

Parametric Design
and
Artificial Wetlands'
Adaption in Landscape Design

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Xi Wang
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ABSTRACT

The philosophy of sustainable development and design has become a widely accepted idea by today's landscape architects. One of the most recent examples of a sustainable design trend is the application of the constructed wetland in an urban environment. By providing a water purification system for damaged water bodies and potential habitats for wildlife, artificial wetlands are considered as panacea to many cities challenged by water pollution and other ecological crisis. Yet artificial wetlands have obvious disadvantages and further improvements could still be made to them.

This Thesis will introduce basic information about artificial wetlands, their typology, advantages and disadvantages, and discuss the possibility of transforming traditional manmade wetlands into more successful systems by introducing the idea of digital design into the design process.

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Chapter 1: Wetlands In Peril

1) Safest Time in history? Urbanization and Globalization

“This is the safest time in human history,” says experimental psychologist Steven Pinker in his book *The Better Angels of Our Nature: Why Violence Has Declined*.¹ To him, we are living in the most peaceful time in human history thanks to the increasing frequency, willingness and speed of exchanging information and globalization. Wars tend to be less violent and usually end faster; food production has been industrialized and the current efficiency is incomparable by any previous historic periods;² in 2008 for the first time in human history more than 50 percent of the world’s total population lives in urbanized areas, which means more productivity and efficiency³ since cities provide their residents with well-established infrastructures, reliable food supplies and convenient transportation systems.

Today nearly 250 years after British inventor James Watt improved the Newcomen steam engine, the machine which marked a turning point in history: the Industrial Revolution. Ever since the Industrial Revolution, technologies and science have become more and more important in our daily lives, and they have

¹ Steven Pinker. 2011. *The Better Angels of Our Nature: Why Violence Has Declined*

² Shawn McKenzie. 2007. *A Brief History of Agriculture and Food Production*

³ United Nations. 2007. *World Urbanization Prospects: The 2007 Revision*.

transformed our society and our views of the world in a dramatic scale which our ancestors could never imagine. Technologies have helped humans to become healthier, live longer and they also expanded our abilities to transform nature. Yet the two World Wars and the aftermath remind us how things could go terribly wrong if technologies and science are not used for the right purpose. More than half century has passed since the end of World War II, and as Steven Pinker pointed out, we live in the most prosperous time in human history. The long lasting peaceful time makes me wonder, is this really the safest time in history or an illusion just like the short prosperous time of Europe before WW II?

In order to answer this question we need to identify the characteristics which define our time. If we make a comparison between the present and the past, we could find that the efficiency of production and the efficiency of sharing information are things that make the post WW2 world stand out from other historic times with less globalization. Every time we drive to a coffee shop on the side of a paved road to get a cup of hot coffee or take an elevator that was manufactured in Japan to get to our office we benefit from urbanization and globalization. These two phenomena are the products of technological achievements accumulated through centuries of development.

We've seen the benefits brought by drastic development at a global level: we can often get cheaper products produced in less developed countries; we have more options to choose in terms of transportation; and the more often we share

information with the others, the less likely a conflict will erupt. The mutual understanding between two nations or two individuals could reduce the risk of misjudgement, and sharing information is a great way to build trust. Almost all social data has shown that an urbanized world is more diverse, more efficient and less violent.

However the increasing population and rapid development rate bring us many challenges. “Mother nature” is a term constantly referred by people as regardless of their nationalities and cultural backgrounds. However the nature we are familiar with is becoming more unstable as exploitive development processes and population growth continue. We know that industrialized agriculture and crowded cities have made the occurrence and transmission of super virus easier than before; and the increasing needs from rapidly developing nations will add burden to the already fragile global eco-system. The 21st century could be a peaceful and prosperous time but not under the continuous increasing ecological crisis and the possibility of fatal virus outbreaks.

2) The Bio-filter: Natural Wetlands

It is the desire and ambition of establishing a better lifestyles and habitats which has helped humans as a species to achieve countless and nearly impossible goals. In the past 200 years technological and scientific achievements have empowered humans with the ability to conquer nature and expand our territory.

Yet development is never a costless process, and as our knowledge of ecosystem continues to grow, we already start to realize how devastating the consequences of uncontrolled development could be. The unimaginable value of hidden assets that nature holds has also been noticed by ecologists and scientists. The definition of natural resources today has been expanded. One of the most recently recognized and studied is the wetland resource.

Wetlands are a term commonly used to describe large area saturated with water. In natural environments, wetlands can function as a distinct ecosystem by themselves. Plants, especially those supported by wetlands, can absorb toxic substances that have come from pesticides, industrial discharges, and mining activities. A natural wetland system can function as a biofilter as it is able to provide purified fresh water for animals and plants.

Wetlands under natural conditions usually act as sieves. As water moves slowly through wetlands' soil and vegetation, many pollutants (heavy metals particularly) and nutrients (phosphorus compounds, nitrite compounds etc.) will be removed from water runoff and those are restored in the soil for plants to absorb. This unique character of wetlands can benefit animals and plants, help to reduce negative human impacts (industrial and agricultural activities) on natural cycles.

Wetlands can also provide shelters and habitats for wild animals. The rich, fertile and continuously saturated soils of wetlands may not be ideal choices for

agricultural crops or to many other plant species, however, these soils are perfect resource of nutrients and freshwater. Animals can also benefit from the food, freshwater and shade produced by lush wetlands' plant communities. Some natural wetlands are capable of maintaining some of the most valuable and sophisticated ecosystem on earth, for instance, the 7,000 square mile fresh water swamp in Sumatra Island, Indonesia. Unlike its humble name, even compared to the Great Barrier Reef, the Swamp of Sumatra Island has a unique and extremely diverse ecosystem. It is able to provide habitats for more than 200 species of mammal and 580 species of birds, among those mammals 14 are endemic, including endangered Sumatran tiger and Orangutan.

3) Wetlands in Peril

Despite the great ecological and environmental value of wetlands, those ecosystems were once considered as an obstacle to human society's expansion and development. In fact in many developing countries like China and Indonesia today, wetlands that are not listed as reservation areas are still considered as worthless swamps which need to be drained for agricultural or other developmental purposes.

Generally, wetlands could occupy vast land resources that might have high development potential. Wetlands are usually located in flat, lower areas near moving water. They can also support plants communities and animals' needs.

These characteristics usually make a wetland's surrounding environment to be aesthetically more enjoyable, which is considered to be valuable by most developers. Wetlands can maintain a large portion of carbon and nitrates. These nutrients make the soils of wetlands to be extremely nutrient rich and valuable for agricultural production. For instance, wetlands along rivers usually have a higher capacity for phosphorus absorption because clay with high bulk density is deposited in the floodplain. Wetlands are also the most important nitro compounds storage on earth. As estimated, the biochemical process of nitrification in the nitrogen cycle can retain the majority of nitrogen (about 70% to 90%) entering wetlands.⁴

However, the natural vegetation occupies most natural wetlands' cultivatable area and leaves limited space for agricultural production. In addition, water levels of most wetlands change depend on climate and seasons. The saturated soils and possibility of flooding makes wetlands very unstable for agricultural use and construction. In order to use the area occupied by wetlands, developers have to establish water management systems to drain water out of wetlands and remove natural vegetation in order to make space for crops. Thus for developers, draining wetland is almost always the first thing to do after they acquire the property. Since a wetland's system's health depends on constant water flow and sufficient restoration, drainage to a natural wetland means degradation of its regeneration ability and eventually its death.

⁴ Robert P. Gambrell. 1994. *Trance and Toxic Metals in Wetlands*.

The results of wetlands' death, typically results in major degradation of a region. If not trapped by wetlands, sediment build-up can overwhelm estuaries and coastal areas, making them less hospitable and suitable to life. The excess nutrients from agricultural fertilizers can cause algal blooms, which in turn deplete the water's oxygen, leading to ocean dead zones. Heavy metal pollutants are poisonous to animals, especially mercury and lead, which will build up in the food chain and can be lethal to fish, marine mammals and humans.

As populations grew at an exploding rate during 20th century, wetlands were destroyed worldwide in order to make space for urban development and agriculture. Across the world, utilities and infrastructures such as channels, pumps and dams were built around many wetland systems. Those infrastructures drained water out from wetlands to make room for agriculture and housing. As a result, cities which sacrificed wetland resources for development enjoyed a faster economy growth for a short term. The aftermath however, proved that such development model based on exploitive development practices was not sustainable and the lost ecological value of wetlands became unimaginable. Disturbed by careless human influence, natural cycles which used to be continuous and functional are now threatened. Issues that may degrade people's life, such as water pollution, heat island effect and insufficiency of green space in urban environment are now witnessed in most major cities worldwide, and the vanishing of wetlands contributes to greatly to this challenge.

One example that demonstrates the result of failing to protect a natural wetland is Dian Lake in Kunming, China. Covering nearly 300 sq km and considered the 6th largest lake in China, Dian Lake was once nicknamed the “Highland’s Sparking Pearl” and harbored hundreds of fish species. For 2000 years wetlands around Dian Lake supported humans with water and food. In recent decades as Kunming city’s population exploded, farm lands were built around Dian Lake to support the growing needs and waste water produced by the villages near Dian Lake was pumped directly into it. Wetlands near Dian Lake were completely destroyed and the lands which previously occupied by wetlands are now sold solely for real estate development. The disappearance of the wetlands ecosystem decreased Dian Lake’s self-purification ability even further. As a result, half of fish population in Dian Lake has been killed off and the water quality is graded level V (level V being the worst). Local government enacted numerous laws and policies and nearly one billion dollars had been spent for the lake’s purification and restoration plan, yet the water is still highly polluted and not drinkable.⁵

⁵ Yao Mu. 2006. *A Case Study in Dianchi Drainage Area*



Figure 1- Algae blooms in Dian Lake

As people's understanding about wetlands continues to develop, people start to realize the value and benefit of wetlands. As with like many other ecosystems, we have started to learn in recent years, not surprisingly, the more knowledge we gain about wetlands as ecosystems, the more valuable we realize they are.

However the harmful outcome of blind development and expansion throughout history has already been done at many places on earth and the reestablishment of a wetland system requires for greater investment than the money we spent on draining them. Across the world wetlands have been drained and destroyed to make room for industrial and residential construction. The aftermath of such practices usually lead to ecological disasters. Severely polluted water bodies now occupy many cities' public spaces and birds which were seen nesting near wetlands area are now disappeared in the urban environment. We now understand a wetland's value, yet the actual actions to protect them are still rare

and often occur too late. In United States, as environmental awareness increased in the 1960's and 70's, there was an increasing need for a more applicable wetland classification system among federal agencies. Numerous laws including the National Environmental Policy Act of 1969, the Federal Water Pollution Control Act of 1972, the Coastal Zone Management Act of 1972, and the Endangered Species Act of 1973 were published during 1960s and 1970s in order to protect and grade the States' wetlands resources.⁶

⁶ Leigh h. Fredrickson. 1983. *Wetlands-A Vanishing Resource*

Chapter 2: Artificial Wetlands and Urban Environment

1) Artificial Wetlands

Artificial wetlands typology and plant communities

A constructed or artificial wetland is usually a swamp or marsh created to restore habitat for wildlife and purify water bodies which are polluted or disturbed by human behaviors and constructions. Many people may confuse artificial wetlands with wastewater stabilization lagoons, but wetland system relies on a self-maintaining and self-balancing processes. With such respect they are usually more efficient and require less land to construct and less energy to maintain.

Similar to natural wetlands, vegetation is a crucial element for a constructed wetland's water purification system. Vegetation in a wetland system can provide a substrate layer made by roots, leaves, stems. Plants in an artificial wetland

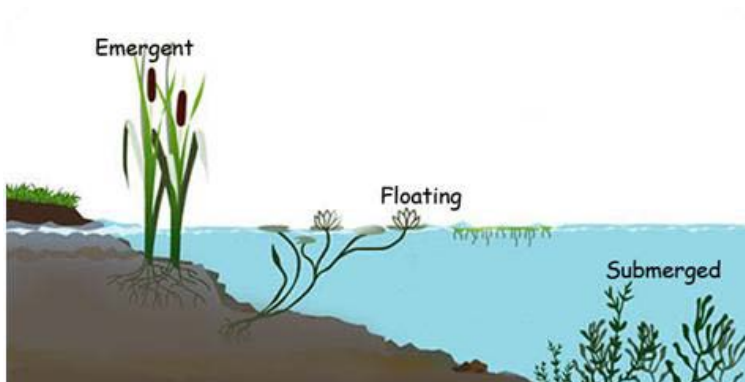


Figure 2- Typical artificial wetland plant community

system can be categorized into emergent plants, submerged plants, floating plants and shoreline plants based on their location in the system.⁷ With the vegetation layer, microorganisms can live and grow as they break down organic materials. This microorganism community is known as the periphyton. The periphyton is responsible for more than 50 percent of a water body's pollutant removal and waste breakdown. The plants can remove about seven to ten percent of pollutants and act as a nutrient source for the microbes after they decompose.

⁷ Rich Axler. 2001. *Innovative Onsite Sewage Treatment Systems*.

Most constructed wetlands we have today can be further classified into two basic types: subsurface-flow and surface-flow:

Free water surface (FWS) wetlands

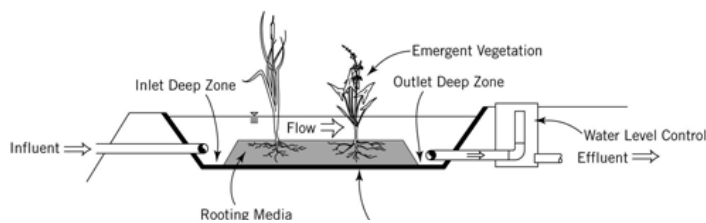


Figure 3- Free water surface (FWS) wetlands

FWS wetlands usually maintain water bodies with a depth of less than 5 feet. As water flows through the wetland system, particles including pollutants settle, pathogens are destroyed, and organisms and plants utilize the nutrients. This type of wetland allows a visible water body to exist. Since visible water is still considered esthetically satisfying by most, FWS wetlands are often considered as an aesthetic element.⁸

Subsurface flow (SSF) wetlands

⁸ *Wetlands For Tropical Applications*, Edited by Norio Tanaka, Wun Jern NG, K B S Jinadasa, 2011

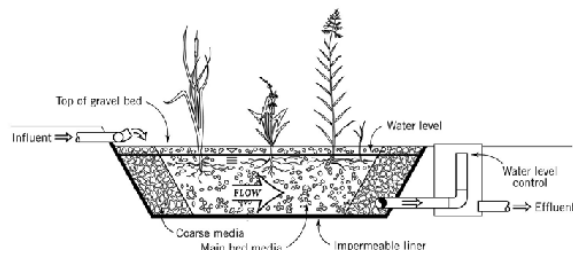


Figure 4- Subsurface flow (SSF) wetlands

Subsurface-flow wetlands transport pollutant from effluent through a medium of gravel or sand on which plants are rooted. Subsurface flow wetlands are sometimes considered as a more applicable option compared to free water surface wetlands since a lack of visible water body typically results in less of a possibility for pests like mosquito to exist and reproduce.



Figure 5- Artificial wetlands development within a two year period

http://en.wikipedia.org/wiki/File:Mature_Constructed_Wetland.jpg

2) Case Study: Hong Kong Wetlands Park

One of the most successful precedents of using constructed wetland in urban landscape design is the Hong Kong Wetlands Park. Located at Northwest New Territories of Hong Kong, this 64 hectares project is predominantly a man-made wetland with fresh water marshes. In response to the absence of an eliminated wetland which was destroyed due to new town development during 1990s, Hong



Figure 6- Hong Kong Wetland Park

Kong government launched Hong Kong wetland park project with the aim to bring wetlands and ecosystem back to Hong Kong's urban environment. After the park was built residents from nearby communities suddenly discovered the grey skyline of this region was broken with a strong stroke of green color and the environment became lively and fresh because newly introduced wildlife. People started to have more discussion about this project's positive influence and the citizens of Hong Kong became to appreciate the benefit brought by artificial wetlands. As a result, this project is indeed a successful artificial wetlands' adaptation in urban environment. Today an educational facility located in the heart of the city provides information about wetlands. It attracts hundreds of visitors every day and provides people with a place to learn and play.⁹ Hong Kong became one of the few cities which successfully utilized the idea of re-establishing an ecosystem in an urban environment.

3) Advantages and Disadvantages of Constructed Wetland:

A constructed wetland system is a cost-effective and technically feasible approach for treating wastewater and runoff.

- o They are expensive to build compared to many other treatment options which require more materials and resources.

⁹ Hong Kong Wetland Park. 2008. *Hong Kong Wetland Park- A Place to Demonstrate Conservation and Sustainable Practices*

- o The energy and expense of a constructed wetland system are comparatively low. After establishment, artificial wetlands will become a self-sustaining system without additional energy input.
- o If established well, this is a process that only needs a periodic labor input.
- o The capacity of wetlands allows them to tolerate fluctuations in flow.
- o Wetlands may provide new habitats for wildlife and may harmoniously fit in most landscape contexts.
- o For cities that are looking for eco-friendly design solutions, constructed wetlands provide a possibility for sustainable development as well as a beautification method for urban environment.

For designers artificial wetlands are handy tools to achieve the goals of green design, yet this is not a panacea for all the environmental problems we face.

Despite the obvious benefits which artificial wetlands can provide, these wetlands do have limitations and disadvantages:

- o Almost all wetlands will require a large land area for implementation. Thus only when a proposed site is available and affordable, will a constructed wetland have an economical advantage.
- o A wetland's performance could vary due to environmental conditions and seasons. Extreme weather conditions like storm or drought could have devastating influence on artificial wetlands.

- o Mosquito and other pest breeding could also be a potential challenge for establishing a successful artificial wetland system. When organic matter accumulates in a wetland system and water flow is too slow, malodors may occur and become an issue.
- o An artificial wetland's efficiency relies on the vegetative communities' health and quality and the task of establishing healthy applicable vegetation communities could be time consuming and unpredictable under particular circumstances.

In addition to the limitations listed above, it is also obvious that manmade wetlands do not inherent the same aesthetic characteristics and value from their natural prototypes. As artificial wetlands are constructed, the harsh outlines, exposed outlet pipes of typical constructed wetlands can hardly be considered as natural or beautiful. The way that people used to design and construct artificial wetlands may help us to create a water treatment system which may require lower maintenance, but it won't take the place of a flourishing natural wetland system.

The limitations of artificial wetlands restrained the practice and opportunities of using manmade wetlands in many urban areas where land resources are scarce and populations are dense. A valuable and ecofriendly design approach like artificial wetland could be even more adaptable if we can be more innovative and

be able to think creativity. We live in a time full of opportunities, as technology is developing in a rapid rate today. Many goals we used to consider as impossible to achieve have been accomplished as a result of increasing efficiency of exchanging information. Experts from different research areas tend to collaborate with each other more than before. Since the knowledge we share and exchange may boost highly innovative ideas, the result of cross-disciplinary collaboration is rewarding. We now can see buildings which resemble vertical forests which are designed by architects and landscape architects in Singapore; we may also enjoy the scenic shoreline of a creek which is studied and maintained by soil scientists and landscape architects. The limitations of artificial wetlands do not necessarily need to be obstacles for us to use them in landscape design. As long as a constructed wetland's approach is proved to be accessible in an urban area, we could use our professional skills and knowledge to bring natural and biological purification systems by using artificial wetlands.

Yet as mentioned the disadvantages of artificial wetlands do exist. A landscape architect's ability and innovative ideas could be crucial to improving the artificial wetlands system we have today. In order to make artificial wetlands more efficient, a solution must be provided first to boost vegetation density within a given land area. The velocity of water also needed to be reduced so that water purification process can function thoroughly. If an artificial wetland can bring more than only economic and ecological benefits, for instance a wetland park with scenic environment which most people adore, developers and decision

makers may become more willing to use their land for wetlands construction.

Thus the key to successful improvement of artificial wetlands relies on the question of how to maximize their surface area and how to improve their esthetic value.

Wetlands require large amount of surface area for implementation since vegetation need space on which to attach and water must flow at a controlled rate for purification process to function thoroughly. The answer to how to boost surface area may rely on the vertical direction instead of modification on two dimensional space.

If we consider a site – a piece of land as a two dimensional square, the amount of vegetation that this square space can support is limited. But illustrated by the diagram below, after folding this square space without changing its width and length, more area will be provided for plants on which to attach since the surface area is increased. Therefore we can increase the number of plants which may

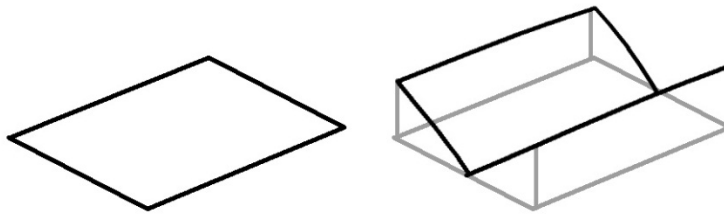


Figure 7- Concept drawing-Increasing surface area by modification of form

inhabit this site. Also by changing the geo-form of a site we can provide more possibilities for different vegetative communities to exist since we are introducing a value of height. This height is critical for the site to have a diverse vegetation community since it is able to create a hierarchy of spaces. Plants have different needs for water, humidity and exposure. With various spaces created by the site after modification, these plants' needs may be satisfied more easily. If water is introduced to the site, modeling it into a three dimensional geo-form will divide the space into an underwater segment and above water segment. This will further increase the possibility of using different plant materials. A diverse plant community could help to establish a more ecologically diverse habitat therefore

the site after modification is more likely to support small predators (frogs, dragonflies etc.), which could become a crucial element to control pests in water. It is also safe to say a diverse and complex constructed wetland is more appealing to its audience compared to past treatment plant filled with randomly growing plants, pipes and rubbles.

Changing the forms and shapes of artificial wetlands may provide more possibilities to create diverse plant communities and aesthetically appealing shapes, however, using traditional ways to modificate geo-forms could be challenging. Grading and drainage calculations are tools that most landscape architects are familiar with but they can hardly be described as efficient tools when dealing with large quantities of land. The amount of labor and time on constructing such documents could be tremendous. The possibility of disturbance to natural cycles during the grading process is another notable issue. Also, designing an artificial wetland naturally is challenging, since a natural wetland's intriguing forms evolve under the influence of natural forces, which could be difficult to recreate by human mind. As for the question of how to increase the diversity of plant species and how to satisfy those plants need, a typical answer might be with constructing planters, water tanks, retaining walls and containers for different plants. But the appearance of traditional landscape structures and materials are generally made by an industrial process and they are not considered as natural by most people. If we really want to design a manmade wetland naturally, a different design process must be first explored.

Chapter 3: New Approach: Digital Fabrication and Parametric Design

1) Parametric Design as a Concept

It is true that a designer who is experienced enough could be able to hide most of the artificial features in a man-made wetland system. They can design the wetlands naturally by using curves and vegetation design but the design process could be very time consuming. Since technology is developing and our understanding about beauty is changing, we don't have to remain tied to traditional design. Design is not a one directional process. We can use new knowledge and technology to help us accomplish our goals.

Today's generation is experiencing a dramatic change in both design philosophy and methods. By using new techniques and technologies, professionals are now able to design more efficiently. Digital tools are advancing at an unprecedented rate. Computer programs such as SketchUp, AutoCAD and Photoshop are now linked tightly to almost every designer's career.

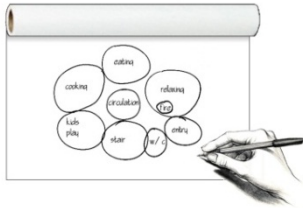
A newly emerged design trend which is known by many people as "parametric design" or "algorithm design" provides digital abilities with new definition. And to

many architects, this new idea is exciting since it can generate forms we could never imagine.

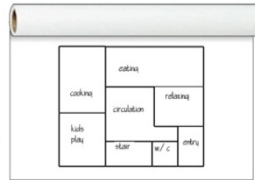
Parametric design is different from the standard digital tools such as AutoCAD and Photoshop yet in many ways it is one of the most beneficial with its revolutionary impact on tasks and design processes which we have traditionally preformed manually. There is no precise definition of parametric design but all projects which could be referred as such share some similar qualities: They are all computer aided forms which are typically generated through software instead of designed manually. Even though the computer did not invent parametric design and this new idea doesn't redefine design as a profession, it still enables designers to design innovative shapes with more exacting quantitative and qualitative results.

Traditional Design Process

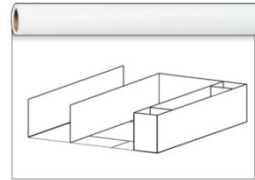
1. Bubble Diagram



2. Plan. Section



3. Space

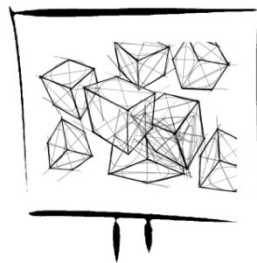


Parametric Design Process

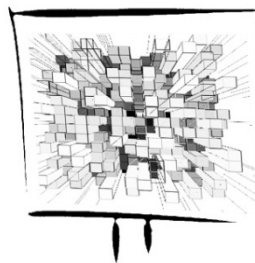
1. Determine Algorithms/Logic



2. Generating forms



3. Single Unit => Complex



Traditional Design Work flow. Simple. Linear



Parametric Design Work flow. Complex. Circular

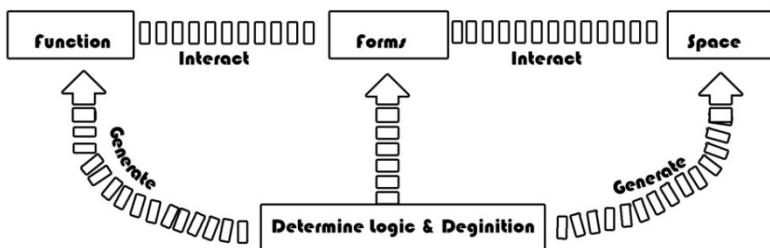


Figure 8- Concept of parametric design

The benefits of parametric design process are impressive. With its help we are no longer bound by previous limitations with demanding calculations anymore. Computers can assist with all the needs for calculation and simulation. All we need to do is define the process by using these digital tools. Parametric design is able to provide us with the ability to evaluate the variants of a project. With parametric design or digital design philosophy it is now possible to use primarily human influenced techniques to reveal and invoke beauty. The simulation effects of digital tools are also advancements for landscape architects since it is now possible to evaluate different natural factors' effects on a landscape project simply by building a landform model and entering some data. The simulation process can give designers the ability to establish a more successful evaluation system. For designers who are trying to establish an efficient wetland system, It is now possible to simulate the constructing process and evaluate the project in a visible way before any actual construction work begins. With the digital tools' evolvement, the promise of creating shelters for animals and plants as well as a water filtration system becomes simpler. As innovative architecture projects designed with the aid such as rhinoceros 3D, CATIA (Computer Aided Three-dimensional Interactive Application) and other software, there is reason to believe landscape architects may use these tools with their designs as well. If parametric design can be introduced into the design and construction process, constructed wetlands may be designed in a different way: Modern and natural with more surface area for plants to grow, multiple layers for vegetation

communities and even habitats for animals diverse enough to create a complete food chain.

2) Grasshopper and Rhinoceros 3D

Grasshopper is a useful plug-in for Rhinoceros 3D, which is a 3D modeling and rendering computer program commonly used in industrial design. As a parametric design tool, Grasshopper is easier to learn compared to CATIA and other parametric design tools. Grasshopper requires almost no knowledge of programming or scripting yet it still allows designers to build form generators from the simple to the complex.

By writing grasshopper definitions and providing landform model in Rhinoceros 3D, a water runoff diagram based on site's elevation and slopes may be created. The final result of this process is below as a diagram, which indicates the patterns of stormwater runoff. If the buffer area between the Everglades in Florida and the adjacent suburb can be modified into particular pattern and proper soil, vegetation materials are provided, storm water will likely be held in key places, and water infiltration process may saturate the site eventually.

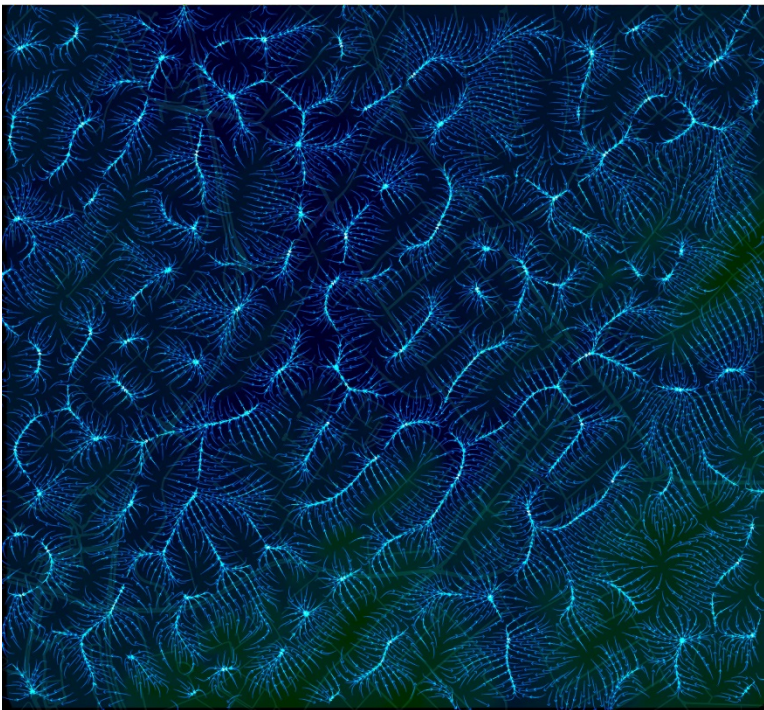


Figure 9- Grasshopper generated water flow analysis

As mentioned previously wetland system is a complex composition of various elements. Vegetation, landform, water, soil etc. are all crucial factors to determine whether a wetland functions efficiently. It is impossible to successfully re-establish a wetland system without the consideration of these elements, and for landscape architects the most desirable result of analysis process is an evaluation diagram with a legend which indicates values and types of features. Most landscape analysis diagrams are created and rendered from information related to features of particular sites. Those images may help designers to evaluate their sites in a direct and thoughtful way. Yet by writing definitions in Grasshopper, the diagrams can be used to generate interesting forms and shapes. Two dimensional diagrams may be transformed into point clouds which are sets of vertices in a three-dimensional coordinate system. Using 3D modeling computer software such as Grasshopper, the point clouds created through grasshopper could be used as start points for modification in a three dimensional space then with the help of 3DsMax and Rhinoceros 3D, each point of the modified point clouds could be used as a joint to generate a mesh or form in space, similar to the process of weaving a fabrication. With innovative thinking and help from computer software, landscape diagrams can be translated directly into a visible form with height, length and width.

Chapter 4: The Everglades

Considered as one of the most valuable wetland systems in the world, the Everglades is a natural wetlands complex in Florida, United States. It was established as a National park in the early 1940s, yet it is currently suffering from degradation and other environmental issues. This thesis proposes to provide a solution and to remind the public of the Everglades' importance. In order to do so, the importance and incomparability of the Everglades must be first fully understood.

1) Introduction of the Everglades

The Everglades are a vast region of subtropical wetlands located in the southern region of Florida. The origin of the Everglades starts from Kissimmee River near Orlando, Florida. Water from the Kissimmee River enters Lake Okeechobee, a vast yet shallow lake. During the wet season water exits Lake Okeechobee and forms a slowly moving river with a length of 100 miles and width of 50 miles. In terms of characters and forming factors, the Everglades has many things in common with other wetlands systems, yet it also possesses some very unique characteristics, most notably its amazingly diverse eco-system and water flow pattern.

The vegetation in the Everglades is primarily consists of sawgrass prairie. This prairie extends from Lake Okeechobee near south central Florida all the way to the mangrove region along Southern Florida's coast.



Figure 10- Sawgrass prairie

<http://miami.about.com/od/photosofmiami/ig/Miami-Wildlife/Sawgrass.htm>

Surface water of the Everglades migrates slowly southward to the sea over a flat limestone plateau with almost unnoticeable slopes. Geologically, this plateau consists of porous and sedimentary rocks. These rocks are made of ancient sea life fossils and calcium. These fossils indicate the evidence of ancient seas that once covered the area, which indicating the lengthy formation of the Everglades. The limestone aquifer under the Everglades acts as the principal water recharge area for all of south Florida.

Hammocks and Sloughs

The Everglades' geomorphology is mainly defined by two distinctive landscapes called sloughs and hammocks.

The Everglades' sloughs are secondary river-delta channels. These low-lying marshy rivers are able to channel water through the Everglades and are the main avenue of water flow. They are relatively deep compared to hammocks and remain flooded all year-round. Water current is relatively slow and mild, about 100 feet (30 meters) per day.

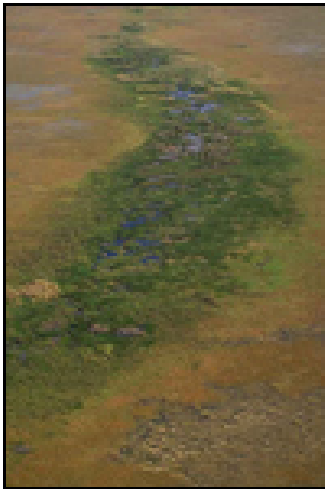


Figure 11- Slough of the Everglades

<http://www.nps.gov/ever/naturescience/freshwaterslough.htm>

The Everglades' hammocks are slightly raised sections of land which occupied by broad-leafed trees. They are also the dominating upland plant community in the Everglades National Park.

A hardwood hammock is a stand of broad-leafed trees that grow on a natural rise of a few inches in elevation. Hammocks could be found nestled in most of the Everglades ecosystems. In the deeper sloughs and marshes, the seasonal flow helps give these islands of trees a distinct aerial teardrop shape.



Figure 12- Hammocks of the Everglades

http://www.nytimes.com/slideshow/2010/10/08/opinion/20101008_LR_Florida-3.html

2) The history of the Everglades

The first group of people settled their foot on Florida peninsula 15,000 years ago, for a long period of time the Everglades remained the same: The River of grass which harbors millions of birds and reptiles. The sad history of this magnificent wetland system began around a century ago. In 1880, Napoleon Bonaparte Broward, the governor of Florida State, announced an ambitious plan to drain the Everglades for future development. By building extensive canals and establishing drainage districts around Everglades, Broward successfully transformed Everglades into a attraction for developers and farmers. The exploitive and disastrous modification of the Everglades reached its top after the establishment of the Central and South Florida Project (C&SFP)

The Central and Southern Florida Project was authorized at 1948 to provide flood protection and fresh water to south Florida. This project accomplished its purpose and allowed people to more easily live in south Florida. However, it did so at tremendous ecological cost to the Everglades. While the population of Florida has risen from 500,000 in the 1950s to more than 6 million today, the numbers of native birds and other animals have dwindled and some have distinct. The size of the Everglades has been reduced by more than a half since 1950. Water is the lifeblood of any ecosystems on earth, in the south Florida ecosystem the lifeblood is threatened. Compared to the historic Everglades, there is 70 percent less water flows through this ecosystem today. And the quality of the

water that enters the ecosystem is also degraded. It does not follow the flow and duration of the natural Everglades and it can't move freely throughout the system. The health of Lake Okeechobee, the second largest freshwater lake in the U.S and an important habitat of fish and other wildlife, is seriously threatened. Clean water is not available to the estuaries. Nor is there enough water for the residents of south Florida.

As several ecological crisis surfaced during 1970s and 80s, the government of Florida realized the importance of the entire Everglades natural water flow region, not just the Everglades National Park. As a result a large project aiming to solve the Everglades eco-crisis was formulated and it is known as the Comprehensive Everglades Restoration Plan. The Comprehensive Everglades Restoration Plan (CERP) is a framework and guide to restore, protect, and preserve the water resources of central and southern Florida. The Plan has been described as the world's largest ecosystem restoration effort and includes more than 60 major components. Since the region's environment and economy are integrally linked, the plan also provides important economic benefits. This plan may result in a sustainable south Florida by restoring the ecosystem, ensuring clean and reliable water supplies, and providing flood protection. Yet this project is a controversial one because of the large investment and uncertainty of the Everglades' fate.

The Everglades was designated as a national park in 1940s and federal government has spent billions of dollars to restore its ecosystem. The so called

“abominable pestilence-ridden swamp” by Broward is now known as the most valuable wetland system on earth.¹⁰ Yet the park itself also suffers from numerous existing management problems including insufficient park rangers and funds, conflict between people’s recreational needs and the Everglades’ need for systematic protection. People now realize that simply protecting the Everglades National Park is not enough to save the dying “River of Grass”. If we don’t do anything about the problems, America will lose this treasure and the damage may never be repaired.

¹⁰ U.S Geological Survey. 2013. *Everglades Agricultural Area*

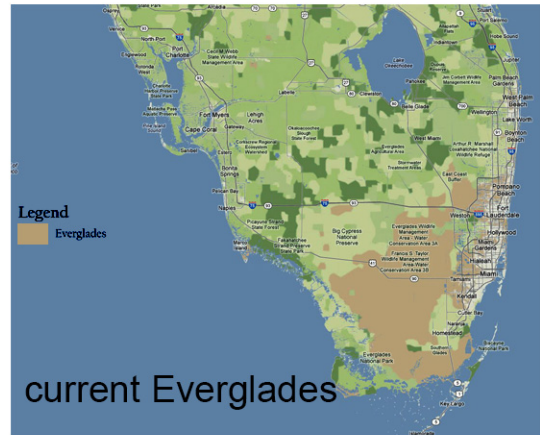
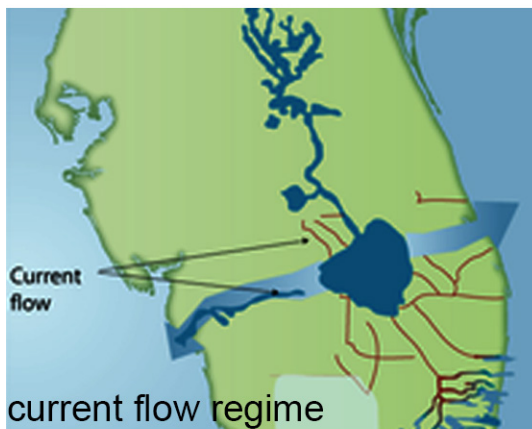
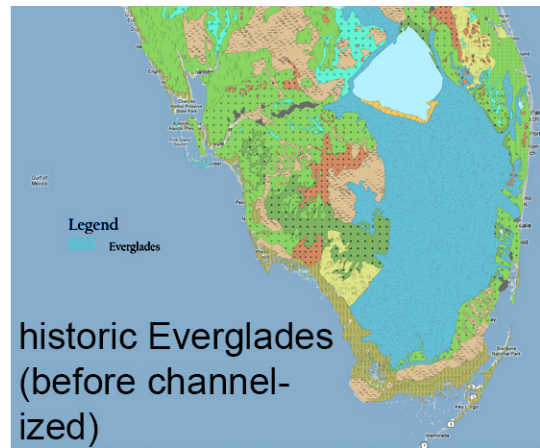
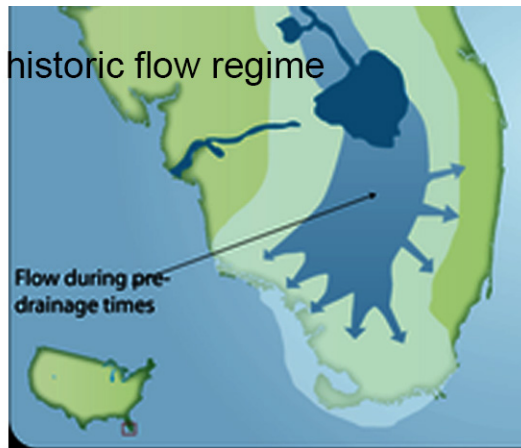


Figure 13- The Everglades' historic flow and current flow

11

5. Site and Design Concept

¹¹ Jane Thomas. 2010. *Historical versus current flow regime through the Everglades wetlands*

1) Project site – water preservation area

The selected site lies adjacent to the west boundary of Broward County, Florida. It is a rectangular flat parcel (slope <1%) which has a width of 3000 feet on east-west direction and a length of 9000 feet (see diagram). The predominant soils of the site are Lauderhill muck and Dania muck, both are all-seasons saturated soils with high fertility and stay unfrozen year round.

2) Opportunities and potentials

The site is located at suburb area of south Florida, it is close to the Everglades Holiday Park which is a famous recreational park and film studio set of the TV program show “Gator Boys”. The selected site is a part of the water preserve areas. Although it is located within the boundary of Florida’s water conservation areas, the site is still largely untouched and currently classified by the City of Weston as land for agricultural use, which means less limitation, restriction and ecological concern. This makes it possible for modification about the site. With a dam several channels which were built during the construction of water preservation area two, the site can be easily flooded and returned to the form it previously as a component of the Everglades’ wetland system. The West Broward High School which is a famous local school in the region is located at

the area adjacent to the site's south edge. There are also several other K-12 schools located nearby. These education facilities indicate a potential need for a park with educational purpose, which can teach children about the Everglades and at the same time enhancing the community identity. On the east side of the site there are many residential communities, yet few public recreational areas are located near this region as shown on the land use map of Broward County. A proposed wetland park can also satisfy residents' need for recreational space and a public park. Flooding the site may also help the water reservation area to control one of the most notorious invasive species in the history of Florida, the melaleuca tree.

Melaleuca trees are also known as punk trees or paperbark trees. They are native to Australia but in that country they are considered as valuable plants. Generally melaleuca can grow to 80 feet tall, with whitish, peeling bark and small, white bottlebrush-like flowers. These characters provide melaleuca with special ornamental value. Melaleuca are planted nationwide in Australia and cherished by local gardeners and beekeepers since melaleuca is very attractive to birds and bats.

Yet in Florida, United States, melaleuca is considered as an invasive species and a pest, especially in the Everglades areas. Melaleuca was first brought to Florida from Australia during 1900s, during that time it was used as an ornamental tree as well as soil stabilizer. It was also considered as a tool to drain the Everglades

during early 20th century. However just like any other species which were introduced without associated enemies (insects and viruses, notably), mealeuca soon became extremely invasive in the Everglades. Unlike many other canopies, melaleuca is capable to survive in both terrestrial and completely aquatic situations. The warm weather of Florida and the Everglades' saturated fertile soil made "the river of grass" into a perfect place for melaleuca to thrive. These trees can also produce large amount of seeds which in turn become small trees. Those small trees can eventually grow into dense, immense forests consuming all other native plant species. In the Everglades, the previous dominating plant species were sawgrass, water lily and live oak, all of those have no compatibility against adaptive melaleuca. Since 1900, melaleuca has taken over several hundreds of thousands of acres in the Everglades and it is turning this special ecosystem into a monocultural of an undesirable nature. It has displace nearly 400,000 acres (1,580 km²) of native plants, namely wet pine flatwoods, sawgrass marshes, and cypress swamps in southern Florida. The selected study site also suffers from melaleuca's invasion. The site used to be part of the Everglades' sawgrass prairie and was able to host birds and fishes. Now the original sawgrass community is almost completely gone and melaleuca is the current dominating plant. About 2/3 of the site's canopy layer consisted of melaleuca currently. By flooding the site, melaleuca could slowly dies out and it may also be easier to remove them from soil.

3) The Design Process of the landform

The design process is mainly about transform a two dimensional bubble diagram to a three dimensional landform which carries visually similar characteristics with the Everglades' hardwood hammocks and sloughs. The main computer programs used in the forming process of this project are Rhinoceros 3D, Grasshopper and 3DsMax.

1) First step: Bubble diagram modification

3D modeling programs can only recognize points, vectors and data. In order for the computer to be able recognize design diagrams and concepts of designers', a translation process must be provided first. The written Grasshopper definition can transform a two dimensional JPEG file to a group of points which could be recognized by 3D modeling programs. During this process the image's colors' lightness is changed into the information about points' density. As presented in diagrams below, bright or white areas of the bubble diagram on left are transformed into blank void space though Grasshopper definition. In the meantime darker areas of the image are turned into points groups with different densities. The darker the color is in a particular area, the denser the generated points cloud will be. The final result of this process is shown of the diagram on right.

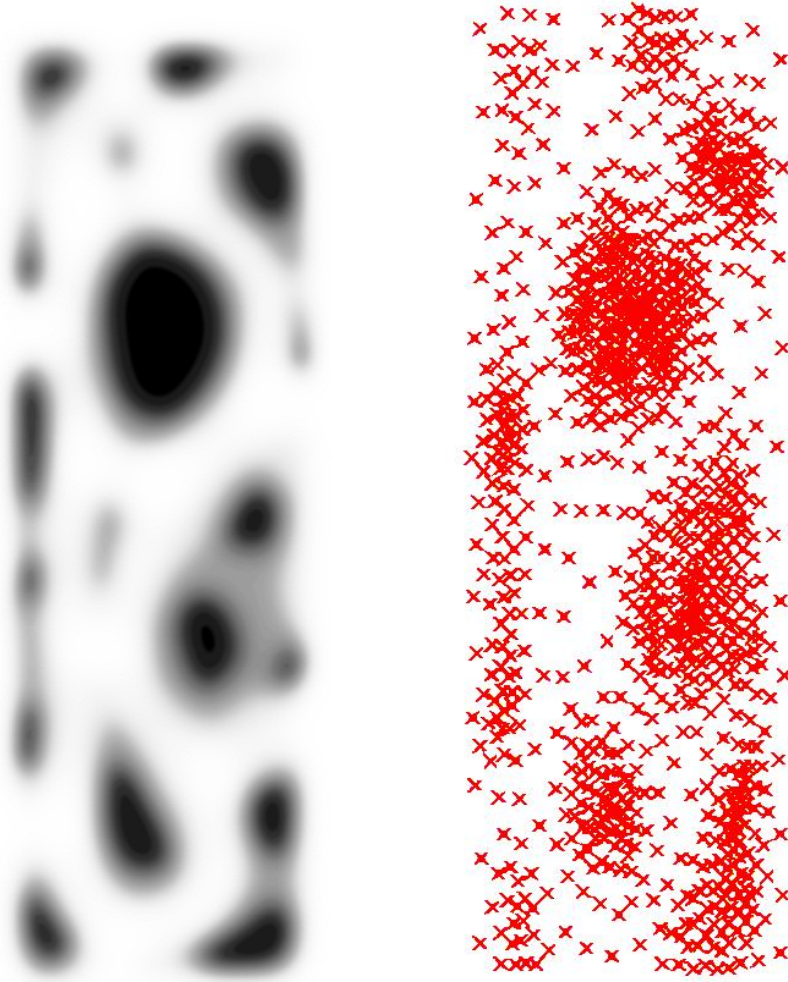


Figure 14- Bubble diagram modification process

2) Second step: Optimization process

The point clouds are able to be used by the computer for further developments. However, the distinctive contrast between loose and dense groups is not similar to the Everglades hammocks which are naturally and sparingly dispersed in a vast area. In order to acquire the similar appearance of South Florida's wetlands system, the point clouds need to be optimized. During the optimization process the concept of Voronoi diagramming is adopted. The Grasshopper definition is able to disperse points

into void space and at the same time maintain each point cloud's visual characteristics. The process is shown in the diagrams below.

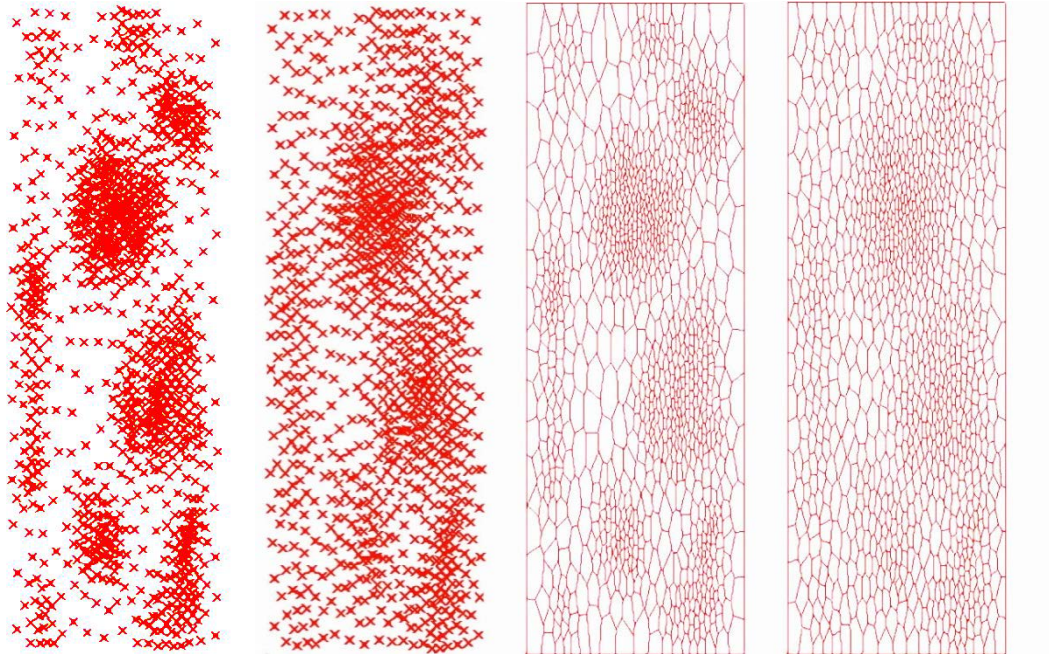


Figure 15- Point cloud Voronoi forming process

3) Third step: Landform formation process

With the points generated through Grasshopper, the computer is able to generate three dimensional forms. A dense cluster of points will generate a large, taller island with comparatively complicated forms, while a loose cluster will generate smaller, shorter island. Isolated points will become small linear islands which are similar to hardwood hammocks of the Everglades.

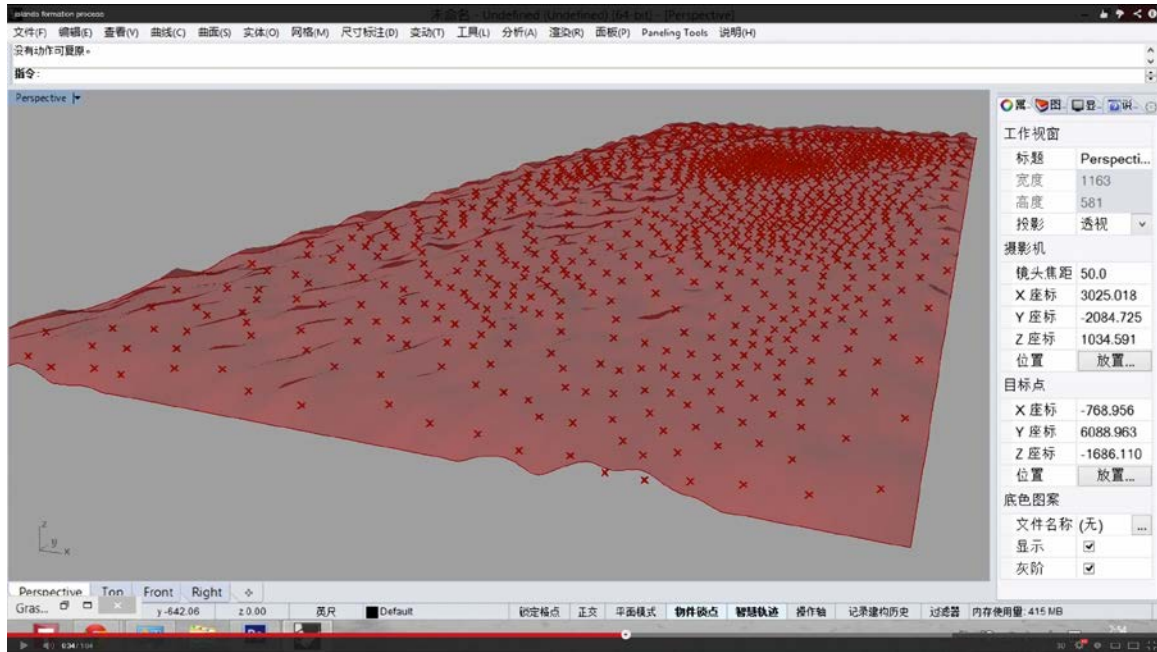


Figure 16- Geoform generating process

4) Parametric Design-micro Everglades

The Everglades is impossible to recreate, yet as mentioned, it is easier for people to understand the importance of the Everglades if a smaller version of this complicated ecosystem can be showcased locally. By using digital tools on this project, the design process may be simplified and resulting the forms and shapes of wetlands will be more natural.



Figure 17- Rendered image, the bridge and wetland park

In order to use digital tools to create the Everglades' most iconic scene, sloughs and islands with different sizes and shapes, starting points must be provided first for the computer to understand where these features should be located.

Therefore a set of points' location must be determined first and in order to simplify the design process, those points must be generated through computer.

The first step of this project's design process is like any other design project: making a diagram to indicate major use areas. However this diagram needs to be simple and has to be created without color, since less information input will be

easier for computer to handle and monochromatic image is also more appealing to designers. After the diagram is completed, a Photoshop filter can make the bubble diagram's edge blurred therefore creating a new diagram. Then by using a definition written in Grasshopper, one is able to transform the new diagram into a points cloud. The previous information about darkness and tone is now transformed into information about points cloud's density and form. The darker areas in the diagram become dense points groups. This will allow Grasshopper to create larger, more complicated islands. On the other hand the areas with light colors in the diagram become a loose group of points, which will then be transformed into isolated, small islands. After the geo form is finished, plants ranging from small submergent aquatic plants to big hardwoods may be used on those islands' shoreline areas or upland areas accordingly. All of the design steps mentioned are done by computer automatically through a simple click and the design's resulting appearance is natural and resembles the Everglades sawgrass marshes and hardwood hammocks.



Figure 18- Master plan and detail plans

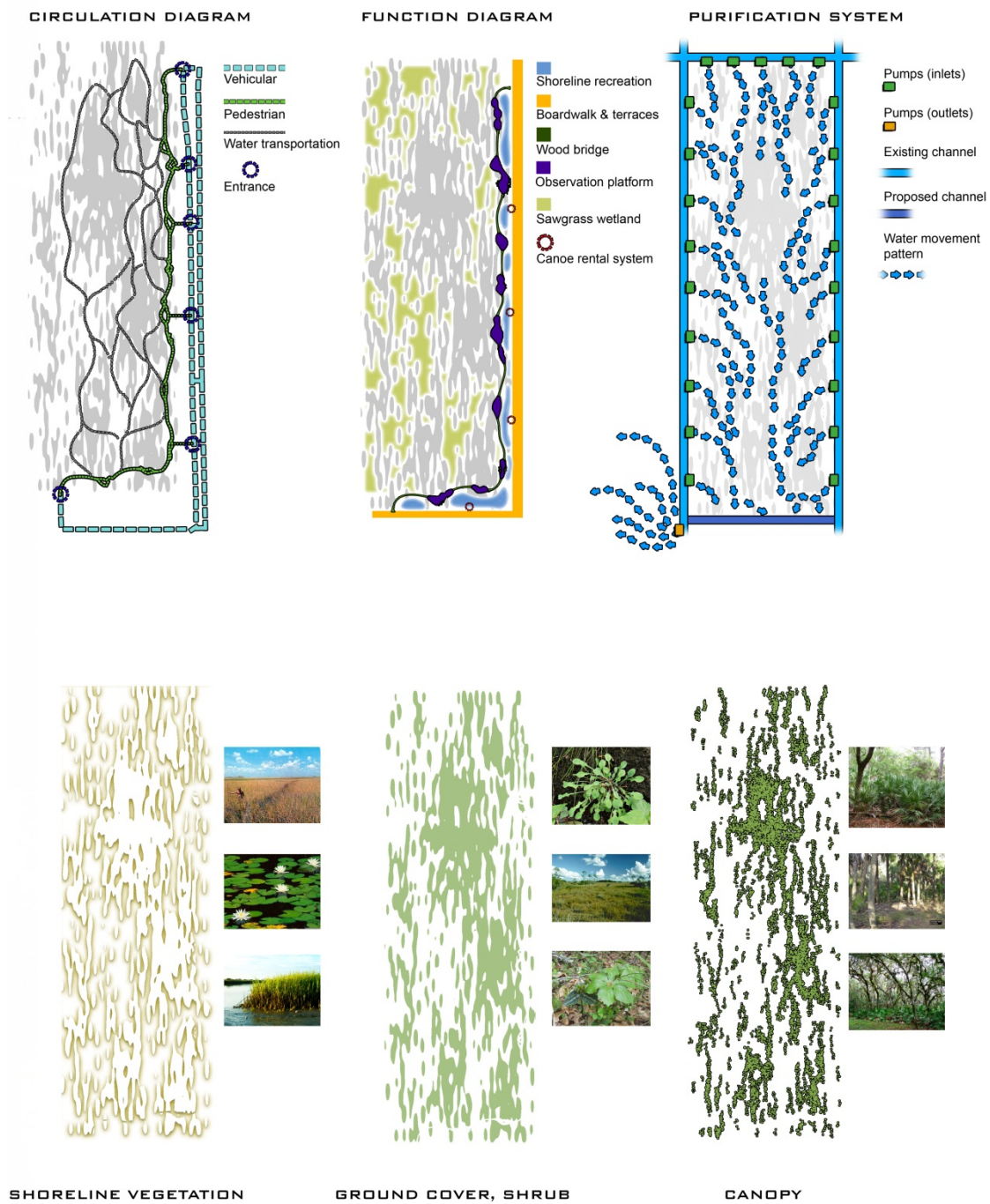


Figure 19- Diagrams

After modification the site is transformed from a flat land with invasive plant and saturated soils into a smaller version of the Everglades ecosystem. As an artificial wetlands with plants, this wetland park can also purify water and allows purified water to re-enter the Everglades' water recharge system through channels built for water reservation area. The islands and sloughs generated through the computer can slow down water velocity so that more pollutants may be removed from water.

5) Parametric Design – Observatory Bridge



Figure 20- Rendered image- The platform

Designing a smaller version of the Everglades is not enough to attract people to come visit and learn. It is also not enough to justify the wetlands park presence while a more intriguing natural ecosystem is still in existence. Therefore this project also provides a unique circulation system with which to experience Florida's wetlands' ecosystem from different perspectives.

The proposed observatory bridge of this project is generated through computer programs in a similar fashion to the islands and sloughs. The supporting structure of this bridge is formed by using diamond-like shapes in an attempt to mimic a Florida python's skin. Through Grasshopper and Rhinoceros 3D the complicated supporting structure is now generated automatically by the computer saving much time and calculations. Every 1500 to 2000 feet the bridge's particular portions are enlarged and holes are created in these areas to provide access for people to be transported from observing platforms to the islands and sloughs below. These enlarged platforms and stairs provide visitors with different perspectives to see and experience a typical Florida wetlands ecosystem.

Visitors may enjoy the shade provided by hardwoods planted while they are on the platforms and they can view the sawgrass marshes near those islands from above. Visitors may also use canoes provided by a canoe rental center on the east shore of the wetlands park to experience the park on waterways as they would at the Everglades National Park. This park would be available to the public as a recreational park and educational entity.



Figure 21- Rendered image- The canoe rental system

6. Conclusion

Wetlands are valuable resources that we have just begin to understand and the Everglades is considered to be one of the most important wetlands in this world. Designing a park or a small replication of the Everglades is not enough to save them, but by doing so what may be achieved is an appreciation and awareness about the vital resource. Reducing the pressure of the Everglades National Park by providing a urban representation that provides recreational activities may provide multiple benefits to the public. Using parametric design tools in this project is the key to the blending of technology and nature. This project is an experiment to fuse landscape architecture design together with digital design language. The result of such a proposal might be considered as difficult to construct but the design process is simplified dramatically and the creativity is enhanced. Parametric design's adaptation in landscape design may not be as practical as it is in other professional design fields, but it enriches our design vocabulary and helps us to create more innovative forms.

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Vita

Xi Wang was born in Kunming, Yunnan Province, China, to the parents of Han Wang and Yanping Hu. He is the only son of the family. He attended Yunnan University for Bachelor of Landscape Architecture study. After graduation he headed to the University of Tennessee in Knoxville, TN, the United States for the Master degree of Landscape Architecture. Xi Wang is graduated with a Master degree in Landscape Architecture in August, 2013.