Volume I
Floating Wetlands Research

Biomimicry/Nature Case Studies // Vernacular Case Studies // Contemporary Local, National and International Case Studies // Proprietary Products // Literature Review of Floating Wetlands Performance

University of Washington
Spring 2013

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Foreword

Wetlands of many types are now recognized for their multiple high functional values, providing critical habitat, food production for many species of fish and wildlife, cleansing and storing water, and regulating temperatures. Yet our wetlands and waterways continue to degrade due to impacts of urbanization. How might we begin to restore the quality of these important environments, using the natural processes that occur in wetlands? Constructed floating wetlands are promising restoration tools, mimicking the processes that naturally occur in wetlands and nearshore environments while being cost and space effective. Yet while floating wetlands have been employed as useful green technologies around the world, little testing of their application has been done in the Pacific Northwest.

This document is the result of a seminar that investigated the feasibility of deploying floating wetlands in King County, WA, offered through the Green Futures Research and Design Lab at the University of Washington in the Spring of 2013. The seminar drew interest from 17 UW students in numerous disciplines who asked the questions "what can we learn from naturally-occurring, vernacular, and proprietary designed floating wetlands?" and "what research can inform the design of floating wetlands?" They applied this knowledge to explore and design floating wetlands for two distinctly different conditions: one, where shading of a newly constructed shallow freshwater wetland is required to keep temperatures sufficiently low to support fish species, and the other to enrich habitat and potentially improve water quality and cultural / ecological literacy in the Duwamish River mouth where excess shading can be problematic for juvenile salmon.

This document is divided into two volumes: Research and Design. The research volume is a window into a larger body of case studies and literature on floating wetland systems, aimed to inform designers, decision-makers and the general public on the breadth of interest in floating wetlands worldwide. The design volume documents the design process in the ten-week seminar, and highlights new floating wetland design ideas for the Lower Stensland Creek Wetland and South Park Bridge Duwamish River sites. It is our hope that these design ideas will be further developed into constructed demonstration projects in the near future.

We extend our many thanks to King County ecologist Mason Bowles, who initially approached the Green Futures Lab with an invitation to investigate the potential of deploying floating wetlands on the Duwamish River, assisted with fundraising and supported our investigations throughout the project. We are sincerely grateful for the generous financial support of Waterfront Construction, Inc., without which the robust research in the seminar and this document would not have been possible. Paul and Zach Wilcox from Waterfront Construction Inc., also presented their carefully designed prototype solutions, deepening the students' understanding of issues and possibilities for floating wetland applications. We are also indebted to our Advisory Committee who informed and guided the students through this creative and scientific process. Finally, thanks to the team of interdisciplinary UW students who have spent countless hours researching and creating over the past ten weeks. We hope that we will all continue the dialogue in the next phase of testing our designs, and that this document will be useful to all.

Nancy Rottle
Professor/Director Green Futures Lab, University of Washington

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Aquatic Plants

Biomimicry / Nature Case Study

Above Photo:
Nuphar polysepala, or Yellow Waterlily, is an aquatic plant native to Washington.

[http://www.keiriosity.com/]

Left Photo:
Aquatic Plants are generally categorized into four groups:
1) Algae
2) Floating plants
3) Submerged Plants
4) Emergent Plants

[http://aquaplant.tamu.edu/, http://www.ecy.wa.gov/]

Aquatic plants are generally categorized into four groups: algae, floating plants, submerged plants and emergent plants. All aquatic plants are adapted to living in water and can provide valuable habitat for fish, aquatic birds and invertebrates.

Algae: Algae are a distinct group of photosynthetic organisms that differ from typical land-based plants. Their size varies from microscopic, to larger plant-like forms. Algae lack true stems, roots and leaves and are found almost everywhere on earth. While healthy water bodies benefit from the presence of algae, increased nutrient loads from runoff may produce an overabundance of algae harmful to people and animals.

Floating Plants: Floating plants are not attached to the bottom, but rather have roots that hang in the water. Many floating plants store pockets of air in their stems and roots to keep them afloat. Examples of true floating plants are duckweed and bladderwort.

Submerged Plants: Submerged plants are rooted with most of their vegetative mass below the water surface, although some portions may appear above the water. Examples of submerged plants include eelgrass and pondweed.

Emergent Plants: Emergent plants are rooted plants often along the shoreline that stand above the surface of the water. The stems of emergent plants are somewhat stiff to withstand wave action. Examples include water lilies, cattail, and sedges. [aquaplant.tamu.edu/plant-identification/]

Design Considerations

Aquatic plants can be studied as a precedent to inform design elements for floating wetlands, taking cues from the field of biomimicry. Some considerations to examine:

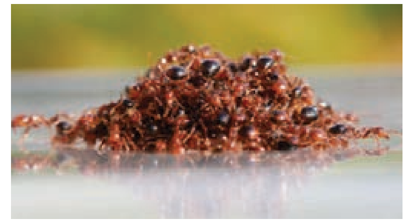
1. buyancy: aquatic plants have varying degrees of flotation, and use a variety of structures to keep themselves afloat (i.e. air pockets)

2. habitat: aquatic plants create habitat, both underwater and at the surface. Their root structures contain healthy microbial 'biofilms' and many native species are found to provide critical refuge for juvenile salmon and other vulnerable fish.

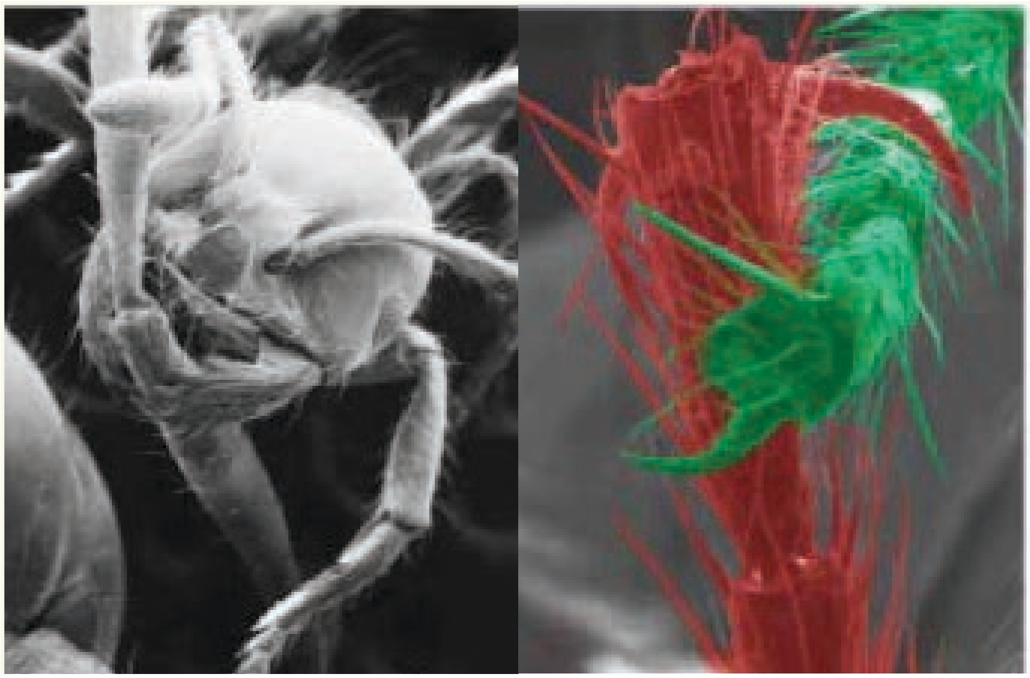
3. species: aquatic plants are adapted to similar conditions as those created by floating wetlands. Many also naturally filter the water and break down contaminants.

Fire Ant Rafts

Biomimicry / Nature Case Study



Above Photo:
A raft of 500 fire ants, composed of a partially wetted layer of ants on the bottom and dry ants on top. [Mlot et al. 2011]



Left Photos:
Scanning electron micrographs display the mandible to leg attachments in fire ant rafts. Individual ants are 0.5-2.5mm high and 1-4.5mm long. [Mlot et al. 2011]

Red Fire Ants (*Solenopsis invicta*), originally from Brazilian rainforests but also established in the United States, parts of Australia, New Zealand, and the Caribbean, self-assemble rafts to survive flooding. A colony can contain up to hundreds of thousands of individuals, and rafts can sail for months at a time. [Masterson 2007]

How:
Red Fire Ants self-assemble in a few minutes. Attachments are made by a combination of mandible, tarsi, and cohesive pads located at the ends of the tarsi. Fire Ants are hydrophobic and can trap a plastron (air) layer next to their body to create a rigid buoyant surface. [Mlot et al. 2011]

Design Considerations:
Flat vessel for flotation, floats due to buoyancy versus watertight qualities; living organisms with highly specialized social structures; self-assembling and self-healing; soap and other surfactants break up surface tension and may cause ants to drown due to density

Fire ants' cuticles are hydrophobic and can trap air creating a buoyant surface
[Mlot et al. 2011, bugguide.net]

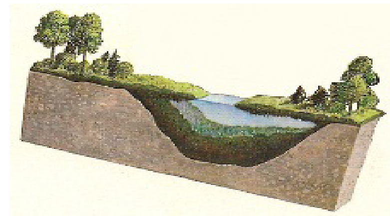
Sources:

Masterson, J. Smithsonian, "Smithsonian Marine Station at Fort Pierce." Last modified 2007. Accessed April 8, 2013. http://www.sms.si.edu/irlspec/Solenopsis_invicta.htm.

Mlot, Nathan, Craig Tovey, and David Hu. "Fire ants self-assemble into waterproof rafts to survive floods"PNAS. 108. no. 19 (2011): 7669–7673. 10.1073/pnas.1016658108 (accessed April 8, 2013).

Quaking Bogs / Schwingmoors

Biomimicry / Nature Case Study



Above Photo:
Section-perspective of a typical natural bog

[http://written-in-stone-seen-through-my-lens.blogspot.com/2011/06/walking-on-water-at-philbrick-cricenti.html]

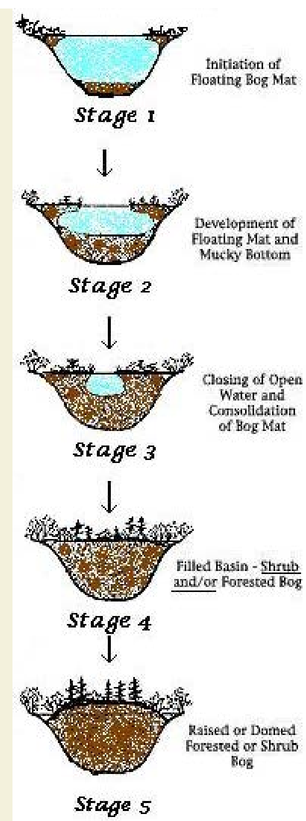
Left Photo:
A natural bog, or schwingmoor, formed from accumulated organic matter in low flow water

[http://en.wikipedia.org/wiki/Bog]

Bogs are formed by an accumulation of organic material in a wet or soggy location with poor or no water circulation. These bogs are often fed by rainwater, and typically acidic. Often these areas are great hosts for Sphagnum moss, whose layers of dead and living organic material create the bog, and an anaerobic environment. In this environment decay is dramatically slowed, allowing for the layers of peat to become very thick. Only certain specialized plants can live in bogs, some of which are Ericaceous shrubs such as heaths, as well as carnivorous plants, and some ferns and reeds.

Quaking bogs, or Schwingmoors, are bogs formed largely of sphagnum moss which floats over wet parts of bogs or in acidic lakes. The moss can be accompanied by, and held together with, other vegetation such as reeds. [Schwingmoor, wiki, 2013]

The floating mat can be up to 10 feet thick.
[What is a Quaking Bog, 2009]



Bog succession. [www.geocaching.com]

Some quaking bogs are able to support trees and human weight, but these loads may fall through if the bog is too weak to support the weight.

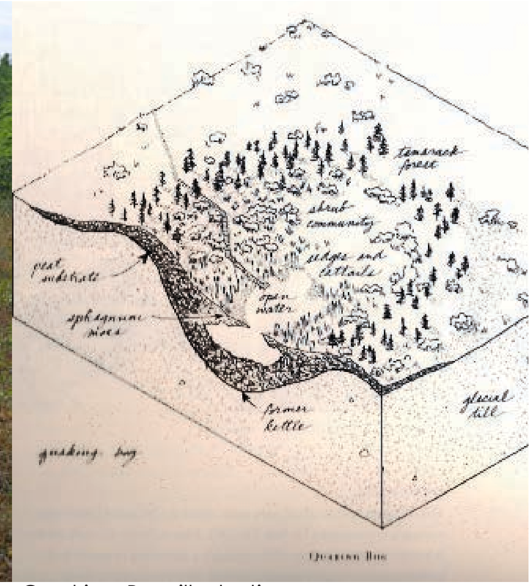
When a person walks on the quaking bog the mat gives with each step, causing the "quaking" of the quaking bog.

Over time, the bog may grow to cover the entire water surface, or may fill in underneath with organic matter so that it is no longer floating.

[Schwingmoor, every, 2013]

A natural Stage 4 Bog

[http://written-in-stone-seen-through-my-lens.blogspot.com/2011/06/walking-on-water-at-philbrick-cricenti.html]



Quaking Bog illustration

[http://nosleepingdogs.wordpress.com/tag/books/page/2/]

A close-up image of Sphagnum Moss

[http://written-in-stone-seen-through-my-lens.blogspot.com/2011/06/walking-on-water-at-philbrick-cricenti.html]

An example of bog/moss inhabitants:
(1) leatherleaf (2) bog rosemary (3) arethusa (4) grasslike-sedges (5) pitcher plant (6) sundew (7) labrador tea (8) cranberry (9) Solomon's seal

[http://written-in-stone-seen-through-my-lens.blogspot.com/2011/06/walking-on-water-at-philbrick-cricenti.html]

Sources:

"Bogs." Minneapolis Park & Recreation Board. N.p., n.d. Web. 13 Apr. 2013. <http://www.minneapolisparks.org/documents/activities/Bogs_Self_Guided_Tour>.

"Dystrophic Lake; Quaking Bog." YouTube. YouTube, 10 July 2008. Web. 13 Apr. 2013. <https://www.youtube.com/watch?v=0zlk615ffxg>.

"Geocaching." Geocaching.com. N.p., n.d. Web. 13 Apr. 2013. <http://www.geocaching.com/seek/cache_details.aspx?guid=171e5ed1-3832-4376-8cad-68a160e9646c>.

"Home Ground: Words of Our Native Land." Nosleepingdogs. N.p., n.d. Web. 13 Apr. 2013. <http://nosleepingdogs.wordpress.com/tag/books/page/2/>.

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"Quaking Bog 1." YouTube. YouTube, 09 May 2012. Web. 13 Apr. 2013. <https://www.youtube.com/watch?v=X01vrOkzljs>.

"Walking on Water." Blogspot.com. N.p., n.d. Web. 13 Apr. 2013. <http://written-in-stone-seen-through-my-lens.blogspot.com/2011/06/walking-on-water-at-philbrick-cricenti.html>.

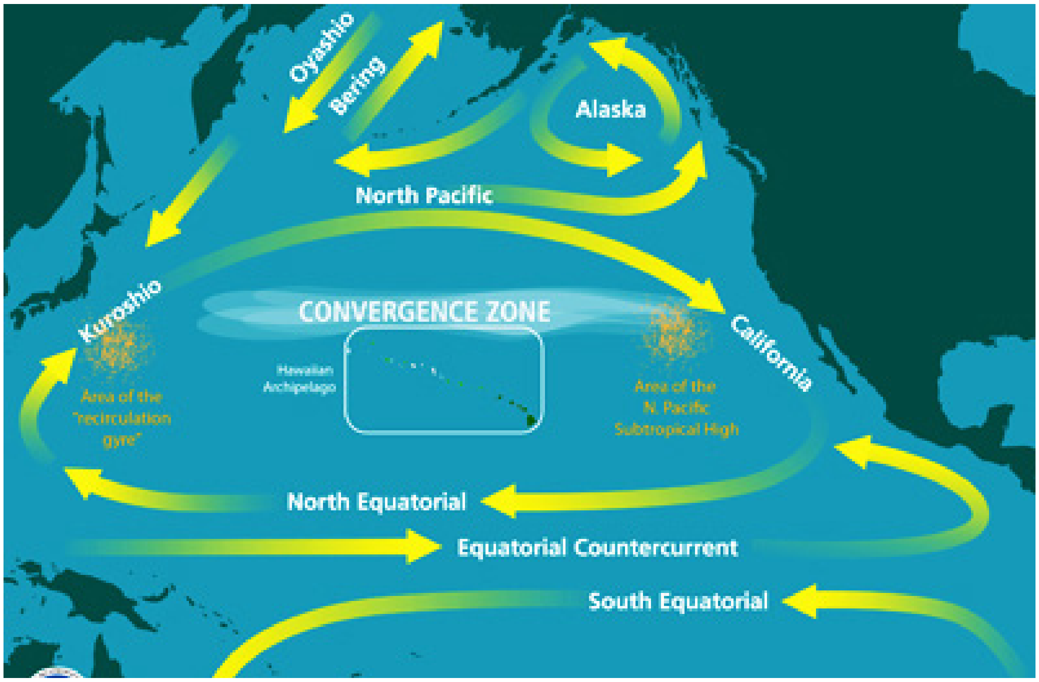
"What Is a Quaking Bog." YouTube. YouTube, 22 Apr. 2009. Web. 13 Apr. 2013. <https://www.youtube.com/watch?v=mOvzscVfbNY>

Great Pacific Garbage Patch

Ocean Current Case Study
Pacific Ocean

Above Photo:
Plastic bags are not indigenous to the Pacific Ocean.

[Norbert Wu/Minden Pictures]



Left Photo:
A highly simplified diagram of ocean currents in the Pacific Ocean that form the Great Pacific Garbage Patch.

[http://marinedebris.noaa.gov/info/patch.html]

The Great Pacific Garbage Patch is a collection of marine debris, mostly human litter, in the North Pacific Ocean. The Great Pacific Garbage Patch, also known as the Eastern Pacific Garbage Patch and the Pacific Trash Vortex, lies in a high-pressure area between Hawaii and California. Debris gets swept up by wind patterns and the forces created by the rotation of the planet in a 'gyre', where it becomes trapped and builds up over time.

No one knows how much debris makes up the entire patch. The North Pacific Subtropical Gyre is about 19 million sq. km (7 million sq. mi.). It is too large for scientists to trawl the entire surface and not all of the trash floats on the surface (denser debris can sink to the middle or bottom of the water). There is currently no way to measure this unseen litter.

The motion of the gyre prevents garbage and other materials from escaping, and the large amount of non-biodegradable materials creates accumulation over time. Many plastics do not ever degrade; they simply break into smaller and smaller pieces.

Trash from the coast of North America takes about six years to reach the Great Pacific Garbage Patch, while trash from Japan and other Asian countries takes about a year.

[National Geographic, 2013]

[www.mnn.com/earth-matters/translating-uncle-sam/stories/what-is-the-great-pacific-ocean-garbage-patch]

Because the Patch is so far from any country's coastline, no nation will take responsibility or provide cleanup funding. Many international organizations, however, are dedicated to preventing the patch from growing any further. Additionally, cleaning up marine debris is difficult. Nets designed to scoop up trash would catch animals as well. The vastness and depth of the ocean makes cleanup nearly impossible.

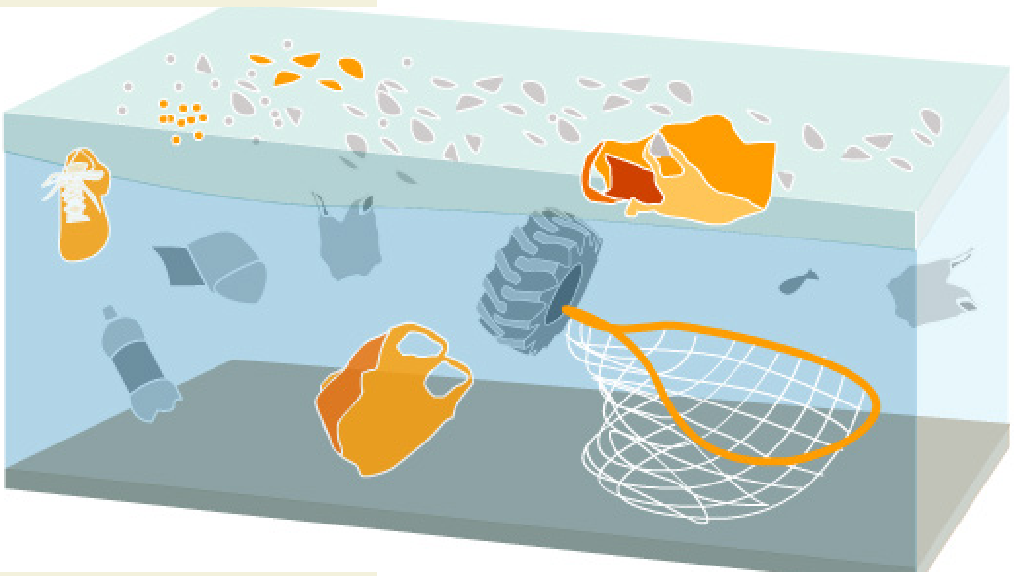
[National Geographic, 2013]

[http://www.localphilosophy.com/articles/great-pacific-grabage-patch.htm]

The patch is mostly made up of tiny bits of plastic, called microplastics. Microplastics can't always be seen by the naked eye. Satellite imagery of oceans does not show a giant patch of garbage.

Scientists have collected up to 750,000 bits of plastic in a single square kilometer (1.9 million bits per square mile) in the Great Pacific Garbage Patch.

[National Geographic, 2013]



[www.mnn.com/earth-matters/translating-uncle-sam/stories/what-is-the-great-pacific-ocean-garbage-patch]

Charles Moore, who discovered the patch in 1997, continues to raise awareness through his environmental organization, the Algalita Marine Research Foundation.
[National Geographic, 2013]

Source:

National Geographic, . "Great Pacific Garbage Patch." National Geographic. National Geographic, n.d. Web. 16 Apr 2013. <http://education.nationalgeographic.com/education/encyclopedia/great-pacific-garbage-patch/?ar_a=1>.

[www.mnn.com/earth-matters/translating-uncle-sam/stories/what-is-the-great-pacific-ocean-garbage-patch]

Lake Titicaca Reed Islands

Vernacular Case Study
Peru / Bolivia border, South America

Above Photo:
Floating Uros Village

[http://d1vmp8zzttzftq.cloudfront.net/wp-content/uploads/2012/04/Travel-To-Peru-Uros-Floating-Islands-Lake-Titicaca-Peru-1600x1066.jpg]

Left Photo:
The Uros people have lived on their floating villages since 1500 CE

[http://wallpaperswiki.org/wp-content/uploads/2012/10/Floating-Uros-Islands-Lake-Titicaca-Puno-Peru.jpg]

Uros people have occupied Lake Titicaca Puna, situated between Peru and Bolivia, since pre-Incan times. One band, the Uru-Iruitos, still live on the Bolivian side of Lake Titicaca and along Desaguadero River.

The Uru-Iruitos live on 57 islands, fashioned from totora reeds (*Schoenoplectus californicus subsp. totora*) a subspecies of the giant bulrush sedge. The islands can last up to thirty years before repair.

Uru-Iruitos rely on totora reeds to provide the majority of their material needs. Housing and other structures, screens, boats, sails, and much more are constructed from totora. Totora is also a staple food source.

Islands are four to eight feet thick. On a seasonal basis, new reeds are added on top to replace decaying reeds below. Reeds also root in waters below the islands, forming an interwoven mesh of roots, a living foundation. Islands are tethered to ropes, in turn tied to sticks anchored in the lakebed.

Aerial images of the floating villages [Google Maps]

Islands range in size from 20 to 30 meters wide and from 30 to 100 meters long.

Floating islands are very flexible and can be moved. Smaller islands can be combined to form larger islands.


[http://farm6.staticflickr.com/5031/7414007460_9a204ae826_z.jpg]


[http://www.perutoursdestinations.com/puno/llachon_island_02.jpg]

Today, the floating islands are a popular tourist destination, and much of the Uru-Iruitos culture has been modified to accommodate this industry. Reeds are still very much a part of daily life.

Sources:

http://www.laketiticaca.org/

http://www.darkroastedblend.com/2009/09/living-growing-architecture.html

https://maps.google.com/maps?hl=en&ll=-15.826939,-69.969212&spn=0.001997,0.002411&t=k&z=19&vpsrc=6

http://productforums.google.com/forum/#!msg/gec-people-cultures-moderated/UsvdtduBH-Q/7t-GJdpgKDYJ

http://en.wikipedia.org/wiki/Lake_Titicaca

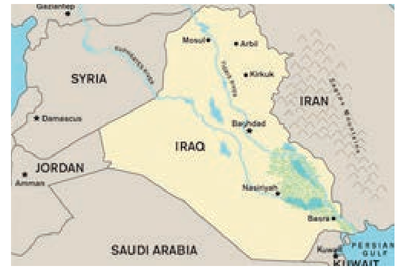
http://en.wikipedia.org/wiki/Uru_people

http://en.wikipedia.org/wiki/Totora_(plant)


[http://commons.wikimedia.org/wiki/File:Uros_kitchen,_lake_Titicaca,_Peru.jpg]

Mesopotamian Marshlands

Vernacular Case Study
Southern Iraq / Southwestern Iran



Above Photo:
The marshland is located between the Tigris and the Euphrates Rivers in southern Iraq and southwestern Iran.

[http://jeffweintraub.blogspot.com/2005/02/environmental-crime-of-century-saddams.html]

Left Photo:
These marshes were once the largest wetlands in southwest Asia and covered more than 15,000 square kilometers.

[http://www.pbs.org/wnet/nature/episodes/braving-iraq/image-gallery/6000/].

Many consider Iraq's Mesopotamian Marshes as the "Garden of Eden," the cradle of Western civilization. [Curtis, 2006]

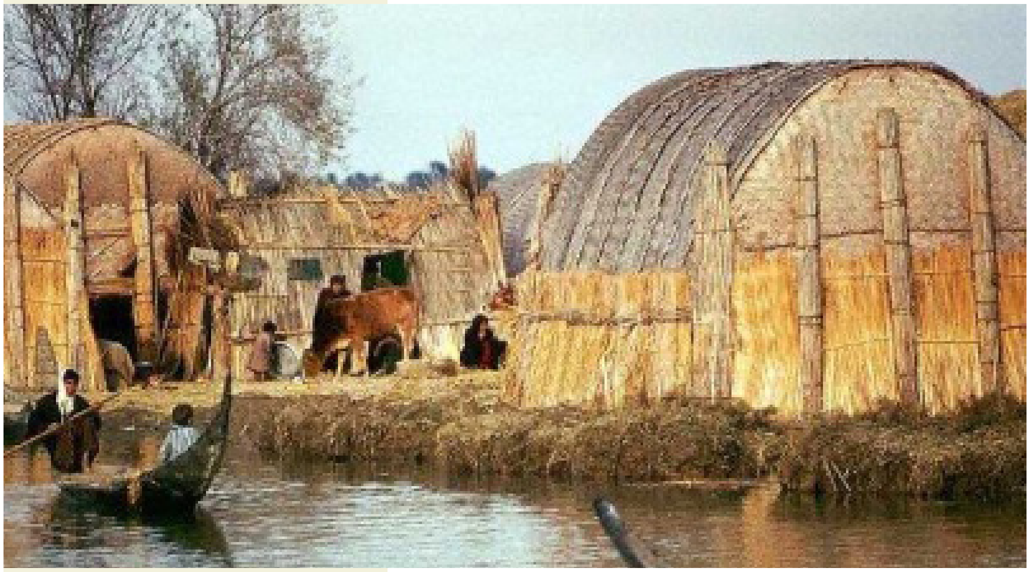
The draining of the marshes was at first intended to reclaim land for agriculture along with oil exploration but later served as a punishment to the Shia Arabs by Saddam Hussein's regime in response to the 1991 uprisings in Iraq. [Masour, 2003]

The marshes had been all but destroyed by the year 2000. They were ditched, diked and drained until less than 10% of the wetland area remained. Not only were these ecologically critical wetlands lost, but many of the 300,000 to 500,000 indigenous Marsh Arabs were displaced. [Curtis, 2006]

[http://www.pbs.org/wnet/nature/episodes/braving-iraq/image-gallery/6000/].

The Marsh Arabs speared fish from slender boats, herded water buffalo and fashioned vaulted houses from what materials the marshes had to offer: reeds, clay and buffalo dung. Reeds were the raw material for homes, baskets and boats. Builders lashed tall and seasoned reed shafts into thick bundles that they bent into arched supports for the vaulted roof. [Joe, 2003]

[http://www.greenprophet.com/2011/03/restoring-iraqs-marshlands/]



[http://db.flexibilni-architektura.cz/o/159]

Muddy stream beds provided clay for sun-dried bricks. Bitumen, a tarry material from shallow oil deposits, served as a waterproofing agent for rafts and roofs. [Joe, 2003]

The typical dwelling was roughly 2 meters wide, about 6 meters long, and a little less than three meters high, and was either constructed at the shoreline or on an artificial island of reeds called a kibasha. A more permanent island of layered reeds and mud was called a dibin. (Wilfred, 2008)

Sources:

Curtis J Richardson and Najah A. Hussain. (June 2006). "Restoring the Garden of Eden: An Ecological Assessment of the Marshes of Iraq." Accessed April 7th, 2013. www.biosciencemag.org.

Joe Rojas-Burke. (May 14, 2003). "Iraq's Marsh Arabs, Modern Sumerians". Simply Sharing. Accessed April 7th, 2013. http://www.simplysharing.com/sumerians.htm.

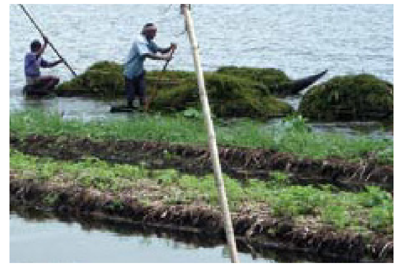
Masour Askari. (February 12, 2003). "Iraq's Ecological Disaster". International Review. Accessed April 7th, 2013. http://www.int-review.org/terr36a.html.

Wilfred Thesiger, The Marsh Arabs (Penguin Classics; Reissue edition 2008), p.92

[http://db.flexibilni-architektura.cz/o/159]

Bairas in Bangladesh

Vernacular Case Study
Baikantapur, Bangladesh



Above Photo:
Bairas are an indigenous practice used in Bangladesh for over 250 years to live with flooding conditions.

[http://www.agriculturesnetwork.org/]

Left Photo:
Bairas use much less water and nutrients than traditional agricultural practices, reduce water weed congestion, and improve household income, nutrition and land-use capacity.

[Wetland Resource Development Society]

Over half of Bangladesh is covered in wetlands, making it extremely vulnerable to flooding, cyclones and seawater intrusion. The effects of climate change- increased intensity and frequency of rain and monsoons- has flooded Baikantapur and other populated areas. The Bangladesh Centre for Advanced Studies is encouraging the ancient practice of 'bairas' as a solution to living in these extreme conditions.

At least 900 families in Baikantapur use bairas, or floating crops, so they can grow food during the flood season. Bairas are moved using boats and are left to decompose once the water recedes. Bairas are constructed in layers. Aquatic plants, mainly water hyacinths, are laid down between bamboo poles. Paddy stubs, straw and coconut husks are then added along with composted remnants of last year's bairas. After 7-10 days a second layer of water hyacinths is added, which decomposes in 15-20 days, and then seeds or seedlings can be planted. Seeds are sometimes placed in a ball of compost, manure and aquatic creepers to ensure successful germination and sufficient nutrients. Floating wetlands are subsequently anchored and covered in nets to prevent water fowl from foraging on crops.

Bairas are an interesting interpretation of floating wetlands- constructed purely through organic means and maximizing agricultural productivity.

[www.ipsnews.net/] [www.irinnews.org]

Sources:

Haq, A.H.M. Rezaul; Ghosal, Tapan Kumar; Gosh, Pritam. 2004.Cultivating Wetlands in Bangladesh. Leisa India.

Haq, A.H.M. Rezaul; Nawaz, K. Wadud. 2009. Soil-less Agriculture Gains Ground. Leisa Magazine. 25(1): 34-35 pp. Accessible from: http://www.agriculturesnetwork.org/magazines/global/farming-diversity/soil-less-agriculture-gains-ground/at_download/article_pdf

Irfanullah, Hasseb Md; Azad, Md Abdul Kalam; Kamruzzaman, Md; Wahed, Md Ahsanul. 2011. Floating Garden in Bangladesh: a means to rebuild lives after devastating flood. Indian Journal of Traditional Knowledge. 10(1): 31-38 pp.

IRIN. 2010. Bangladesh: Spreading the floating farms' tradition. Accessible from: http://www.irinnews.org/Report/90002/BANGLADESH-Spreading-the-floating-farms-tradition

Islam, Tawhidul; Atkins, Peter. 2007. Indigenous floating cultivation: a sustainable agricultural practice in the wetlands of Bangladesh. Development in Practice. 17(1): 130-136 pp.

Hicklin Lake Floating Islands

Local Case Study
King County, WA Department of Ecology Algae Control Program
Hicklin Lake, White Center WA

Above Photo:
Hicklin Lake in West Seattle is an impaired water body. Floating wetlands are currently being proposed as a way to improve water quality.

[www.westseattleherald.com/2011/09/30/features/hello-hicklin-lake-hicks-lake-white-center-ge]

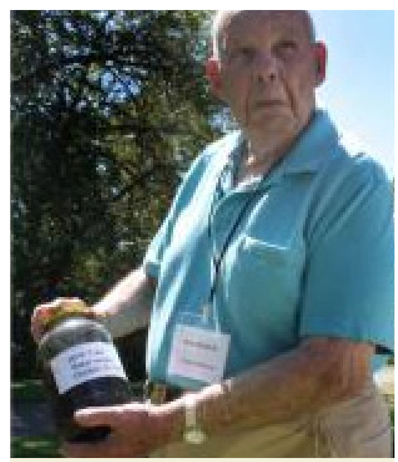
Left Photo:
The community and King County are hoping that the floating island technology will eventually lead to a clean Hicklin Lake where the community will once again congregate and swim.

[www.westseattleherald.com/sites/robinsonpapers.com/files/imagecache/3col/images/wwwwestseattleheraldcom/2012/08/img0038.jpg]

The Washington State Department of Ecology has identified Hicklin Lake as having "impaired" water quality because of excessively high phosphorus concentrations, which create dense algae blooms and biotoxins harmful to people and pets that come in contact with the water. Sewer discharges create an additional hazard for human and ecological health with fecal coliform bacteria. King County will be experimenting with technology that uses floating "islands" of vegetation to improve water quality. The lake has been treated twice with alum to reduce phosphorus levels – in 2005 and 2011. It is hoped that the floating islands will help reduce the need for alum or other in-lake nutrient controls.

A $50,000 grant from the WA Dept. of Ecology Algae Control Program will install and monitor four 250 SF floating islands in Hicklin Lake in the summer of 2013. Each island will be built of a durable polycarbonate, planted with native wetland plants and anchored in place.

DNRP is currently in the process of obtaining bids from floating island manufacturers, completing the permitting process, and finalizing the location and design plans with King County Parks. They hope to install the floating island system by the end of July, 2013.



King County staff will take monthly water quality samples from locations throughout the lake to test the islands' effectiveness at absorbing pollutants for three summers.

The project is expected to start spring 2013 and will be completed by June 2015 at a total cost of more than $86,000.

[www.westseattleherald.com]

Sources:

"Feb. 25: Water quality improvement actions floating into King County's Hicklin Lake ." King County, Washington. http://www.kingcounty.gov/environment/dnrp/newsroom/newsreleases/2013/February/02-22-hicklin-lake.aspx (accessed April 12, 2013).

Swenson, Ty. "Hicklin Lake will get four "Floating Islands" to aid cleanup effort | West Seattle Herald / White Center News." West Seattle Herald / White Center News. http://www.westseattleherald.com/2013/02/27/news/hicklin-lake-will-get-four-%E2%80%9Cfloating-islands%E2%80%9D-aid (accessed April 12, 2013).

Lake Union Floating Mystery

Local Case Study
Natural occurrence or unknown designer
Agua Verde Paddle Club, Seattle WA

Above Photo:
Agua Verde Paddle Club Dock and two employees

[photo by Don Mack]

Left Photo:
"The Little Mystery"

[photo by Don Mack]

A mystery floats upon Lake Union, resting and bobbing amidst boat wakes and gusty spring winds. Nestled in a corner between an armored shoreline edge and a sturdy concrete dock, a patch of saturated earth anchors the roots of a few dormant cattails, green grasses and rushes, a few stray and yellowed lily pads, and a string of English ivy.

What ecological functions does this living cast away perform?
The possibilities are many, but no definitive answers to this question yet.

What social boundaries and/or cultural limitations does this bio raft encounter and/or provoke?
The student investigator engaged two employees of Agua Verde Paddle Club, a kayak outfitter and rental service. When these two were asked if they were aware of a floating wetland in the vicinity, one immediately knew what the author was referring to. Yet he seemed to know nothing more.

See paraphrased quote on side-bar to right.

Based upon his statements, three conclusions rise to the surface.
a) He has heard this question before.
b) He doesn't like this "bunch of roots".
c) His dislike hasn't compelled him to remove it.

Design note: Aesthetics and Communication Matter.

Turtle Green. [photo by Don Mack]

"It just showed up, floated up to our dock. So we moved it over here. We don't know where it came from. Do you want it? Please take it away...
It used to have more soil. Now it's just a bunch of roots."

~Paddle Club Employee

Duwamish Living Barge

Local Case Study

Sarah Kavage (UW MUP), Nicole Kistler (UW MLA) + South Park Arts
Duwamish River, Seattle WA

Above Photo:
The Duwamish Living Barge art installation

[South Park Arts, 2013]

Left Photo:
The Living Barge was designed to create a dialogue about the history and future of the Duwamish

[South Park Arts, 2013]

The Duwamish Living Barge was a temporary art installation by University of Washington students partnered with local organizations. The 60' barge was planted with over 400 native ferns, shrubs and trees in April 2006. The purpose of the project was to create lasting, positive dialogue about the history and future of the Duwamish and the neighbors and businesses that surround it, while addressing the highly polluted industrialized river.

The project was a great success and the welcome reception included a performance from the Duwamish Native Tribe's dance troupe T'ilibshudub, tours of the adjacent South Park community and a wide attendance including council members.

Partners:
University of Washington, Environmental Coalition of South Seattle, South Park Neighborhood Association, Duwamish River Cleanup Coalition, Concord Elementary, Aviation High School, Friends of Cesar Chavez Park

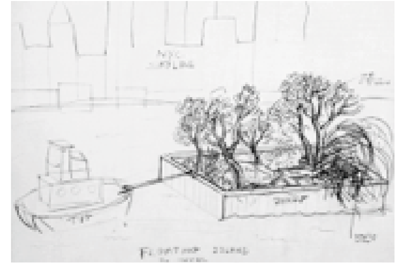
Funders and Donors:
Artist Trust, City of Seattle Department of Neighborhoods, Neighbor to Neighbor Fund, Duwamish Shipyard, Crowley Maritime Corporation, Denny Wetland Nursery, MsK Rare Plant Nursery, Natural Building Solutions, JS Landscape Design, King Conservation District, the Port of Seattle, Lehigh Cadman, The Re-Store, Starbucks, Cordova and Jones

The project was built using 400 native plants, pallets, pots, burlap bags to cover pots to prevent soil from leaking when it rained, beach logs and a barge loaned by Duwamish Shipyard [South Park Arts, 2013]

Source:
South Park Arts, "The Living Barge Project." Accessed April 16, 2013. http://www.livingbarge.com/index.htm.

Floating Island to Travel Around Manhattan Island

National Case Study
Robert Smithson
New York City, NY



Above Photo:
Robert Smithson's conceptual sketch of the Floating Island

[by Robert Smithson, http://www.nytimes.com/2005/09/16/arts/design/16floa.html]

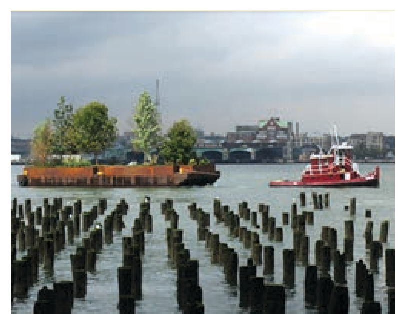
Left Photo:
Image of designed Floating Island to Travel Around Manhattan

[Robert Caplin, The New York Times, http://www.nytimes.com/2005/09/16/arts/design/16floa.html]

Floating Island to Travel around Manhattan was conceptualized by Robert Smithson in 1970. His rough sketch showed a man-made island with trees and boulders being pulled around Manhattan by a barge. Smithson was unable to secure funding for his project during his lifetime, however it was realized posthumously in 2005, corresponding with a travelling retrospective show at the Whitney Museum of Art.

The project cost about $200,000 and took about a week to construct [Kennedy 2005]. The island was created on a 30' by 90' barge and was pulled by a 45' long tugboat [Robert Smithson Floating Island 2008]. The installation was comprised of several species of full-grown trees in addition to boulders that were borrowed from Central Park.

Smithson was interested in the idea of bringing art out of the gallery and into the landscape [Robert Smithson Floating Island 2008]. The floating island was inspired by Central Park [Kennedy 2005]. Smithson was intrigued with the park's construction from an area that was formerly a wasteland. The island project speaks to the whimsy of Central Park and comments on this rise out of wasteland. At the time the project was conceived by Smithson, the waterfront along Manhattan was largely industrialized and inaccessible to the general population [Robert Smithson Floating Island 2008].



When the project was realized in 2005, the project funders hoped that the island would raise questions in the minds of those who had seen it.

[http://lyndsss.blogspot.com]

Sources:

Robert Smithson Floating Island, (December 2008), posted by user jlcpc on You Tube, available online at http://www.youtube.com/watch?v=UiimctQ9qWI.

Randy Kennedy, (September 16, 2005), "Its Not Easy Making Art That Floats," The New York Times, available online at http://www.nytimes.com/2005/09/16/arts/design/16floa.html.

Minneapolis Park

National Case Study
Tom Leader Studio and Kennedy + Violich Architecture
Minneapolis, MN

Above Photo:
A schematic rendering of RiverFIRST: A Park Design Proposal and Implementation Plan for the Minneapolis Upper Riverfront. Floating wetlands will be integrated within the proposed park.

[http://www.hraadvisors.com/news/minneapolis-park-and-recreation-board-officially-adopts-riverfirst/]

Left Photo:
Rendering of proposed floating wetlands as part of the feasibility study for the park.

[http://www.minneapolisparks.org/default.asp?PageID=1352#Background].

Floating wetlands are being proposed as part of the design of Minneapolis Upper Riverfront Park. The design intent of the floating wetlands is to demonstrate renewed stewardship of the river, add habitat, and cleanse the river water.

The park is in the feasibility stage of design and is projected to be completed over 5 years (2012 - 2016). The park will be 5.5 miles of the upper Mississippi River, with 11 miles of river coast and connecting into 8 riverfront parks and 6 regional and national parks.

The floating wetlands were designed to offer water quality rehabilitation while providing scenic views and habitat for native plants and animals, including migrating birds.

Potential maintenance issues include winter removal or tethering vs. ice flows, becoming an "attractive nuisance", and access throughout the growing season.

Potential permitting issues are the structures have to be narrower than 8' to avoid a DNR permit (if combined are larger than 8' do require a DNR permit), structures must be no longer than necessary to accomplish their task, and the river is a USACE navigation channel.

Sources:
[http://www.minneapolisparks.org/documents/design/RiverFirst/2013-3-26RiverFirstSDUpdateAFCAC.pdf]

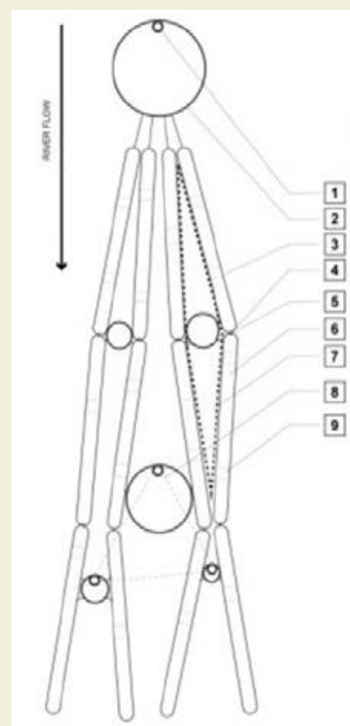


Diagram of a potential floating island module configuration.
[http://www.minneapolisparks.org/documents/design/RiverFirst/2013-3-26RiverFirstSDUpdateAFCAC.pdf]

Spiral Island

International Case Study
Richie Sowa
Mexico

Above Photo:
Spiral Island, designed by Richie Sowa

[http://www.playa.info/playa-del-carmen-forum/24640-spiral-island.html]

Left Photo:
Two story house on Spiral Island.

[http://www.environment.gen.tr/habitat-world/54-spiral-island.html].

Spiral Island was built by Richie Sowa in 1998 in Mexico based on his idea of low impact living. The structure was built on a base of 250,000 reclaimed plastic bottles sealed full of air and placed in mesh bags or nets.

The floatation devices were then attached to a bamboo frame and covered in plywood. The island was 66'x54', and was able to support full-size mangrove trees, whose roots penetrated the floating base and helped hold the structure together. [Environment, 2012]

The island was destroyed in 2005 by Hurricane Emily, but Sowa has built Spiral Island II in safer waters and hopes to take it out to sea. [Spooky, 2010]

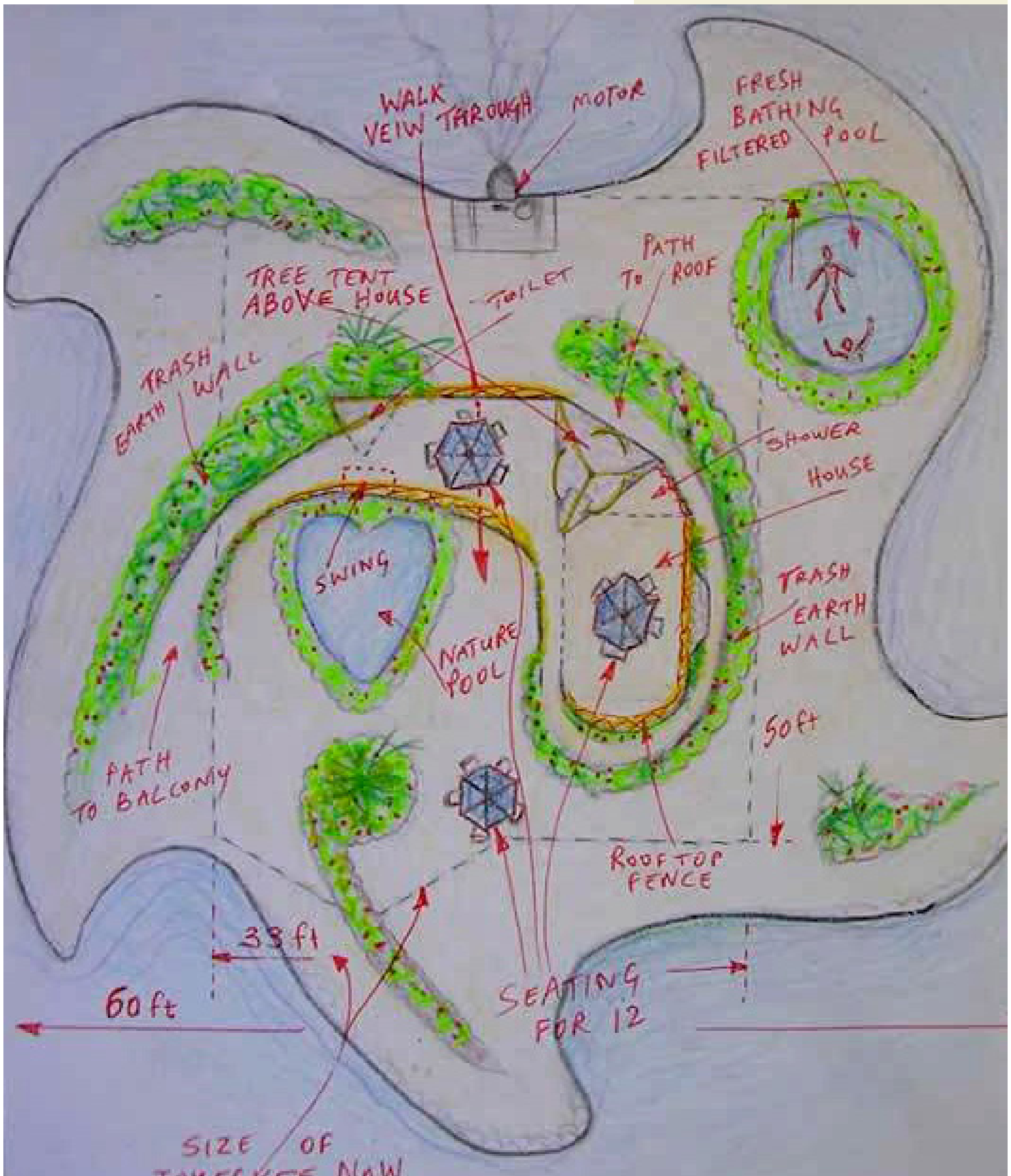
Plastic bottles in mesh bags are connected to a bamboo frame, supporting the island and allowing it to float.

[http://www.environment.gen.tr/habitat-world/54-spiral-island.html]

Construction of the floating base. [www.odditycentral.com]

Collecting and bagging plastic bottles for floatation [www.odditycentral.com]

Mangrove roots, a major benefit to holding the island together. [www.mbgnet.net]



Plans for Spiral Island II, also known as Joyesxee Island. [www.odditycentral.com]

Sources:

Environment - Ecology - Nature - Habitat - Gaia – Permaculture, "Spiral Island on Floating Bottles, Richie Sowa (Re)Builds Mexican Island Paradise on 250,000 Recycled Floating Bottles." n.d. Web. 19 Nov. 2012. <http://www.environment.gen.tr/habitat-world/54-spiral-island.html>.

Spooky, "Environmentalist Builds Floating Island with 100,000 Plastic Bottles." Oddity Central. Oddity Central, 16 Sept. 2010. Web. 24 Nov. 2012. <http://www.odditycentral.com/pics/environmentalist-builds-floating-island-with-100000-plastic-bottles.html>.

Rehberg Ranch Aerated Wastewater Lagoon

National Case Study

Floating Islands International, Headwaters Floating Island, the City of Billings and the Montana Board of Research and Commercialization Technology; Billings MT

Above Photo:
Rehberg Ranch first installation, Nov. 2009.

[www.floatingislandse.com/images/02._Rehberg_Ranch_Case_Study_1_.pdf]

Left Photo:
Rehrberg Ranch Lagoon about a year after completion, July 2010.

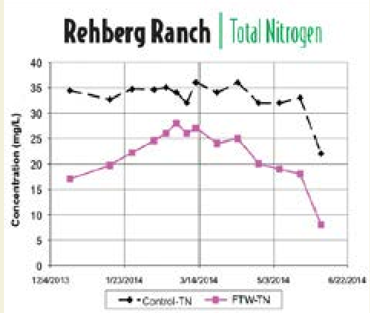
[www.floatingislandse.com/images/02._Rehberg_Ranch_Case_Study_1_.pdf]

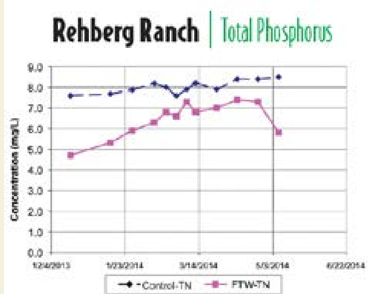
"Aerated lagoons are relatively shallow lagoons in which wastewater is added at a single point either at the edge or middle of the lagoon and the effluent is removed from another point"

"Located on the outskirts of Billings, Montana (pop. 120,000), the Rehberg Ranch residential subdivision (pop. 560) was built beyond the reach of the city's municipal sewer system. Developers constructed an aerated lagoon wastewater treatment system engineered and designed to meet US EPA secondary standards for Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS). Discharge options were limited to land application or surface water discharge, and nutrient levels in treated wastewater needed to be lower than the lagoons alone could deliver.

In this case, the treated wastewater is being land-applied to surrounding prairie grasses, rather than discharged into surface or groundwater. Prairie grasses are able to assimilate only low nutrient loads. In November 2009, FII, Headwaters Floating Island (HFI), the City of Billings and the Montana Board of Research and Commercialization Technology installed an experimental FTW design in one of the subdivision's two aerated lagoons. HFI continues to implement a rigorous monitoring regime to monitor efficacy of the FTW system in comparison to the control lagoon with no FTW. Both lagoons receive the same wastewater."

[FloatingIslandse, 2013]





The Rehberg Floating Treatment Wetland (FTW) has proven effective at removing nitrogen and phosphorus.

[www.floatingislandse.com/images/02._Rehberg_Ranch_Case_Study_1_.pdf]

“Floating Islands are made of layers of plastic matrix bonded together with marine foam. The foam provides buoyancy as well as adhesion. The plastic is 100% recycled polyester, PET, sourced from drink bottles, though other forms of plastic could be used. The foam is polyurethane. The standard reserve buoyancy is adjustable, from a typical island which is 5.5 lbs per square foot up to 61.5 lbs per cubic foot of island.” [FloatingIslandse, 2013]

[www.floatingislandse.com/aboutfloatingislands/islandscience.html]

Location: Billings, Montana USA
Installation: November 2009
Installed Cost: $70,000

Size: 8” thick; 2,300 sf FTW (1,300 sf submerged treatment area and 1,000 sf elevated plant growth perimeter)
Water Quality Improvement: Ammonia, nitrate, total nitrogen, total phosphorus, phosphate, TSS, BOD

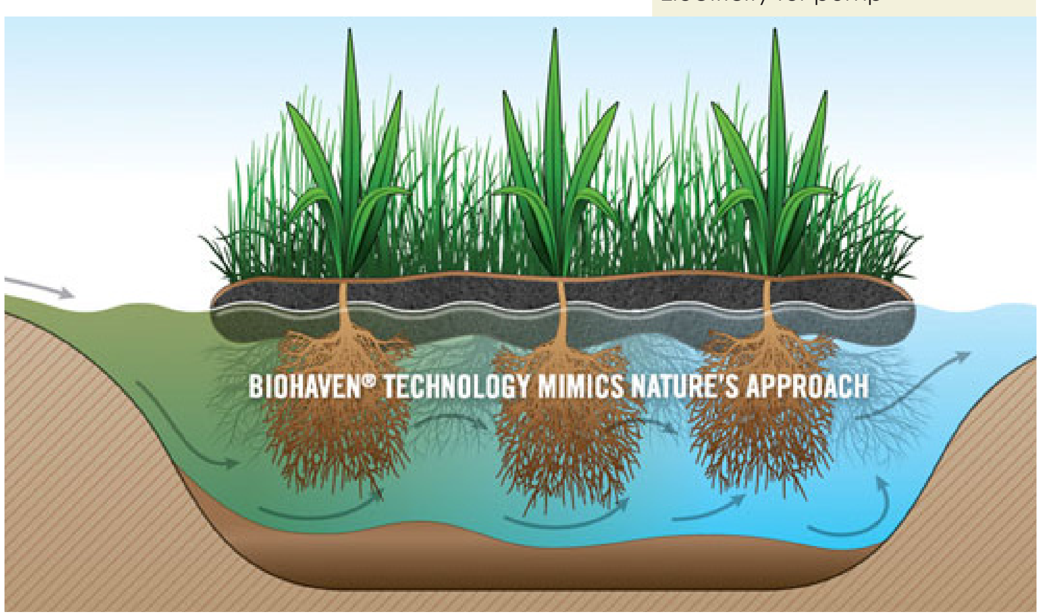
Water Source: Municipal wastewater from 140 homes
Flow Rate: 12 gpm (2.7 m3/hr)
Water Body Depth: ~ 12 ft
Water Body Area: 36,000 ft2
% Coverage: 6.4% of Lagoon Covered by FTW

Avg O&M Costs: 2 hrs/wk
Anticipated Lifespan: 10 years
Required Additional Inputs: Electricity for pump

[www.floatingislandse.com/moreinformation/viewslideshow.html]

Results:
“As of April 2010, FTW nutrient removal, compared with the control lagoon, has been significant. Removal of ammonia has improved by 38%, while the phosphorus removal rate has improved by 27%. Removal rates of TSS and BOD are 9% higher in the FTW lagoon than the control lagoon. Costs have been reduced because the lower nutrient levels in the water allow treated water to be applied to less land area at higher rates, reducing overall discharge costs by 50%.”

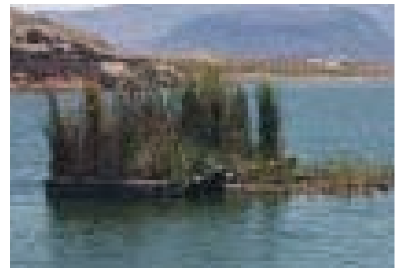
Source:
FloatingIslandse. Floating Island Southeast. Web. 9 Apr 2013. <http://www.floatingislandse.com/images/02._Rehberg_Ranch_Case_Study_1_.pdf>.



[www.floatingislandinternational.com/products/ftw-a-deeper-understanding/]

Las Vegas Bay FWIs

National Case Study
U.S. Department of the Interior's Bureau of Reclamation
Las Vegas Bay, Lake Mead, Nevada



Above Photo:
Planted floating wetland islands in Las Vegas Bay.

[www.lvwash.org/assets/pdf/resources_wqresearch_islands.pdf]

Left Photo:
Floating wetland islands were installed to simulate ecosystem services that were lost due to natural wetland habitat destruction.

[www.lvwash.org/assets/pdf/resources_wqresearch_islands.pdf]

In 2000 the U.S. Department of the Interior's Bureau of Reclamation began a project to construct and monitor a series of floating wetlands in Las Vegas Bay, Nevada. The main goal was to determine if artificially constructed islands could perform some of the ecosystem services that had previously been performed by wetlands in the area. This wetland floodplain area is commonly referred to as the Wash and has important resource implications for many western states including California, Arizona, and Nevada. Additionally, the Wash is an important source of habitat for many species and a vital water source for the Mojave Desert [LVWCAMP, 1999].

The wetland acreage in the Wash has been reduced from more than 2,000 acres in the 1970s to about 300 acres remaining today. At the same time, the amount of flow entering the system has increased dramatically. This increased runoff is largely from wastewater treatment and other urban sources and can be compounded by the occurrence of storm events [LVWCAMP, 1999].

The islands were constructed in 2000 and planted in 2001. The design was similar to that of a boat slip with two 122' x 26' floating platforms that each had twelve slips where the planted, floating platforms were anchored. The floating platforms were composed largely of steel welded into a frame and supported by flotation billets. The floating islands were made from high-density polyethylene plastic shipping pallets [Boutwell 2002].

Project Objectives:
1) Determine the effectiveness at nutrient removal and water quality improvement.
2) Develop floating platforms that are structurally durable.
3) Evaluate the riparian vegetation so that vegetative growth can be compared to the nutrient uptake.
4) Evaluate plant establishment and different planting techniques.

Cost:
Basic construction design was similar to a boat slip. Total construction cost for two slips was $88,700 or about $23 per square foot.

Plant Species:
Include Southern Cattails, Olney's Bulrush, Common Three-Square Bulrush, River Bulrush, Salt marsh Bulrush, and Creeping Spikerush

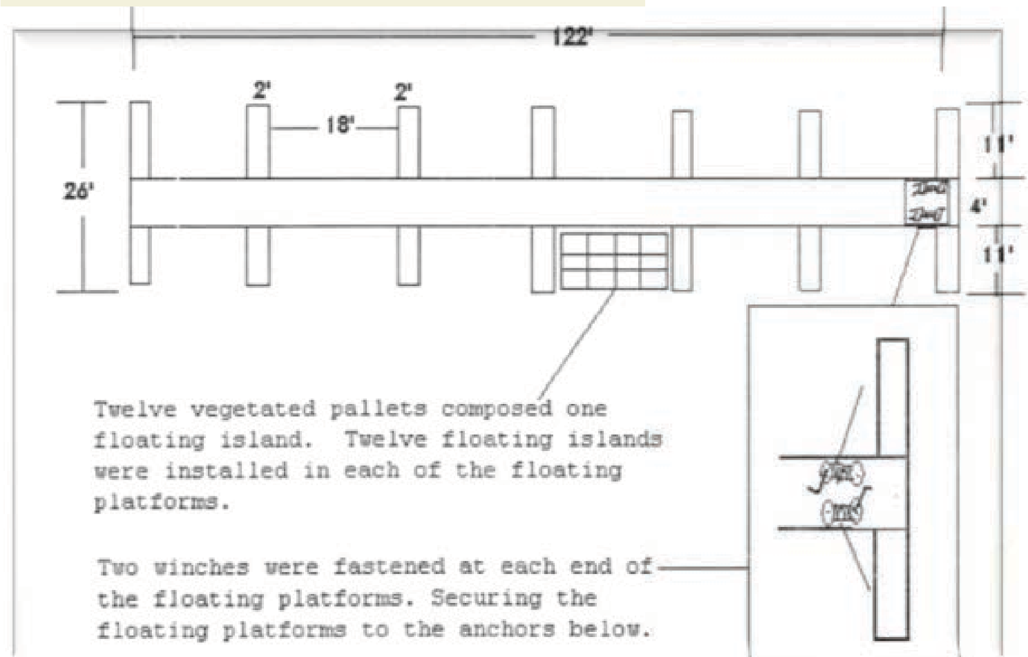
[Boutwell 2002]

Each of the floating pallets was planted with vegetation harvested from nearby nature areas. Because of invasives appearing and beaver and waterfowl feeding on the young plants, some of the pallets had to be replanted [Boutwell 2002]. Additionally, there were four areas of concern in measuring project success:

Sedimentation - Extremely high degrees of sedimentation were seen over the course of the project. The islands are estimated to have accumulated at least 500 pounds of silt. Some of the pallets may sink due to these extremely high sediment loads [Boutwell 2002].

Beavers damaged plants and structure.
[www.lvwash.org/assets/pdf/resources_wqresearch_islands.pdf]

Water Quality – The zone directly under the floating platforms showed reduced nutrient loads. Nitrate was reduced by 80% in one week of the study and potassium was reduced by 75% in one month [Boutwell 2002]. It was unclear what the broader implications for this reduction was for the system and further analysis should be performed.



Basic construction design. [www.lvwash.org/assets/pdf/resources_wqresearch_islands.pdf]

Vegetation – Eighteen species of plants are found on the islands and species diversity continues to increase [Boutwell 2002]. Beavers have continued to feed off of the plants and cause damage to both the structures and plant life. Plants become dislodged during storms.

Island Durability – The platforms have shown signs of considerable stress, likely due to the sediment deposits, the weight of the plant life and wave action. Attachment ropes have been replaced on an annual basis and the pallets appear to be close to their load capabilities [Boutwell 2002].

Sources:

John E Boutwell, (2002) Water Quality and Plant Growth Evaluations of the Floating Islands in Las Vegas Bay, Lake Mead, Nevada Technical Memorandum No. 8220-03-09, U.S. Department of the Interior, available online at: http://www.lvwash.org/assets/pdf/resources_wqresearch_islands.pdf.

LVWCAMP (Las Vegas Wash Comprehensive Adaptive Management Plan) produced for the Las Vegas Wash Coordination Committee (1999), available online at http://www.lvwash.org/html/resources_library_lvwcamp.html.

Islands before Planting. [www.lvwash.org/assets/pdf/ resources_wqresearch_islands.pdf]

Summerlee Bioremediation

National Case Study
Plateau Action Network, Charlestown Aquatic Nursery
Headwaters of Wolf Creek, Summerlee WV

Above Photo:
Close up of the bioremediation components.

[www.charlestonaquatic.com/summerlee/]

Left Photo:
The Summerlee Bioremediation Project was installed in August 2011 to clean up Wolf Creek from acid mine drainage.

[https://picasaweb.google com/110381267540073140466]

The Plateau Action Network harnessed $173,000 in state and local funds to build a bioremediation site on Wolf Creek in Summerlee, West Virginia. The floating bioremediation created the conditions for microorganisms, fungi, green plants and their enzymes to treat the problematic acidity and iron in the water.

The bioremediation project is a Passive Treatment Project intended to exploit natural processes to remove iron and aluminum from acid mine drainage. Construction began in August 2011 [Burgos, 2005]. Biomass removal is critical in metal bioremediation [Varrone, 2008].

Moisture loving plants work the best for bioremediation. The plants used on this project include *Typha latifolia, Sagittaria latifolia, Carex crenate, Pontederia cordata, Scirpus validus,* and *Juncus effusus*. [Varrone, 2008].

The floating bioremediation project used Island Grow Mix that contains loose bark, peanut hull (that keeps the roots from being super saturated) and calcinated clay that absorbs vital nutrients. [Varrone, 2008].

[www.charlestonaquatic.com/summerlee/]

[www.charlestonaquatic.com/summerlee/]

"This project is all about recreating the environment where you create a space for bacteria to grow" ~Levi Rose, Project Manager [Sendor, 2011]

Sources:

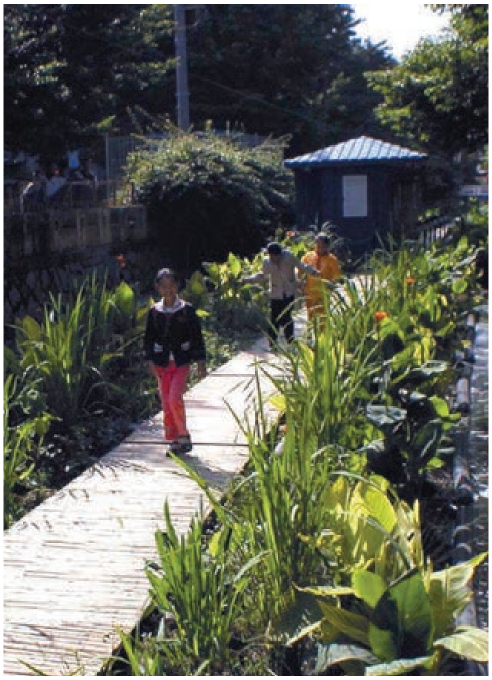
Burgos, William D. "Summerlee Bioremediation Project." Plateau Action Network. 2005-2013. http://www.plateauactionnetwork.org/projects/summerlee-bioremediation-project.html (accessed APR 08, 2013).

Sendor, Julia. "The Register-Herald.com." The Register-Herald.com. MAR 06, 2011. http://www.register-herald.com/todaysfrontpage/x831628610/PAN-project-uses-natural-methods-to-treat-acid-mine-drainage (accessed APR 08, 2013).

Varrone, Kevin. Cheasapeake Home + Living. April 11, 2008. http://www.chesapeakehome.com/2008/04/11/botanical-isles/ (accessed April 07, 2013).

Urban Municipal Canal Restorer

International Case Study
John Todd Ecological Design + Ocean Arks International
Baima Canal, Fuzhou China



Above Photo:
Conceptual sketch
[www.toddecological.com]

Left Photos:
Constructed Canal Restorer
[www.toddecological.com]

Before:
Raw Sewage Levels
Estimated Flow: 750,000 gpd
COD mg/l: Influent 480
Chemical oxygen demand
BOD mg/l: Influent 240
Biochemical oxygen demand
NH3 mg/l: Influent 40
Ammonia

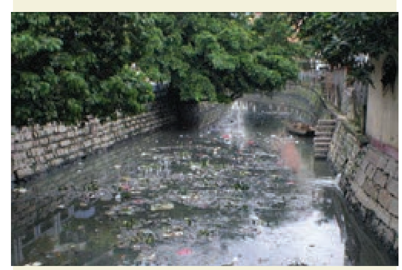
After:

COD	= 40, -92%
BOD	= 19, -92%
NH3	= no data
TSS	= 20 mg/l

Fuzhou, a city of 6 million people, empties its commercial wastewater and sewage into an 80 km network of canals. **A 600-meter canal named Baima had extreme problems with odor and floating solids created by the influx of 750,000 gallons per day of untreated domestic sewage.** In 2002, John Todd Ecological Design collaborated with Ocean Arks International to design a Restorer for their Chinese partners on the Baima canal using 12,000 plants composed of 20 native species. **A 500-meter linear Restorer was installed in the summer of 2002.**

The plant root zones and fabric media of the Restorer provide biophysically diverse surface areas necessary for effective biological treatment of wastewater. Wastewater entering the end of the canal is recycled to the top of the canal for treatment. An anoxic zone at the top of the canal allows for denitrification. The fine bubble aeration system distributes air along the canal from blowers located on a central floating barge. Low-intensity and uniformly distributed aeration circulates the water while forcing it past biologically active zones. The Restorer automatically inoculates the system with beneficial bacteria at two locations. A variety of bacteria species were selected specifically for their ability to aid in sludge and grease digestion as well as nitrogen removal.

Performance and Results
The Restorer system successfully met the goals set by the City of Fuzhou, **reducing odors, eliminating floating solids, and drastically improving the aesthetics of the neighborhood.** Furthermore this technology reduced the negative impact of the pollutants in the canal on downstream aquatic ecosystems. **The clarity of the water in the canal increased from <6" to several feet**, while meeting several secondary effluent standards. [Todd, 2002]



Before photos of the canal
[www.toddecological.com]

Source:
John Todd Ecological Design, "Urban Municipal Canal Restorer" Sustainable Water Management. 2002. www.toddecological.com

Pier 53 on the Delaware River

National Case Study
BioHabitats, Inc.
Philadelphia, PA

Above Photo:
floating wetlands at Pier 53

[www.plancentraldelaware.com/2011/01/a-closer-look-at-washington-avenue-green/]

Left Photo:
The Pier 53 floating wetlands were carefully located in an urbanized area away from healthy aquatic areas so as to avoid shading.

[www.plancentraldelaware.com/2010/07/ecology-and-floating-wetlands-workshop/]

The Pier 53 Floating Wetlands were a design/build project by Biohabitats in partnership with the Central Delaware Advocacy Group, the Pennsylvania Horticultural Society, the Philadelphia Water Department and the Delaware River Waterfront Corporation. The wetlands were built in June 2010 with community participation.

The purpose of the floating wetlands was to absorb nitrogen and phosphorus as well as provide fish habitat(including habitat for horseshoe crabs and freshwater mussels) in the Delaware River. The floating wetlands were carefully located to be used on the edges of urban areas and not over healthy aquatic areas that might shade out natural and healthy habitats.

The materials used were hardwood, coir fibre, a fabric sock material, and recycled soda bottles for buoyancy. Plants used include Spartina, Black Needlerush and Marsh Hibiscus.

Source:

http://www.plancentraldelaware.com/2010/07/ecology-and-floating-wetlands-workshop/

The wetlands were installed with community participation in a floating wetlands workshop hosted by the Pennsylvania Horticultural Society.

[http://lyndsss.blogspot.com]

McLean's Pit Landfill Leachate Treatment

International Case Study
Floating Islands International
Town of Greymouth, South Island, New Zealand

Above Photo:
The extensive root system of the native plants serves both in nutrient uptake and as a substrate for biofilm development.

[www.floatingislandinternational.com]

Left Photo:
Floating treatment wetlands constructed from post-consumer polymer fibers implemented in a treatment lagoon for the McLean's Pit Landfill in New Zealand

[www.floatingislandinternational.com]

Cost: Company Standard $29/SF

Floating wetlands were installed in a treatment lagoon in order to improve treatment of landfill leachate due to runoff from heavy rainfall in the area. The lagoon is made up of six ponds of 40m x 12m with a water depth of 0.6m. The project was implemented in three stages:

Stage 1: 288 sq. m. coverage in three of six ponds
Stage 2: 288 sq. m. coverage in remaining six ponds
Stage 3: Media for biofilm added

The biofilm is of the utmost importance for floating treatment wetlands. Some research suggests that up to 80% of the efficacy is due to microorganisms that build up in a biofilm on the structural support as well as the plant roots themselves. Other studies suggest that plant life plays a larger role but that biofilms are still of utmost importance.

Two native plant species were used in the system:

Carex virgata: hardy and adaptive to variable environments
Cyperus ustulatus: swamp grass typical of NZ coasts

The floating wetlands were effective in reducing total suspended solids (TSS), total nitrogen and biochemical oxygen demand (BOD)

Parameters	FTW Removal Rate (mg/day/ft^2)	Improvement Compared to Pre-FTW
TSS	160	89%
Total Nitrogen	2000	40%
BOD	685	46%

Left canister displays water from influent of the treatment lagoons and right canister displays water taken from effluent. The decrease in TSS is readily visible.

[www.floatingislandinternational.com]

Sources:
www.nznativeplants.co.nz/

www.waterworld.com/articles/print/volume-28/issue-6/editorial-features/floating-wetlands-help-boost--nitrogen-removal-in-lagoons.html

Water Monitoring and Assessment- EPA: http://water.epa.gov/type/rsl/monitoring/vms52.cfm

Bass Spawning Habitat

National Case Study
Floating Islands International + New Mexico Bass Fishing Assoc.
Elephant Butte, NM

Above Photo:
Preparing a spawning bed with substrate. Once ready, the bed will be lowered and suspended in the water beneath the island.

[www.facebook.com/pages/Floating-Islands-West/147363928610512—suspended fish spawning bed and nursery album]

Left Photo:
Floating Island structure for Elephant Butte. Suspended spawning beds are located under island. Native plants provide cover.

[floatingislandinternational.com]

A floating island structure was installed in 2009 in a reservoir in Elephant Butte, New Mexico to promote bass spawning and recruitment. The reservoir is characterized by fluctuating water levels- water flowing in from spring runoff and out for crop irrigation. Prior to the installation there was little coverage for fry, which had a low survival rate in the region.

The suspended platforms had specified spawning beds for different fish under the floating islands. The spawning beds were filled with gravel (which turned out to be difficult to maintain because catfish and other fish empty the gravel). Once the bed was prepared with gravel substrate, it was lowered and suspended in the water beneath the island. On the island portion, native vegetation was planted. The roots of the plants provide cover for growing fry.

Design considerations: the potential for floating islands to closely mimic shallow nearshore habitat conditions; structural consideration with weight; maintenance concerns

A view of two of the chains that will serve to suspend the spawning bed once it is lowered.

Plants were installed by the Junior Bassmaster Club

[floatingislandinternational.com]

Sources:

www.bassmaster.com/news/new-mexico-juniors

www.floatingislandinternational.com/research/case-studies/

www.facebook.com/pages/Floating-Islands-West/147363928610512—suspended fish spawning bed and nursery album

Bangor International Airport Floating Wetlands

National Case Study
Floating Islands International
Bangor International Airport, MA

Above Photo:
The freshly planted floating wetland, June 2008

[basswg.blogspot.com/2010_07_01_archive.html]

Left Photo:
Floating treatment wetlands in Bangor Airport stormwater pond, August 2010 at the former Dow Air Force Base. Military and airport use of the property resulted in contamination from fuel spills, hazardous waste dumping and fire training.

Project Objectives:
To remove trace amounts of propylene glycol (deicing agent), nitrogen, phosphorus, and reduce the water temperature.

[www.floatingislandinternational.com]

In the spring of 2008, Bangor International Airport started conducting experiments with floating treatment wetlands to help improve water quality, specifically propylene glycol, at the outfalls near the airport. The wetlands were installed in a 4' deep aerated stormwater pond, with about 0.2% of the pond covered by the floating system.

The islands are composed of fibers made from 100% post-consumer polymer fibers and recycled plastic bonded with foam to provide buoyancy. The island is 8" thick and approximately 64 sq. ft.

Because the island was so small, its effect on removing glycol concentrate was unable to be tested. To better determine the efficacy of the island, a pilot-scale floating wetland (0.88 sq.ft.) was used in a series of lab tests. In the lab tests, glycol concentrations were reduced from greater than 500 mg/L to less than 1 mg/L in only 14 days. It is believed that glycol is converted to carbon dioxide by aerobic bacteria attached to roots and other underwater surfaces of the floating wetland.

The full scale floating wetland island has survived three Maine winters and thrived each summer. The island is now home to a weasel.

Sources:

www.floatingislandinternational.com/research/case-studies/
www.umaine.edu/waterresearch/pearl/window/ws/penobscot/research_waterquality.htm

One year after installation.

6 months later a contractor removed the island because it was in the way and it died.

The following spring it was placed back in the water and it regrew.

[basswg.blogspot.com/2010_07_01_archive.html]

Mill Creek Floating Wetlands

National Case Study
Butler Soil and Water Conservation District
Cincinnati, OH

Above Photo:
Floating wetlands being implemented to improve water quality in Mill Creek.

[http://fuelcincinnati.org/home/projects/floating-wetlands/]

Left Photo:
The Mill Creek Floating Wetland Project consists of 13 rafts tied to an anchor line. After 2 weeks there was new plant growth.

[www.facebook.com/media/set/?set=a.272780346160150.58932.271639349607583&type=3]

Due to intense urbanization, channelization and industrial use Mill Creek is one of the most severely polluted and physically degraded streams in the United States. Ohio EPA recommended that there be no public contact with the stream. The growth of aquatic weeds is promoted by excess nutrients such as nitrates and phosphates. Floating wetlands can help control the amount of nitrates and phosphates in the water through nutrient uptake.

The project was awarded $2,000 to install floating wetlands in August 2012.

The floating wetlands installed in Mill Creek consist of a buoyant structure, or raft, which supports plants in a growing media over the water column. Plants used were perennial, non-invasive emergent plants that mimic that filter and process nutrients, suspended solids, metals and other pollutants.

Due to the floating wetlands ability to adjust with water levels, the suspended roots are always in contact with the water, which allows for an increase in nutrient uptake toward the center of the body of water as opposed to just the banks.

[Butler, 2013]

The wetlands are easily movable for repair and observation.

Perennial, non-invasive emergent plants were used.

[www.facebook.com/media/set/?set=a.272780346160150.58932.271639349607583&type=3]

A buoyant structure, or raft, which supported plants in a growing media was used. Plants installed were emergent wetland plants tolerant of water pollution.

[Butler, 2013]

[www.facebook.com/media/set/?set=a.272780346160150.58932.271639349607583&type=3]

[www.facebook.com/media/set/?set=a.272780346160150.58932.271639349607583&type=3]

High levels of suspended solids can increase water temperature and lower dissolved oxygen levels. Decreased dissolved oxygen in the water is a threat to most aquatic species and may alter the biodiversity health.

[Butler, 2013]

The suspended roots in floating wetlands trap particles that are suspended in the water column and decrease the amount of particles suspended in the water.

[Butler, 2013]

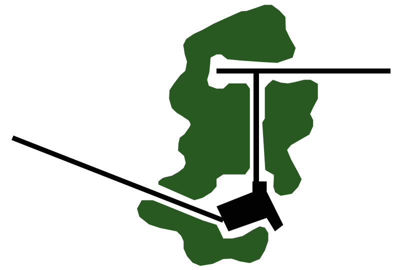
Source:

Butler Soil & Water Conservation District. Accessed April 15th, 2013. http://www.butlerswcd.org/Ponds/FloatingWetland.html

[www.facebook.com/media/set/?set=a.272780346160150.58932.271639349607583&type=3]

Sengkang Floating Wetland

International Case Study
CPG Consultants + Singapore National Water Agency
Punggol Reservoir, Singapore



Above Photo:
Diagram of Sengkang Floating Wetland shows recreation and connectivity of the system.

[Kaie Kuldkepp]

Left Photo:
The Sengkang Floating Wetland functions not only as a water treatment system but also as an interactive community space.

[www.cpgcorp.com.sg/CPGC/Project/Project_Details?ProjectID=1296]

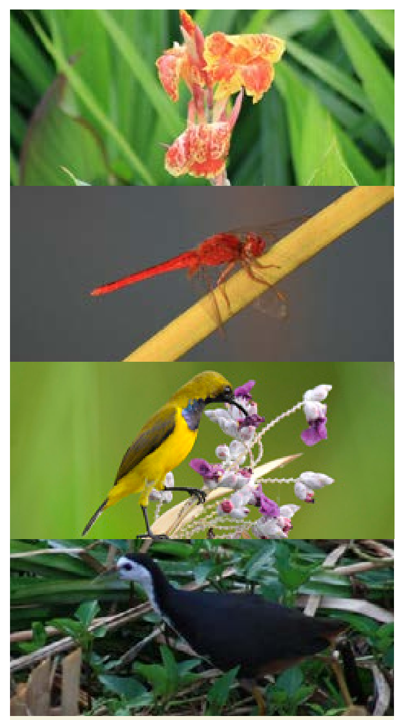
Sengkang Floating Wetland, half the size of a football field, is the largest man-made floating wetland in Singapore, and possibly the world. The Sengkang Wetland was developed by Singapore's National Water Agency as part of their Active, Beautiful, Clean Waters Programme (ABC) which aims to improve the quality of water and life and bring water and nature closer to the residents. The Water Agency has developed ABC Waters Design Guidelines which set the reference for design considerations, process, construction, and maintenance.

[www.pub.gov.sg]

The Sengkang wetland is a natural habitat for fish and birds and home to about 18 wetland plant species. [www.pub.gov.sg]

The wetland system maximizes the surface area for microbial growth and grows both terrestrial and aquatic plants. It requires minimal infrastructure and maintenance. [www.biohavenenvironmental.com]

The constructed wetland grows plants on floating mats where roots clean the water in the reservoir by taking up nutrients from the water through microorganisms that break down pollutants. The plants beautify the wetland and also provide shelter and food for animals in and around the reservoir. [www.abcwaterslearningtrails.sg]



Since the completion of the wetland, more birds and dragonflies were noticed to be attracted in the area

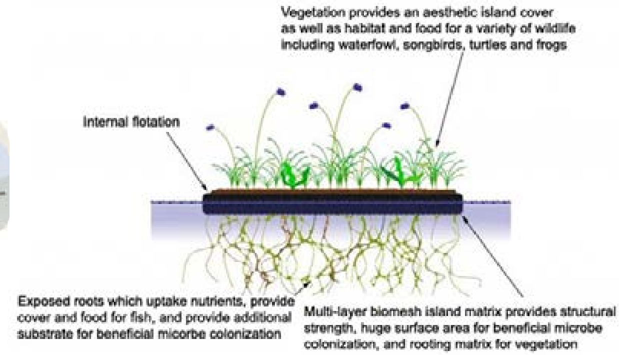
[www.simplygreen.com.sg/sengkang.html]

Left:
The Sengkang Wetland connects the Sengkang Riverside Park to Anchorvale Community Club, by way of the Water's Edge Trail creating a recreational node.

[www.eco-business.com]

Right:
The wetland is built using the BioHaven Floating Wetland Technology
[[www.biohavenenvironmental.com]

[http://punggolec.vault.com.sg/?page_id=20]



[www.biohavenenvironmental.com/technology.php]

Designed by CPG Consultants, the theme "Discover Nature" brings people closer to the water to learn about wetland ecosystems, while creating community spaces.

[www.cpgcorp.com.sg]

Offering an "outdoor classroom" the site has installations for learning, such as telescopes. A floating deck just above the wetland contains play elements, benches and a pavilion. A fixed bridge connects the deck and the floating wetland to Anchorvale Community Centre and Sports Complex and provides space for canoeing and kayaking.
[www.unescap.org]

[PUB, Active, Beautiful, Clean Waters Master Plan 2008]

A floating boardwalk connects the wetland to existing mangroves on the riverbank. [www.cpgcorp.com.sg]

[www.singaporebuilder.com/sengkang-floating-wetland/sengkang_floating_wetland_02/]

Sources:

www.eco-business.com/news/singapore-opens-sengkang-floating-wetland/

www.pub.gov.sg/abcwaters/ExploreABCA-roundYou/Pages/SungeiPunggol.aspx

www.biohavenenvironmental.com/technol-ogy.php

www.abcwaterslearningtrails.sg/web/seng-kang.php

www.cpgcorp.com.sg/CPGC/Project/Proj-ect_Details?ProjectID=1296

www.unescap.org/esd/environment/infra/sun-cheon/documents/Case_studies/SINGAPORE-ABC-Waters-Programme.pdf

Maryland Aquatic Nurseries

National Case Study
Maryland Aquatics, Pulte Homes, the U.S. Department of Agriculture, and the University of Maryland
Easton Club East, MD

Above Photo:
Yellow Lotus, Nelumbo 'Perry's Giant Sunburst', at Maryland Aquatic Nurseries.

[http://www.chesapeakehome.com/2008/04/11/botanical-isles/]

Left Photos:
Floating Island planted with Bald Cypress *(Taxodium distichum)* and under planted with Blue Moneywart *(Lindernia grandiflora)* at Maryland Aquatic Nurseries.

[www.chesapeakehome.com/2008/04/11/botanical-isles/]

Maryland Aquatic Nurseries are container gardens consisting of specially designed plant containers nested in floatation collars that keep them partially submerged in a reservoir of water. The bottoms of the containers have holes that allow water from the reservoir to penetrate the soil and nourish the plants. The roots of the plants are nestled in Island Grow Mix that contains loose bark and peanut hull (to keep the roots from becoming supersaturated) and calcinated clay that absorbs vital nutrients. Wide containers, which allow the islands to bob freely in water work best; vertical centerpiece plants should not exceed in height the diameter of the island itself, so as to avoid a top-heavy island that might tip over.

Single pot floating wetlands range in size from 5-24" in diameter. The host vessel should be 2" larger in diameter than the wetland. Mid-sized wetlands range from 24-108" and can be tethered together to form mini wetlands that float on rafts anchored to the pond floor.

Plants in the Floating Wetlands consume excess nutrients during the growing season. When foliage from the plants are trimmed back and removed, the excess nutrients are removed permanently from the water Because the plants in Floating Islands are continuously self-watered, maintenance amounts to little more than removing spent flowers and foliage.

Source:
www.chesapeakehome.com/2008/04/11/botanical-isles/

Easton Club East pond before and after floating wetlands that cleaned the water.

[www.unitygardens.org/assets/documents/KB_IWGS_2010_]

Lake Rotorua Floating Island

International Case Study
Rotorua District Council Infrastructure Services, Bay of Plenty Regional Council and Te Arawa Lakes Trust
Lake Rotorua, North Island, New Zealand

Above Photo:
Artist rendering of the Rotorua Floating Wetland

[http://www.scoop.co.nz/]

Left Photo:
A freshly installed Rotorua Floating Wetland boasts to be the largest floating wetland in the world.

[http://www.scoop.co.nz/]

A floating wetland was installed in July 2012 at the second largest lake in New Zealand, Lake Rotorua, to improve water quality (an excess of nitrogen and phosphorus created a dense green algal scum) and to mitigate natural wetlands lost due to airport developments. The system is 525' long by 131' wide, spells 'Rotorua' and is believed to be the largest floating wetland in the world (it can be seen from the air). The wetland was funded by a $900,000 environmental initiative through the Rotorua District Council, Bay of Plenty Regional Council and Te Arawa Lakes Trust.

Research indicates floating wetlands can be 2-4x more effective at stripping nitrogen and phosphorus than conventional wetlands. Plant material must be harvested to increase plant vigor and nutrient uptake. The Rotorua Wetland is expected to remove 4 tons of nitrogen and 1 ton of phosphorous from the lake per year, in addition to providing wildlife habitat and becoming a tourist attraction and branding effort.

The wetland was constructed from over 400,000 plastic bottles (imported from the U.S.) topped with coconut fiber matting and over 20,000 native plants. Modules were bolted together with steel and wire (like knitting a scarf row by row).

[http://www.scoop.co.nz/]

Sources:

Adams, Amy. 2012. Floating wetland helps clean up Lake Rotorua. Press Release from New Zealand Government. Accessible from: http://www.scoop.co.nz/stories/PA1209/S00431/floating-wetland-helps-clean-up-lake-rotorua.htm

Brendish, Lynda. Unknown. Floating wetlands to combat algal scum. Accessible from: http://good.net.nz/blog/lynda-brendish/floating-wetlands-to-combat-algal-scum

Hamill, Keith; MacGibbon, Roger; Turner, James. 2010. Wetland Feasibility for Nutrient Reduction to Lake Rotorua. Prepared for Bay of Plenty Regional Council. Opus International Consultants. 82 pp. Accessible from: http://www.boprc.govt.nz/media/99878/wetland_feasibility_for_nutrient_reduction_to_lake_rotorua.pdf

Martin, Matthew. 2012. Floating wetland slips anchor. The New Zealand Herald. Matthew Martin of the Daily Post. Accessible from: http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10852590

NZ Newswire. 2012. Floating Rotorua sign a lake cleaner too. Accessible from: http://nz.news.yahoo.com/a/-/top-stories/14976020/floating-rotorua-sign-a-lake-cleaner-too/

Rotorua Te Arawa Lakes Programme. 2013. Floating Wetlands. Accessible from: http://www.rotorualakes.co.nz/floating_wetlands

Floating Wetlands at Clemson University

National Case Study
Dr. White and her research lab
Clemson, SC

Above Photo:
Plant material being researched at Clemson University.

[www.clemson.edu/extension/horticulture/nursery/remediation_technology/floating_wetlands/plants.html]

Left Photo:
A research lab at Clemson University is studying the effectiveness of floating wetland systems

[www.clemson.edu/extension/horticulture/nursery/remediation_technology/floating_wetlands/index.html].

Research at Clemson University studies various floating wetland systems, and plant species on the effectiveness of nutrient uptake. Three test sites were implemented from 2008-2011.

2008

- The floating mats were established with Canna flaccida, Juncus effusus, Eleocharis montana, and Agrostis sp.
- After 5 months of sampling, floating wetlands reduced both nitrogen and phosphorus effluent concentrations.
- Nitrogen and phosphorus removal were consistent in both the pond and vegetated channel floating wetland treatments.

2009

Floating treatment wetlands were established with Canna flaccida, Juncus effusus, and Agrostis sp. After 6 months of sampling we found the floating wetlands reduced both nitrogen and phosphorus effluent concentrations. Nitrogen and phosphorus removal were consistent in both the pond and vegetated channel floating wetland treatments.

2010-11

Mesocosm scale study evaluating nutrient uptake into Canna flaccida in aerated and non-aerated conditions, with various planting densities and percent coverage.

["Floating", www.clemson.edu/extension]

Site 1

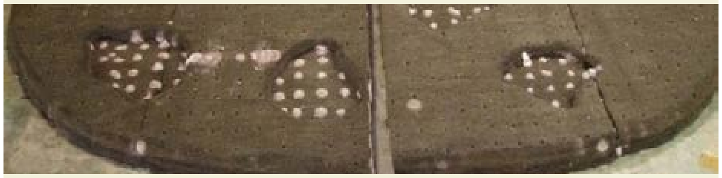
Site 2

Site 3

www.clemson.edu/extension/horticulture/nursery/remediation_technology/floating_wetlands/index.html

Types of Treatment Wetlands Studied:

Each floating treatment wetland has its benefits and detractions. Choice of a floating wetland type simply depends upon budget, desired appearance, and desire to harvest materials to remove more nutrients from the pond "nutrient" cycle.

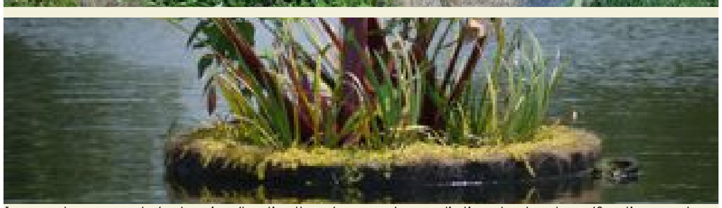


1) Biohaven Floating Islands

Eight-inch thick plastic (recycled, PET) matrix layers bonded with marine foam (polyurethane) comprise the floating island. The foam provides buoyancy and adhesion. Island buoyancy is adjustable. Organic matter is placed on top of the island before plants are seated.

2) Managed Aquatic Plant System Floating Wetlands

A half-inch thick mat made of a buoyant material that floats on the pond's surface. Plants growing in special containers are placed in the holes; their roots grow freely in the water to "mine" the water for nutrients and to provide a large surface area for colonizing microorganisms.



[www.clemson.edu/extension/horticulture/nursery/remediation_technology/floating_wetlands/float_type.html]

3) Modular Floating Wetlands

A closed cell foam provides buoyancy, a biomatrix foam (recycled plastic) provides increased surface area for microbial colonization, and coir inserts permit "pre-growing" so that the modular floating wetland can stay consistently hydrated.

Plants used in Floating Wetlands:
Emergent plants that worked best at Clemson: *Canna 'Australia', Typha latifolia, Salix caroliniana, Colocasia esulenta 'Black Magic', Canna faccida, Arundo donax, Iris laevigata, Iris ensenata 'Variegata' Saururus cernuus, Panicum hemitomon, Pennisetum purpureum, Agrostis sp., Juncus effusus, Eleocharis montana, Stenotraphrum secundatum, Hibiscus moscheutos, Thalia geniculata, Cynodon dactylon, Panicum milliaceum*

["*Plant*", www.clemson.edu/extension]

Sources:

"Floating Treatment Wetland Research : Extension : Clemson University : South Carolina." Clemson University, South Carolina. http://www.clemson.edu/extension/horticulture/nursery/remediation_technology/floating_wetlands/research.html (accessed April 6, 2013).

"Plant selections for floating treatment wetlands : Extension : Clemson University : South Carolina." Clemson University, South Carolina. http://www.clemson.edu/extension/horticulture/nursery/remediation_technology/floating_wetlands/plants.html (accessed April 8, 2013).

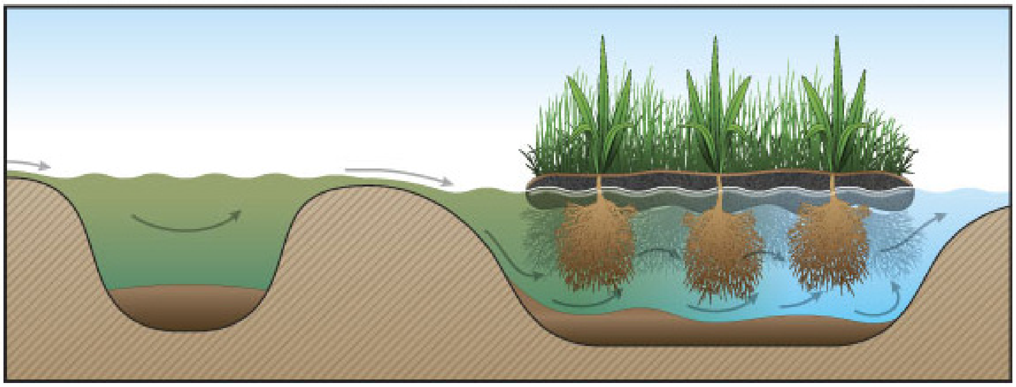
"Types of floating wetlands : Extension : Clemson University : South Carolina." Clemson University, South Carolina. http://www.clemson.edu/extension/horticulture/nursery/remediation_technology/floating_wetlands/float_type.html (accessed April 7, 2013).

BioHaven® Floating Islands

Floating Island International
Proprietary Product

Above Photo:
Example of BioHaven installation

[www.floatingislandinternational.com/products/biohaven-technology/]



OPTIONAL SEDIMENTATION BASIN
(coarse sediment removal)

FLOATING TREATMENT WETLAND
(removal of fine particulates, metals, denitrification)

Left Photo:
Host pond with floating treatment wetland connected to an optional sedimentation basin

[www.floatingislandinternational.com/products/biohaven-technology/]

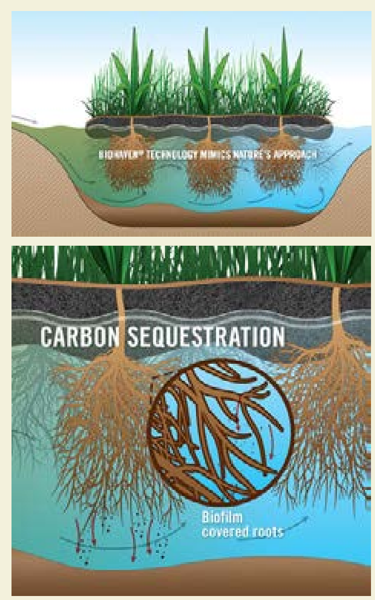
Contact:
10052 Floating Island Way,
Shepherd, MT 59079
(406)373-5200
info@floatingislandinternational.com

The BioHaven® Floating Islands are a proprietary product made by Floating Islands International.

"Constructed of durable, non-toxic post-consumer plastics and vegetated with native plants, BioHaven islands float on top of the water, providing a beautiful habitat for birds and animals. But underneath the surface, a dynamic process takes place. Microbes are responsible for breaking down nutrients and other water-borne pollutants, but to be effective, they need a surface to stick to. The floating island matrix, with its dense fibers and porous texture, is the perfect surface area for growing large amounts of microbes (in the form of biofilm) in a short time. Nutrients circulating in the water come into contact with these biofilms and are consumed by them, while a smaller fraction is taken up by plant roots. Suspended solids slough off into the benthic zone below the island. Organic solids stick to the biofilms and become the base of the freshwater food web."

"250 square feet of island translates to an acre's worth of wetland surface area. Independent laboratory tests showed removal rates far in excess of previously published data: 20 times more nitrate, 10 times more phosphate and 11 times more ammonia, using unplanted islands. They are also extremely effective at reducing total suspended solids and dissolved organic carbon in waterways"

[www.floatingislandsinternational.com]



BioHaven® Floating Islands are a specially design plastic system that promotes the formation of Biofilm that cleans the water.

[www.floatingislandsinternational.com]

PhytoLinks™

C + M Aquatic Management Group
Proprietary Product

Above Photo:
Test installation of the PhytoLinks™ System

[www.cmaquatics.com]

Left Photo:
The frame of the PhytoLinks™ Modular Floating Wetland Treatment System

[www.cmaquatics.com]

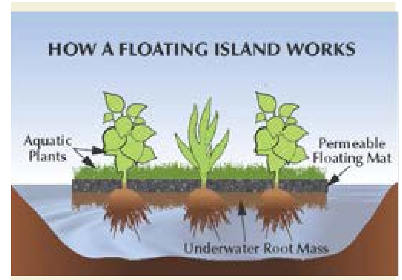
Contact:
954 1st Ave W
Owen Sound, Ontario
(877) 372-0109
info@cmaquatic.com

The PhytoLinks™ Modular Floating Wetland Treatment System is a proprietary product made by C&M Aquatic Management Group.

"The PhytoLinks™ system was designed specifically for larger scale applications such as stormwater ponds. Easily scalable and flexible enough to allow for any desired size or layout, PhytoLinks™ is a very cost effective solution for management of water quality for a variety of different applications."

"Some of the key benefits of the system include:
- Lightweight, durable and easy to install components
- Modular design allows for creation of virtually any different shape
- Anchoring system is incorporated into each module for increased strength
- Quick-attach modules can be reconfigured and/or relocated with minimal effort
- Plant biomass can be harvested without total system replacement
- Environmentally friendly design with minimized use of raw materials for reduced carbon footprint
- Weather resistant HDPE construction for year round use
- Non-toxic safe for drinking water applications"

[www.cmaquatic.com/phytolinks.php]



PhytoLinks™ are designed for large scale applications

[www.cmaquatic.com/phytolinks.php]

Aqua Biofilter™

Aqua Biofilter Inc.
Proprietary Product

Above Photo:
Aqua Biofilter™ system

[www.aquabiofilter.com/index.html]

Left Photo:
Example of Aqua Biofilter™ installation 5 months after construction

[www.aquabiofilter.com/index.html]

Contact:
info@aquabiofilter.com

The Aqua Biofilter system is made by Aqua Biofilter Inc.

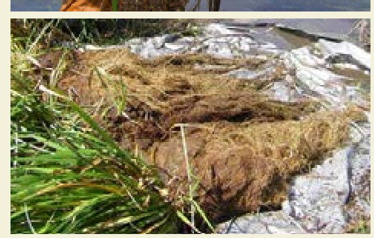
"The Aqua Biofilter™ is an advanced Floating Wetland Treatment Technology that can be utilized within a Wetland Treatment Train either retrofitting or designed into future wetlands, by contacting Aqua Biofilter™. Detention basins can be designed larger & deeper, effectively providing more storage and HRT. Wetlands can also be sized smaller as a result, bringing down costs, achieving best practice and effectively treating TN, TP, TSS and reducing heavy metals."

"Aqua Biofilter™ performance indicates the following is routinely achievable:

TN Reduction 40-80%
TP Reduction 50-80%
TSS Reduction 50-80%
Transparency 50- 252%
Heavy Metals 50 - 95%
Pathogens 50 - 90%"

"Previous projects have ranged up to $30 - $200/m2 installed"

[www.aquabiofilter.com/index.html]



Aqua Biofilter™ Bega Urban Stormwater Wetlands Trial, Carex after 14 months growth, 2.2 metres in length, at planting only 30cm length.

[www.aquabiofilter.com/index.html]

Beemats MAPS Floating Wetlands

Beemats, LLC
Proprietary Product

Above Photo:
Installation of Beemats floating wetland system in a salt water setting

[http://beemats.com]

Left Photos:
Beemats floating wetland system

[http://beemats.com]

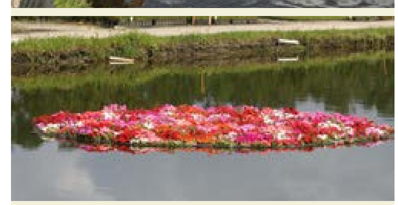
Contact:
3637 SR44
New Smyrna Beach, FL 32168
(386) 428-8578
Beemats@gmail.com

The Beemats Managed Aquatic Plant System (MAPS) Floating Wetlands are made by Beemats, LLC.

"Over the past twenty years, we have been conducting experiments to devise a system that provides the benefits of vegetated littoral shelves without having to deal with the problems associated with changing water levels. Using interlocking mats, combined with aquatic plants in perforated pots, we can suspend a simulated shallow water environment. This not only takes care of fluctuating water levels, but also produces oxygen, takes nutrients and pesticides out of the water, and provides habitat for wildlife utilization. Our patented floating plant mat consists of puzzle cut mats held together by nylon connectors. These mats may be assembled in any size or shape. After the mats are connected, plants are inserted into pre-cut holes. The plants may be any species of emergent aquatics. The mats can be attached to anchors or shoreline stakes.

Plant removal is KEY! As plants grow, the excess nutrients in the water get stored in their tissues. If not removed periodically, the nutrients will reenter the water as the plants die. Our system provides an easy way to remove the entire plant and replant the mats to increase nutrient removal. This is what separates us from other floating systems. "

[http://beemats.com/cgi-bin/p/awtp-home.cgi?d=beemats]



Beemats systems are designed for easy removal and recycling to maximize plant cleansing or reuse in a different way, such as this installation shown above

[http://beemats.com]

Modular Floating Wetlands

Charleston Aquatic Nurseries
Proprietary Product

Above Photo:
Modular Floating Wetlands system by Charleston Aquatic Nurseries

[www.floatingwetlands.com]

Left Photo:
Example of Modular Floating Wetlands system

[www.floatingwetlands.com]

Contact:
3095 Canal Bridge Road
Johns Island, SC 29455
(800) 566-3264
Charleston@FloatingWetlands.com

Charleston Aquatic Nurseries makes the Modular Floating Wetlands system for pollution removal, beautification and habitat creation.

"Our new and improved Modular Floating Wetlands have been designed to improve shipping, handling, installation and to be horticulturally sound. Our modular floating wetlands are comprised of three components including bio matrix foam, closed cell foam and coir inserts.

-the bio matrix foam (recycled plastic) has improved the structural quality and longevity of the product while increasing surface area for microbial activity

-the closed cell foam has been upgraded to improve the integrity of the product

-the coir inserts allow for each modular unit to be pre grown meeting the needs of the customer"

[www.floatingwetlands.com]

rectangular modular
36"x48"x3"
installed price $269.99

[www.floatingwetlands.com]

circle modular
48"x48"x3"
installed price $260.36

[www.floatingwetlands.com]

Floating Biospheres™

Floating Islands Australasia Pty Ltd.
Proprietary Product

Above Photo:
Installation of ornamental floating islands by Floating Islands Australasia

[www.fiatechnology.com.au/]

Left Photos:
Floating Biospheres™ installation

[www.fiatechnology.com.au/]

Contact:
8 Montpelier Drive
Lower Plenty Vic 3093
0434-674-228
info@fiatechnology.com.au

Floating Biospheres are made by Floating Islands Australasia (FIA).

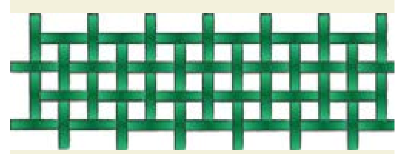
"FIA technology separates key functions:

- Buoyancy features & structure to support the island panels,
- Filler medium & structure with maximum surface area in which the plants can grow,
- Retaining cover & structure to hold the filler and provide additional features including evaporation suppression and wave damage minimisation.

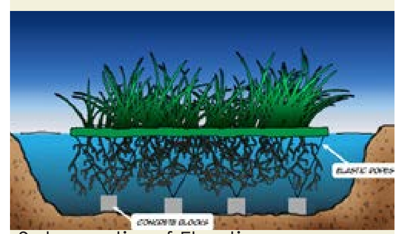
FIA Floating Biospheres™ designs:

- Meet all key floating island performance criteria
- Can use post-consumer polymer waste
- Contain very high internal surface areas leading to increased efficiency
- Provide improved water quality at lower treatment cost
- Floating Biospheres™ are flexible, stable and of modular design – Patent App
- Can improve water treatment, reduce evaporation & wave damage, remove hydrocarbons"

Evaporation Cover Panels
"The benefits of the shade mesh covers includes continued access of air, thus keeping the water aerobic and in good quality, reduced water temperature (less algal growth) and easy penetration of rain water."
[www.fiatechnology.com.au/]



Open grid configuration of Floating Biospheres™
[www.fiatechnology.com.au/]



Schematic of Floating Biospheres™ Design
[www.fiatechnology.com.au/]

Planting the Floating Biospheres™
[www.fiatechnology.com.au/]

BlueWing Floating Treatment Wetlands

BlueWing Environmental Solutions and Technologies
Proprietary Product

Above Photo:
Installation of BlueWing Island

[www.bluewing-env.com/floating-islands/]

Left Photo:
30 acre natural floating wetland in Chippewa Flowage Wisconsin

[www.bluewing-env.com/floating-islands/]

Contact:
PO Box 746
Parkton, Maryland 21120
(240) 375-4919

BlueWing Environmental Solutions and Technologies created the BlueWing Floating Treatment Wetlands constructed from 100% recycled PET plastic matrix sheets bonded together with marine foam for buoyancy

"BlueWing Islands basic components:
Matrix - Nonwoven fibers from recycled PET plastic drinking bottles have been tested and found to be non-toxic to fish.
Foam - Coast Guard approved polyurethane, inert marine foam provides adhesion and buoyancy.
PVC Pipe - A frame of PVC pipe is inserted between tw0 layers of matrix and cable is thread through it to connect islands to one another (PVC piping may or may not be present on islands provided by BlueWing).
Peat moss- Placed on the surface along with **natural vegetation** in the plant holes"

"There are many sizes and shapes of islands available, ranging from 25 SF up to 400 SF (and larger if requested), with a standard thickness of 8" and buoyancy of 9 lbs/SF. Each island contains wicking channels (also called planting holes) at 8" on center spacing (meaning about 3 per SF). These holes are only cut through the top 2 layers of the island and are either 2 ½" or 4" diameter circles. Islands can even be made to support custom walkways and floating decks if requested."

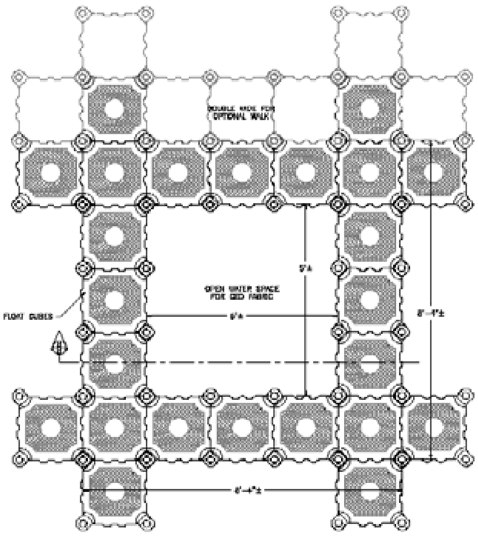
[www.bluewing-env.com/floating-islands/]

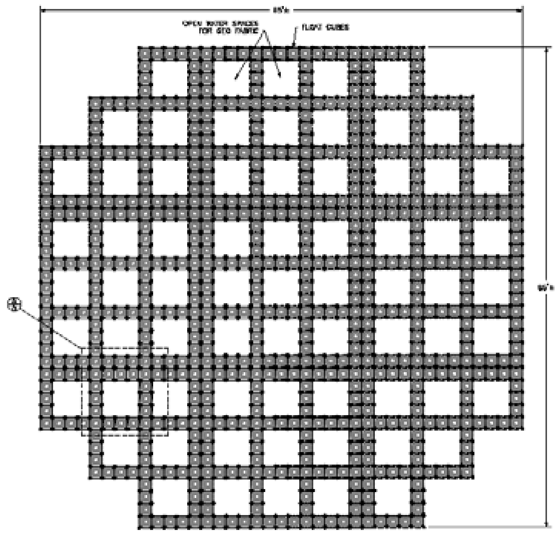
BlueWing Island structure
[www.bluewing-env.com/floating-islands/]

Hanging roots provide a biological haven for biofilm
[www.bluewing-env.com/floating-islands/]

Waterfront Construction Floating Wetland Islands

Waterfront Construction, inc.
Proprietary Product





Above Photo:
Modular floats at 12" scale by Waterfront Construction

[www.fiatechnology.com.au/]

Left Photos:
Single unit design and compiled floating island example
[www.fiatechnology.com.au/]

Contact:
205 NE Northlake Way, Suite 230
Seattle WA 98105
(888) 827-7784
Phil@waterfrontconstruction.com

Waterfront Construction, Inc. is in the process of developing modular Floating Wetland Islands. The images on this page are preliminary design ideas for the system using modular floats.

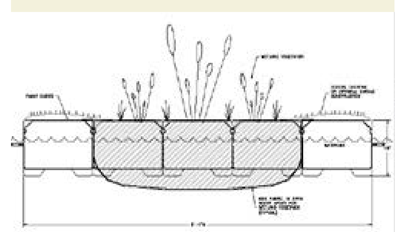
Components of proposed Floating Wetland Islands:

- Modular floats
- Supporting structure
- Filter / geo fabric
- Plant medium / water wicking
- Anchoring (elastic tendons to account for water level fluctuation)

Benefits of Waterfront Construction's Floating Wetland Island system:

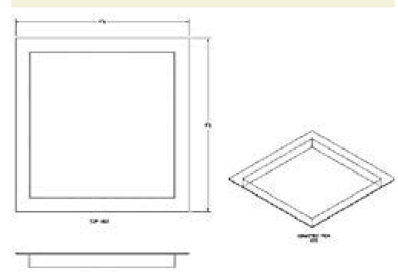
- flotation can be easily calculated
- predictability of outcome speeds up design and development
- modular / scalable
- customization ability
- industrially practical
- easy assembly
- longevity / durability
- cost effective

[www.fiatechnology.com.au/]



Section of Floating Wetlands Islands displaying float cubes, geo fabric and vegetation

[Waterfront Construction]



Aluminum frame / geo fabric mount assembly

[Waterfront Construction]

Literature Review of Floating Wetlands Performance

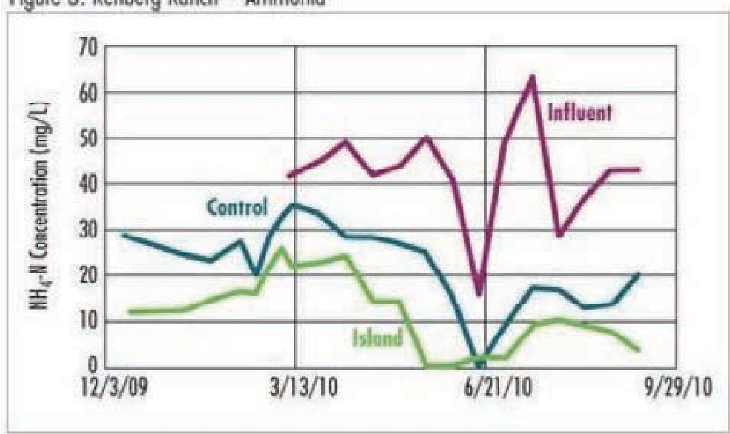
a brief examination of available articles to help understand the performance of floating wetland systems

Reinsel, Mark A. 2012. "Floating Wetlands Help Boost Nitrogen Removal in Lagoons".WaterWorld. 28 (6).

Summary: Floating Treatment Wetlands (FTWs) developed by Floating Islands International (FII) are effective in reducing nutrient levels in small-scale lagoon treatment plants

- Treat agricultural runoff, raw wastewater, etc.
- Remove/purify: nitrogen (15-52% removed vs. controls), ammonia, phosphorus (9% and 5% more removal than controls), BOD and TSS
- Total nitrogen removal requires aerobic and anoxic conditions (different locations or treatment stages)
- 80% of efficacy due to bacteria attached to plant roots and polymer matrix, 20% due to uptake by plants

Figure 3: Rehberg Ranch – Ammonia



Moortel, Annelies M. K., Filip M. G. Tack, Filip M. G. Tack, and Filip M. G. Tack. 2010. "Effects of Vegetation, Season and Temperature on the Removal of Pollutants in Experimental Floating Treatment Wetlands". Water, Air & Soil Pollution. 212 (1-4): 1-4.

Summary: This article discusses the effect of a constructed floating wetland with a macrophyte mat on the removal of various pollutants associated with wastewater including nitrogen, phosphorous, organic material, heavy metals (Cu,Fe, Mn, Ni, Pb and Zn) and ph as influenced by various seasons and temperatures.

- In this system the vegetation grows in a matrix that floats on the surface of the water.
- The vast majority of plant species were from the Carex family although they also briefly mention Typha as a possibility.
- The CSFs were constructed of 18-mm plywood panels sealed with a liner. The floating mat was made of two plastic pipes filled with foam to enhance its buoyancy and covered with rough-meshed wire netting. The vegetation was rooted in a coconut coir.
- Removal of the pollutants was increased in the presence of the floating mats. The presence of vegetation influenced the removal of pollutants more than season or temperature. Removal was greatest in moderate temperatures between 5 and 15 degrees Celsius.
- The season affects the buoyancy of the mats. The mats will sink in the summer months when there is more vegetation.

"Shoreline remediation and floating wetlands : Hartbeespoort Dam remediation". 2012.Civil Engineering = Siviele Ingenieurswese. 20 (7): 38-41.

Summary: The article is about the development of criteria for habitat reconstruction and rehabilitation in the littoral and riparian zones by the Hartbeespoort Dam in South Africa.

Floating Wetland Objective:
-Aimed at replicating wetland ecosystem functionality, thereby extending and maintaining the functionality of shoreline vegetation during fluctuating water levels.
-To mimic what occurs in nature, in terms of naturally buoyant floating mats.
-Create a link between deeper and shallow water for fish to travel (thereby establishing a vital 'aquatic nursery migration zone'.)
-To establish designs that provide functionality and stability.
    -Functionality includes above-the-water vegetation growth, as well as below-the water root growth and biodiversity such as microbes, beneficial bacteria and fungi colonize the roots and matrix.
    -Stability is vital, as the floating wetlands need to be firmly anchored to withstand very high winds and wave action.

Prototype Monitoring:
-For growth patterns of the various vegetation species above and below the water.
-Invertebrates present
-Species' ability to propagate sideways, its natural buoyancy, and its ability to flourish at local temperatures and withstand frost.
-Components in construction and assembly are also monitered.
    -Checking bamboo growth nodes to ensure that no water enters the sealed end and causes rotting,
    -Ensuring that all bamboo joints are tied together securely with steel-rope,
    -PVCcoated wire-mesh cable ties are attached (rusting remains a big concern),
    -Silicon-sealed 'screwits' are placed at all mesh cut ends.
    -To stop plants from washing out at the sides of the floating wetland a zigzag of steel-rope is attached on the sides between the top and bottom frame.

Maintenance:
-Regular maintenance is done on shorelines and floating wetlands, and invasive species such as hyacinth and snakeroot are removed.
-Litter and debris that accumulate are removed and any stormwater damage is repaired.

Van de Moortel, Annelies, De Pauw, Niels, and Tack, Filip. 2010. Influence of water depth, coverage and aeration on the treatment efficiency of experimental constructed floating wetlands. Society of Wetland Scientists (SWS); http://hdl.handle.net/1854/LU-1075771.

Summary: This is an article about the effects of aeration upon full scale retention ponds 'batch loaded' with domestic waste water.

- Increased aeration increases removal performance.
- The process is quick, w/in 4 days.
- 100% plant coverage results in best removal performance.

Van de Moortel, Annelies, Meers, Erik, De Pauw, Niels, and Tack, Filip. 2010. Effect of aeration on the treatment performance of constructed floating wetlands. http://hdl.handle.net/1854/LU-1075798.

Summary: pollutant removal is improved by aeration, shorter residence times and smaller installation footprints can be used.

Chua, L.H.C., S.B.K. Tan, C.H. Sim, and M.K. Goyal. 2012. "Treatment of baseflow from an urban catchment by a floating wetland system". Ecological Engineering. 49: 170-180.

Summary:
-The objective of this study was to investigate the use of Floating Wetland Systems (FWS) as treatment units to treat the baseflow from the tributaries feeding into the Kranji reservoir, in Singapore
(the study focuses on the baseflow tributaries because a previous study indicated that 40% of the total nutrient loading contained in the inflow (reservoir) are coming and cozed by the baseflow nutrient loading)

the study happend in two phases:
Phase 1: testing the three chosen plants (Chrysopogon zizamioides " Vetiver grass", Typha angustifolia and Polygonum barbatum) in water samples from the 3 tributaries of the Kranji reservoir, to find out about the percentage reduction that each plant can do to the Nitrogen (TN), phosphorus (TP), Orthophosphate (OP) as PO4 and ammoniacal nitrogen (AN) as NH+4.

Phase 2: the experimentation and testing moved to site on one of the 3 tributaries , in this phase monitoring the plant growth and testing the plant uptake for nutrients were conducted.
(the floating mat system used in both phases was the Bestmann Green Systems (BGS). it is a two layered mat system. the lower layer is made of UV resistant, non-degradable polypropylene foam material to provide the necessary buoyancy; and the upper planting layer is made of coconut fiber (www.bestmann-green-systems.com)

The scope of the study:
- investigate type of plants (testing)
-assess the nutrient uptake rates in prototype scale experiment.
-engineering assessment of FWS size requirements

Lesson learned as the study indicate:
-In the study's environment they realized that successful initial establishment of plants in FWS is important to the overall sucess of FWS start-up. in addition, harvesting in a FWS serves as mechanism for effective nutrient removal and in maintaining the wetland vegetation in long growth phase of high physiological activity which enhance nutrient removal.
- the size of the FWS was estimated by dividing the unit loading rates of TN and TP by average nutrient uptake.

Li, Xiuzhen, Ülo Mander, Zhigang Ma, and Yue Jia. 2009. "Water Quality Problems and Potential for Wetlands as Treatment Systems in the Yangtze River Delta, China".Wetlands. 29 (4): 1125-1132.

Summary: This article discusses the water quality problems in the Yangtze River Delta in China and the use of constructed wetlands or floating mats as a potnetial solution.

- The purification efficiency with subsurface-flow and integrated vertical flow wetlands on the alluvial flat of a heavily polluted river shows 60% reduction in COD Mn and 85% in NH4-.
- Different plant species are efficient in removing different pollutants (e.g. Canna Indica is best at P and N removal).
- Potential areas for the placement of constructed wetlands are road sides, river/canal sides, green space around buildings, near outlets of small enterprises or residential complexes; floating mats of vegetation in rivers/canals and lakes/ponds; emergent plants along the banks, coupled with well managed biomass collection.

Van de Moortel, Annelies M.K., Gijs Du Laing, Niels De Pauw, and Filip M.G. Tack. 2012. "The role of the litter compartment in a constructed floating wetland". Ecological Engineering. 39: 71-80.

Summary: Screens designed to catch litter (dead plant matter) and house decomposer organisms at edges of Constructed Floating Wetlands, situated in a tertiary treatment facility; for the purpose of testing nutrient cycling, with focus on dead biomass generated atop CFW's (and caught in litterbags).

The carbon released during decomposition can be an important C-source supporting denitrification when dealing with C-deficit waste streams.

- Decomposing plant matter may serve as a C-source for denitrifiers.
- Biofilm formation on the dead leaves in the litter bags compensated for initial dry matter/ biomass losses.
- Plant uptake is not a final long-term removal process, but rather an intermediate step.
- Decomposition of plant biomass releases of stored elements to the water.
- Full invertebrate population exists only in natural waterbodies (crucial for decomposition).
- CFL's not generally impacted by variable water level changes. Thus well suited for treatment of event-driven waterflows such as storm water or CSO water.

Judith S. Weis, Peddrick Weis, Metal uptake, transport and release by wetland plants: implications for phytoremediation and restoration, Environment International, Volume 30, Issue 5, July 2004, Pages 685-700, ISSN 0160-4120, 10.1016/j.envint.2003.11.002.

Summary: This article is about the uptake and possible distribution of toxic metals by wetland plants.
Key words:

- 'phytostabilization'' - plants immobilize metals and store them below ground in roots and/ or soil
- ''phytoextraction'' - plants hyperaccumulate metals from the soil and store them above ground, where they can then be harvested. Wetland plants do not typically hyperaccumulate metals, and harvesting can be harmful to the wetlands.
- "Mycorrhizae (symbiotic fungi associated with roots) provide an interface between the roots and the soil increasing the absorptive surface area of root hairs and are effective at assimilating metals that may be present at toxic concentrations in the soil"

Major species' discussed:

- Spartina alterniflora, Cordgrass, is often used in wetland restoration. However, it transports metals to leaves and stems, and my introduce mercury into the food chain. it has been shown to "actively excrete metals in salt crystals."
- Phragmites australis, Common Reed, stores metals primarily below ground
- (Both S. alterniflora and P. autstralis are considered invasive in Washington)- not in article, but found at http://plants.usda.gov/java/noxious?rptType=State&statefips=53

General:

- In general, "individual leaves accumulate greater concentrations of metals over their lifespan"
- "Metal release by plants can increase the bioavailability of metals within estuaries, especially in urban and industrialized areas, where even small releases from contaminated sites can have toxic effects on estuarine food webs"
- "Using wetlands for water purification may serve only to delay the process of releasing toxicants to the water."

Conclusion/Application to Course:

- If our intention is to remove toxins from the site, we may want to design a floating wetland which is intended for regular monitoring and harvesting of contaminated biomass.
- We should also look into other, non-invasive, plants which can accumulate toxins.

slam, Md. Kamrul. 2011. Nutrient removal from urban stormwater using floating treatment wetland system. Orlando, Fla: University of Central Florida. http://purl.fcla.edu/fcla/etd/CFE0004013.

Summary: This 74 page Master of Science thesis talks about using floating wetlands (FTW) at microcosm and mesocosm levels with different sorption media to address nutrient removal effectiveness of stormwater detention ponds under varying nutrient and weather conditions.

- Addition of sorption media – significantly improve nutrient removal (as well as heavy metals, pathogens, pesticides and toxins) production of plant biomass, and tissue culture responses
- Incorporation of sorption media may promote attraction between pollutants and sorption media; phosphorus may be removed by absorption and adsorption.
- Plants with the highest nutrient intake faired best in cold temperatures.
- Regular harvesting recommended and mixed planting advantageous to keep system going during the winter. Remove senesced or decomposed plants before nutrients return to water.
- Mesocosm level – water level not a concern in nutrient removal efficiency (such as the case in seasonal water fluctuations).
- FTW deployment should not be within vicinity of pond outlet because assimilated nutrients around root zone might break off and contaminate discharged water through outlet.
- Suppresses algae and duckweed significantly that may harm fish populations or create aesthetic issues.
- Probable evolution of unwanted plants noted.

NOTED SUITABLE PLANTS
Typha latifolia - broadleaf cattail
Typha angustifolia – narrowleaf cattail
Phragmites australis – common reed
Panicum hemitomon - maidencane
Glyceria maxima – reed mannagrass
Carex lasiocarpa – woollyfruit sedge
Menyanthes trifoliate – buck bean
Myrica gale - sweetgale
Chamaedaphne calyculata – leather leaf
Water hyacinths (Eicchornea crassipes) and duckweed species also commonly used in large-scale FTW.

Others:
Typha japonica – young rush or oriental cattail
Pistia stratiotes – water cabbage
Agrostis alba – redtop grass
Juncus effussus – soft rush or common rush
Scirpus californicus – California bulrush
Pontederia cordata – pickerel weed
SE US Native
Canna flaccida – golden canna

SORPTION MEDIA
Sorption media may include (but not limited to): sawdust, peat, compost, zeolite, wheat straw, newspaper, sand, limestone, expanded clay, wood chips, wood fibers, mulch, glass, ash, pumice, bentonite, tire crumb, expanded shale, oyster shell, and soy meal hull

Bold and Gold Stormwater™ - reduces N up to 47% and P up to 87%, can be used without frequent replacement.

Wang, Q., Cui, Y. and Dong, Y. (2002), Phytoremediation of Polluted Waters Potentials and Prospects of Wetland Plants. Acta Biotechnol., 22: 199–208. doi: 10.1002/1521-3846(200205)22:1/2<199::AID-ABIO199>3.0.CO;2-T

Summary: This study examines 5 wetland plant species and their ability to uptake pollutants (namely Nitrogen, Phosphorous, Cadmiun, Lead and Mercury).

The findings are as follows for each plant species:

1. sharp dock (Polygonum amphibium)- accumulates N and P in shoots
2. water hyacinth (Eichornia crassipes)- accumulates Cd
3. duckweed (Lemna minor)- accumulates Cd
4. water dropwort (Oenathe javanica)- accumulates Hg
5. calamus (Lepironia articulata)- accumulates Pb

NOTE: heavy metal uptake occurred primarily in roots-- thus it is harder to harvest the biomass and remove this waste from system

Howard, G.W. and Harley, K.L.S. 1997. How do floating aquatic weeds affect wetland conservation and development? How can these effects be minimized? Wetlands Ecology and Management. 1997, Volume 5, Issue 3, pp 215-225. http://link.springer.com/article/10.1023%2FA%3A1008209207736#page-1

Summary: The article discusses how the three main floating aquatic weeds influence water resource management.

- They can form dense mats and growth rates are increased by high nutrient levels and temperatures
    - A dense cover of floating aquatic weeds drastically reduces and may prevent light penetration of the water
    - Without light, photosynthesis is restricted, which causes the decrease of oxygen levels
- Organic decomposition is likely to increase under a weed mat with formation of humic acids and a decrease in pH, which may result in a change in the color of the water
- Water loss
    - Through evapotranspiration of massive floating aquatic weeds
    - As mats increase, the flow rate of water decreases causing increased siltation
- Fish populations and catches are reduced by floating aquatic weeds
- Weed control:
    - Physical: manual and mechanical removal
    - Chemical: herbicides
    - Biological: use of host-specific natural enemies to reduce the population density of a pest

"Application of Floating Wetlands for Enhanced Stormwater Treatment: A Review" http://www.midwestfloatingisland.com/files/floatingisland/files/TP324%20Floating%20Wetland%20Review-Final.pdf

Summary: Excellent overview of precedents.

"This report examines the potential of developing and applying a novel 'floating treatment wetland' concept for the provision of enhanced stormwater treatment, particularly with regards to copper, zinc and fine particulate removal."

http://www.howstuffworks.com/science-vs-myth/everyday-myths/how-long-does-it-take-for-plastics-to-biodegrade.htm

Summary: In 2009, researchers from Nihon University in Chiba, Japan, found that plastic in warm ocean water can degrade in as little as a year.

This article is about how plastic can never really be degraded only turned into smaller and smaller pieces which have harmful effects on wildlife and the environment. An alternative being explored is biodegradable plastic made out of corn.

http://science.howstuffworks.com/environmental/green-science/corn-plastic.htm -Corn Plastic

Krippner, Linda and Conquest, Jessica. Use of Floating Islands for Sustainable Houseboat Living. Lake Union Houseboat Replacement, Seattle WA. January 2012.

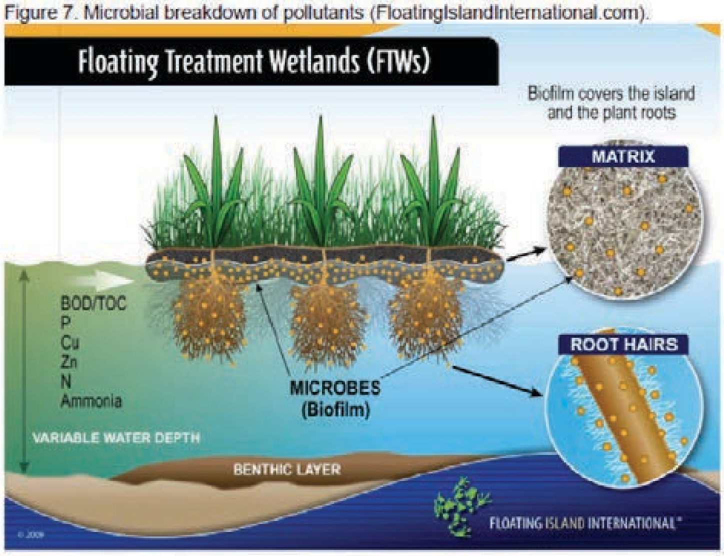
Summary: Design using "Floating Islands" integrated into decking systems for Lake Union, Seattle Houseboats.

- Floating Islands use Floating Islands International patented technologies, primarily consisting of a floating plane, made of biodegradeable polymer layers, in which plants are planted into, and roots hang down in the water below. Biofilm does the majority of water cleaning, and lives in floating plane and on plant roots.
- Underwater habitat around roots under planes, and habitat around and on planes, created sources of habitat, e.g. sunning, small fish, microbe prey, etc.

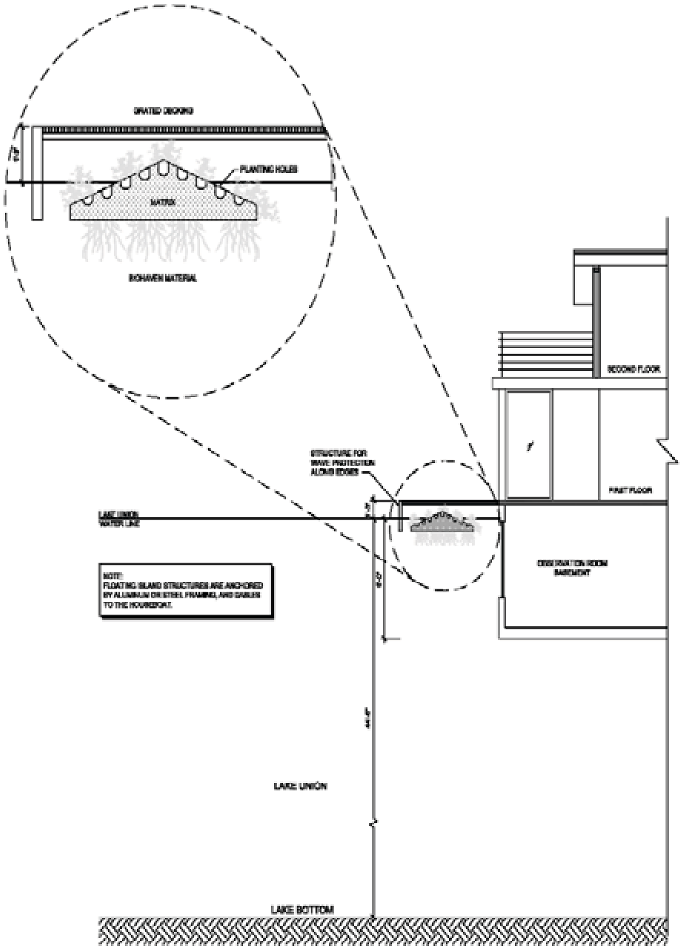
Major Design Elements:

- Polymer Floating Matrix (Planted with Natives) (Engineering buoyancy) Will break down and be replaced by plants in 10-20 years.
- Open water gaps between islands for edge habitat, air diffusion, and phytoplankton photosynthesis to increase DO.
- Installed below decking for human foot traffic, attached to houseboat with cables, able to move in waves.
    - some areas of decking will be grated for sunlight and air, other will be totally open for larger plant growth.
- Polymer Matrix edge will extend 6" horizontally below water surface, providing habitat
- This design provides habitat immune to engineering water level changes in Lake Union, i.e. important habitat

Figure 7. Microbial breakdown of pollutants (FloatingIslandInternational.com).



floating wetland system used



section of floating wetland design

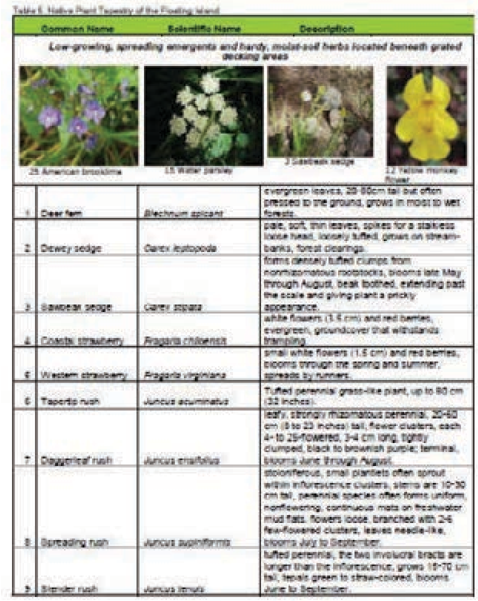
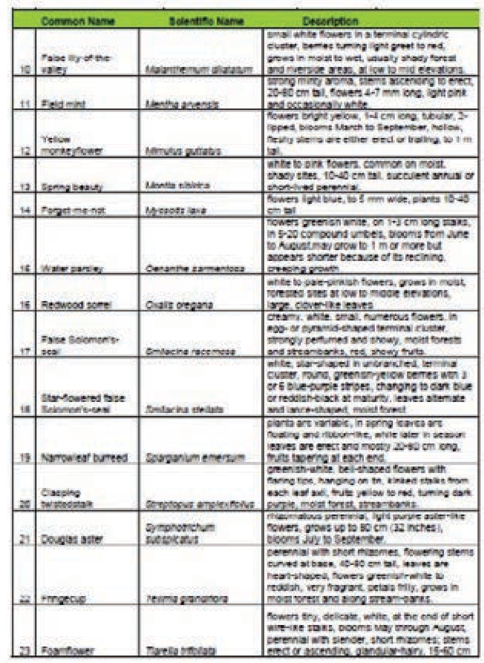
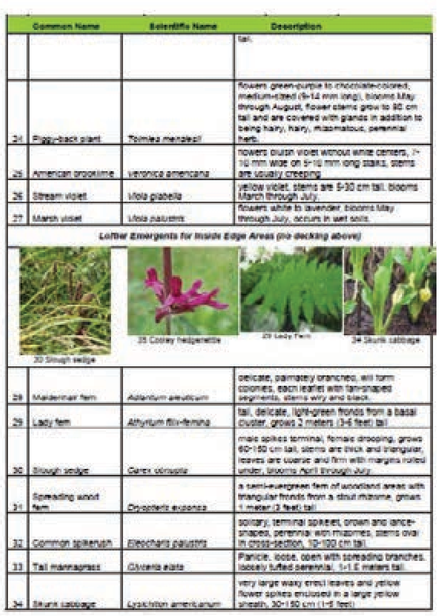


Table 6. Native Plant Tapestry of the Floating Island

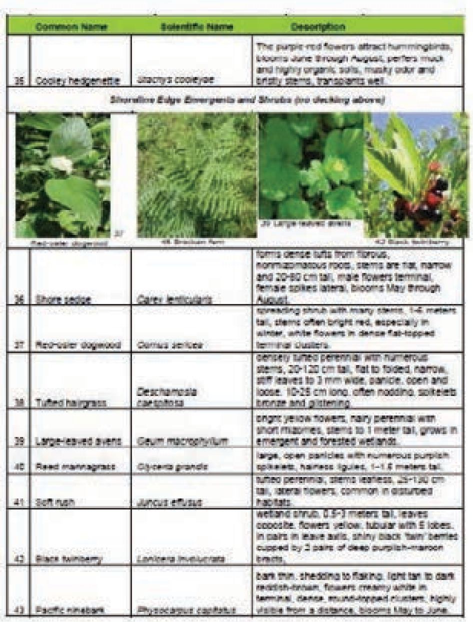
	Common Name	Scientific Name	Description
	Low-growing, spreading emergents and hardy, moist-soil herbs located beneath grated decking areas		
1	Deer fern	*Blechnum spicant*	evergreen leaves, 20-80cm tall but often pressed to the ground, grows in moist to wet forests.
2	Dewey sedge	*Carex leptopoda*	pale, soft, thin leaves, spikes for a stalkless loose head, loosely tufted, grows on stream-banks, forest clearings.
3	Sawbeak sedge	*Carex stipata*	forms densely tufted clumps from nonrhizomatous rootstocks, blooms late May through August, beak toothed, extending past the scale and giving plant a prickly appearance.
4	Coastal strawberry	*Fragaria chiloensis*	white flowers (1.5 cm) and red berries, evergreen, groundcover that withstands trampling.
5	Western strawberry	*Fragaria virginiana*	small white flowers (1.5 cm) and red berries, blooms through the spring and summer, spreads by runners.
6	Tapertip rush	*Juncus acuminatus*	Tufted perennial grass-like plant, up to 80 cm (32 inches).
7	Daggerleaf rush	*Juncus ensifolius*	leafy, strongly rhizomatous perennial, 20-60 cm (8 to 23 inches) tall, flower clusters, each 4- to 25-flowered, 3-4 cm long, tightly clumped, black to brownish purple; terminal, blooms June through August.
8	Spreading rush	*Juncus supiniformis*	stoloniferous, small plantlets often sprout within inflorescence clusters, stems are 10-30 cm tall, perennial species often forms uniform, nonflowering, continuous mats on freshwater mud flats, flowers loose, branched with 2-6 few-flowered clusters, leaves needle-like, blooms July to September.
9	Slender rush	*Juncus tenuis*	tufted perennial, the two involucral bracts are longer than the inflorescence, grows 15-70 cm tall, tepals green to straw-colored, blooms June to September.



	Common Name	Scientific Name	Description
10	False lily-of-the-valley	*Maianthemum dilatatum*	small white flowers in a terminal cylindric cluster, berries turning light greet to red, grows in moist to wet, usually shady forest and riverside areas, at low to mid elevations.
11	Field mint	*Mentha arvensis*	strong minty aroma, stems ascending to erect, 20-80 cm tall, flowers 4-7 mm long, light pink and occasionally white.
12	Yellow monkeyflower	*Mimulus guttatus*	flowers bright yellow, 1-4 cm long, tubular, 2-lipped, blooms March to September, hollow, fleshy stems are either erect or trailing, to 1 m tall.
13	Spring beauty	*Montia sibirica*	white to pink flowers, common on moist, shady sites, 10-40 cm tall, succulent annual or short-lived perennial.
14	Forget-me-not	*Myosotis laxa*	flowers light blue, to 5 mm wide, plants 10-40 cm tall
15	Water parsley	*Oenanthe sarmentosa*	flowers greenish white, on 1-3 cm long stalks, in 5-20 compound umbels, blooms from June to August,may grow to 1 m or more but appears shorter because of its reclining, creeping growth.
16	Redwood sorrel	*Oxalis oregana*	white to pale-pinkish flowers, grows in moist, forested sites at low to middle elevations, large, clover-like leaves.
17	False Solomon's-seal	*Smilacina racemosa*	creamy, white, small, numerous flowers, in egg- or pyramid-shaped terminal cluster, strongly perfumed and showy, moist forests and streambanks, red, showy fruits.
18	Star-flowered false Solomon's-seal	*Smilacina stellata*	white, star-shaped in unbranched, terminal cluster, round, greenish-yellow berries with 3 or 6 blue-purple stripes, changing to dark blue or reddish-black at maturity, leaves alternate and lance-shaped, moist forest.
19	Narrowleaf burreed	*Sparganium emersum*	plants are variable, in spring leaves are floating and ribbon-like, while later in season leaves are erect and mostly 20-60 cm long, fruits tapering at each end.
20	Clasping twistedstalk	*Streptopus amplexifolius*	greenish-white, bell-shaped flowers with flaring tips, hanging on th, kinked stalks from each leaf axil, fruits yellow to red, turning dark purple, moist forest, streambanks.
21	Douglas aster	*Symphyotrichum subspicatus*	rhizomatous perennial, light purple aster-like flowers, grows up to 80 cm (32 inches), blooms July to September.
22	Fringecup	*Tellima grandiflora*	perennial with short rhizomes, flowering stems curved at base, 40-80 cm tall, leaves are heart-shaped, flowers greenish-white to reddish, very fragrant, petals frilly, grows in moist forest and along stream-banks.
23	Foamflower	*Tiarella trifoliata*	flowers tiny, delicate, white, at the end of short wire-like stalks, blooms May through August, perennial with slender, short rhizomes; stems erect or ascending, glandular-hairy, 15-60 cm



	Common Name	Scientific Name	Description
			tall.
24	Piggy-back plant	*Tolmiea menziesii*	flowers green-purple to chocolate-colored, medium-sized (9-14 mm long), blooms May through August, flower stems grow to 80 cm tall and are covered with glands in addition to being hairy, hairy, rhizomatous, perennial herb.
25	American brooklime	*Veronica americana*	flowers bluish violet without white centers, 7-10 mm wide on 5-10 mm long stalks, stems are usually creeping
26	Stream violet	*Viola glabella*	yellow violet, stems are 5-30 cm tall, blooms March through July.
27	Marsh violet	*Viola palustris*	flowers white to lavender, blooms May through July, occurs in wet soils.
	Loftier Emergents for Inside Edge Areas (no decking above)		
28	Maidenhair fern	*Adiantum aleuticum*	delicate, palmately branched, will form colonies, each leaflet with fan-shaped segments, stems wiry and black.
29	Lady fern	*Athyrium filix-femina*	tall, delicate, light-green fronds from a basal cluster, grows 2 meters (3-6 feet) tall
30	Slough sedge	*Carex obnupta*	male spikes terminal, female drooping, grows 60-150 cm tall, stems are thick and triangular, leaves are coarse and firm with margins rolled under, blooms April through July.
31	Spreading wood fern	*Dryopteris expansa*	a semi-evergreen fern of woodland areas with triangular fronds from a stout rhizome, grows 1 meter (3 feet) tall
32	Common spikerush	*Eleocharis palustris*	solitary, terminal spikelet, brown and lance-shaped, perennial with rhizomes, stems oval in cross-section, 10-100 cm tall
33	Tall mannagrass	*Glyceria elata*	Panicle, loose, open with spreading branches, loosely tufted perennial, 1-1.5 meters tall.
34	Skunk cabbage	*Lysichiton americanum*	very large waxy erect leaves and yellow flower spikes enclosed in a large yellow sheath, 30-150 cm (1-5 feet)



	Common Name	Scientific Name	Description
35	Cooley hedgenettle	*Stachys cooleyae*	The purple-red flowers attract hummingbirds, blooms June through August, perfers muck and highly organic soils, musky odor and bristly stems, transplants well.
	Shoreline Edge Emergents and Shrubs (no decking above)		
36	Shore sedge	*Carex lenticularis*	forms dense tufts from fibrous, nonrhizomatous roots, stems are flat, narrow and 20-60 cm tall, male flowers terminal, female spikes lateral, blooms May through August.
37	Red-osier dogwood	*Cornus sericea*	spreading shrub with many stems, 1-6 meters tall, stems often bright red, especially in winter, white flowers in dense flat-topped terminal clusters.
38	Tufted hairgrass	*Deschampsia caespitosa*	densely tufted perennial with numerous stems, 20-120 cm tall, flat to folded, narrow, stiff leaves to 3 mm wide, panicle, open and loose, 10-25 cm long, often nodding, spikelets bronze and glistening.
39	Large-leaved avens	*Geum macrophyllum*	bright yellow flowers, hairy perennial with short rhizomes, stems to 1 meter tall, grows in emergent and forested wetlands.
40	Reed mannagrass	*Glyceria grandis*	large, open panicles with numerous purplish spikelets, hairless ligules, 1-1.5 meters tall.
41	Soft rush	*Juncus effusus*	tufted perennial, stems leafless, 25-130 cm tall, lateral flowers, common in disturbed habitats.
42	Black twinberry	*Lonicera involucrata*	wetland shrub, 0.5-3 meters tall, leaves opposite, flowers yellow, tubular with 5 lobes, in pairs in leave axils, shiny black "twin" berries cupped by 2 pairs of deep purplish-maroon bracts.
43	Pacific ninebark	*Physocarpus capitatus*	bark thin, shedding to flaking, light tan to dark reddish-brown, flowers creamy white in terminal, dense, round-topped clusters, highly visible from a distance, blooms May to June.

	Common Name	Scientific Name	Description
44	Marsh cinquefoil	*Potentilla palustris*	flowers are wine-red borne in loose clustered cymes from leaf nodes, creeping stems, leaves are pinnately compound, grows along lake edges, wet meadows, streambanks, blooms June to August.
45	Bracken fern	*Pteridium aquilinum*	the world's most widespread fern, fronds large, solitary, erect, deciduous, to 3 meters tall, rhizomes spreading, much-branched below ground surface.
46	Wapato, arrowhead	*Sagittaria latifolia*	tall, semi-aquatic perennial of marshes or lake margins, with large arrowhead-shaped leaves and small white flowers, up to 90 cm (3 feet)
47	Hardstem bulrush	*Schoenoplectus acutus*	stout, 1-3 meter tall bulrush, gray-green stems are tubular and can form extensive stands, flower spikelets are tightly compact, dull gray-brown, borne on terminal clusters, blooms June to August.
48	Three-square bulrush	*Schoenoplectus americanus*	flower spikelets single to few, attached directly to stem, stems are thin, firm and sharply triangular, leaves are 2-4 mm broad, 15-100 cm tall, blooms May to August.
49	Brown woolly sedge	*Scirpus cyperinus*	flower spikelets numerous and bristly, round, almost woody stems, 60-150 cm tall, blooms from July to August.
50	Small-fruited bulrush	*Scirpus microcarpus*	inflorescence diffuse, with many erect branches emerging from a single point on the end of the stem, stems triangular with rounded edges, made of spongy tissue, 60-150 cm tall, blooms from June to August.

(Plant descriptions are from Cooke 2007 and Pojar and MacKinnon 1994).]

Local plant list included in document

more information available at
http://greenfutures.washington.edu/