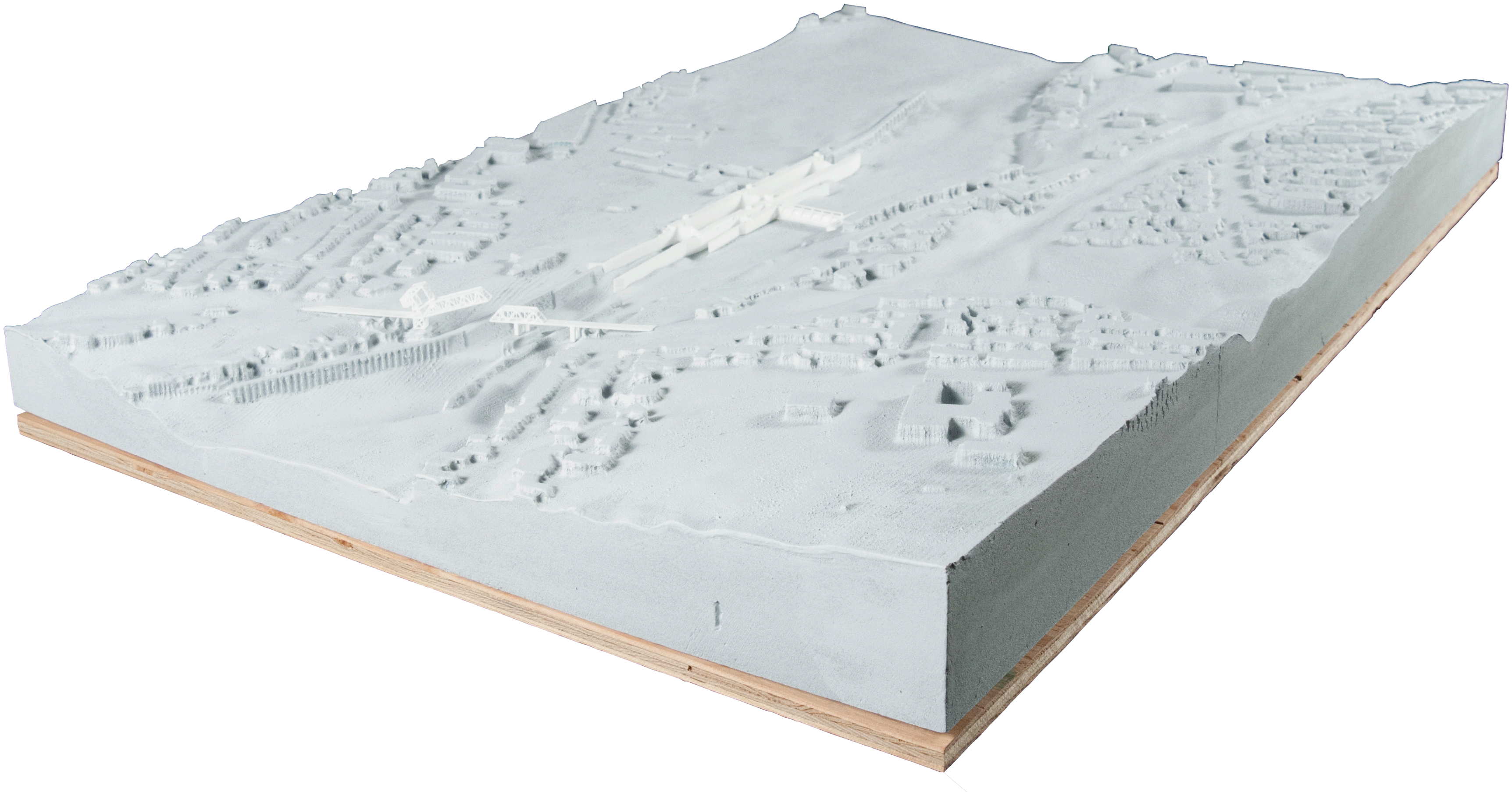
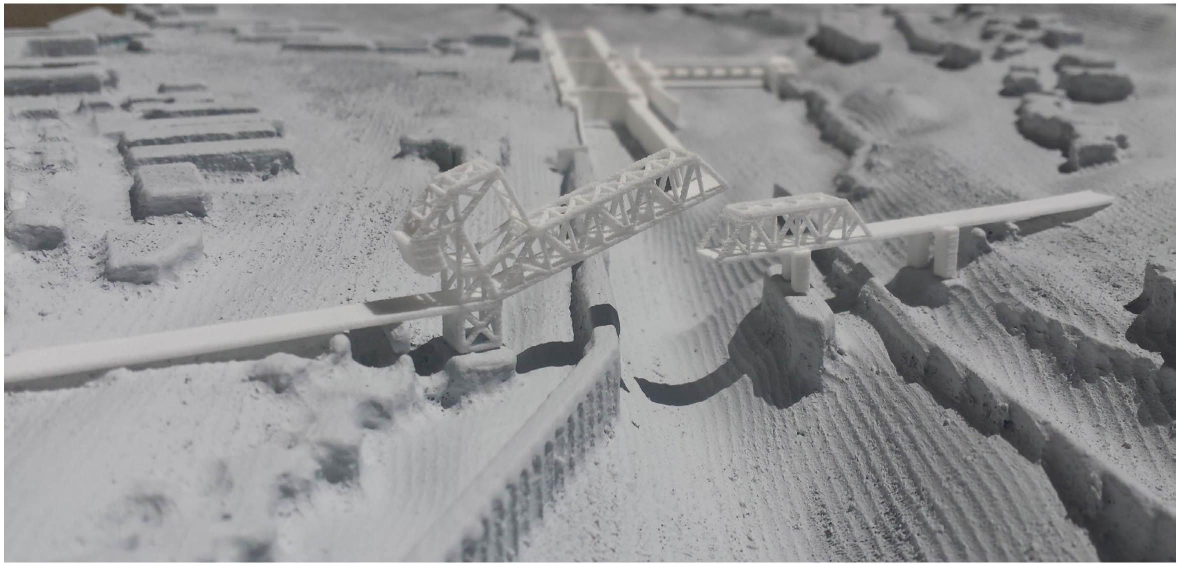


Figure A.3 (above) and A.4 (opposite page): 3 x 2' model depicting site and context. Base: plywood. Topography, bathymetry, buildings: CNC milled foam, painted with gesso. Locks complex and Salmon Bay Bridge: 3D print.



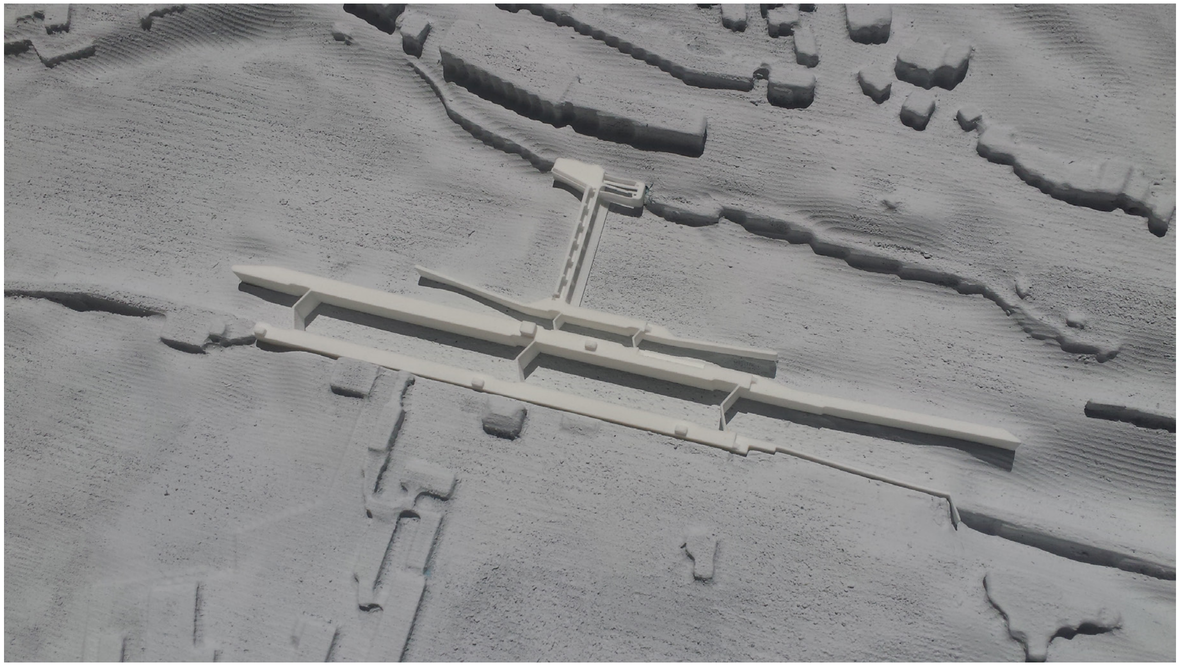


Figure A.5 (above left), A.6 (left), and A.7 (opposite page): 3 x 2' model depicting site and context. Base: plywood. Topography, bathymetry, buildings: CNC milled foam, painted with gesso. Locks complex and Salmon Bay Bridge: 3D print.