The Experiential Bridge:
Remedial Landscape for Hanford's Nuclear Future

by

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ABSTRACT

The groundbreaking discovery of nuclear fission opened up new possibilities for generating power and resources for people. Nuclear energy was much preferred over fossil fuel because of its efficiency in production, availability of resources, and cost. However, the reoccurring nuclear disasters around the world provoke us to reconsider the future of nuclear energy. This thesis acknowledges the contemporary issues particularly surrounding nuclear waste contamination and the risks that associated toxins present to human health and the existing ecosystem. The risk of exposure to radioactive materials and groundwater contamination can be reduced with proven technological methods but the public perception of nuclear waste treatment remains a daunting deterrent, preventing people from confronting the waste management issues effectively.

The thesis investigates ways to create new typology of remedial infrastructure where nuclear waste management technologies can co-exist with cultural programs; the new typology becomes an instrument that helps people to rethink the future of nuclear energy. The Experiential Bridge enables greater adoption of environmentally friendly nuclear waste treatment by exposing the process to the public and creating an educational experience for people. The Experiential Bridge not only treats toxins, but also serves as a pathway for recreational activity, and a source of education for the treatment of contaminated water and soil.

Thesis Supervisor: Andrew Scott
Title: Associate Professor of Architecture

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CHAPTERS

DISCOURSE

The Experiential Bridge is a reflection on the use of nuclear energy and the consequences associated with it. The idea for the Experiential Bridge was born from reading essays by Sanford Kwinter, Peter Galison, and Pierre Belanger.

Sanford Kwinter, an architectural theorist, states in the Notes on the Third Ecology that if we were to think ecologically, we cannot exclude the existential territories that define the world that we inhabit and the place that humans have created. Referencing the Deep Ecology movement in the 1970s and the Gaia Hypothesis, Kwinter suggests that the ethical philosophical thought cannot be divorced from scientific creativity. The Deep Ecology movement was "to think human being within and as part of the larger ecosphere, and not simply as an independent entity that inhabits it." The environment was not to be seen as resources or services for human purposes[1].

Pierre Belanger, an associate professor at Harvard Graduate School of Design, in his essay, "Redefining Infrastructure," addresses the importance of learning from failure and disasters around the world. Since the discovery of nuclear power a series of disasters (e.g., power plant meltdown, radioactive materials leakage, radiation) has struck around the world, endangering humans and the environment. Because of humans' innate fearful nature, and reliance on a "culture of contingency and preparedness," humans are forced to plan for the failure of nuclear production and nuclear waste management for successive generations[1].

Peter Galison, a physics professor, gives an example of a proposed habitation of a nuclear waste burial site in his essay, "Underground Future." The proposal was a commission from the Department of Energy to assess how to inform the users of the existence of wastes and how to prevent keep out the users from entering the contaminant sites. A group of anthropologists, archeologists, physicist, semioticians, and other experts gathered to design a monumental marker that demarcated the legacy of 100 years of nuclear weapons production. One of the concepts "Forbidding Blocks" was designed to barricade users from the site by creating a structure that was "exploded, irregular, non-respected, and narrow"[1].

1 Ecological Urbanism / edited by Mohsen Mostafavi with Gareth Doherty. Baden, Switzerland : Lars Müller, c2010.

As nuclear energy will remain an essential resource for future generations, humans cannot ignore the risk and damage associated with nuclear energy and the possible environmental damage it can have. Humans need to find ways to live in an environment with nuclear production and nuclear wastes. For these reasons, the future of nuclear energy challenges us to think about: 1) how to deal with current impact nuclear energy production and nuclear waste management has on environment; 2) the ways to remediate contaminated site; and 3) redefining the future relationship humans have with nuclear wastes; and 4) how to reduce the fear people have about living in a nuclear waste site.

The architectural agenda is not to criticize or alter the nuclear technologies available to humans, but to come up with an innovative way to embrace the use of nuclear energy, address the waste issues, prepare for further disasters, and educate people about the consequences. As more energy is used, more wastes will be accumulated, less land will be available to store the waste and environmental and health risks will be higher than before.

Image source from http://www.dailykos.com/story/2010/05/23/868939/

Image source from Dallas Observer
http://blogs.dallasobserver.com/unfairpark/2012/04/dallas-owned_west_texas_nuclea.php

INTRODUCTION

The Era of Nuclear Energy

The production of energy has significantly evolved since nuclear fission was discovered in the early 20th century. Nuclear fission was a groundbreaking discovery that opened up new possibilities for generating energy and power. Nuclear fission not only releases a large amount of energy initially, but also creates a self-sustaining chain reaction that causes a net generation of an enormous quantity of energy. The discovery of fission led to testing out the suitability of different neutrons, and eventually finding the right fit with uranium-235 [2]. In the 1930s and 1940s the emphasis of the production was on developing an atomic bomb. The U.S. took on the research done by the British and started to build pilot plants to generate nuclear energy. These pilot plants were constructed at Argonne, Oak Ridge, and Hanford. Most of the effort was geared toward developing an effective weapon to be used in World War II; the first project was called the Manhattan Project. After testing the nuclear weapon in New Mexico, the bomb was dropped on Hiroshima in 1945, marking a new era in the history of nuclear war tactics and nuclear energy use [3].

Post World War II, many of the power plants were shut down or shifted to generate electricity and steam. The United States is currently one of the largest producers of nuclear energy generating approximately 20 percent of the United States' electricity production[4].

Nuclear energy still remains one of the primary sources for creating electricity as the production has less environment impact compare to the production of electricity from firing coal. With just 1 gram of uranium-235, the same amount of energy can be produced as when using 3 tons of coal [5]. Although there has been an increase in the renewable energy research and use, renewable energy cannot substitute for all the energy use, or for nuclear weapon production. Nuclear power is more beneficial in cost, environmental protection, and efficiency in producing electricity.

2 *U.S. Department of Energy. "The History of Nuclear Energy." U.S. Department of Energy. 20 March 2012. http://www.ne.doe.gov/pdfFiles/History.pdf.*

3 *"Three Mile Island Emergency."Three Mile Island. Dickinson College, 23 March 2012. www.threemileisland.org/virtual_museum/index.html.*

4 *"Nuclear Energy." Nuclear Energy Clean Energy US EPA. United States Environmental Protection Agency, 1 April 2012.*

5 *Aref, Lana. "Nuclear Energy: the Good, the Bad, and the Debatable." The National Institute of Environmental Health Sciences. NIEHS, 1 April 2012. http://www.niehs.nih.gov /health/assets/docs_f_o/nuclear_energy_the_good_the_bad_and_the_debatable.pdf.*

Timeline of Nuclear Energy

- **1932** Neutron is discovered
- **1937** 5 million volt Van de Graff generator built
- **1945** Hiroshima and Nagasaki bomb drop
- **1946** First nuclear reactor created
- **1948** Commercialize nuclear power
- **1954** Atomic Energy Act - allow private sectors to build and operate nuclear power plants
- **1974** Energy Reorganization Act of 1974 - oversee development and refinement of nuclear power; handle safe handling
- **1979** Three Mile Island, PA failure in cooling system
- **1986** Chernobyl, Ukraine plant explosion
- **2011** Fukushima power plant fails due to earthquake

Image source from http://www.greatachievements.org/?id=3691

The Future of Nuclear Energy

In February 2010, Obama announced a proposal to increase the funding for nuclear power plants from 18 billion to 54 billion. The plan includes building a new nuclear power plant in Georgia. The rationale for continuing nuclear power production includes: Earth's natural resources such as oil and natural gas will deplete; the coal mining process is costly and gives rise to concern about its effect on global warming; and there is a limited scope for using renewable energy sources, such as solar or wind power [6].

According to the Annual Energy Outlook 2013 data, the future nuclear energy supply and demand is on the rise. The U.S. projection for nuclear energy production is to grow by 14 percent, from 790 billion kilowatt-hours (2011) to 903 billion kilowatt-hours (2040) [7]. As the nuclear energy consumption is steadily increasing, the U.S. is expected to continue to see an increase in nuclear energy demand.

A $8.3 billion loan (from $54 billion set aside for nuclear loan guarantees) is provided to build a nuclear power plant in Georgia — the first nuclear power plant built in the U.S. in 30 years[8].

"There's no reason why technologically we can't employ nuclear energy in a safe and effective way,"
"Japan does it and France does it and it doesn't have greenhouse gas emissions, so it would be stupid for us not to do that in a much more effective way[9]."

6 Hore-Lacy, Ian. *Nuclear Energy in the 21st Century: The World Nuclear University Primer/Ian Hore-Lacy. London: World Nuclear University Press, 2006.*

7 *"Electricity Generation." AEO2013 Early Release Overview. U.S. Energy Information Administration, 1 April 2012. http://www.eia.gov/forecasts/aeo/er/early_elecgen.cfm.*

8 *Merchant, Brian. "Obama Announces Plans for First Nuclear Power Plant in 3 Decades." Treehugger, 3 April 2012. http://www.treehugger.com/corporate-responsibility/obama-announces-plans-for-first-nuclear-power-plant-in-3-decades.html.*

9 *"University of New Orleans." Remarks by the President in Town Hall Meeting. The White House, 29 February 2012. http://www.whitehouse.gov/the-press-office/remarks-president-town-hall-meeting-university-new-orleans.*

Image source from wikipedia and lbl.gov

The Future of Nuclear Energy

As one of the largest producers of nuclear energy, the U. S. faces the consequences of dealing with the largest amount of nuclear wastes. According to the U.S. Department of Energy, there are millions of gallons of radioactive wastes and spent nuclear fuels, and currently deals with a large portion of contaminated soil and water resulted from early military activities — including weapons testing [10]. In the second half of the 20th century, when new nuclear technologies were being developed and the dangers of radiation were not clearly understood, radionuclide discharges — some accidental, others deliberate — occurred. These discharges resulted in the contamination of both production sites and local inhabited areas. Moreover, many of the nuclear facilities and storages do not meet present safety requirements for surface water bodies and underground cavities. As a result, nuclear waste poses environmental threats that are challenging, if not impossible, to predict.

Only in the last 30 years have people started to recognize the serious issues associated with nuclear waste management. In 1979, the U.S. faced one of the worst accidents in U.S. commercial reactor history, the Three Mile Island incident. Due to equipment failure and operator error, the power plant experienced a meltdown[11]. Three Mile Island presented for the first time the potential dangers of producing nuclear power.

10 *Irvine, J. M. (John Maxwell) Nuclear Power : A Very Short Introduction/ Maxwell Irvine. Oxford: Oxford University Press, 2011. P. 59.*

11 *"Three Mile Island Emergency."Three Mile Island. Dickinson College, 23 March 2012. www.threemileisland.org/virtual_museum/index.html.*

One of the major flaws and controversial aspects associated with nuclear energy production are the risk for contamination and exposure to radionuclide and the long duration of the time necessary for the radioactive materials to neutralize. The most dangerous long-lived components of the waste include plutonium, which has a decay rate of over 10,000 years unless reused as nuclear fuel[12].

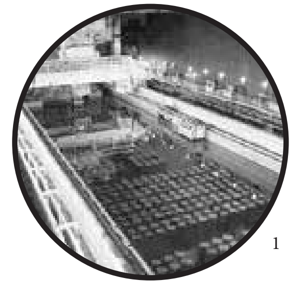
The waste has different degrees of radioactivity and is classified into three categories: low-level waste, intermediate-level waste, and high-level waste. The low-level waste is usually embedded in concrete or bitumen and is buried near the ground level where as the high-level waste is sent to deeper repositories. It is estimated that the high-level wastes are increasing by approximately 12,000 tons per year, of which a huge portion is uranium and non-recyclable materials[13].

12 *Irvine, J. M. (John Maxwell) Nuclear Power : A Very Short Introduction/ Maxwell Irvine. Oxford: Oxford University Press, 2011. P. 56.*

13 *Irvine, J. M. (John Maxwell) Nuclear Power : A Very Short Introduction/ Maxwell Irvine. Oxford: Oxford University Press, 2011. P. 58.*

Depending on the type of the waste materials, there are three general principles in managing radioactive wastes: concentrate-and-contain, dilute-and-disperse, delay-and-decay[14]. The first two methods entail either concentrating and then isolating or diluting the waste to acceptable levels and then discharging to the environment. Delay-and-decay requires storing of waste and allowing the radioactivity to decrease naturally through decay of the radioisotopes[15].

Currently, the method of delay-and-decay has proven ineffective because stored wastes have leaked and spread through groundwater, soil, and air. Because of nuclear waste storage, wildlife species and habitats are in danger of extinction and degradation, respectively, due to the radioactive materials. Some of the man-made radionuclide emits into the air and aquatic systems. The radionuclide transfers to living organisms from the air, soil, water, and sediment. Eventually, the radionuclide is transferred to marine life and wildlife, which are at risk for mutation or mass extinction. Humans rely on these species for survival, thus there is a need to develop a better way to manage and mitigate the spread of radionuclide emissions and prevent the waste site from leakage or exposure[16].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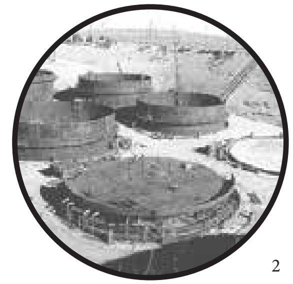
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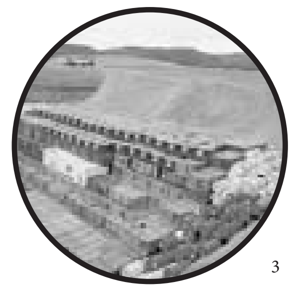

3

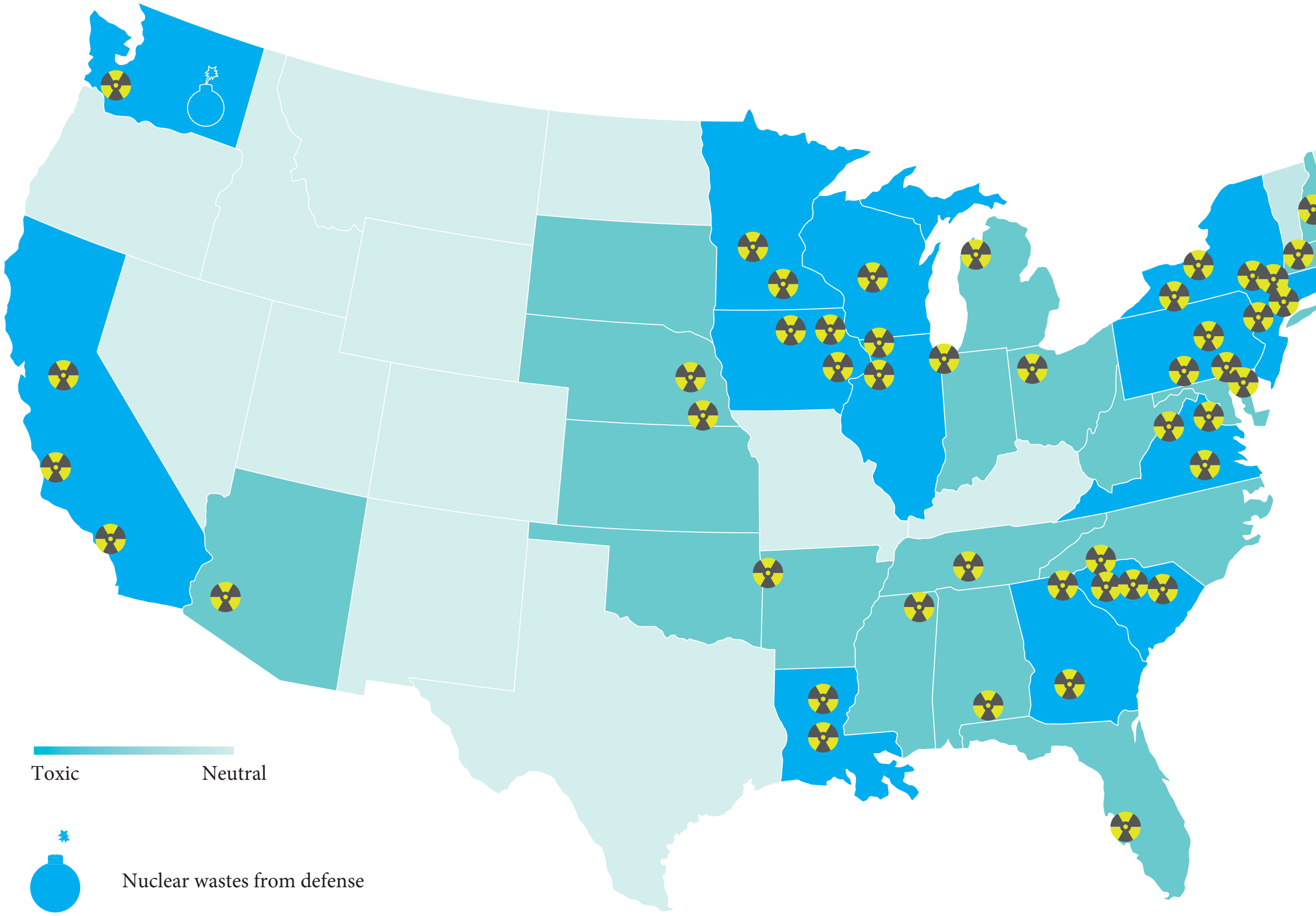
1. Barrels containing radioactive nuclear waste being stored at Sellafield
2. Hanford storage tank
3. low-level radioactive waste, Nevada Test Site

14 *Hore-Lacy, Ian. Nuclear Energy in the 21st Century: The World Nuclear University Primer/Ian Hore-Lacy. London: World Nuclear University Press, 2006. P. 77.*

15 *"Waste Management: Overview." Nuclear Waste Management. World Nuclear Association, 3 April 2012. http://www.world-nuclear.org/education/wast.htm.*

16 *Nuclear Power and the Environment / editors: R.E. Hester and R.M. Harrison. Cambridge, U.K.: RSC Publishing, 2011.*

Image 1 source from World Nuclear Association ://www.world-nuclear.org/education/wast.htm
Image 2 source from Hanford Site Annual Environment Reports http://hanford-site.pnnl.gov/envreport/2001/summanage.stm
Image 3 source from fopnews http://fopnews.wordpress.com/2012/06/



Toxic Neutral

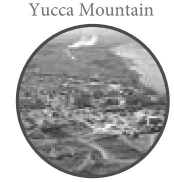
Nuclear wastes from defense

Commercial dry storage sites
DOE-owned SNF and high-level waste
commercial high-level waste

56 Nuclear weapon waste in U.S.A. (million gallons)

Farallon Island

Yucca Mountain



Hanford Site

Source from city-data.com
http://www.city-data.com/forum/las-vegas/1257516-info-environment-las-vegas.html
Image 1 Source from wikipedia http://en.wikipedia.org/wiki/File:SE_Farallon_Island.jpg
Image 2 Source from world nuclear nuews
http://www.world-nuclear-news.org/WR-NRC_chairman_cleared_on_Yucca_Mountain_decision-0906115.html
Image 3 Source from wikipedia http://en.wikipedia.org/wiki/Hanford_Site

Nuclear Waste Facts

Waste produced per year in OECD countries

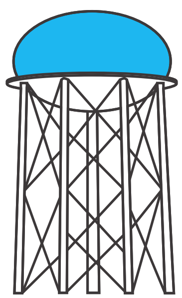
300 million tonnes

Waste decaying time

10,000 years (plutonium)

Waste produced per year per plant

21,000 cubic meters

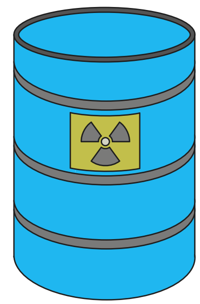


x **11**
1,900 cubic meters
water tank

Total waste produced per year in U.S.

2.1 million cubic meters

Comparison of materials needed to provide energy



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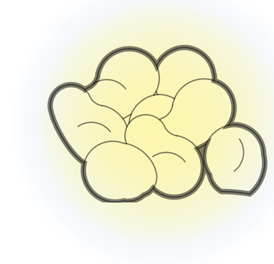
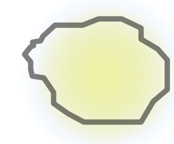


1 gram Uranium

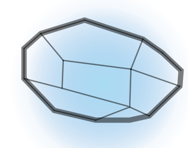
3 tons Coal

Materials used to provide energy

Uranium -235



Plutonium - 239

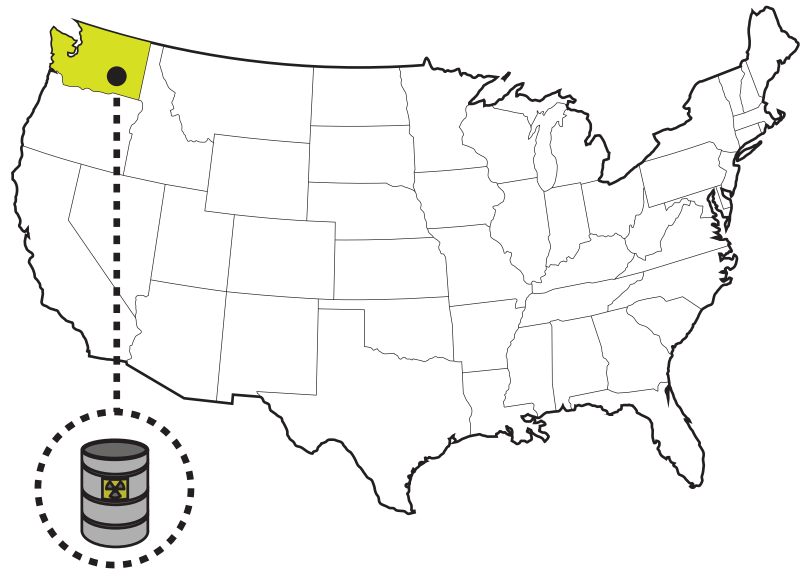


SITE

Hanford, Washington

Hanford, Washington, is one of the waste sites in the U.S. that is currently dealing with the issue of nuclear waste disposal. The Hanford Site, located in Benton County of Washington State, borders two major rivers – the Columbia River and the Yakima River. Also, 20 miles downstream from the waste site locates one of the largest metropolitan cities in the state – Richland, Pesco, and Kennewick which is known as the tri-cities.

In 1943 Hanford was designated as a plutonium production site for making nuclear weapons to use during World War II. The semi-arid area in the southern part of Washington State was selected for production of nuclear weapons because of its isolation and access to water resources such as the Columbia River[17]. After the shutdown of the power plants, the site transformed into a dump site storing over 53 million gallons of wastes.



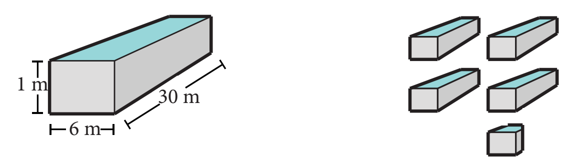
200 SQUARE MILES OF CONTAMINATION

67 metric tons of plutonium was created at Washington. After the shutdown of the reactors, 53 million gallons of wastes were stored.

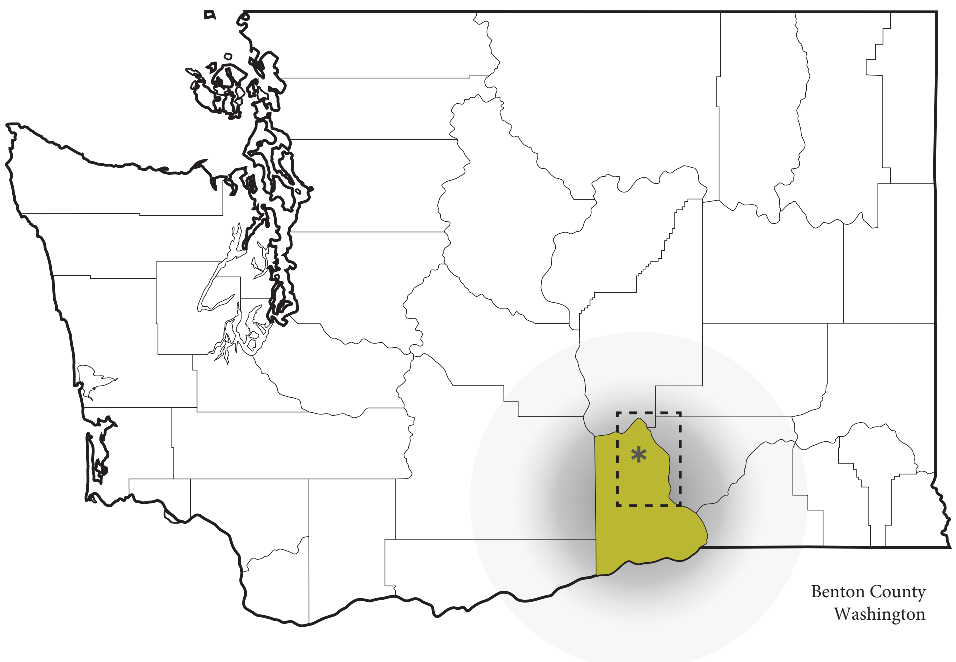
770 CUBIC METER HIGH-LEVEL RADIOACTIVE LEAKAGE

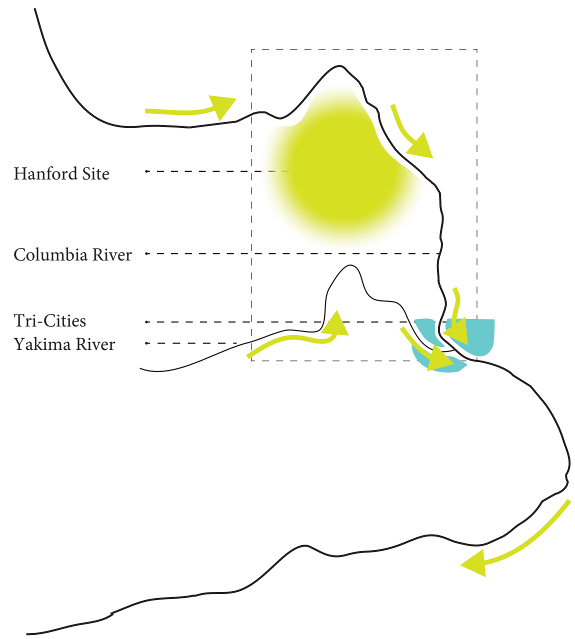
swimming pool 180 cubic meter

4.25 swimming pool



17 Murray, Raymond LeRoy. 1920- Understanding Radioactive Waste. Columbus : Battelle Press, 1994. P. 60.


Benton County
Washington


Hanford Site
Columbia River
Tri-Cities
Yakima River

Timeline of Hanford Site

1943 Hanford site reactors are activated to make deadly nuclear weapon to bomb Hiroshima

1949 Relationship with Soviet Union deteriorates; 8 new reactors are built to produce more nuclear weapon

1960 Peak of nuclear power production

1964 All powerplants are shutdown except one; no need for mass production

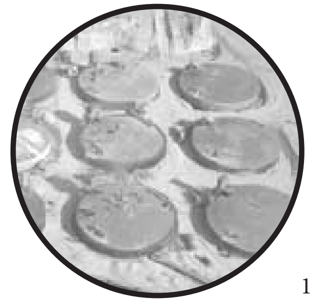
1972 Massive nuclear waste burial; plus energy research, development, and technology was added to the

1973 Nuclear wastes leakage was announced

1977 The U.S. Department of Energy starts cleanup process realizing leakage

2001 Vitrification plant work begins to extract and treat leaked nuclear wastes

2030 Projected completion date for cleanup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2


3

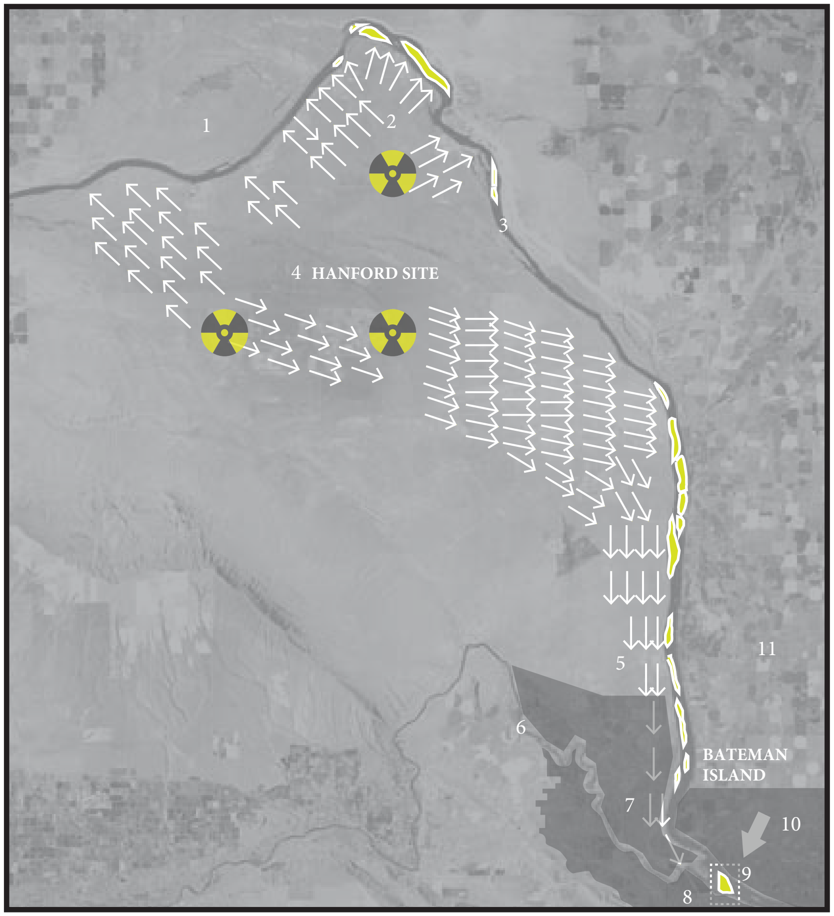
1. Tank farm at Hanford
2. Nuclear reactors along the Columbia river in January 1960.
3. Aerial view of Hanford Nuclear Reservation

18 *Stringfellow, Kim. "Safe as Mother's Milk: The Hanford Project." Safe as Mother's Milk., 3 April 2012. http://www.hanfordproject.com/timeline.html.*
Image source from Department of Energy
http://blogs.seattletimes.com/uwelectioneye/2012/06/08/hanford-site-nuclear-waste-storage/

Image source from Department of Energy
http://blogs.seattletimes.com/uwelectioneye/2012/06/08/hanford-site-nuclear-waste-storage/
Image source from Defense Nuclear Facilities Safety
http://www.dnfsb.gov/about/where-we-work/doe-defense-nuclear-facilities?page=1

The 53 million gallons of nuclear waste consisted of 177 underground storage tanks and 149 leak-prone single-shelled tanks which store highly radioactive materials from production[19]. Some of the materials that were disposed are: 1) uranium or thorium used for source for fissionable material; 2) plutonium and uranium-233 used for reactor fuel or weapons; and 3) by-product material, or the residue from the extraction of uranium from ore[20].

Of this 53 million gallons of waste, 1 million gallons leaked underground and contaminated the soil and groundwater, thus polluting the Columbia River[21]. Because the Columbia River runs through many urban settlements down river, it is crucial to strategize a new way of remediating toxins that are mobile. If the contaminant from the river is not controlled, Richland, Pesco, and Kennewick are in further danger of exposure to radioactive materials.

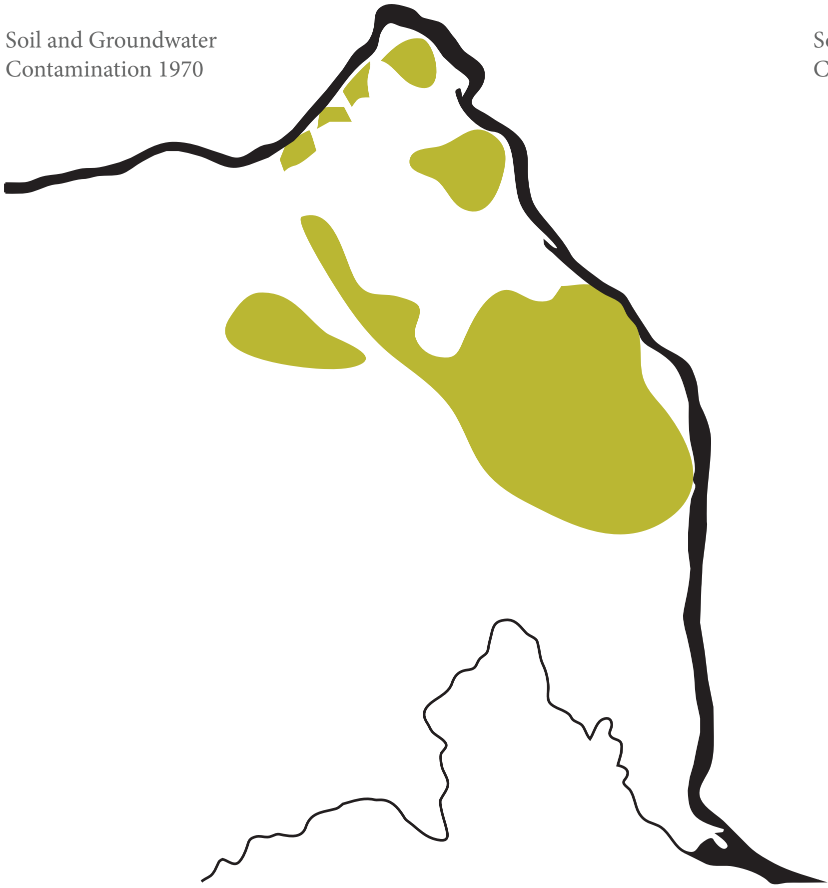


1. Wildlife Reserve
2. Hanford Reactor Areas
3. Yakima River
4. Central Plateau/ Wastes burial
5. Experimental Laboratories
6. Yakima River
7. Richland
8. Kennewick
9. Bateman Island
10. Pasco
11. Agriculture

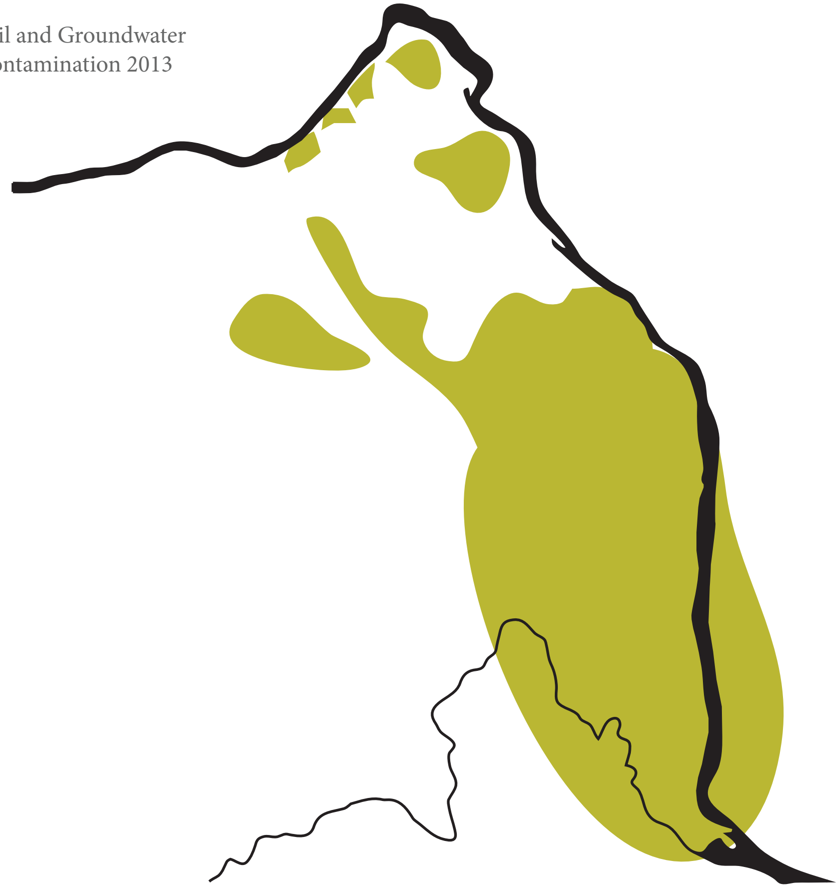
19, 21 *Washington State Department of Ecology. "Economic Risks to the Region-Hanford, the Columbia River and the Economy." Hanford Site Cleanup. Department of Ecology., 3 April 2012. http://www.ecy.wa.gov/features/hanford/hanfordecon.html.*

20 *Murray, Raymond LeRoy. 1920- Understanding Radioactive Waste. Columbus : Battelle Press, 1994. P. 61.*

Soil and Groundwater
Contamination 1970



Soil and Groundwater
Contamination 2013



Toxic Spread

Hanford Site deals with approximately 85 feet of soil contamination and groundwater contamination under the nuclear facilities and landfills. The groundwater needs to be cleaned up to prevent toxic from spreading further into Columbia River.

TOXIC STORAGE

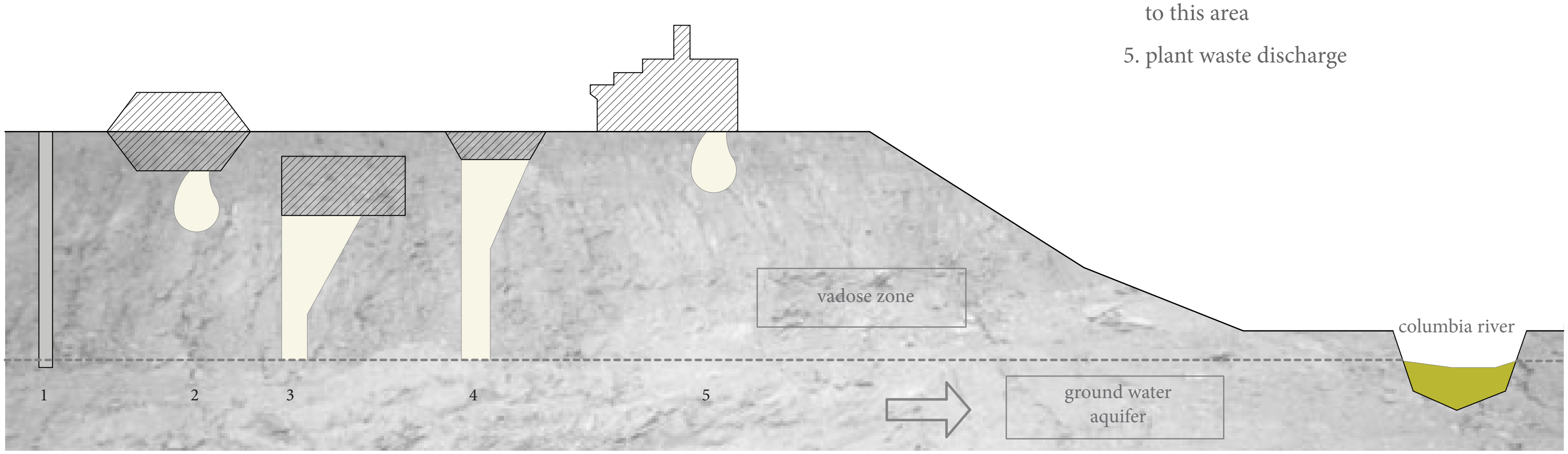
1. reverse wells
   disposal areas for liquid contaminants; contaminants are pumped directly back to the soil

2. pits, trenches, landfills
   solid and liquid waste buried

3. underground tank
   store more than 53 million gallons of high and low-level waste

4. cribs, ponds, trenches
   cooling and waste water was directed to this area

5. plant waste discharge



22 *"Hanford Nuclear Reservation." Columbia Institute of Water Policy., 7 September 2012. http://columbia-institute.org/blackrock/Issues/Hanford.html.*

Nuclear Waste Remediation

In order to apply the right technological method for treatment, a series of remedial technologies were researched. There are 5 main methods for treating nuclear waste contamination. Currently, the main strategy to remediate Hanford Site is by a vitrification treatment, a process in which radioactive waste is excavated and then mixed with glass at extremely high temperatures. This plan makes the waste solid, prevents wastes from leaking, and makes the waste easily transportable[23].

The vitrification facilities include a laboratory that takes 10,000 samples of water and soil every year. In addition to the sampling labs, the facilities come with 4 nuclear service areas and 20 supporting units to remediate the buried toxins. The facilities will be approximately the size of 1.5 football fields in length, 70 yards wide, and 12 stories high. The facility consists of 13.9 million cubic feet of space and 100 miles of piping to transport and treat the waste[24]. To construct this new facility, 260,000 cubic yards of concrete and 40,000 tons of steel are being used[25].

Other remediation methods used are pump and treat technology, asphalt/resin barrier, biostimulation and phytoremediation. The pump and treat method involves pumping up groundwater that contains chromium and then treating it before releasing it back to the groundwater. The system can treat 25 billion gallons of groundwater at a rate of about 2,500 gallons per minute[26]. Another method for remediation is to create an asphalt or resin wall around the waste leakage site. Two-thousand tons of asphalt pavements was poured near Columbia River to serve as a moisture barrier protecting the wastes from coming into contact with the surface water. The barrier prevents precipitation from seeping into the soil and spreading contaminants deeper underground[27]. Both pump and treat and asphalt/resin barrier are not suitable as a long term solution; they are not environmentally friendly and require significant resources to construct.

23 *"Hanford." Hanford- Government Accountability Project., 15 April 2012. http://www.whistleblower.org/program-areas/environment/nuclear-oversight/hanford.*

24 *"Waste Treatment & Immobilization Plant Project."Department of Energy Hanford., 27 March 2012. http://www.hanford.gov/page.cfm/WTP.*

25 *"Hanford VIT Plant." Bechtel. U.S. Department of Energy Office of River Protection., 5 September 2012. http://www.hanfordvitplant.com/page/the_project/.*

26 *Cary, Annette. "Hanford 'Pump and Treat' Plant Halfway Built." Tri-City Herald., 5 September 2012. http://www.tri-cityherald.com/2011/05/04/1476534/hanford-pump-and-treat-plant-halfway.html.*

27 *"TY Tank Farm Interim Barrier." Inland Paving Asphalt Co., 1 November 2012. http://www.inlandasphaltpaving.com/projects/104.*

On the other hand, biostimulation and phytoremediation have very little impact on environment, are cost effective, and can treat large quantities of soil and water over a period of time. Biostimulation is a process where materials like molasses and vegetable oil are pumped into the ground, where tiny microorganisms in the soil then absorb the molasses and vegetable oil and reproduce. Over time, they alter the chemistry of the groundwater and render the contaminants inert and harmless to the environment[28]. According to the Pacific Northwest National Laboratory report, biostimulation can potentially treat soil mass that is the size of a cylindrical tank with a 15-meter radius and 5.6-meter depth, when applying 594,000 liters of molasses over 3.25 days at 125 liters per minute[29].

Phytoremediation uses plants to remove or destroy contaminants in the soil and groundwater. Plants have proven to work for extracting metals, radionuclide, pesticides, explosives, fuels, volatile organic compounds and semi-volatile organic compounds[30].

Despite the effectiveness of vitrification facilities, pump and treat technology, asphalt/resin barrier, biostimulation, and phytoremediation, the use of these facilities and inventions are uncertain after the completion of the treatment. Vitrification facilities, pump and treat technology, and asphalt/resin barrier are substantial in size and cost, require a lot of building materials to construct, and are hard to retrofit after the treatment has completed. The three methods lack in adaptability and flexibility as the building/infrastructure are designed exclusively to treat and are permanent structures. However, biostimulation and phytoremediation processes open up possibilities for new usage for the contaminated sites as they have less environmental impact and the materials used to construct and treat are easily acquired and removed. As a result of this research, the thesis investigates further into phytoremediation and biostimulation methods for design implementation.

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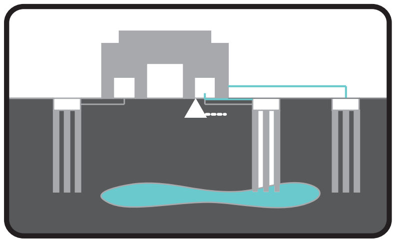
28 *"Hanford Cleanup."Department of Energy Hanford., 27 March 2012. http://www.hanford.gov/page.cfm/HanfordCleanup.*

29 *Truex, M., Vermeul, V., Fruchter, J. WM Symposia. "Treatability Testing of an In Situ Biostimulation Barrier for Nitrate and Chromium Treatment – 9126.", 7 September 2012. http://www.wmsym.org/archives/2009/pdfs/9126.pdf.*

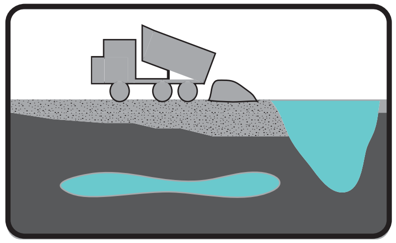
30 *"Phytoremediation." Center for Public Environmental Oversight., 7 September 2012. http://www.cpeo.org/techtree/ttdescript/phytrem.htm.*

Nuclear Waste Remediation Methods

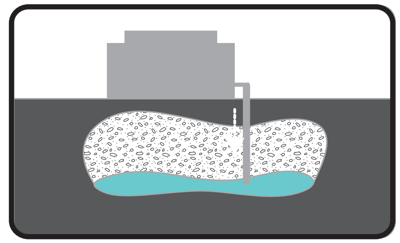
Pump and Treat



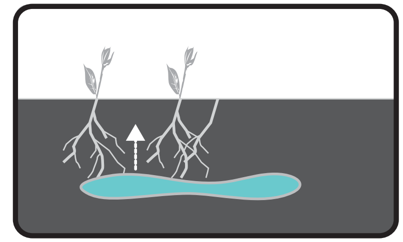
Asphalt / Resin Wall



Biostimulation



Phytoremediation



1

2

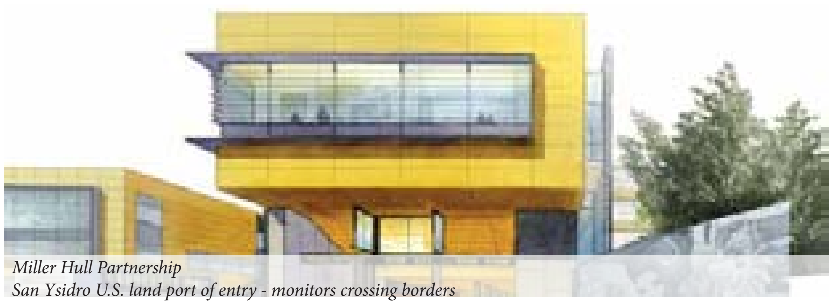
3

4

Image 1 source from Department of Energy http://www.djc.com/news/en/12045378.html
Image 2 source from http://www.ashurmichael.com/
Image 3 source from http://www.nrc-cnrc.gc.ca/eng/achievements/highlights/2009/gost.html
Image 4 source from http://www.guaddunes.com/northsouth.html

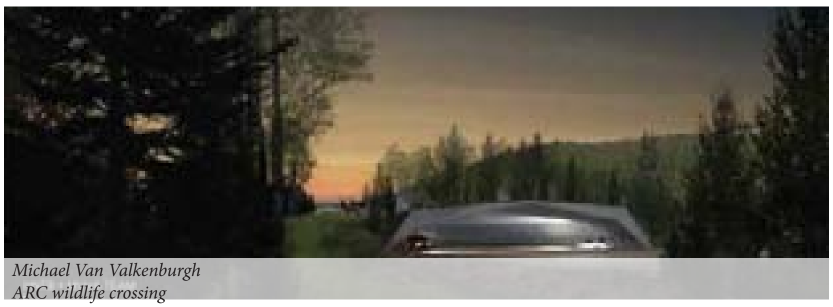
PRECEDENTS

Monitor, Treat, Preserve



Miller Hull Partnership
San Ysidro U.S. land port of entry - monitors crossing borders

SOM
Beinecke Library for rare books



Michael Van Valkenburgh
ARC wildlife crossing

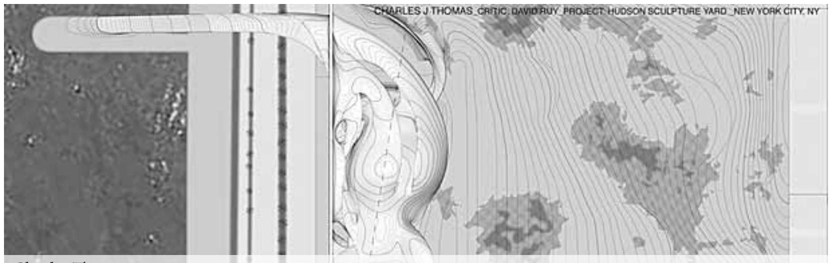
BNKR Arquitectura
The Earthscraper

Cesare Griffa
Design for Gowanus Toxic Site

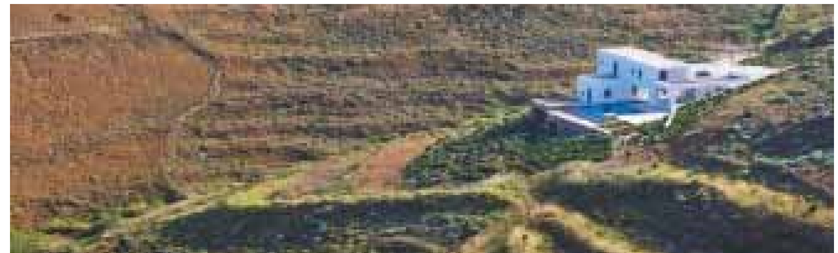
Katya Larina
Kyiv Urban Wildlife Park

Image source from archdaily.com

Synthetic Landscape



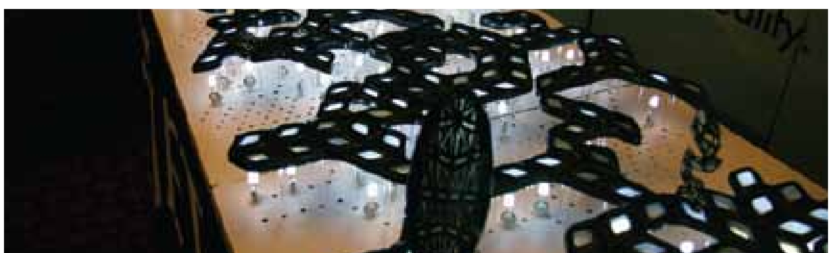
Charles Thomas
Synthetic plants containing nano-sized dynamos are implanted on surfaces to harness kinetic energy



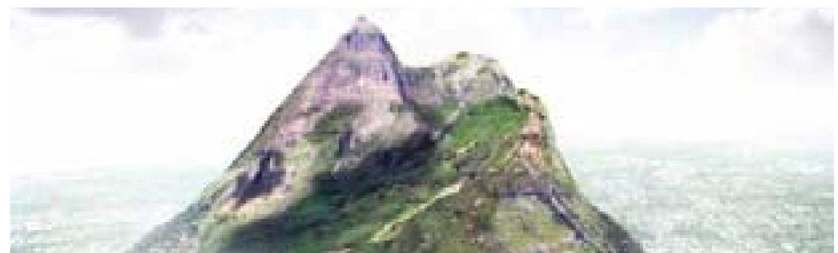
Doxiadis
Landscape of Cohabitation: a man-made sustainable structure

SAO architecture
A museum building as a "living organism": with bioclimatic features

Hydramax
Port Machinese: a synthetic waterfront model



Acadia
Synthetic Landscape



Jakob Tigges
Berg - the biggest artificial mountain in the world

Image source from archdaily.com

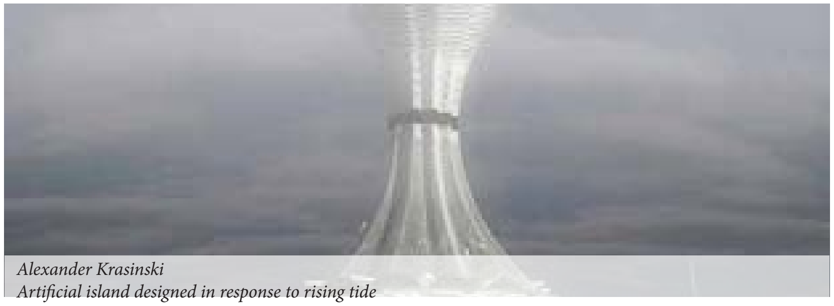
Design for Environment

Batlle & Roig Architects
Waste Treatment Facility

Ifat Finkelman_Ofer Bilik Architects
Habitat for Urban Wildlife

SBA Design
Low Carbon Future City

WORKac
Nature-city

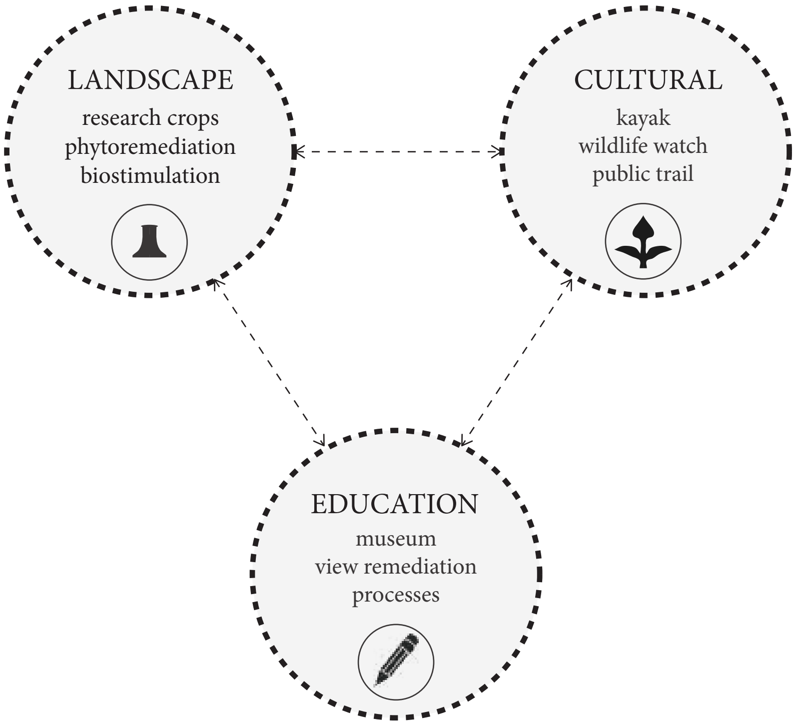


Alexander Krasinski
Artificial island designed in response to rising tide

Solar Decathlon
Refract House by SCU + CCA

Image source from archdaily.com

THE EXPERIENTIAL BRIDGE

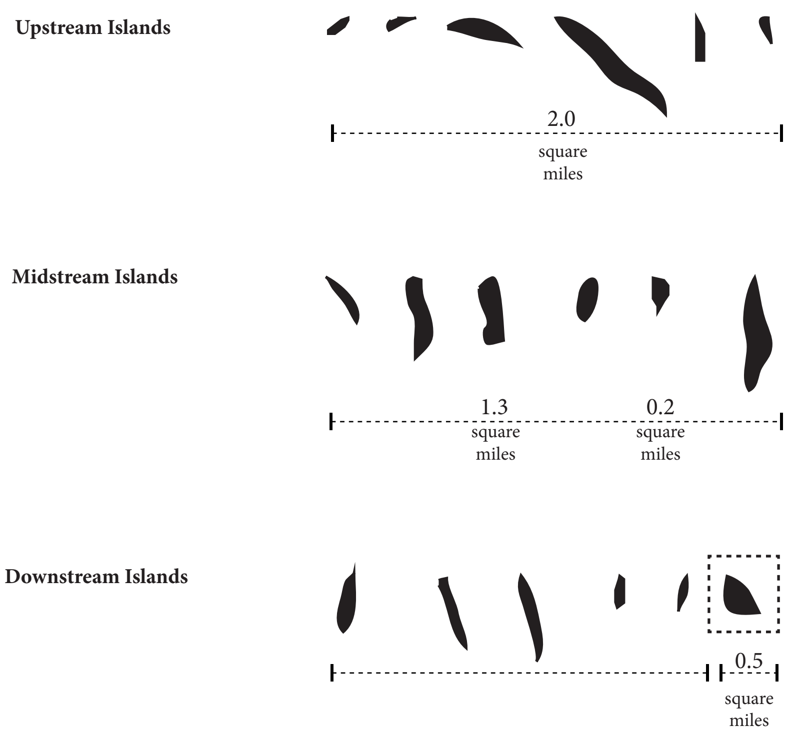


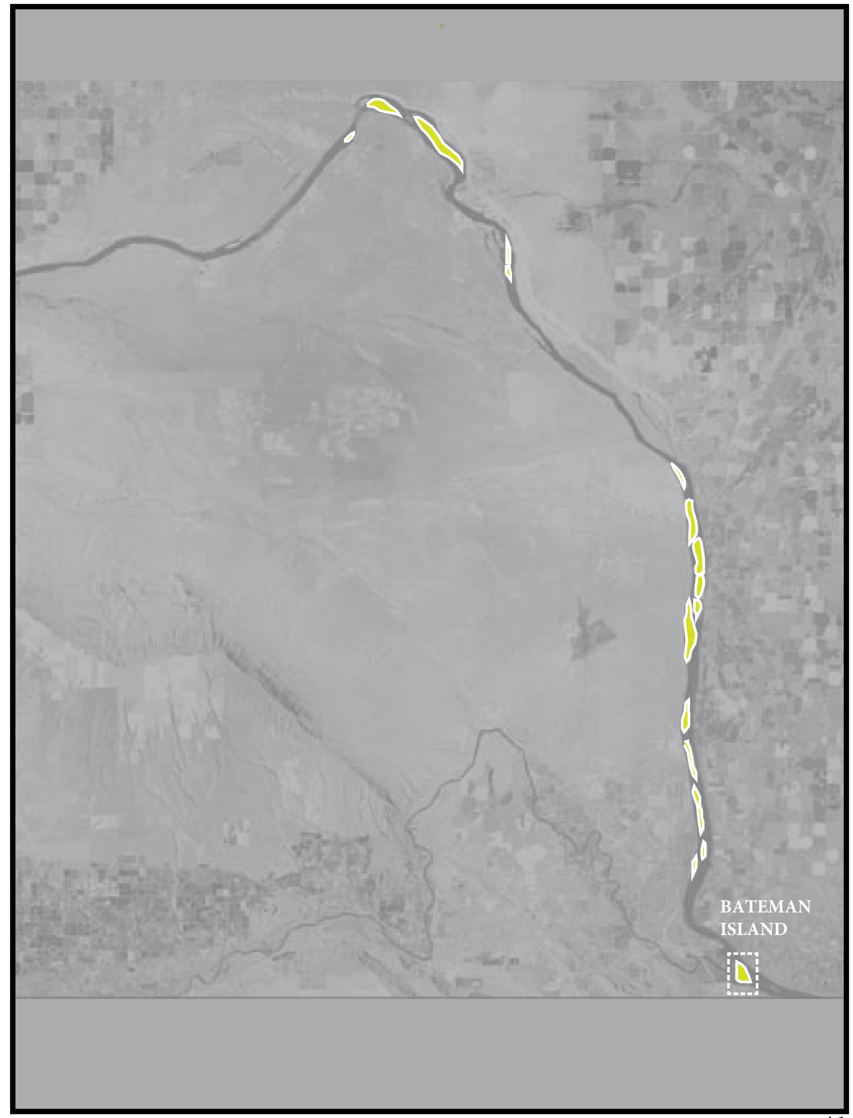
Concept

Despite the multiple remediation treatment technologies and new facilities available at the Hanford Site, the scope of the treatment needed at Hanford and the long term plan for the surrounding contaminated sites require new strategy of treatment and architectural intervention. The Experiential Bridge takes into account the possibility of the contaminants reaching the urban settlement where asphalt barrier and football-size treatment facilities are not viable solutions. The new strategy not only includes the technology needed for the treatment, but also takes into consideration the interaction that humans have with the infrastructure. The idea is to confront the attitude people have about nuclear wastes because it is a reality that people need to learn to live with the wastes. The new prototype - Experiential Bridge - includes remedial landscape, educational platforms, and recreational zones where the remedial process is exposed to public for educational and recreational purposes. The Experiential Bridge introduces flexibility by construction method and designing of modular units which have different performances and programmatic functions.

Topography and Hydrology

One of the primary considerations for designing the Experiential Bridge is to utilize the topographical and hydrological conditions of the Columbia River and the surrounding sites. The Columbia River has a series of islands located downstream of the Hanford Site. When the islands are flooded, the islands can act as sponges to absorb and treat the toxins in the water and soil. Contrarily, the islands can be barricaded to prevent the toxins from contaminating the islands. The sizes of the islands along the Columbia River vary from 0.2 square miles to 1.3 square miles.





Bateman Island

The thesis zooms into one of the islands – Bateman Island - to serve as a prototype for the new remediation system. Bateman Island located at the intersection of the Yakima River and Columbia River, floods completely and has the opportunity to treat and sample water from both rivers. The island currently serves as a public trail for outdoor recreation for people in Richland.

The Columbia River is about 2,000 feet wide, similar in width to the Charles River in Cambridge, MA. The island is approximately 0.5 square miles, which is equivalent to 230 football fields.

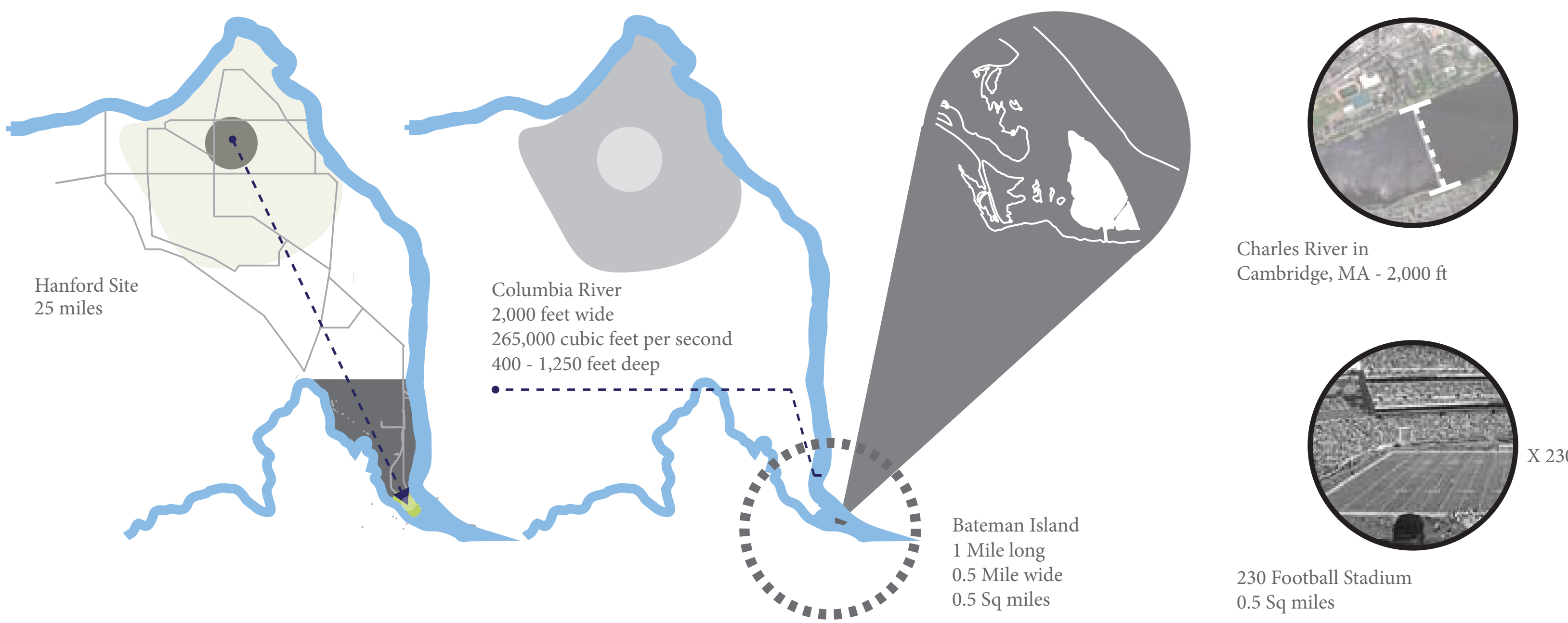
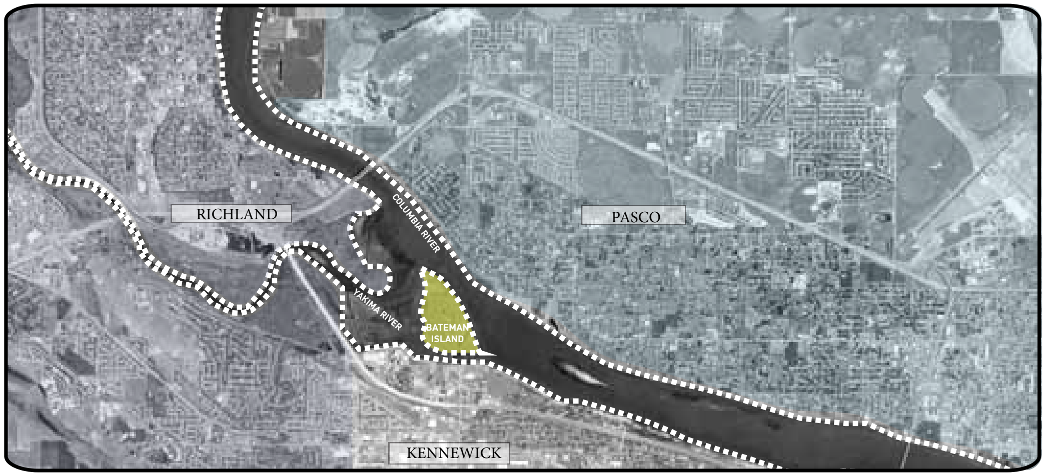
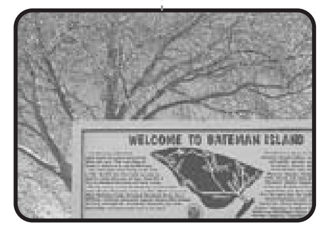


Image source from maps.google.com

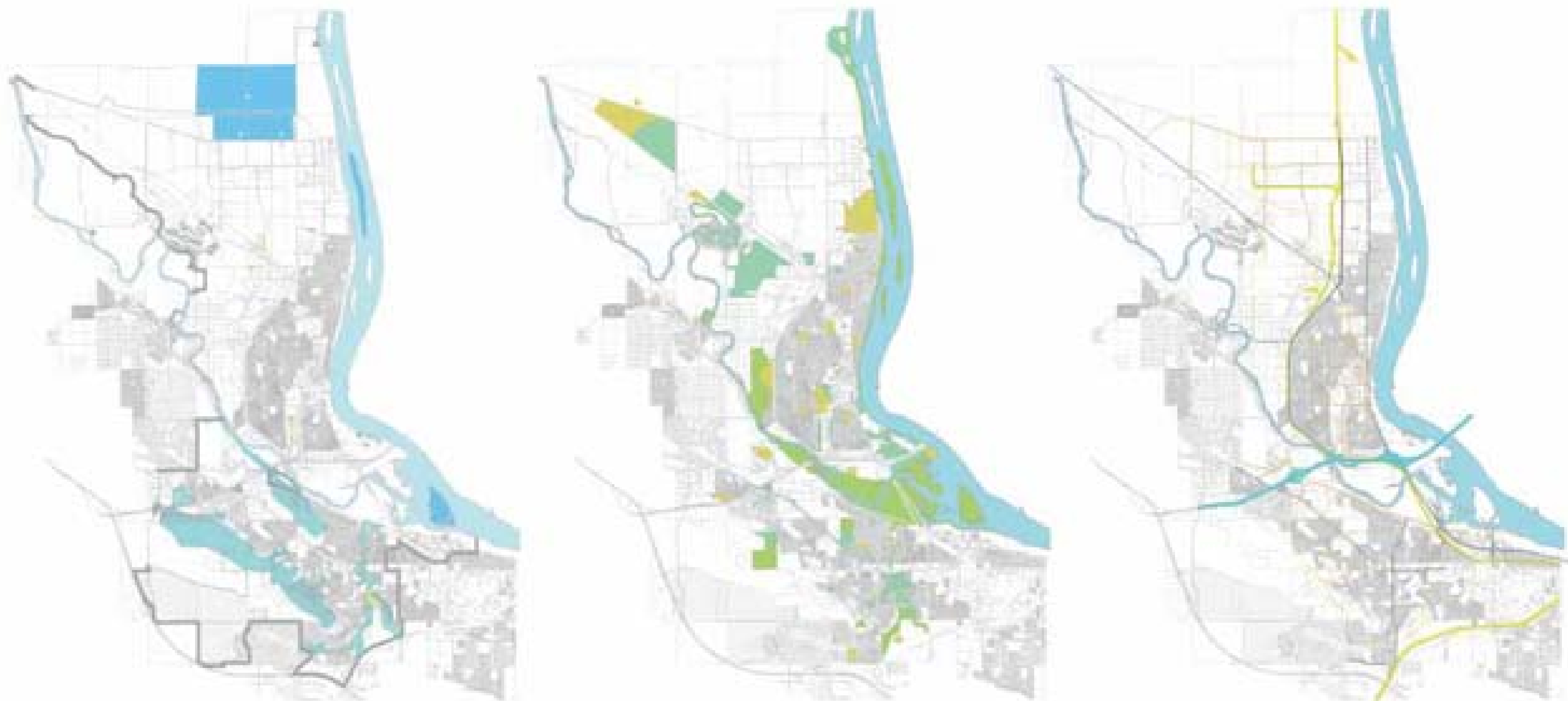
Bateman Island





Images 1 from http://richlandparksandrec.com/facilities.aspx?RID=3&Page=detail
Image 2 from http://columbiariverimages.com/Regions/Places/bateman_island.html
Image 3 from http://columbiariverimages.com/Regions/Places/bateman_island.html
Image 4 from http://www.flickr.com/photos/32569657@N00/2782828781
Image 5 from http://dipity.com

Bateman Island



Geological Sensitivity

- Priority Habitat
- Hazard Area

Land Use

- Natural Open Space
- Public Space
- Developed Open Space

Access

- Interstate
- Railroad

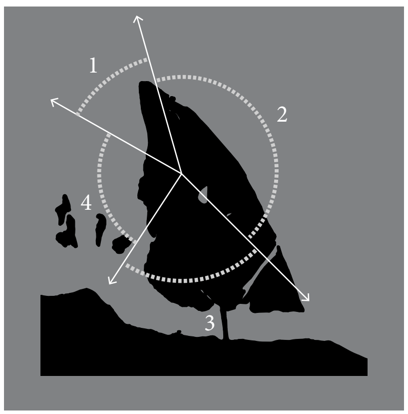
Source from Richland GIS Maps

Image provided by City of Richland

Bateman Island

The island is surrounded by several natural reserve sites and parks including Yakima Delta Wildlife Nature Area, Riverview Natural Reserve, and Pasco and Chiawana Park. The island generates interesting views of the tri-cities as well.

Island View

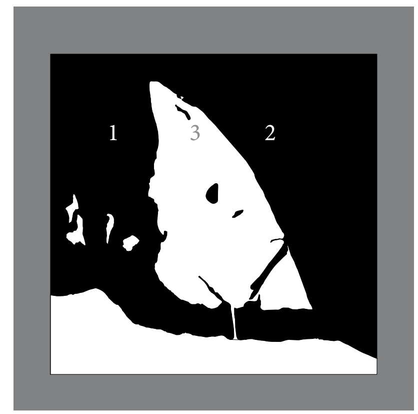


1. Riverview Natural Reserve
2. View of Pasco
3. View of Richland
4. View of Yakima Delta

Existing Trail

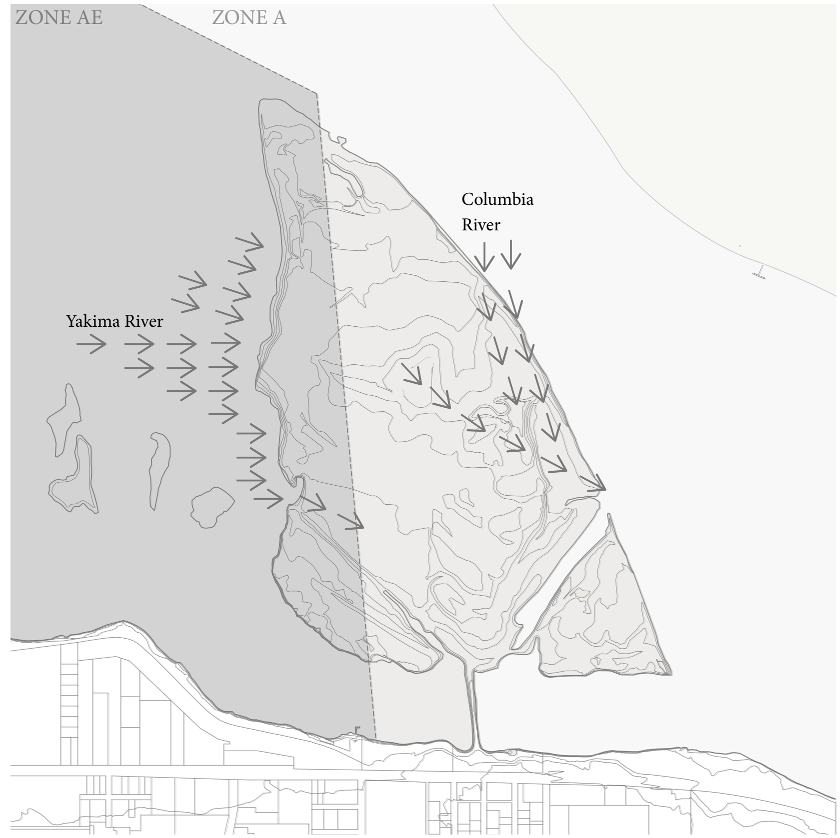
Trail Map on Site

Existing Water



1. Yakima River
2. Columbia River
3. Island Lakes

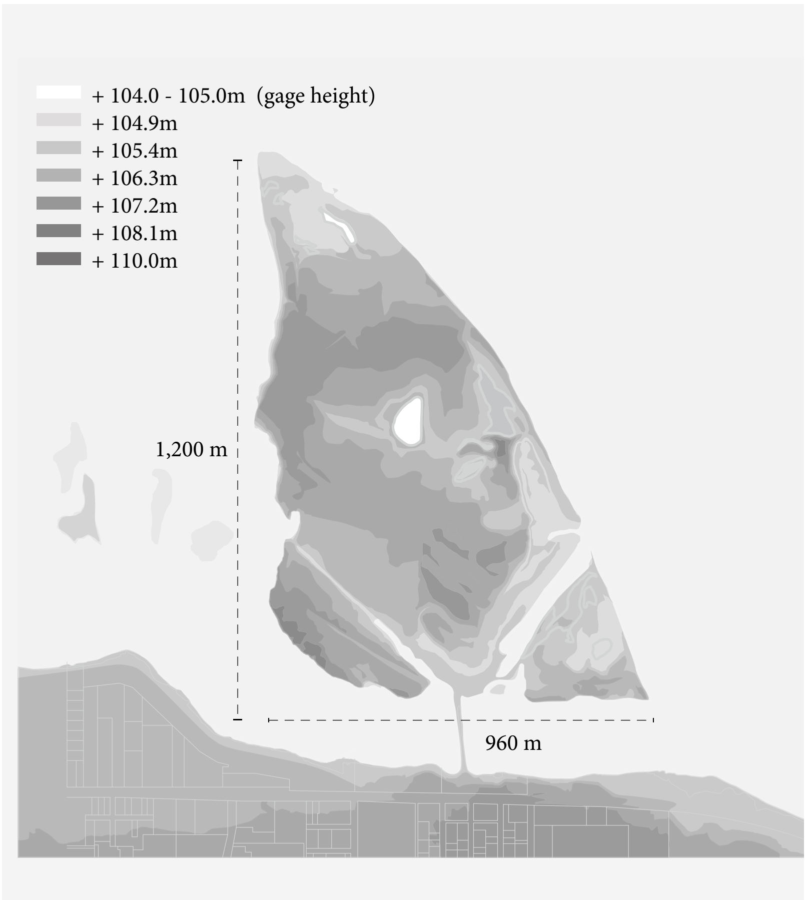
Because the island sits at the intersection of two rivers, the island has two variant hydrological conditions. According to the flood insurance rate map[31], the western part of the island is prone to more flooding than the eastern part of the island as the Yakima River water elevation is not regulated. The western shoreline is most vulnerable to flooding and is likely to be inundated periodically. The western part of the island - Zone AE - is categorized as floodway which means the area must be kept free from building. The eastern part of the island - Zone A- is susceptible to annual and 100 year flooding. The thesis uses three flooding scenarios to design programs: annual flooding, 25 years flooding, and 100 years flooding.

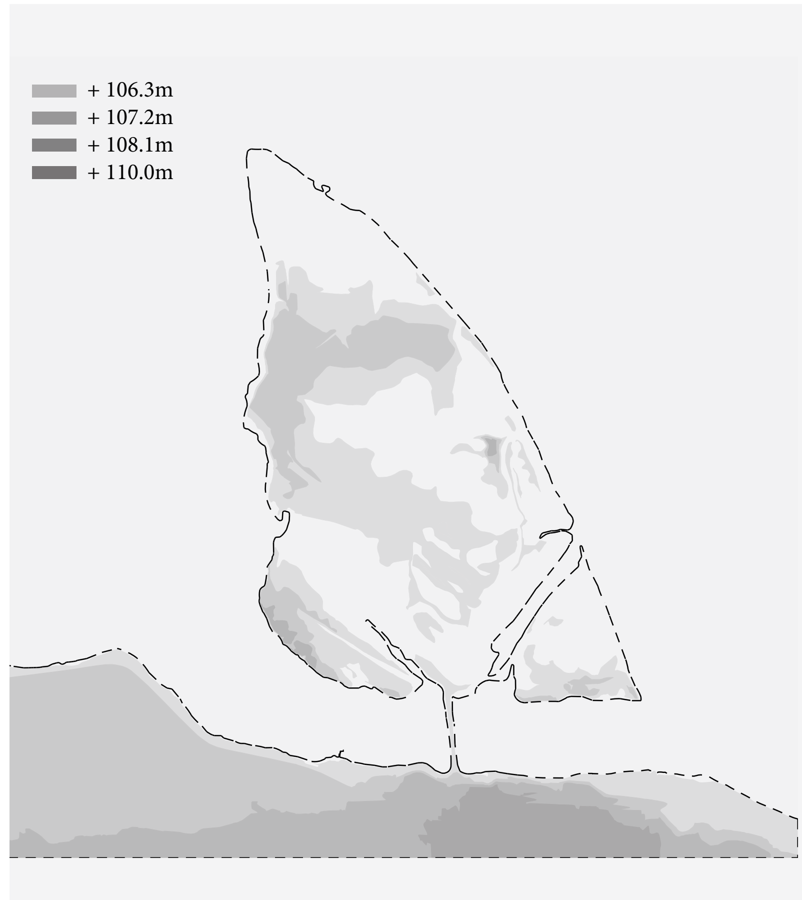


31 *Flood Insurance Rate Map provided by City of Richland Public Records*

The area of the island is about 0.5 square miles with the elevation difference between the lowest and highest areas being approximately 3.6 meters.

When the island is completely flooded, the island is left with less than 50% of dry area shown on the map on the right.



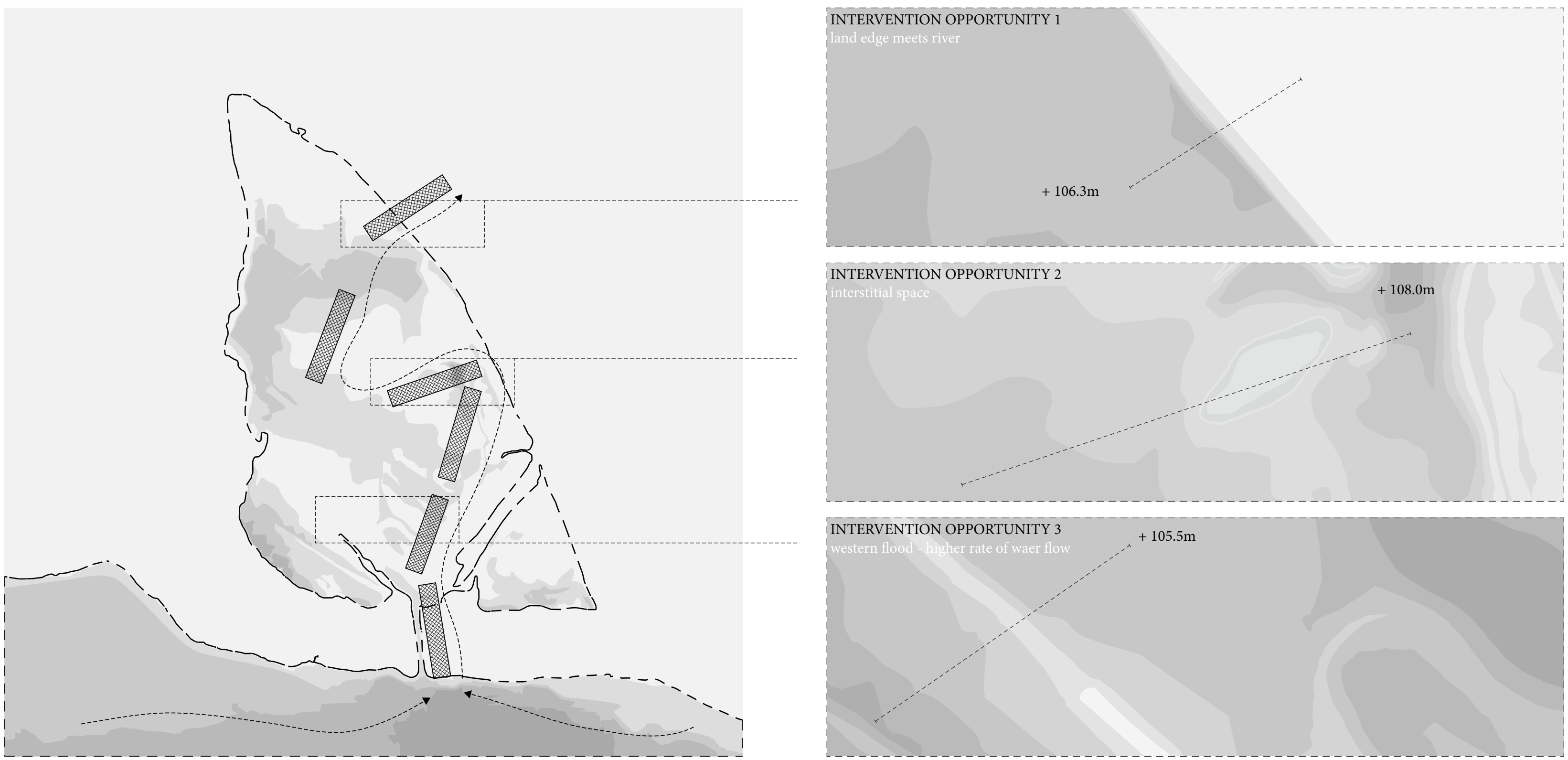


Within the island there are three types of water flow conditions and sites of opportunity for remediation methods.

The first site of opportunity is located at the western shoreline where there is a flushing condition. The western edge has very gentle bluff and consists of large flat surface area where water can filter and drain out quickly generating opportunity to treat large quantity of water and expedite the biostimulation technology.

The second condition is situated at the interstitial space between two valleys where the watershed drains out. This area allows for water treatment and other activities to happen simultaneously as the dry areas can be altered to introduce interactive programs.

The third is the edge condition where the island meets the water directly. The edges of the island can transform into an armor to keep the toxins out keeping the island away from contamination.

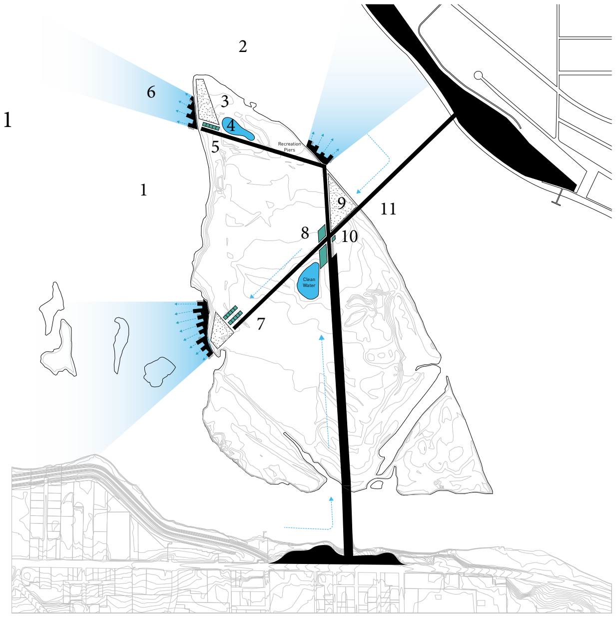


Remediation Strategy

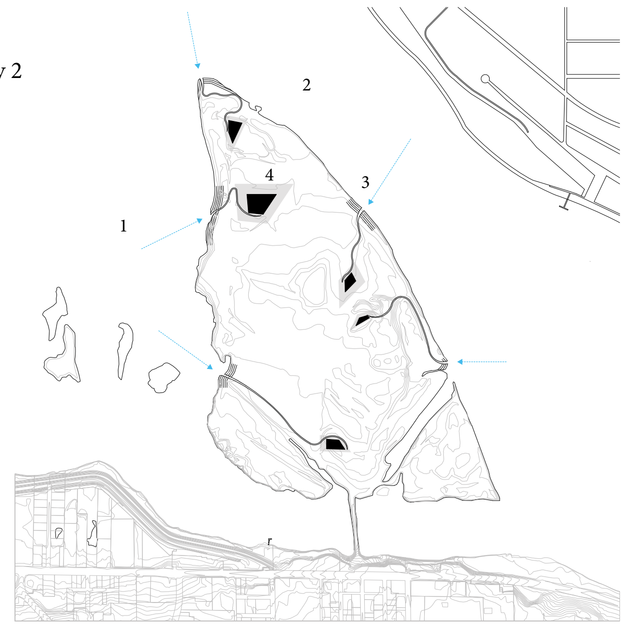
The first strategy localizes the biostimulation and phytoremediation processes by pumping and channeling water from the rivers using a man-made infrastructure. The water is drawn to the interstitial space for treatment and released it back to the western edge of the island. The infrastructure becomes an extension/bridge that connects the island to the public areas of Pasco and Richland.

The second strategy maximizes the idea of waste treatment and minimizes intensive building construction using the topographical and hydrological conditions of the island. Taking advantage of the elevation changes and the flooding conditions, the island itself is used as a tool to remediate the contaminants. The island is carved away to make pathways for the water to flow in, and then is contained at the lowest elevation areas of the island for treatment.

Strategy 1



Strategy 2



Strategy 1

1. Yakima River
2. Columbia River
3. Phytoremediation
4. Clean Water
5. Recreation Piers
6. View of the Wildlife Reserve
7. Eco-Lodge
8. Research & Sample Lab
9. Testing Ground
10. Bike Rental
11. Water Infrastructure

Strategy 2

1. Yakima River
2. Columbia River
3. Water Passage
4. Phytoremediation Beds

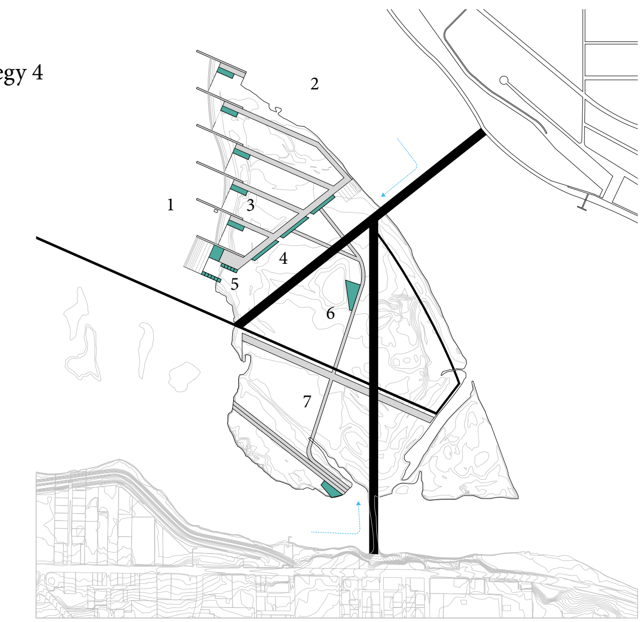
Remediation Strategy

The third strategy uses the edges of the island to keep out the contaminants while drawing in water from both rivers to treat the contaminant and use for water recreation afterward. The edge of the island becomes a destination spot for visitors.

The last scheme focuses on the experience of the visitors rather than the remediation processes by designating the island as a gateway and material resource hub to access and provide for Hanford Site where the contamination was started. The island serves as a ferry port allowing visitors to travel to Hanford Site to experience the treatment process in situ.

Strategy 3

Strategy 4



Strategy 3

1. Wildlife watch pods
2. Wildlife watch site
3. Yakima River
4. Entrance to the Park
5. Research Center
6. Water Storage
7. Water Path
8. Bike/Walk Trail
9. Chiawana Park
10. Columbia Park Trail
11. Columbia River

Strategy 4

1. Yakima River
2. Columbia River
3. Ferry Port
4. Eco-Lodge
5. Research and Sample Lab
6. Camping Ground
7. Trail

Basic Metrics for Treatment

Molasses Variables:

594,000 Liters of molasses =
15m radius, 5.6m depth volume treated
Total volume treated = 4,000 cubic meter of soil and water
Total area treated = 177 square meter
594 cubic meter of molasses =
4,000 cubic meter of volume treated
150 Liters of molasses = 1 cubic meter of volume treated

Bateman Island Area that needs to be treated:

Bateman Island area = 0.25 square miles =
630,000 square meter
630,000 square meter x 5.6m depth =
3,528,000 cubic meter volume
3,528,000 cubic meter = 529,200,000 Liters of molasses needed
529,200,000 Liters = 3,000 swim pools

Molasses Production:

Production: 8,000,000 grams of sucrose / 1 Acre (4,050 sqm)
2,000 grams of sucrose = 1 sqm
2 Liters / 1 sqm

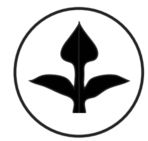
Land Required:

529,200,000 Liters / 2 Liters / sqm = 264,600,000 sqm
16,200 m x 16,200 m land is needed

Water Requirement

1,100 - 1,500 mm/Ha of water needed
0.0011m x 264,600,000 sqm = 290,000 cubic meter
1,600 swim pools

Molasses Use for Phytoremediation:



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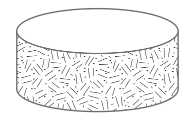


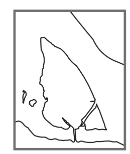
5.6 m

150 liters molasses / cubic meter

594,000 liter molasses

30 m diameter soil

Bateman Island Volume that Needs to be Treated:



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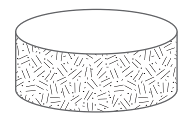
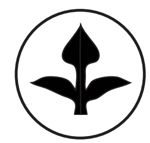


x 880

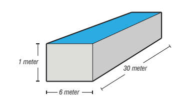
529,200,000 liters of molasses

0.25 sq miles area

=

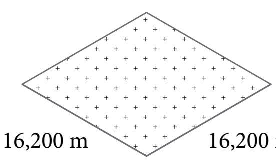


x 880



x 3,000

Molasses Production:

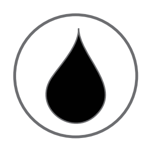


16,200 m

16,200 m

264,600,000 square meter of land

Water Requirement:



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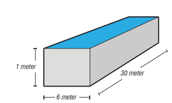


x 1,600

290,000 cubic meter of water

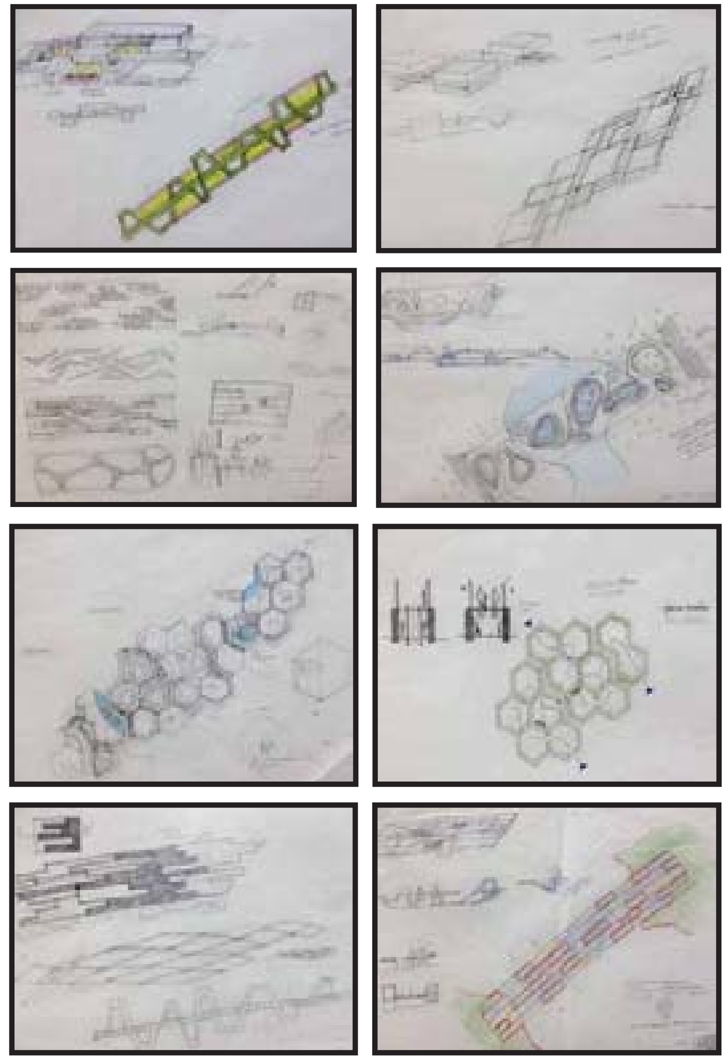
290,000 cubic meter

32 *Truex, M., Vermeul, V., Fruchter, J. WM Symposia. "Treatability Testing of an In Situ Biostimulation Barrier for Nitrate and Chromium Treatment – 9126.", 7 September 2012. http://www.wmsym.org/archives/2009/pdfs/9126.pdf.*

DESIGN CRITERIA

Architectural Design

The result is a combination of natural remediation processes and considerations for visitors' experience of the island. The basis for the sequence and methods for remedial process is driven from the topographical and hydrological characteristics of the island. Utilizing the flooding nature of the Bateman Island, the Experiential Bridge serves as a platform to connect the dry parts of the island while treating the toxins in the soil and water. The Experiential Bridge becomes a public extension of the tri-cities providing recreational and educational experiences for the visitors.



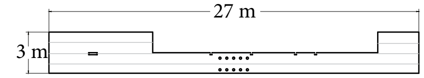
Design Iterations

Modular System

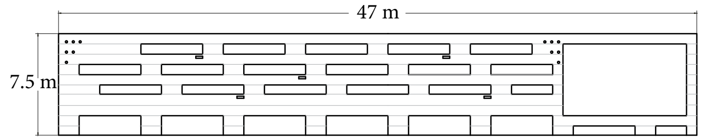
In order to minimize the impact on the environment, the Experiential Bridge addresses flexibility through modularity, materiality, and construction method. Depending on the characteristics of the region, the modules can be rearranged and reconfigured to maximize the treatment process and/or visitors' experience.

The Experiential Bridge consists of 6 modular units which are: 1) processing unit to generate molasses for biostimulation; 2) phytoremdiation treatment unit; 3) experiential unit; 4) learning unit; 5) research unit; and 6) recreation unit.

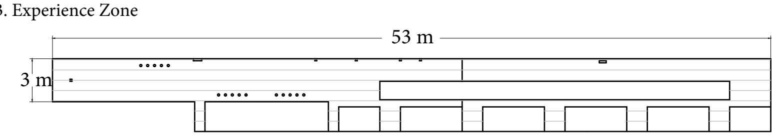
1. Processing Zone



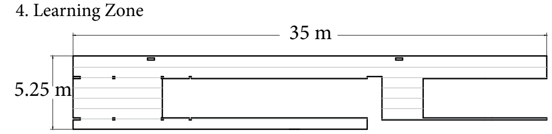
2. Treatment Zone



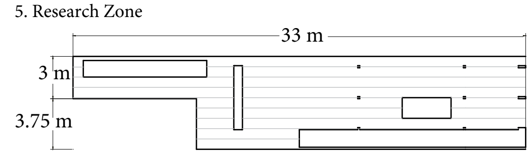
3. Experience Zone



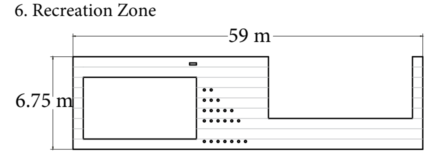
4. Learning Zone



5. Research Zone



6. Recreation Zone

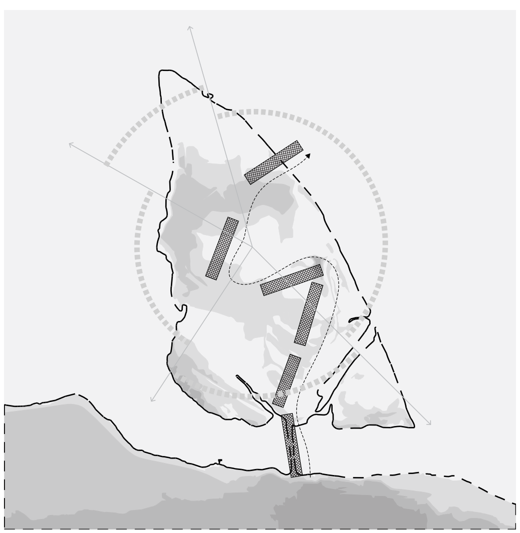


Modular System

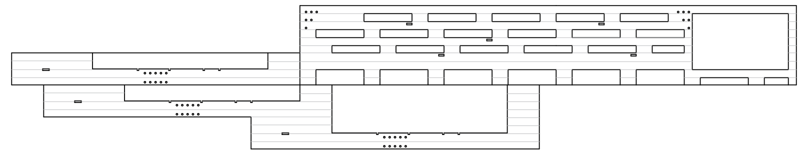
The first configuration shows conditions for maximum treatment process combining only the research and treatment units. This configuration can be applied at flushing zone (refer to topography and hydrology section of the book) where there is a large influx of water.

The second configuration shows conditions for the interstitial space where the watershed draining point is located; the low velocity water flow and the elevation changes allow for diverse range of human activities to occur. The Experiential Bridge maintains the infrastructure for recreational and educational purposes even after all the toxic has been treated.

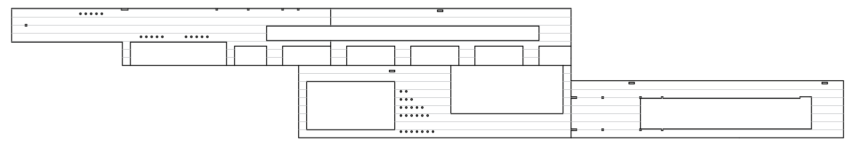
The Experiential Bridge can change in both scale and performance by arranging the different modular units.



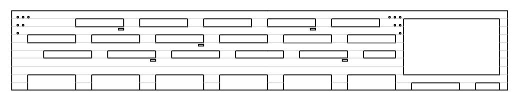
Maximize Treatment Process



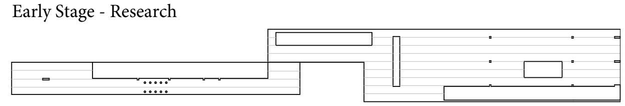
Maximize Activities



High Toxicity



Early Stage - Research



Structure

The bridge uses a lightweight structure for easement of construction and minimizing environmental impact.

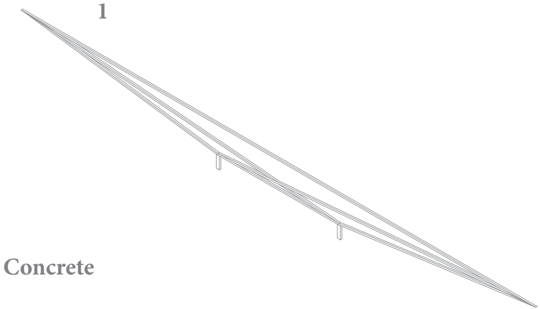
Timber Cross Bracing for Ramps
1. Beam: 0.6m x 0.3m
2. Column: 0.3m x 0.3m
3. Truss Bracing: 0.3m x 0.3m

Steel Rod Structure
1. Metal Tripod: 75mm x 75mm
2. Metal Mesh: 100mm spacing

Steel Structure with Light Weight Concrete Pour for Foundation
1. Beam: 0.6m x 0.3m
2. Column: 0.3m x 0.3m
3. Truss Bracing: 0.3m x 0.15m

Timber Frame Structure
1. Beam: 0.6m x 0.3m
2. Column: 0.3m x 0.3m
3. Truss Bracing: 0.3m x 0.15m

1



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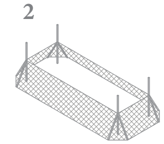

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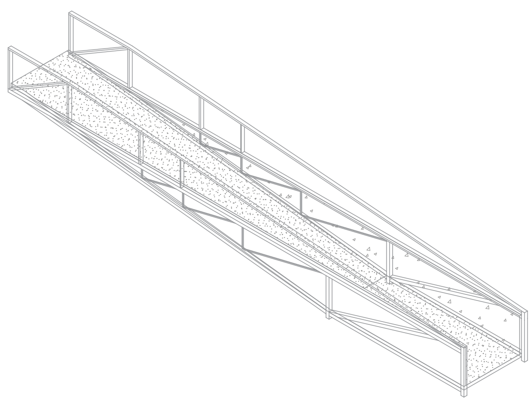

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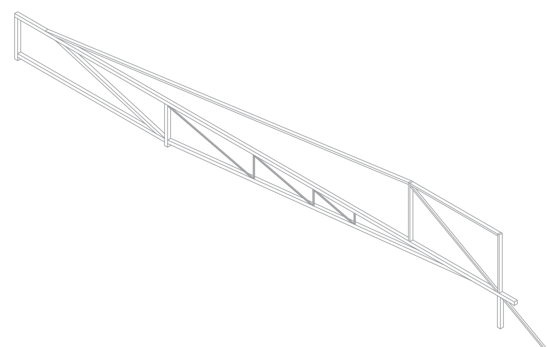
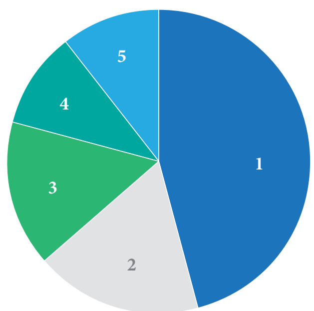


Landscape Criteria

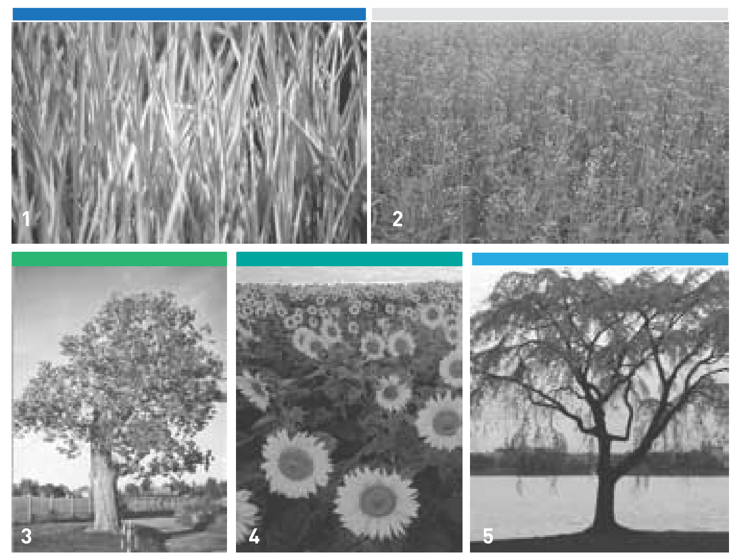
Based on the research of remediation processes, the most effective plants used for phytoremediation and biostimulation treatment are corn, sugarcane, poplar, willow, grass, Indian mustard, and sunflower. These plants have unique soil conditions and varying quantity for water absorption. To take advantage of the elevation changes in water from flooding, the plants are arranged in a way to maximize the effectiveness of the treatment.

PHYTOREMEDIATION



TOP FIVE VEGETATION USED FOR PHYTOTECHNOLOGY

1. Grasses (62%)
2. Indian mustard (24%)
3. Hybrid Poplar (21%)
4. Sunflower (14%)
5. Willow (14%)

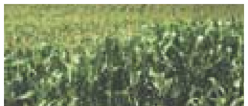
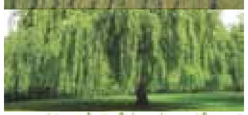
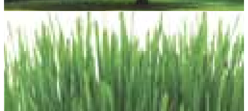
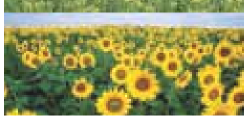


TREATMENT QUANTITY

1 & 2 : 10 pounds per acre
3 & 5 : one tree treats 7 sqm
4: one flower treats 4 sqm

33 *"Use of Field-Scale Phytotechnology for Chlorinated Solvents, Metals, Explosives and Propellants, and Pesticides." Environmental Protection Agency., 5 May 2012. http://www.cluin.org/download/remed/542-r-05-002.pdf.*

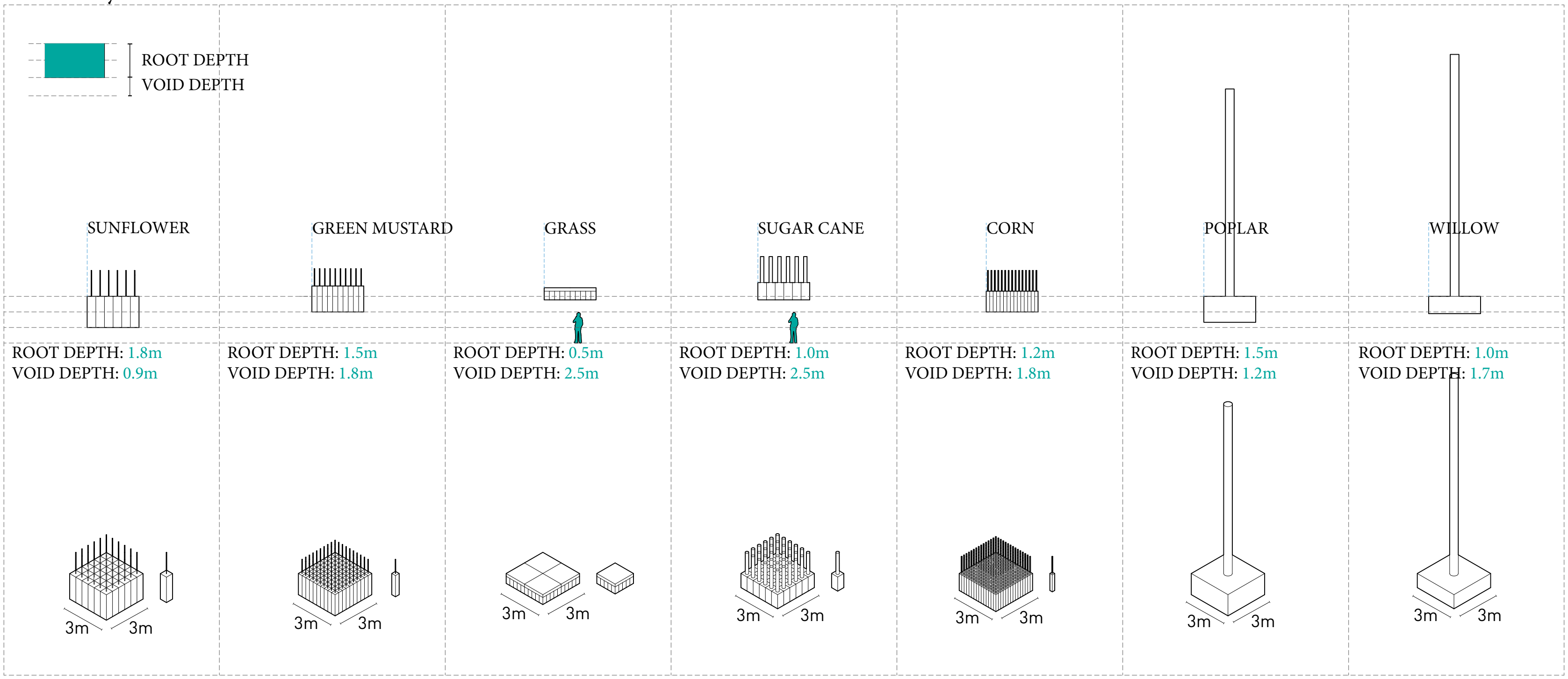
Landscape Criteria

	PLANTATION	TEMPERATURE	SOIL TYPE	GROWTH	HEIGHT	WATER
	**CORN**	68-73 F	SANDY LOAM	70 DAYS	7 FEET	3,500 GAL/ACRE/DAY
	**SUGARCANE**	89-100 F	SANDY/CLAY LOAM	11 MONTHS	4-12 FEET	250 KG/1KG SUGAR
	**POPLAR**	50-70 F	FERTILE SOIL	5-7 YEARS	40 FEET	RAIN WATER
	**WILLOW**	45-80 F	SANDY LOAM	15 YEARS	45 FEET	RAIN WATER
	**GRASS**	55-70 F	ANY	10 DAYS	6 INCHES	RAIN WATER
	**INDIAN MUSTARD**	60-65 F	SANDY LOAM	40-60 DAYS	3 FEET	RAIN WATER
	**SUNFLOWER**		SANDY/CLAY LOAM	80-90 DAYS	3-18 FEET	0.15 INCHES/DAY

Sources from
sugar cane: http://www.sugarcanecrops.com/soil_requirement/
corn: http://ucce.ucdavis.edu/files/repositoryfiles/ca3108p13-63306.pdf
corn: http://www.iowacorn.org/en/corn_use_education/faq/
poplar: http://www.arborday.org/treeguide/treeDetail.cfm?id=31
http://hybridpoplar.com/home/sr1/growing_main.html
willow: http://www.ehow.com/info_8247973_growth-rate-willow-trees.html
willow: http://www.cottagefarmsdirect.com/ViewPlantingGuide.aspx?PID=982
http://www.ehow.com/about_6300180_root-system-weeping-willow.html
http://www.plantingdirections.com/hybrid-willow-planting-directions/
http://www.gardenguides.com/100231-grow-white-willow-trees.html
grass: http://www.seedland.com/tips1.html
green mustard: http://www.hort.purdue.edu/newcrop/duke_energy/Brassica_juncea.html
green mustard: http://www.hort.purdue.edu/newcrop/afcm/mustard.html
sunflower: http://www.buzzle.com/articles/facts-about-sunflowers.html
http://www.theflowerexpert.com/content/mostpopularflowers/morepopularflowers/sunflower
http://www.hort.purdue.edu/newcrop/afcm/sunflower.html

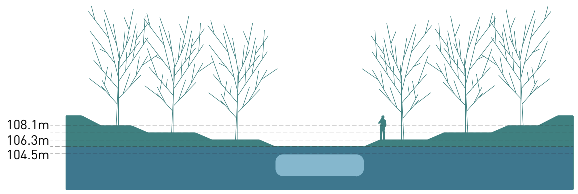
Landscape Criteria

Plant Study



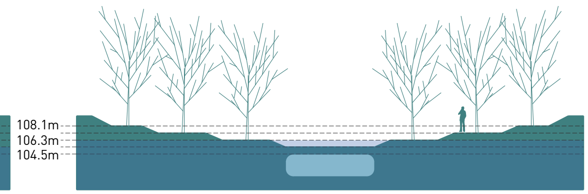
Landscape Criteria

ELEVATION - VERY LOW
+ 102.7m



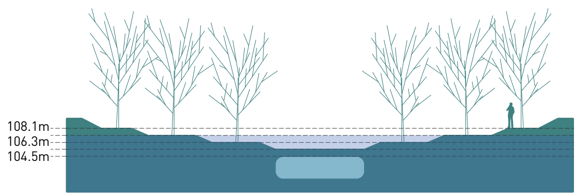
1 YEAR

ELEVATION - LOW
+ 104.5m



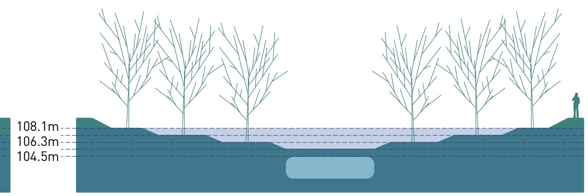
25 YEARS

ELEVATION - MESIC
+ 105.4m

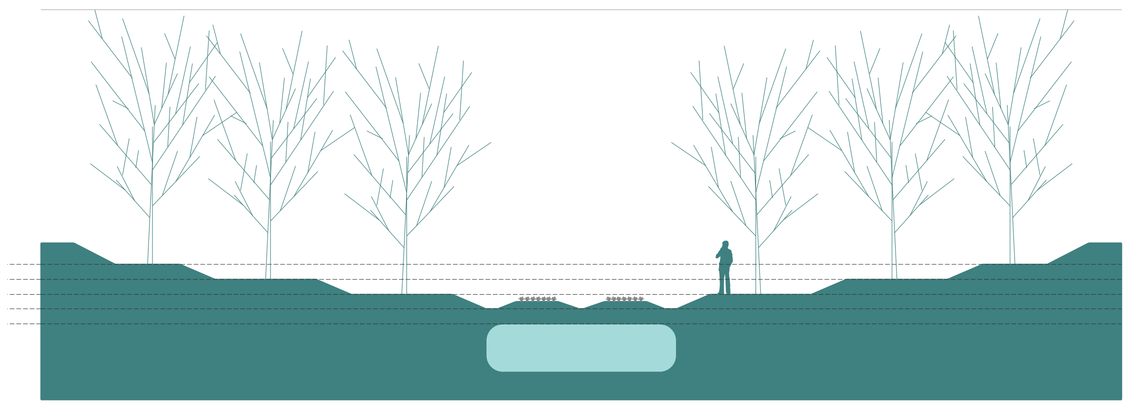


100 YEARS

ELEVATION - HIGH
+ 106.3m

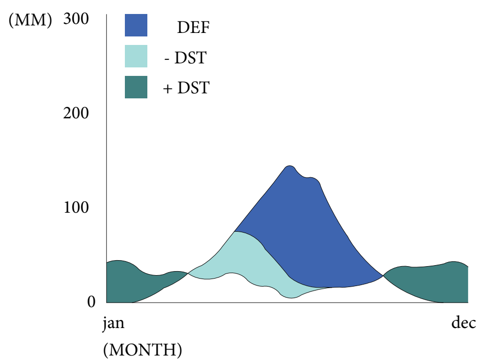


ALTERED ELEVATION - LOW
+ 104.5m



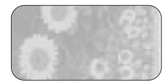
Landscape Criteria

WATER BALANCE AT HANFORD

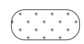


Source from WebWIMP
http://climate.geog.udel.edu/~wimp/index.html

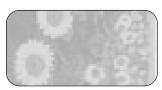
PHYTOREMEDIATION

AREA	BED QUANTITY	TOTAL AREA
 72 m^2	8	580 m^2
 48 m^2	5	240 m^2
 27 m^2	11	300 m^2
		1,120 m^2

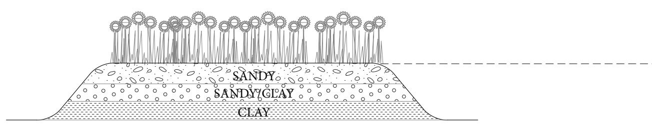
BIOSTIMULATION

AREA	BED QUANTITY	TOTAL AREA
	13	430 m^2

PLANT DISTRIBUTION

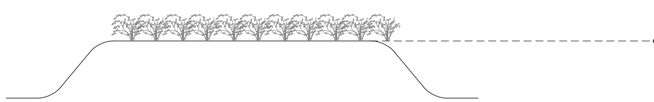


SUNFLOWER
CORN



100 YEARS FLOOD

GREEN
MUSTARD



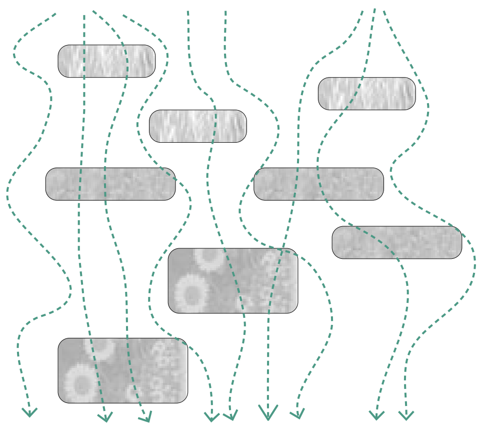
25 YEARS FLOOD

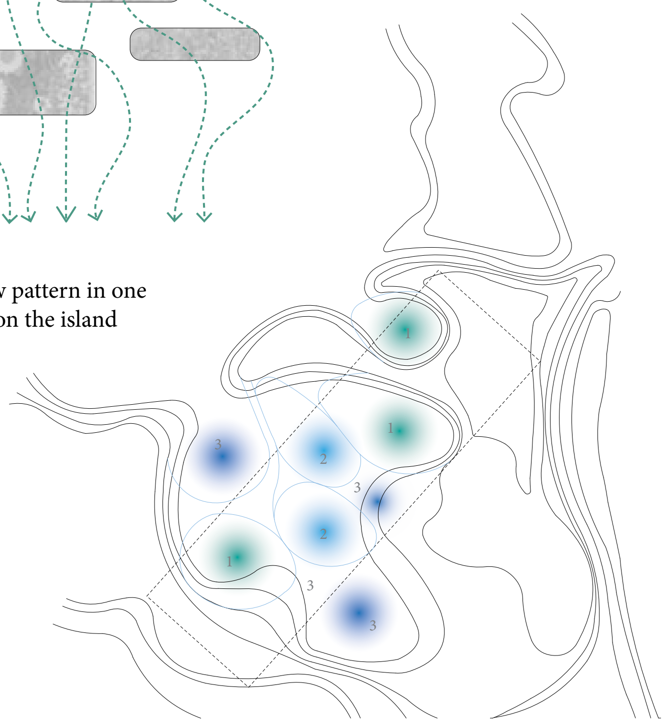
GRASS

1 YEAR FLOOD

Landscape Criteria

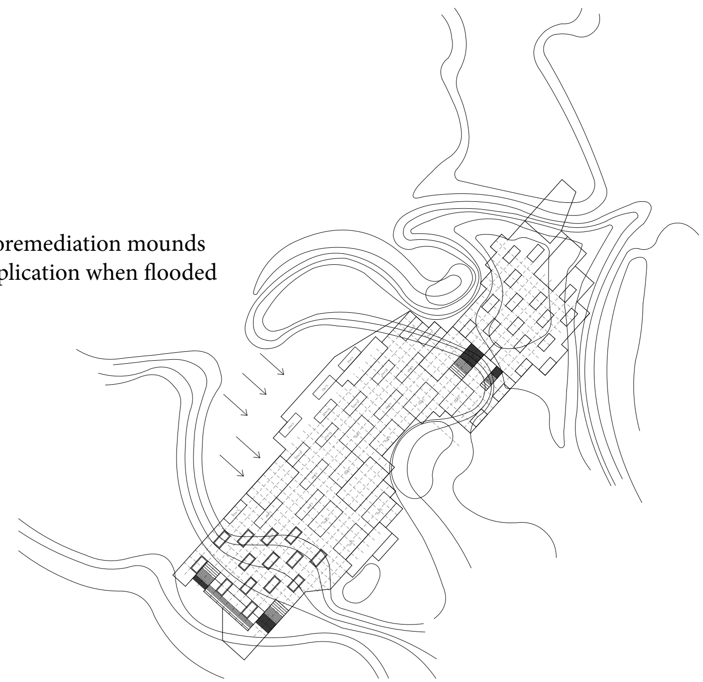
Phytoremediation mounds are laid out in sequence. The small mounds slow down the water flow and the large mounds absorb and treat large quantity of toxins in the water.





Water dynamic and flow pattern in one of the interstitial space on the island

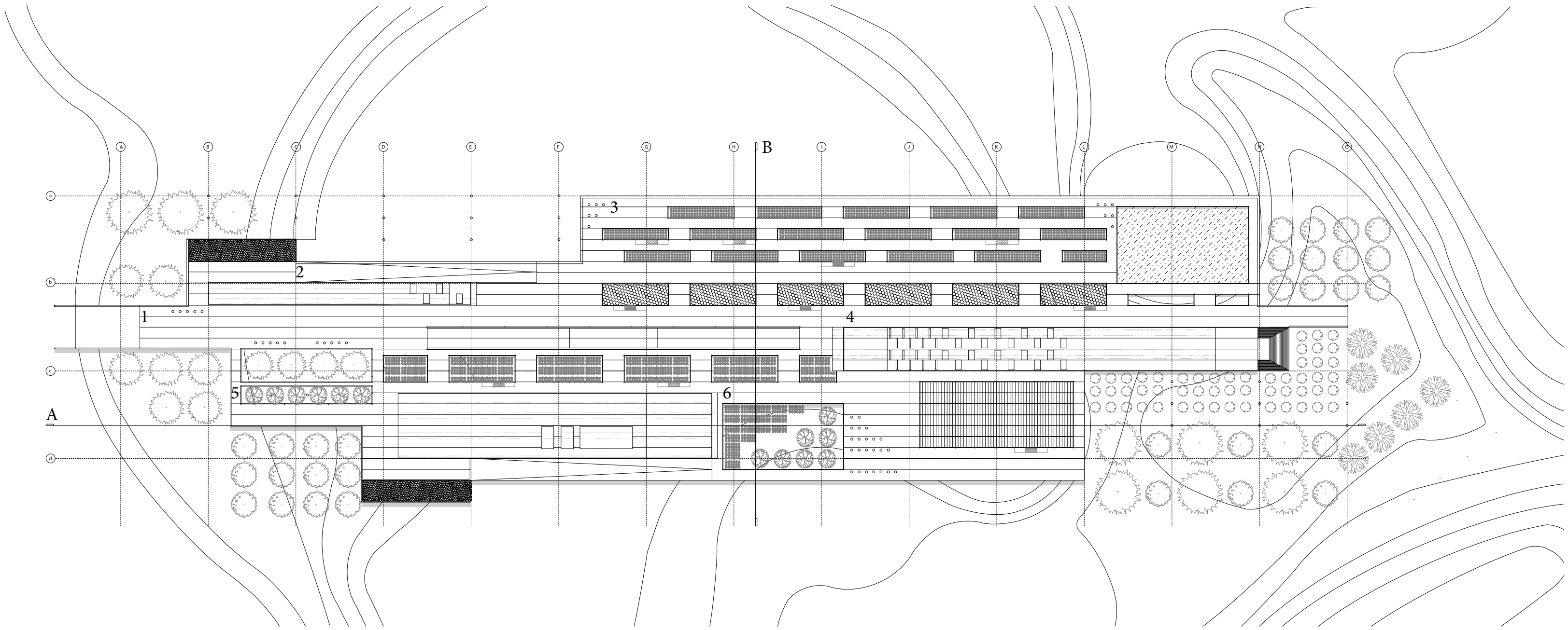
1 vortex
2 slow water flow
3 fast water flow



Phytoremediation mounds in application when flooded

PROGRAM

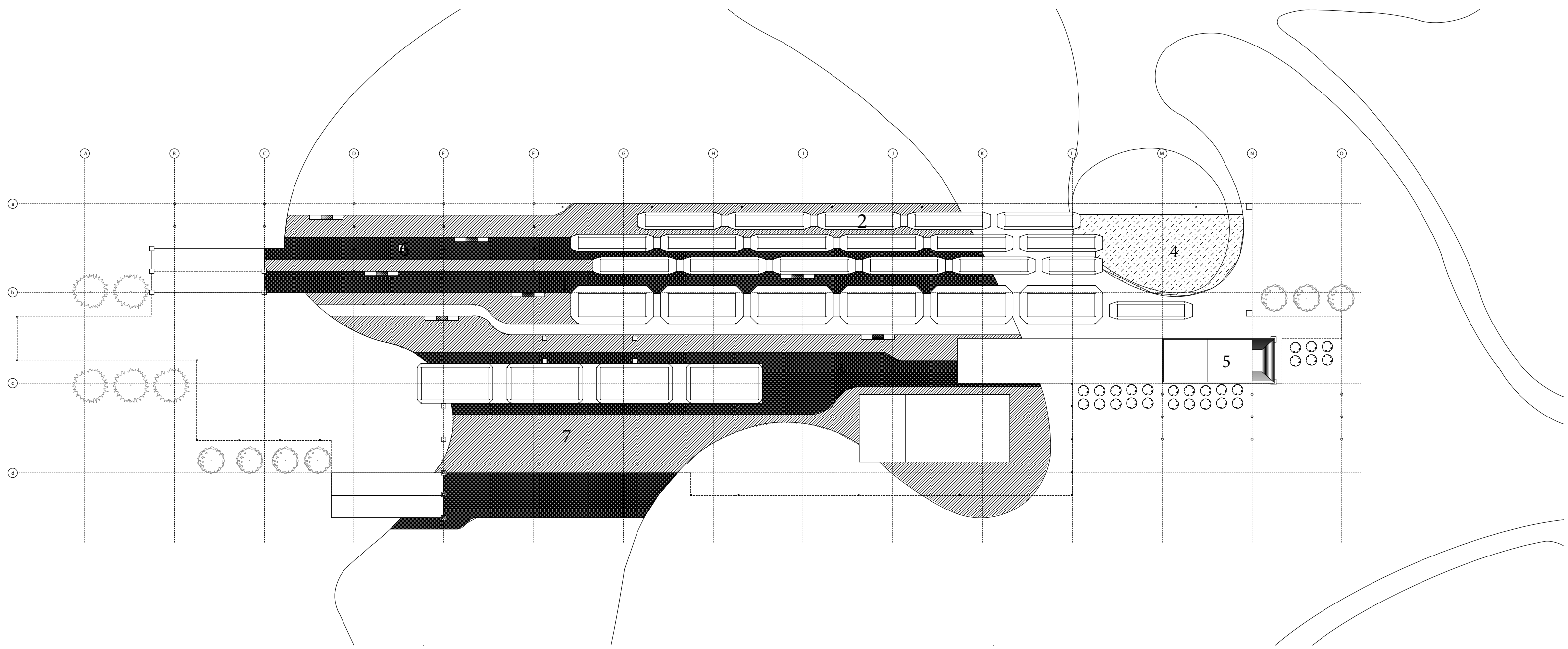
Programs



1:1000 SITE PLAN

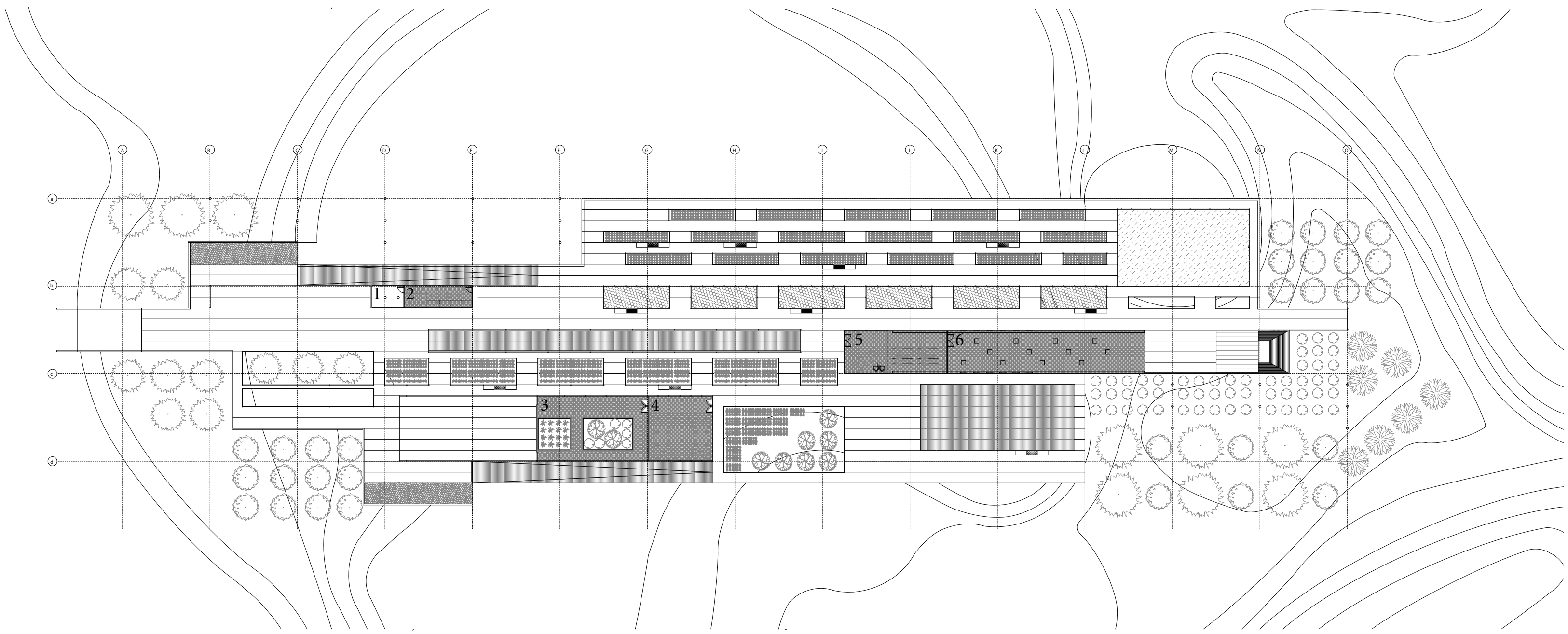
1. Close Experience Zone
2. Preparation Zone
3. Treatment Zone
4. Learning Zone
5. Research Zone
6. Recreation Zone

The Experiential Bridge is composed of a series of interrelated programs that support the learning experiences and the use of natural remediation technology. The main programs include testing and sampling labs, museum, processing and production lab, and landscape mounds that implement phytoremediation and biostimulation processes.



1:1000 GROUND PLAN

1. Viewing Area
2. Phytoremediation Mounds
3. Kayak Area
4. Water Storage/Biostimulation
5. Main Entrance
6. Biostimulation Testing
7. Phytoremediation Testing

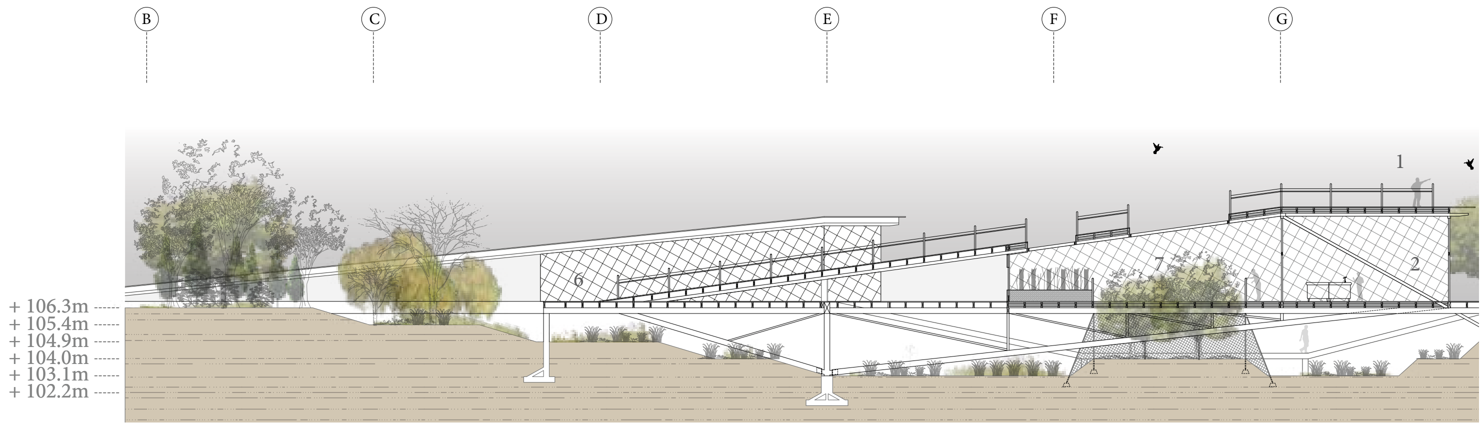


1:1000 BRIDGE PLAN

1. Biostimulation Testing
2. Processing
3. Phytoremediation Testing
4. Sample Lab
5. Recreation Zone
6. Museum

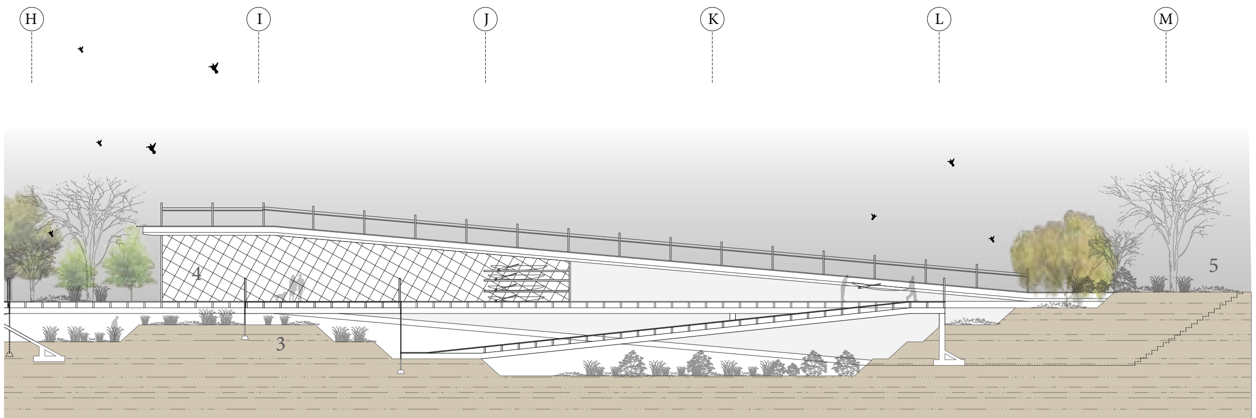
PERFORMANCE

Section A



1:400 SECTION A

1. Wildlife Watch
2. Sample Lab
3. Phytoremediation Mounds
4. Recreation Area
5. Main Entrance
6. Biostimulation Testing
7. Phytoremediation Testing


H
I
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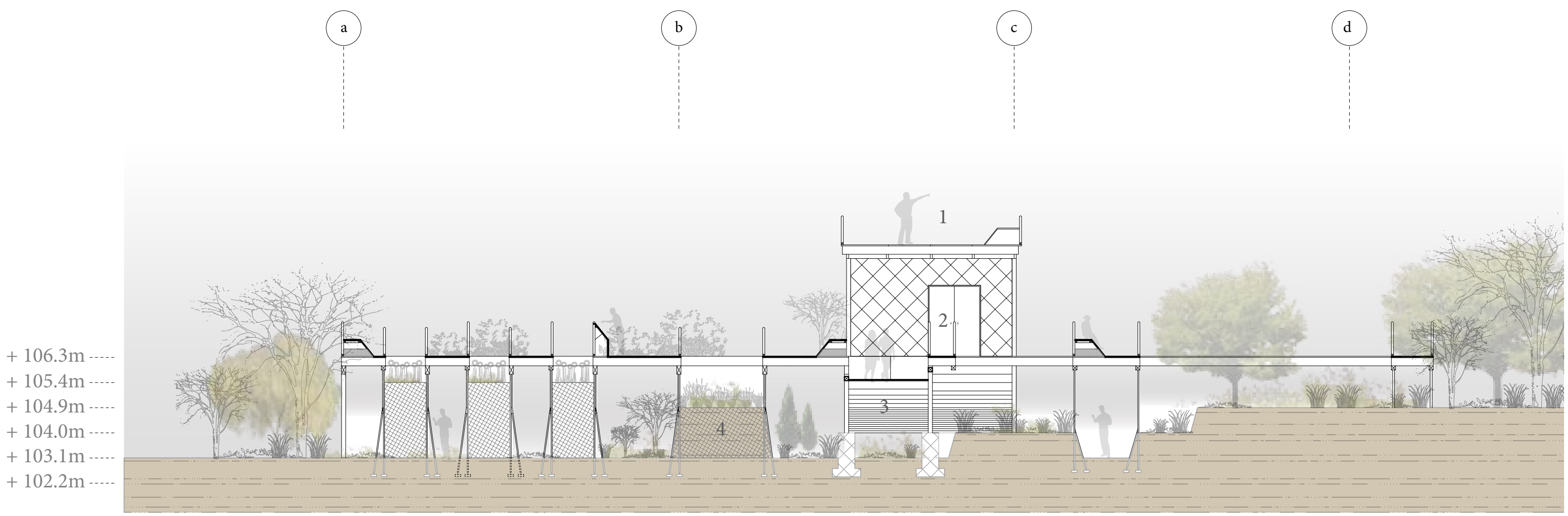
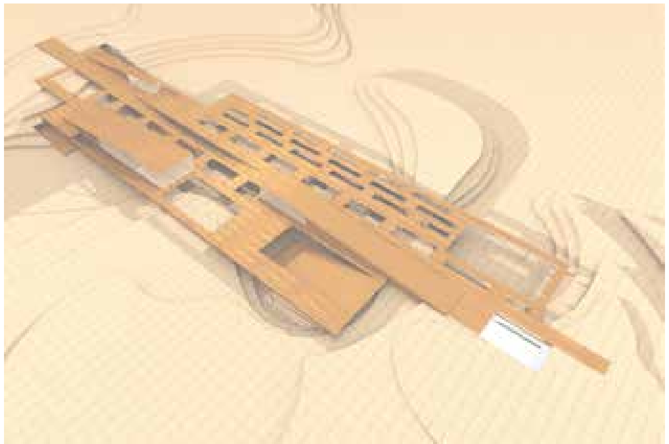
Section B



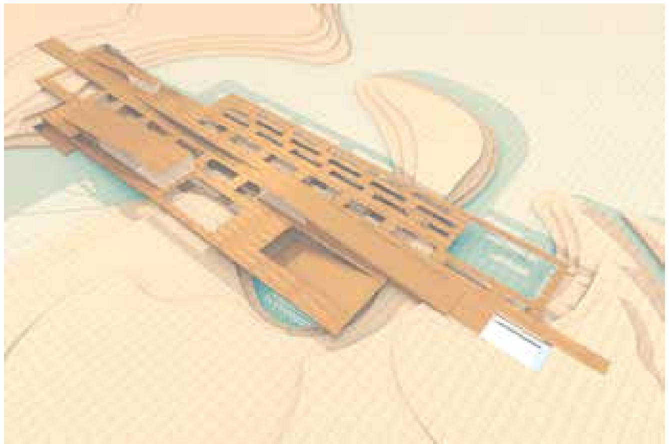
1:400 SECTION B

1. Wildlife Watch
2. Recreation Area
3. Learning Ramp
4. Phytoremediation Mounds

Activities

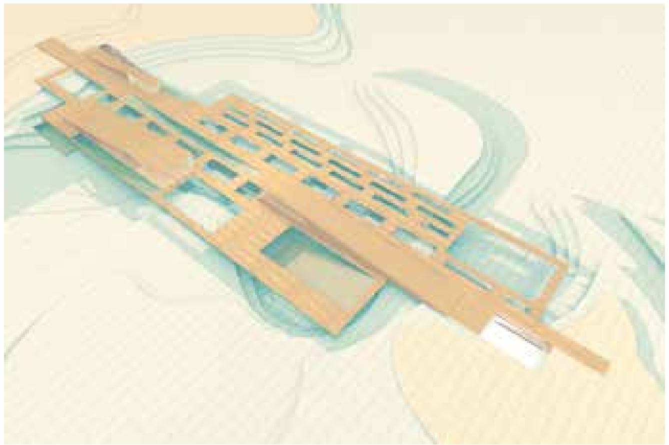


Unflooded
Water Elevation at +106.3m
Biostimulation Process: 100%
Activities: Landscape Viewing, Trail



Annual Flood
Water Elevation at +107.2m
Phytoremediation Treatment: 10%
Activities: Phytoremediation and Biostimulation Watch, Museum

25 Years Flood
Water Elevation at +108.1m
Phytoremediation Treatment: 25%
Activities: Kayaking & Fishing



100 Years Flood
Water Elevation at +110.0m
Phytoremediation Treatment: 100%
Activities: Wildlife Watch

The activities and interactions that occur at the Experiential Bridge change based on the flooding scenarios. When there is no flooding, the visitors are encouraged to visit the landscape area below the bridge as the phytoremediation mounds and biostimulation pipes are revealed.

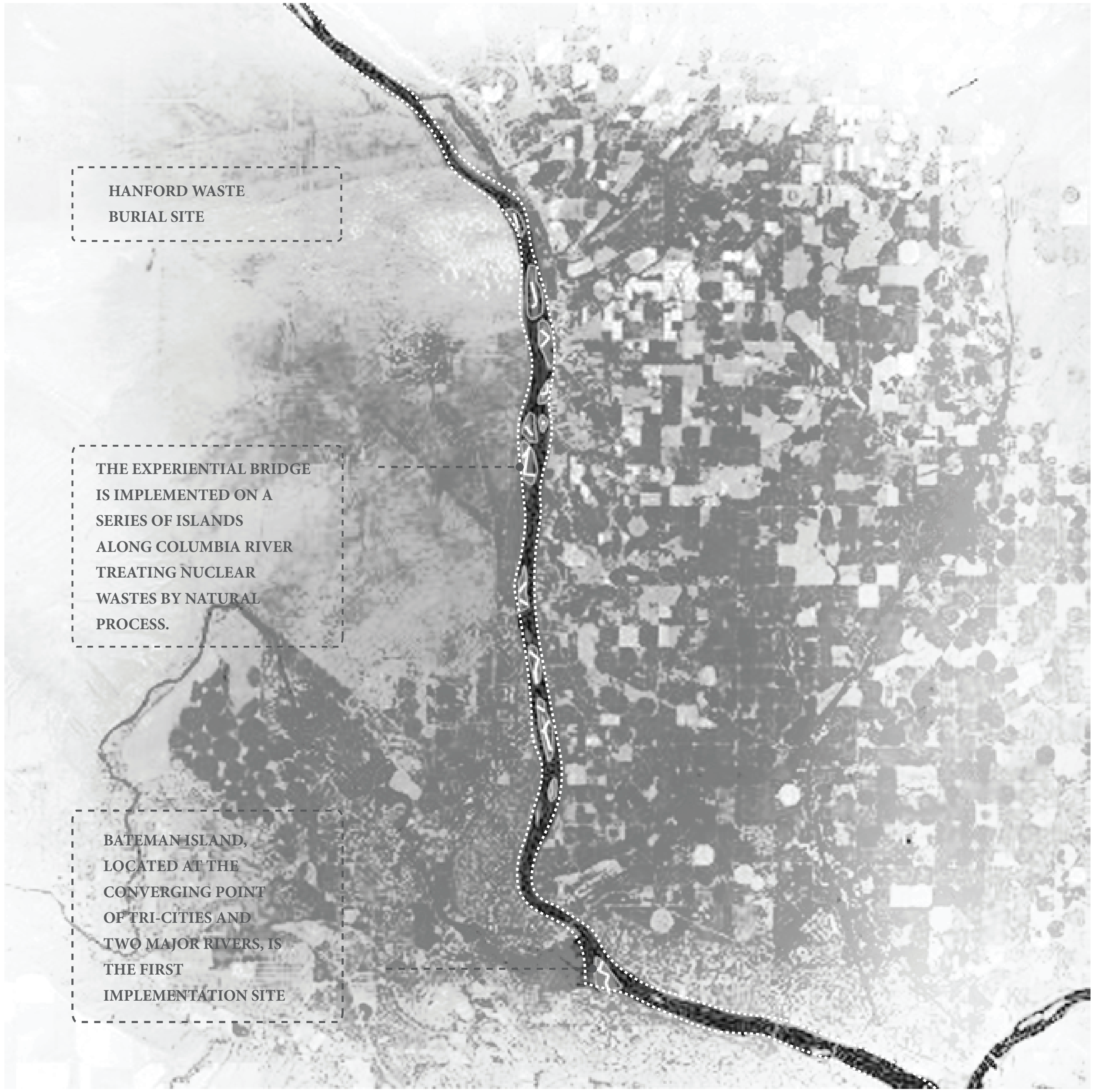
The ramps on the side of the bridge allow opportunities for people to see the sampling and processing inside the research labs as they make their way down to the phytoremediation mounds.

At annual flooding, the ramp located at the center is used to view the phytoremediation and biostimulation process. The ramp stops at 0.9 meters above the ground, thereby preventing humans from being in contact with the contaminated water when the island is flooded.

At 50 year flooding, kayaking is encouraged and remediation process is maximized.

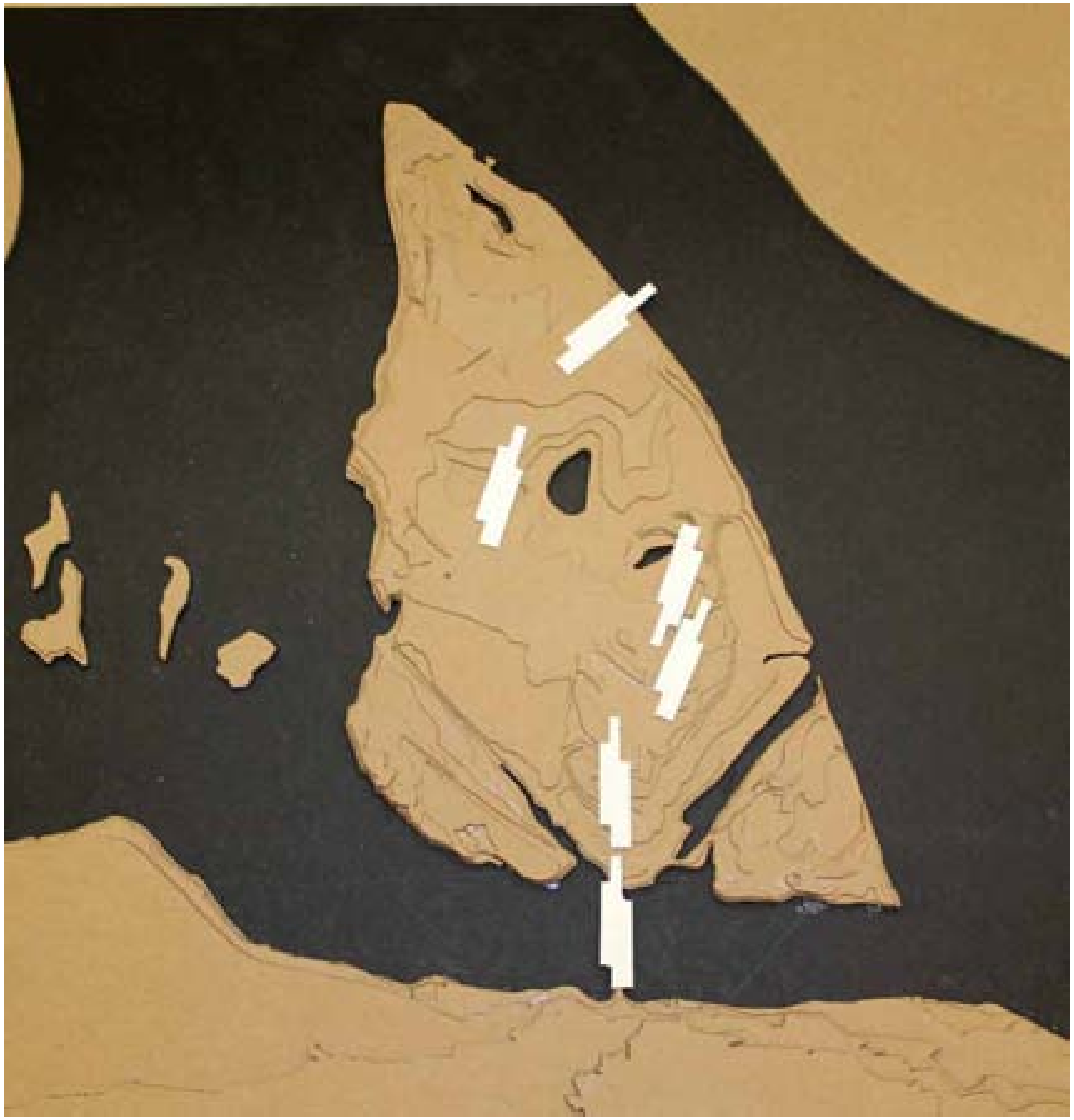
At 100 year flooding, the infrastructure is used as a pathway for people to travel and watch the wildlife.

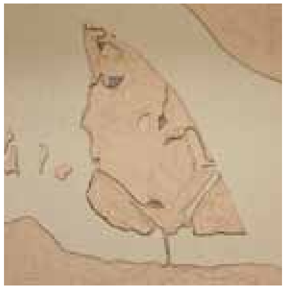
Details of phytoremediation mounds under bridge.

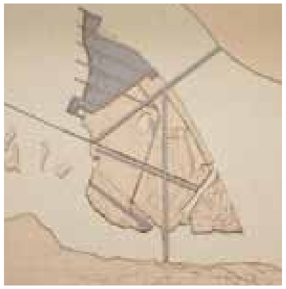

HANFORD WASTE BURIAL SITE
THE EXPERIENTIAL BRIDGE IS IMPLEMENTED ON A SERIES OF ISLANDS ALONG COLUMBIA RIVER TREATING NUCLEAR WASTES BY NATURAL PROCESS.
BATEMAN ISLAND, LOCATED AT THE CONVERGING POINT OF TRI-CITIES AND TWO MAJOR RIVERS, IS THE FIRST IMPLEMENTATION SITE

Each island has a series of bridges that connect the dry areas of land. Depending on the topographical and hydrological conditions, the bridges can be reconfigured as needed.

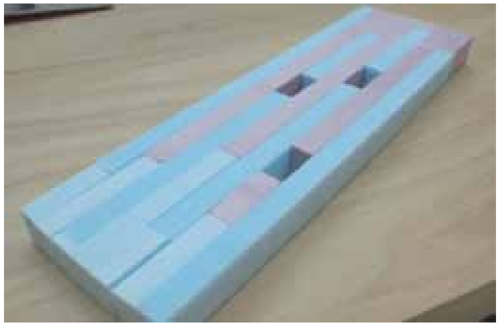
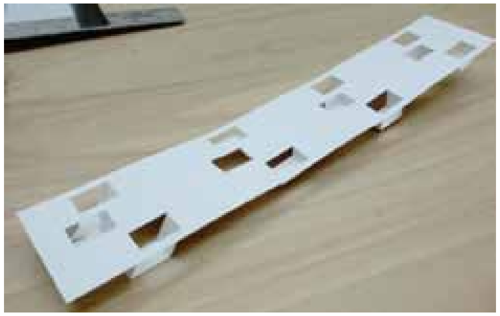
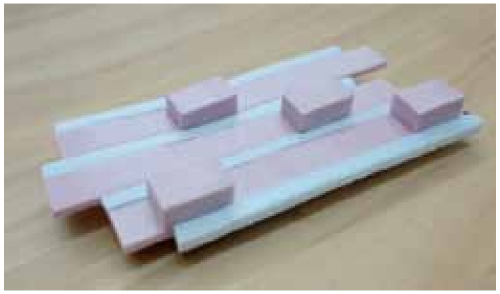
MODEL

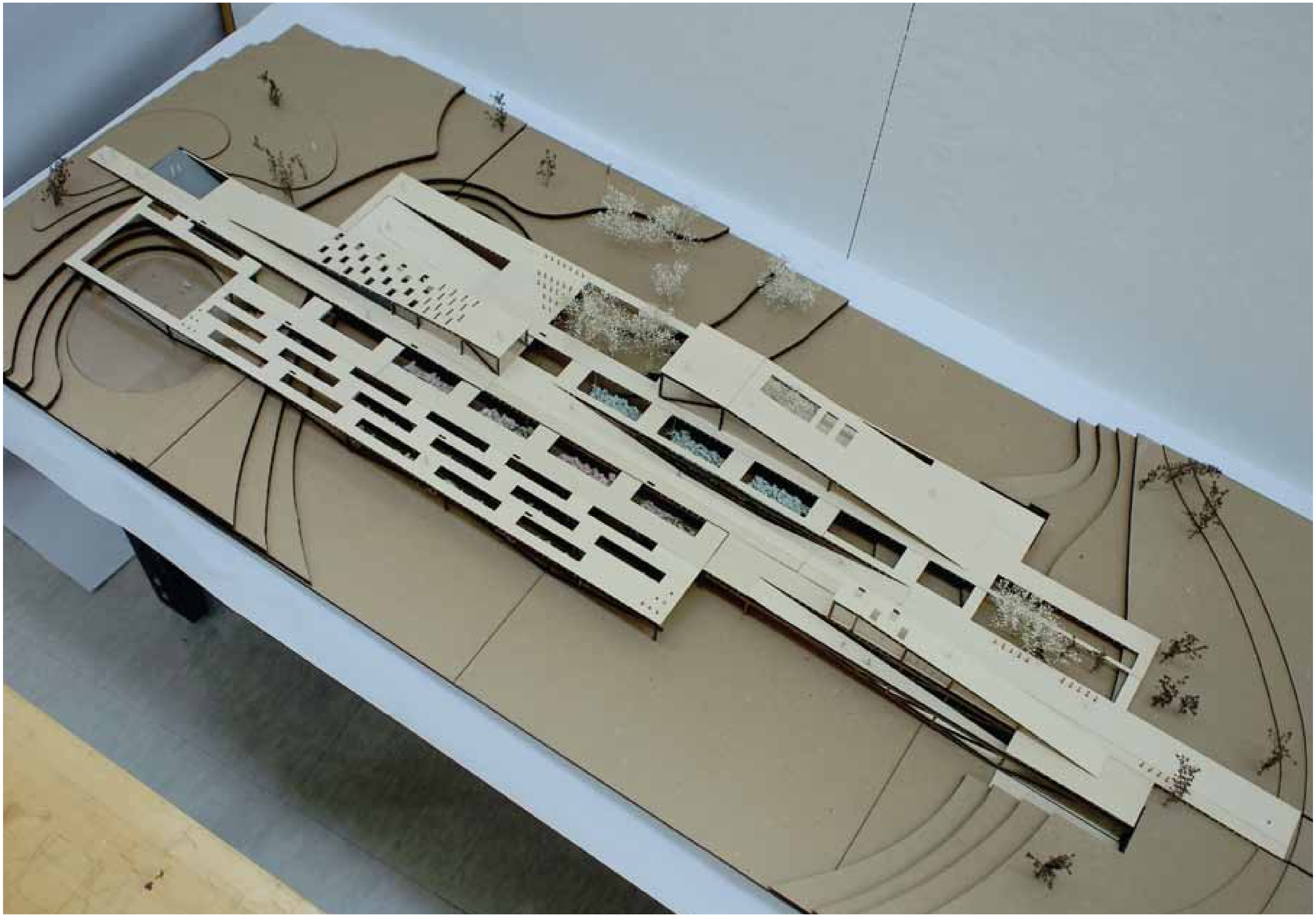


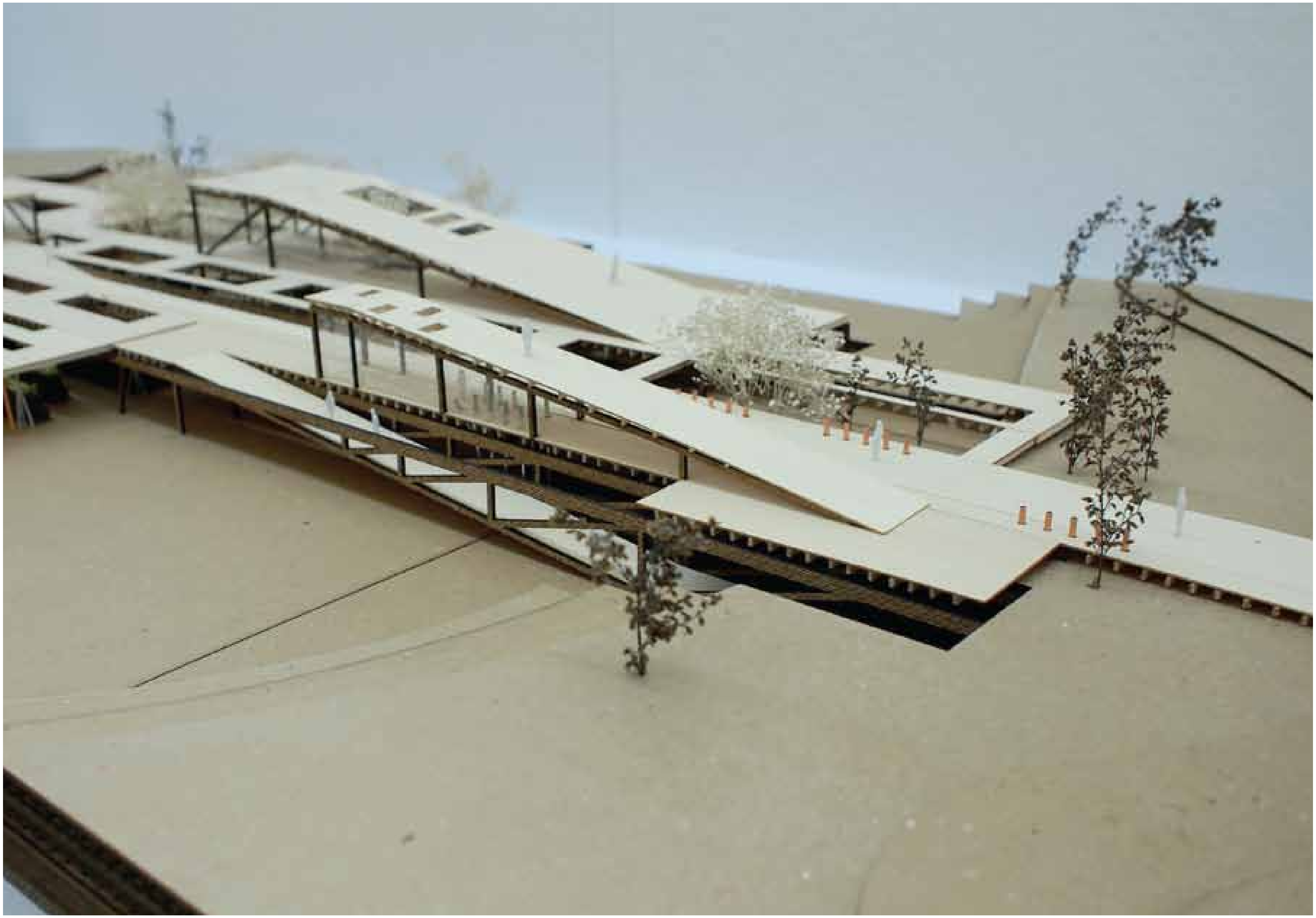


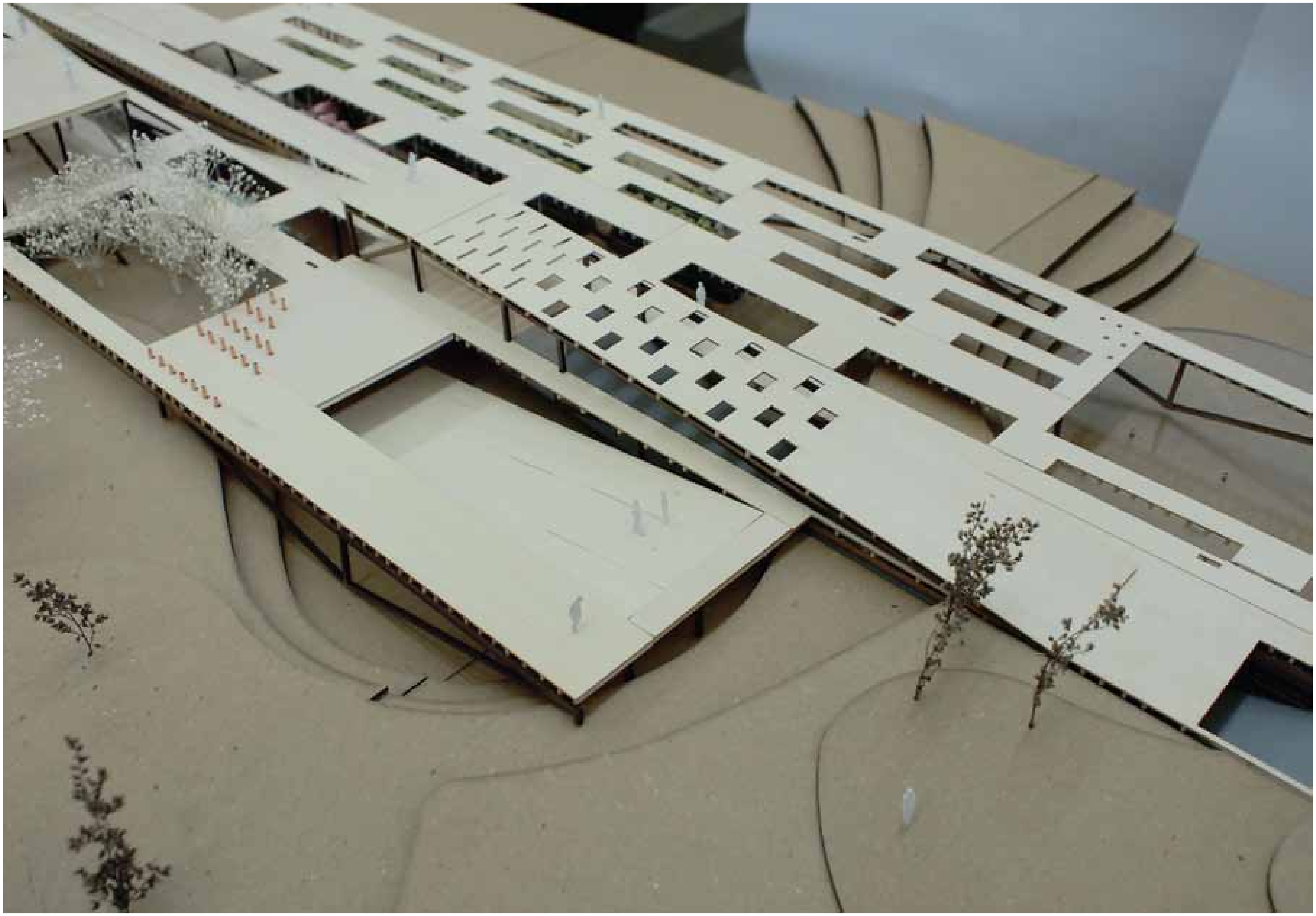


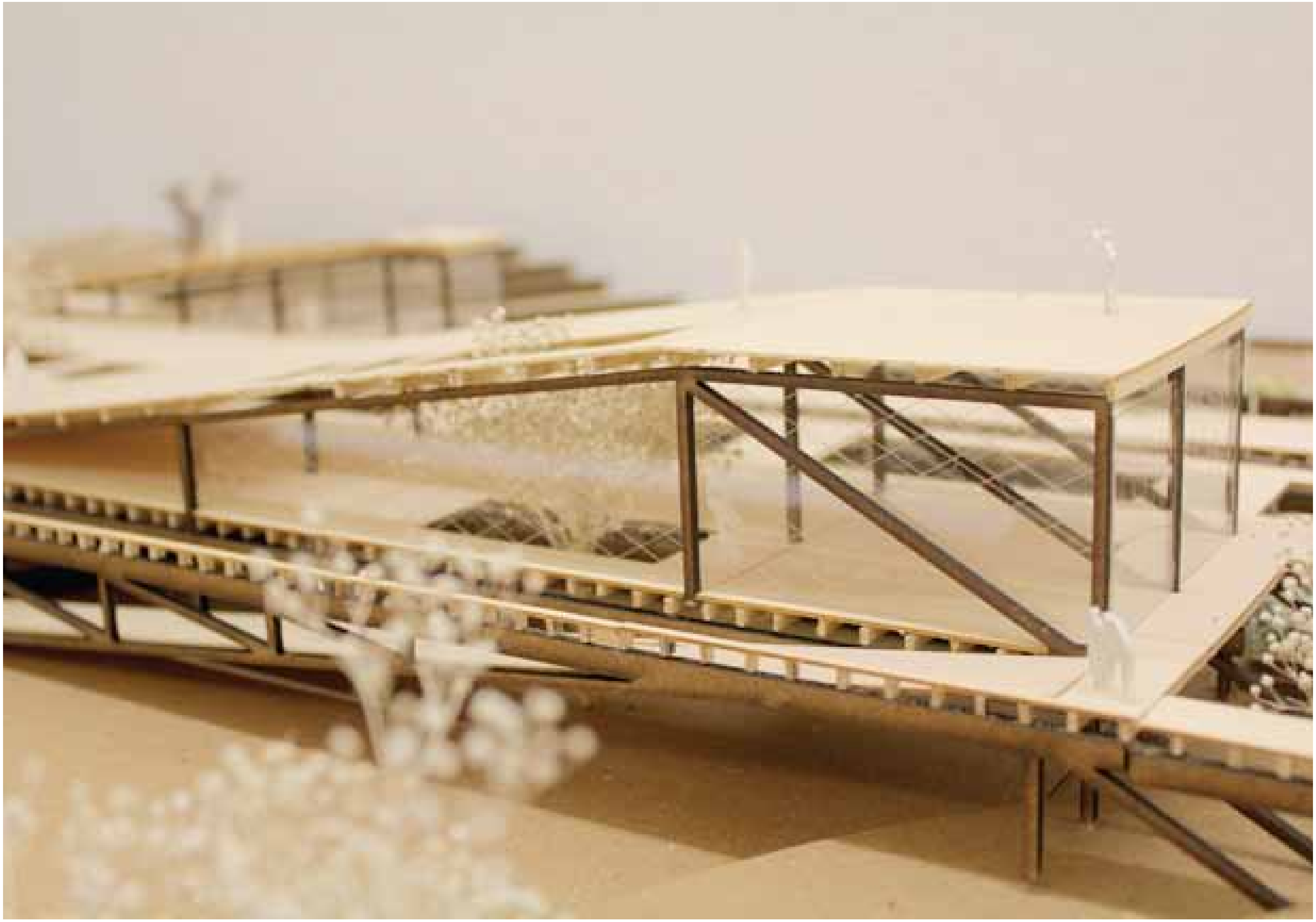


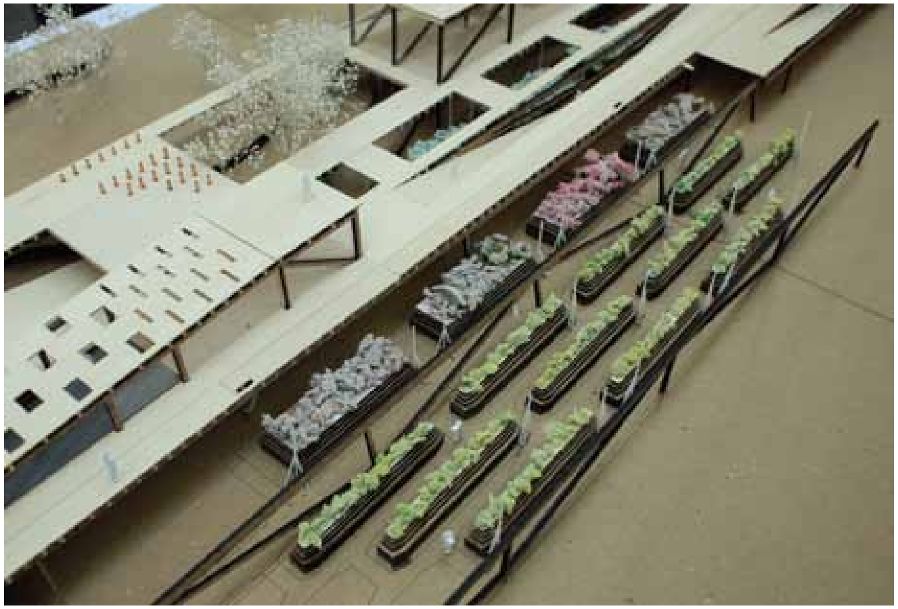




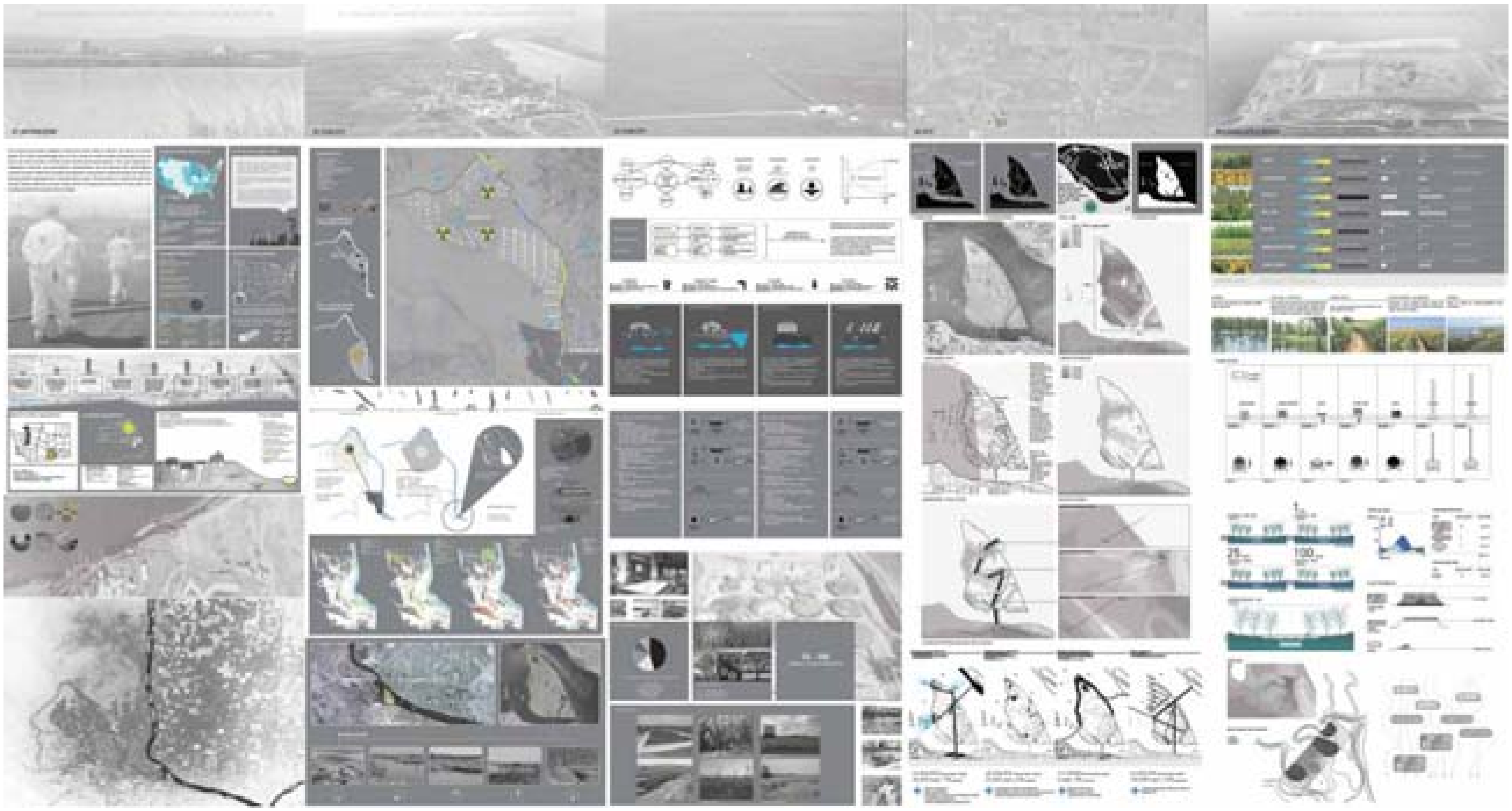


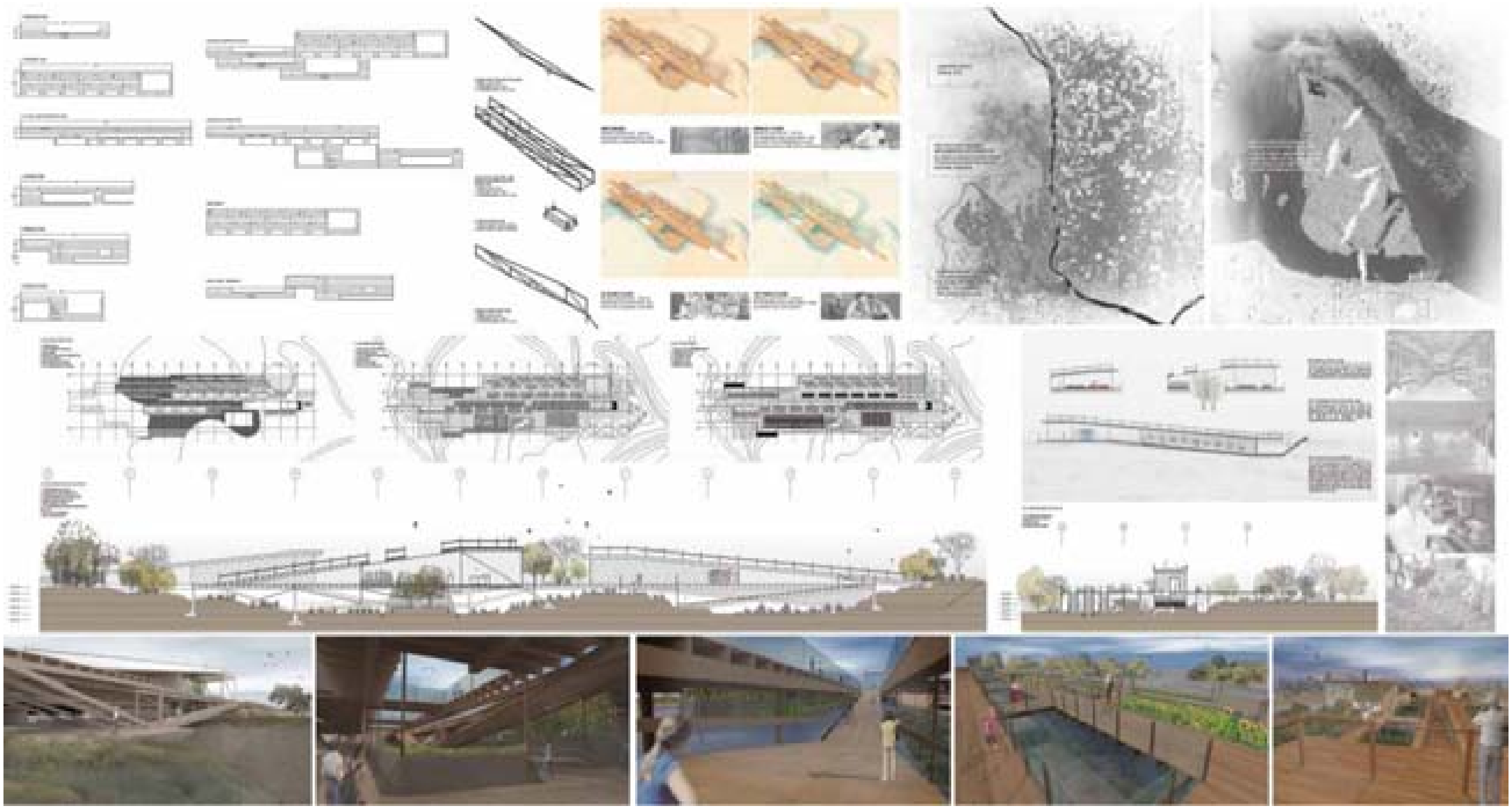






PRESENTATION





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The Experiential Bridge:
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