Bridging the Gap: Living Machine in Educational Nature Preserve Center

Zakeia Benmoussa

Abstract**—**Pressure on freshwater systems comes from removing too much water to grow crops; contamination from economic activities, land use practices, and human waste. The paper will be focusing on how water management can influence the design, implementation, and impacts of the ecological principles of biomimicry as sustainable methods in recycling wastewater. At Texas State, United States of America, in particular the lower area of the Trinity River refuge, there is a true example of the diversity to be found in that area, whether when exploring the lands or the waterways. However, as the Trinity River supplies water to the state's residents, the lower part of the river at Liberty County presents several problem of wastewater discharge in the river. Therefore, conservation efforts are particularly important in the Trinity River basin. Clearly, alternative ways must be considered in order to conserve water to meet future demands. As a result, there should be another system provided rather than the conventional water treatment. Mimicking ecosystem's technologies out of context is not enough, but if we incorporate plants into building architecture, in addition to their beauty, they can filter waste, absorb excess water, and purify air. By providing an architectural proposal center, a living system can be explored through several methods that influence natural resources on the micro-scale in order to impact sustainability on the macro-scale. The center consists of an ecological program of Plant and Water Biomimicry study which becomes a living organism that purifies the river water in a natural way through architecture. Consequently, a rich beautiful nature could be used as an educational destination, observation and adventure, as well as providing unpolluted fresh water to the major cities of Texas. As a result, these facts raise a couple of questions: Why is conservation so rarely practiced by those who must extract a living from the land? Are we sufficiently enlightened to realize that we must now challenge that dogma? Do architects respond to the environment and reflect on it in the correct way through their public projects? The method adopted in this paper consists of general research into careful study of the system of the living machine, in how to integrate it at architectural level, and finally, the consolidation of the all the conclusions formed into design proposal. To summarise, this paper attempts to provide a sustainable alternative perspective in bridging physical and mental interaction with biodiversity to enhance nature by using architecture.

Keywords**—**Biodiversity, design with nature, sustainable architecture, waste water treatment.

I. Introduction

THROUGHOUT history, architects have looked to nature as inspiration for building forms and approaches to decoration. There will be numerous examples in nature that we could benefit from studying.

Remarkable solutions emerge from reinterpreting the nature and function of energy and nutrients, allowing us to achieve greater resources efficiency, to build competitive industries, and to adopt innovations that generate jobs and create added value. This is how ecosystems evolve to ever more efficient systems, requiring ever less energy expenditure forever more species [1]. Therefore, the diversity of the system continues to increase all the way through to the climax ecosystem. The reason of this is that, all the time, the number of ecological niches is increasing and making it possible for growing number of interdependent species to become established. Janine Benyus, who introduce the concept of biomimcry, neatly summarizes this characteristic conductive to life "the more those ecosystems mature, the more they enhance their environment and allow for greater diversity [2]. However, biomimicry is a way of providing sustainable solutions by imitating the ecological system of diverse living creatures in transforming materials to sustain a habitat [5].

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II. Waste-Water Treatment

Conventional treatment uses environmentally harmful chemicals (namely chlorine) to disinfect effluent following precipitation of solids (sludge) from the wastewater stream. Ecological treatment uses biological processes instead of chemical inputs, Fig. 1 [3].

Traditional processes do not adequately sequester heavy metals, and the sludge can also contain manmade organic compounds that are extremely difficult to break down. A contained microsystem can be very successful in recycling nutrients, organic matter, and water. In this case, more treatment is necessary, which can be achieved by drainage into constructed wetlands which provide a different type of ecosystem that provides a fresh lineup of ecological players and services that can further process pollutants, Fig. 2 [3].

A. Mimicking Ecosystems

To mimic nature's technologies out of context not enough. But, if we invite plants into our buildings, in addition to their beauty, they can filter wastes, absorb excess water and purify air. And that's what John Todd proposed, Todd is a biologist working in what is sometimes considered the general field of ecological design, in that his ideas often involve applications that become the basis of alternative technologies. His proposal system the "living machine" mimics the patterns of local marshes by assembling ecologies of organisms that polish water to a potable state [4]. This system uses organisms as combine bio-assisted technologies with the biomimetic process.

For the past 30 years, the Todds and their associates have been applying the teachings of ecology to resource management and infrastructure support in both industrial and agrarian societies [5]. This work has included the development of ecological technologies for food production, fuel generation, waste conversion, water purification, chemical detoxification, environmental restoration, and ecological innovation in architecture that created bioshelters [5]. Living Machine Process mimics nature by:

- Recycles and reuses waste (Waste=Food)
- Integrates natural methods with human devices
- Decreases output of harmful and wasteful material to the environment [6].

B. Living Machine's Theory

Today, a wide range of treatment technologies is available for use in our efforts to restore and maintain the chemical, physical, and biological integrity of the nation's waters. During the past 20 years, considerable interest has been expressed in the potential use of a variety of natural biological systems to help purify water in a controlled manner. These natural biological treatment systems include various forms of ponds, land treatment, and wetlands systems [7].

The theory is that you can purify wastewater with living organisms rather than using traditional systems, Fig. 1. Each step of the machine introduces new organisms that can digest or absorb particulates.

A living machine is a water treatment plant that uses living organisms instead of chemicals or machinery to purify water. Living machines get the majority of their power from the sun.

A Living Machine (LM) contains many types of organisms including: invertebrates, vertebrates, higher plants. Most common animals are plankton, fish and mollusks like snails, these life forms are gathered from wild environments, or from living machines already at work. The system is so effective at controlling pathogens, odor, and other nuisances often associated with waste water [8].

C. The Process

Living Machines are made up of tanks that are connected together to form an engineered 'river'. The following six steps are in each living machine:

1. Anaerobic Reactor: The first step in the process, similar in appearance and operation to a septic tank (underground tank).
2. Anoxic Reactor: Low oxygen tank that encourages floc-forming and denitrifying organisms to remove a significant portion of the biomass.
3. Closed Aerobic Reactor: Used to reduce the dissolved wastewater and odorous gases and to stimulate nitrification.
4. Open Aerobic Reactors: Similar in function to a closed aerobic reactor, but instead of having a filter they have a layer of vegetation supported by racks.
5. Clarifier: A settling tank that allows remaining solids to separate from the treated wastewater, the solids are then pumped back to the closed aerobic reactor. The surface is often covered in duckweed to prevent algae from growing.
6. Ecological Fluidized Beds: An EFB consists of an inner and outer tank, the inner tank contains crushed rock or shaped plastic pieces that the wastewater is pumped through to encourage aerobic conditions. The second stage has a bubble diffuser at the bottom to prevent the rock medium from clogging, thus making it a fluidized bed rather than just a coarse filter [8].

D. Advantages of the System

1. Chemical, odor, and noise-free
2. Small ecological footprint
3. Aesthetically pleasing
4. Relatively low costs
5. Little maintenance
6. Micro-finance options for developing communities

E. Disadvantages of the System

1. Can attract insects/rodents
2. Need to tailor to site location
3. Linked with Flow rate/ Climate/ Flora and fauna

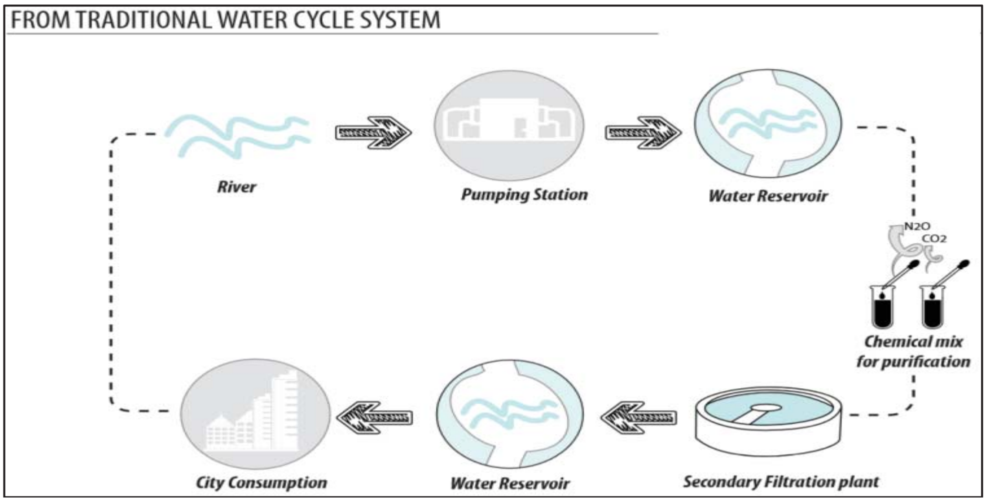

Fig. 1 Schematic diagram of a traditional water treatment cycle system

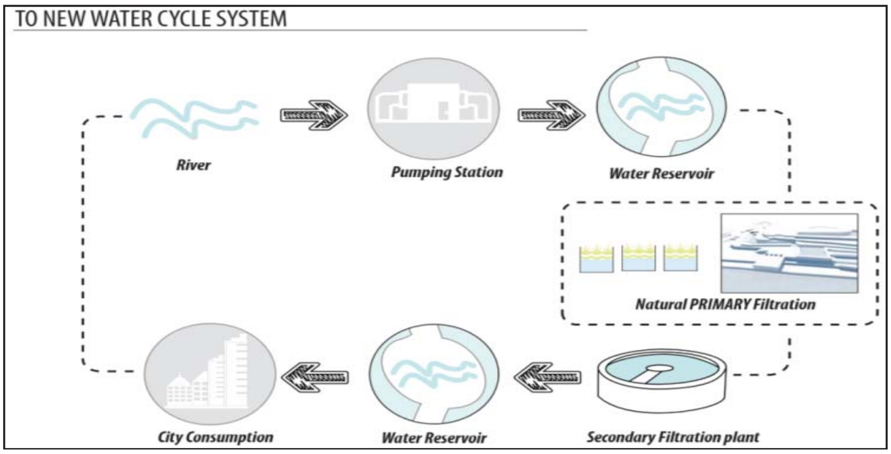

Fig. 2 Schematic diagram of an alternative water treatment cycle system

III. Living Machine in Large Scale

A. Site Location

During the colonial period of Texas State, the land along the lower course of the Trinity County was settled as far up as Anderson County [9]. The annual rainfall in the watershed varies from thirty to forty inches in the upper basin to forty to fifty inches in the lower [9]. The most disastrous flood on record was that of 1908. Reservoirs on the upper branches control the floods to a certain extent and provide municipal water supplies [9]. Over the past century, the waters of the Trinity have become increasingly polluted. Runoff containing pesticides and herbicides and dumping of industrial and human waste-particularly in the Dallas-Fort Worth metroplex-have combined to cause serious deterioration of water quality. A water quality management plan was adopted in the 1970s; however, pollution problems have continued [9].

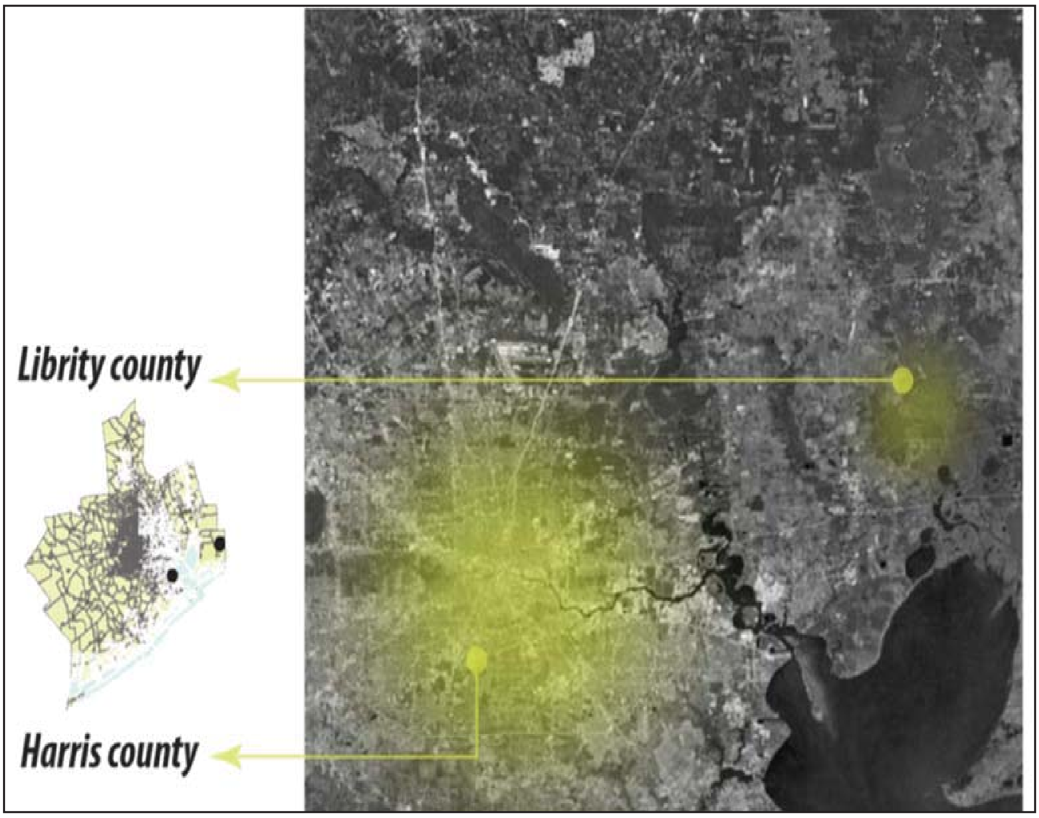

Fig. 3 Site location at Texas State

B. Natural Features

The Trinity River flows 423 miles from the confluence of the Elm and West forks to the coast, making it the longest river having its entire course in Texas, Fig. 3. The river rises on the North Central Plains, but most of its course is in the

Coastal Plains area. The total drainage basin area is 17,969 square miles and includes all or part of thirty-seven counties [9]. The largest cities in the basin include Dallas and FortWort.

Human Demographics and Water Use within the Trinity River Basin More than 5.5 million people are dependent on the Trinity River as a main source of water. These people are unevenly spread throughout the basin and beyond, with large numbers congregating in urban areas such as Dallas-Fort Worth (Dallas and Tarrant Counties) and Houston (Harris County). Intervening counties along the water course have lower population densities [10].

C. Major Problem and Findings

The lower part of the Trinity River is a true example of the diversity to be found in Texas, whether exploring the lands or the waterways. Starting as a typical flat-water river, this section becomes a swampy marshland with all the characteristics one would expect to have found centuries ago, Fig. 4. The wildlife habitation is rich and diverse, from mammals to aquatic creatures to birds of all sorts. The flow is slow and meandering down a twisting river channel lined with old growth hardwood trees and dense ground cover vegetation [11]. This highly valuable habitat is used during migration or nesting by nearly 50 percent of the neotropical migratory bird species, and the existing refuge contains more than 620 plant species and 400 vertebrate species [12]. From this point, a rich beautiful nature is mostly abandon which it can be a treasure to the whole state of Texas. It could use as an education destination, observation, adventure, and most important is in providing fresh water to the major cities especially Houston city.

Fig. 4 Site location images

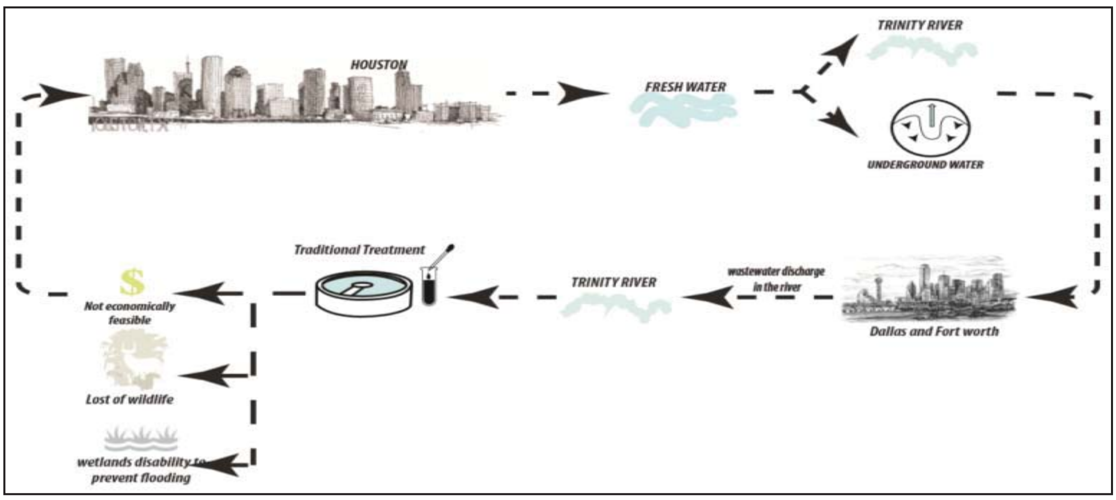

Fig. 5 Schematic diagram of a Houston city water supply from Trinity River

D. The Case

As the population of Texas continues to grow, water issues will become a central focus. Water supplies are not growing. Clearly, alternative ways and seeking new innovations for conserving water to meet future demands must be considered. Conservation efforts are particularly important in the Trinity River Basin because the river supplies water to approximately 40% of the state's residents. Faced with water shortage and quality issues, Texans have a growing interest in gaining information regarding watershed and land management practices. Once called the "River of Death" because it was so polluted with sewage and waste from slaughterhouses, the Trinity River has defied the great drought and helped maintain one of Houston's critical supplies of water. And much of the credit goes to what a century ago made the river so polluted: the wastewater from Dallas-Fort Worth. In fact, without the Dallas-Fort Worth wastewater, the drought may have nearly dried up the Trinity. Decades ago, that happened. But now, the Metroplex sends so much wastewater down the Trinity, even in the driest year in Texas, the river continues to flow. Which means the wastewater is far more concentrated. The river authority uses a series of treatments to clean the waste water before it's released to flow down the Trinity. They include screens, aeration, filters made of sand and cloth, and chlorine [10]. Therefore, there should be another system can provide cleaning the water naturally; Natural Systems used in areas where there is ample land, natural systems feature constructed wetlands. These systems feature a basin of gravel through which wastewater flows, and encounters a natural system with "biological, physical, and chemical conditions for purification." They are often planted with indigenous plant species to enhance biodiversity. Plants and bacteria, which are powered by the sun, break down pollutants and cleanse the wastewater, Fig. 5.

IV. The Premise

A. The Target Site

- Location: The intersection between Liberty and Chambers Counties in deep southeast Texas near the Gulf Coast. Adjacent to the river and a few miles away on the east side is the lower part of the Big Thicket National Preserve, with Houston just a few miles to the southwest and Beaumont a few miles to the southeast, Fig. 7.
- County: Liberty
- Closest City/Town: Liberty, Beaumont, Houston.
- Distance from major cities: Beaumont 53 miles; Houston 60 miles; Dallas 265 miles; Fort Worth 295 miles.
- Site Type: wetlands, Bottomland, Forest, Lake, Park/ Refuge, River
- Site assets: Existing Pump station, Fig. 6.

Fig. 6 Site location's existing Pump station

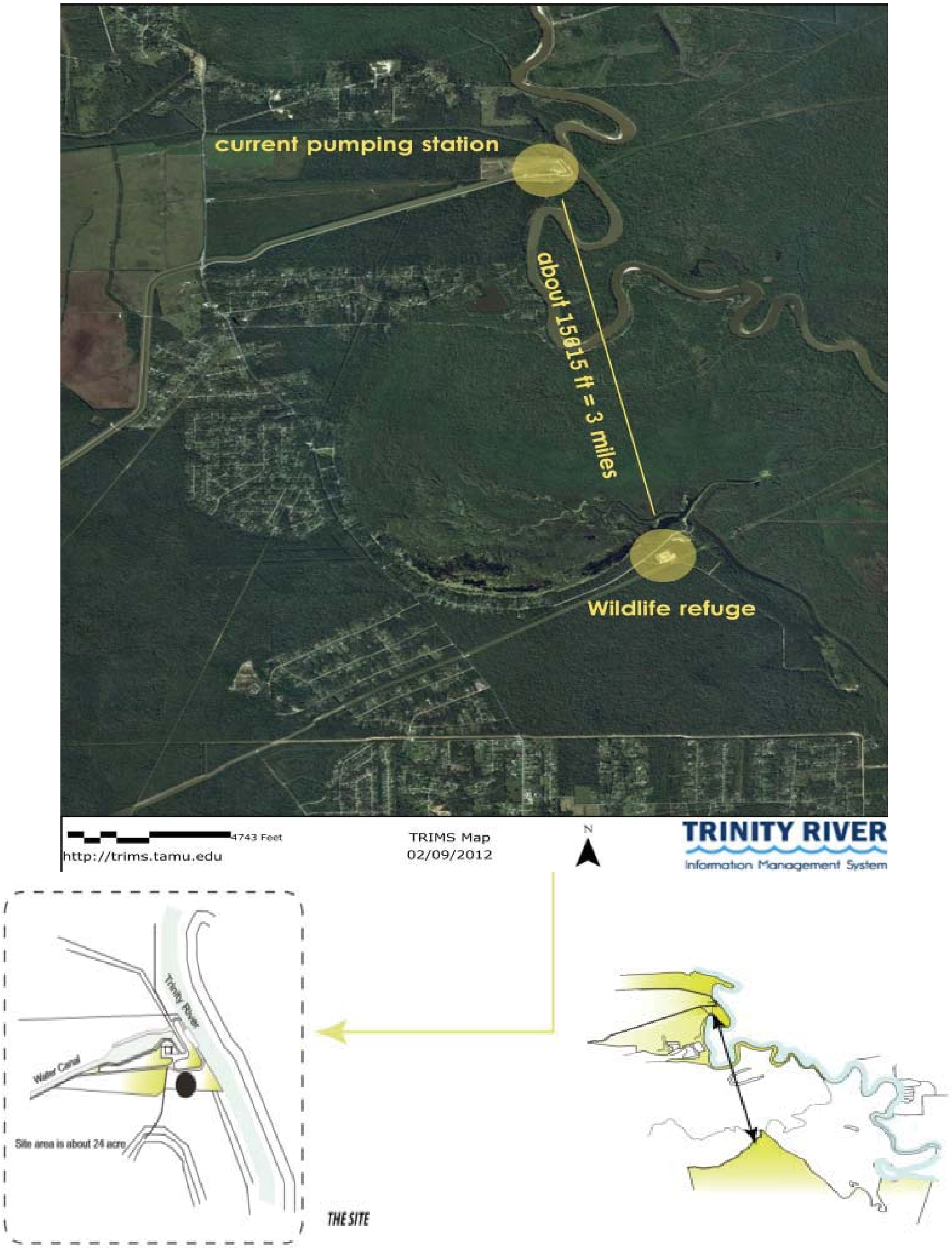

Fig. 7 Target site location

B. Wetland Benefits

Wetlands are one of the main kinds of ecosystems imitated in living machine, as they typically contain water-loving plants. The wetland cells are filled with a solid aggregate medium providing extensive surface area for beneficial biofilm (treatment bacteria) growth. It allows for denser and more diverse micro-ecosystems to form than does a liquid medium. Tidal cycles are used to passively bring oxygen into the wetland cells. This action mimics the same type of biological action of natural tidal estuaries [13]. However, the benefit of wetlands can conclude in:

1. Clean Water - Wetlands filter surface water, retaining excess nutrients and some pollutants, and reducing sediment.
2. Flood Control - Wetlands act much like a sponge. They absorb large volumes of water, protecting cities and towns from flooding.
3. Streambank / Shoreline Stabilization Vegetated wetlands along the edges of streams help control erosion caused by stream currents and flooding. They also protect lake shores from wind generated waves, and coastlines from storm surges.
4. Recreation and Aesthetics - Wetlands are home to a wide diversity of animals, but also to humans with diverse hobbies. Hikers, photographers, bird watchers, hunters and those with an appreciation of nature love to visit wetlands.
5. Habitat for Fish and Wildlife -Wetlands are a crucial part of the food chain, and many other animals and plants depend on them for survival, Fig. 8.
6. Scientific and Educational Value Wetlands provide a unique outdoor laboratory for scientists, they can also serve as outdoor classrooms where teachers can explore many concepts related to nature.
7. Natural Products - People use a variety of products that come from wetland areas.
8. Wetlands also provide timber for wood products and firewood, dried plants for flower arrangements, and animal pelts used in clothing.
9. Groundwater Recharge – Wetland areas are often connected to a groundwater system and may provide a site for water to infiltrate the soil and recharge an underlying aquifer. This can be a very important function for individuals or drinking water systems that rely upon wells for water supply [13].

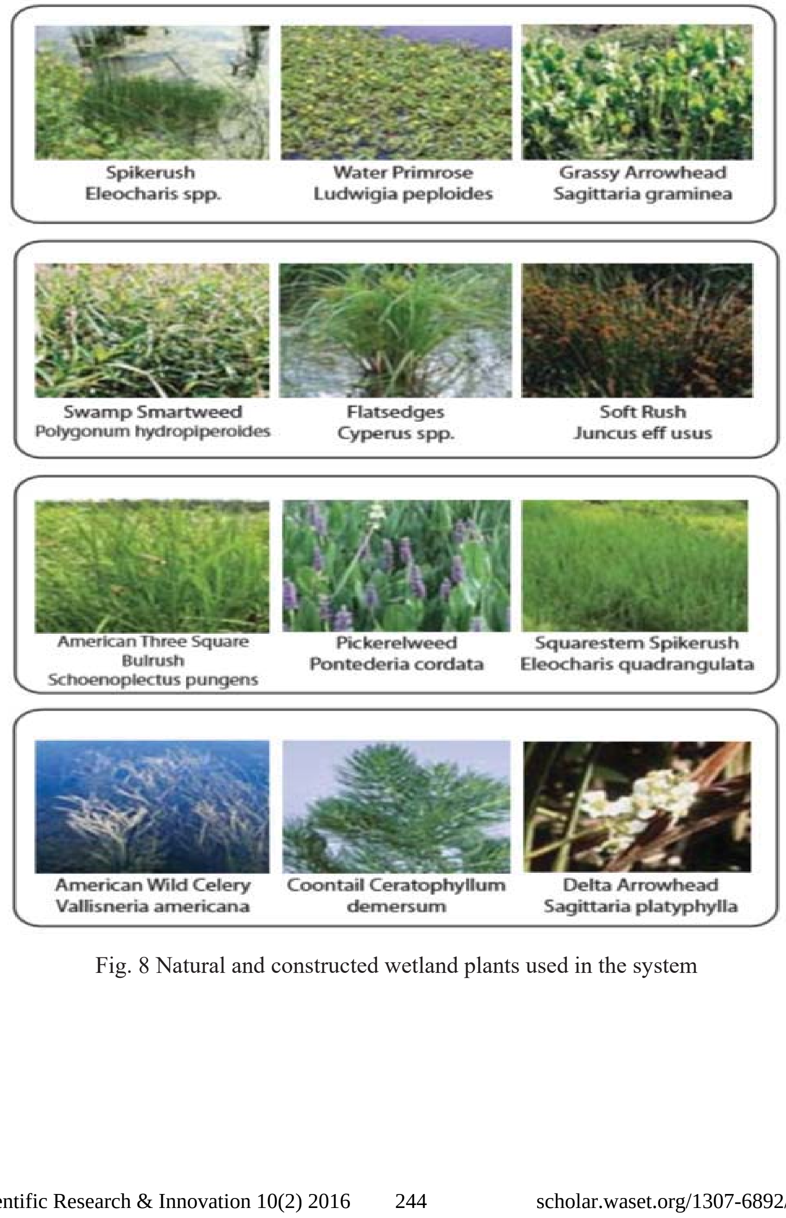

Fig. 8 Natural and constructed wetland plants used in the system

C. Living Machine Technology Integration

The proposed center is a space to become a living organic that purify the water in natural way through architecture. The site has an existing pump station, which assist in facilitating the intake process. The proposal consists also of ecological program of Plant and Water Biomimicry study which is based on outdoor environmental education, in order to create physical linkage between the two worlds and the living machine. In addition, it provides hands on education for visitors who can socialize in term of the biodiversity aspect, a research facility to preserve living plants collection and bird habitats, also to monitor the conditions of a magical territory. The living machine system is visibly expressed and integrated into the architecture at all times to give visual reference to the ecological process of natural forces to both students and public alike, Fig. 9.

On the building level, the center explores architecture as a medium that Occupants analyze and understand the systems established in the artificial wetlands and apply that understanding to a natural wetland. In other words, "the Living Machine system" will used to adapt and enhance the ecological processes in a tidal wetland, nature's most productive ecosystem. So, the water system mimics the natural water cycle at the wetland which indirectly leads to the growth of the artificial wetland that cleanses the river and restores biodiversity. Therefore, the center is not only economically and ecologically sustainable, it's also socially sustainable that turns a preserve to a distention to explore nature diversity and becomes as a model to understand biomimicry.

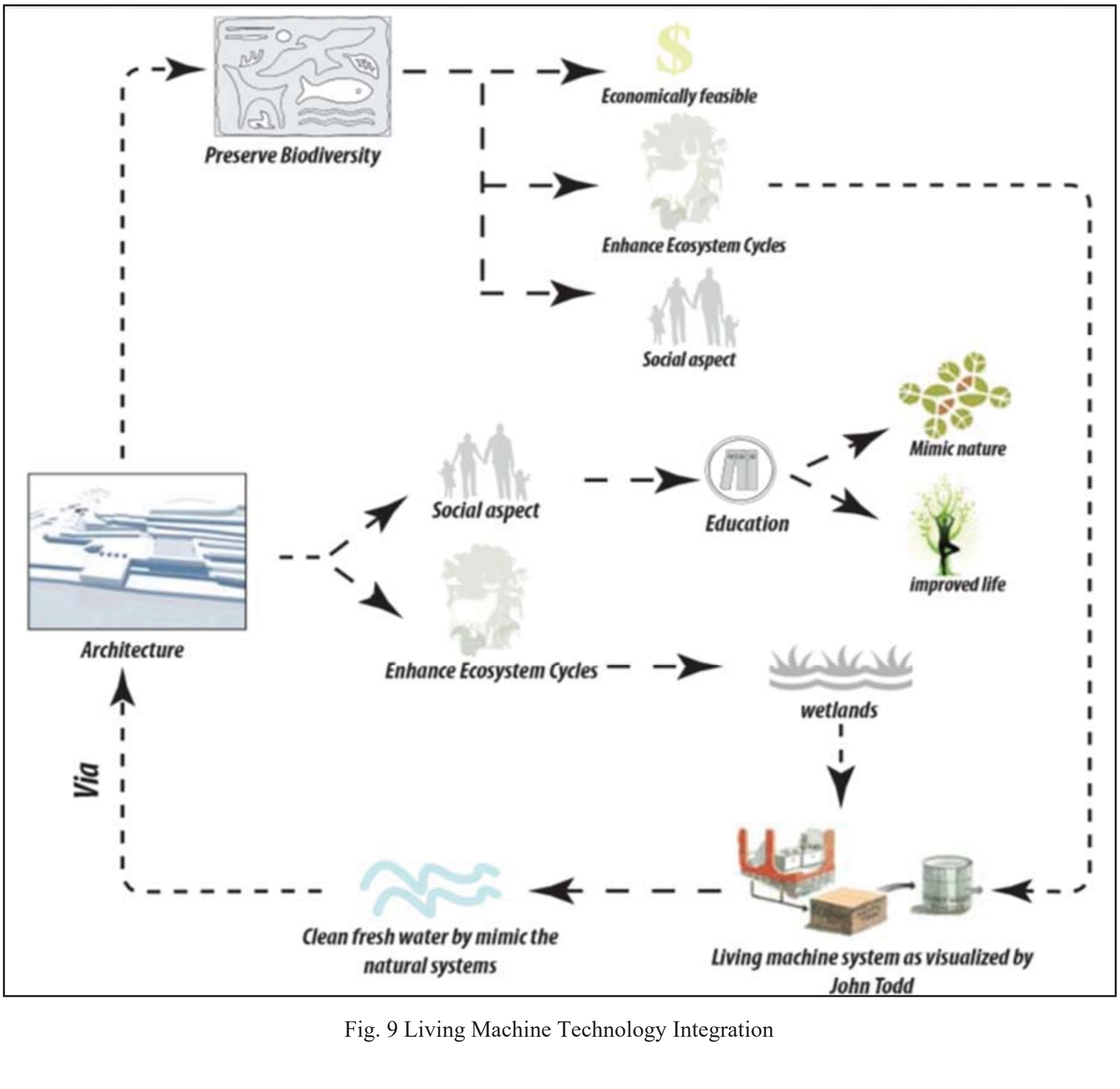

Fig. 9 Living Machine Technology Integration

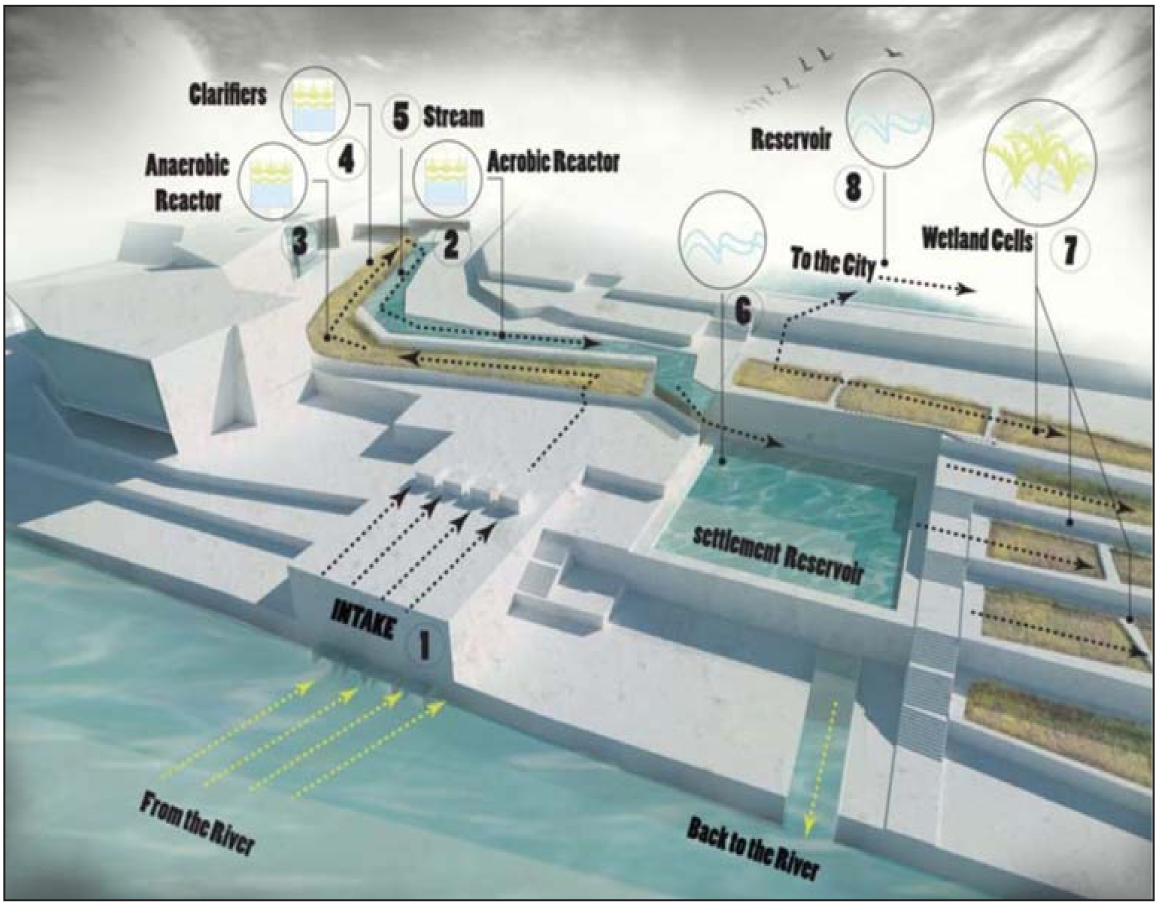

Fig. 10 Living Machine Technology Integration in the proposal center

The system in the building divided into three lines, Fig. 10:

First Line:

1. From The River.
2. Intake.
3. Aerobic Reactor.
4. Anaerobic Reactor.
5. Clarifiers.
6. Stream.
7. Settlement Reservoir.
8. Back to the River

Second Line

1. The same Cycle from the first Line to the Settlement Reservoir.
2. Open Wetland Cells.
3. Existing Reservoir.
4. To the city or area irrigation

Third Line:

1. The same Cycle from the Second Line.
2. Adding greywater filtration cell to treat the water that coming from the building and use it back to the building or the site irrigation Fig. 11.

Specific contaminants removal of this system:

1. Reducing loads of BOD/COD.
2. Nitrogen removal.
3. Organic nitrogen.
4. Ammonia removal.
5. Phosphorus.

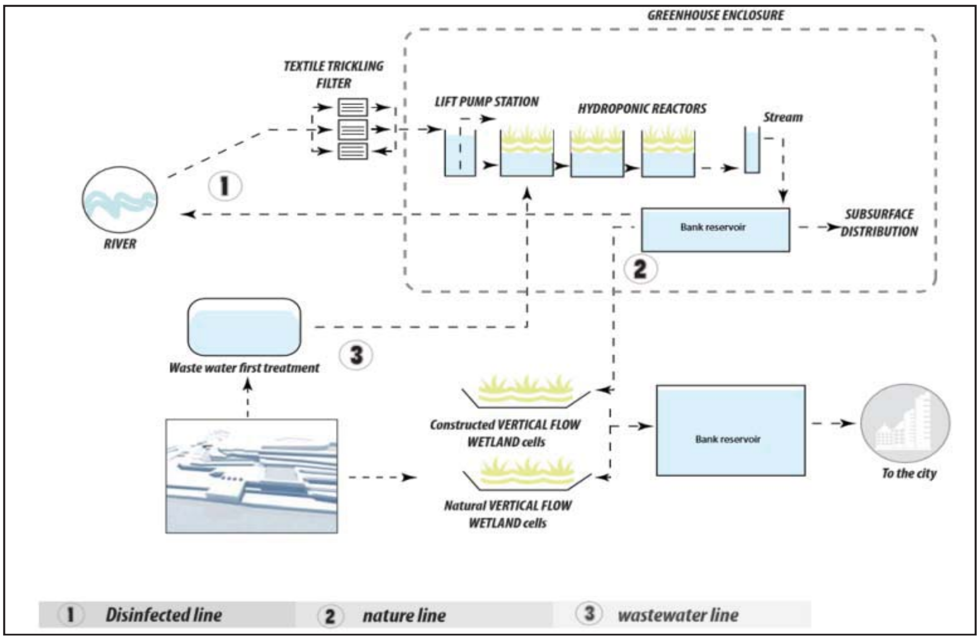

Fig. 11 The system application at the building level

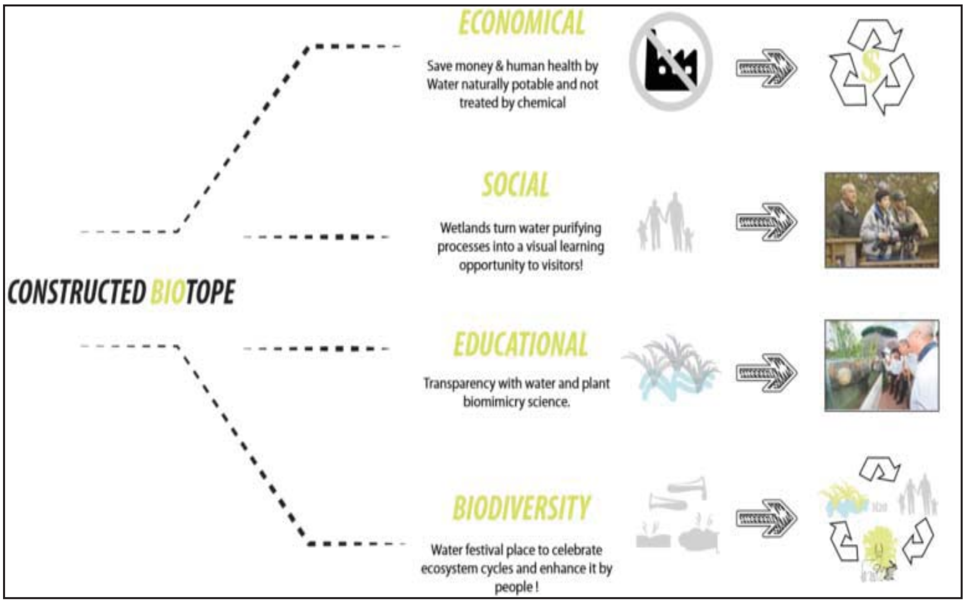

Fig. 12 The solution impact on the surrounding environment and the society

V. THE IMPACT

Emerging concepts in design began to build on new understandings and attempt to seek a partnership with nature to create a mutual beneficial outcome instead of just preserving or minimizing man's impact on nature, Fig. 12.

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