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A SunCam online continuing education course

Creating Self-Sustaining Ecosystems

Suncoast Conservation Center

by

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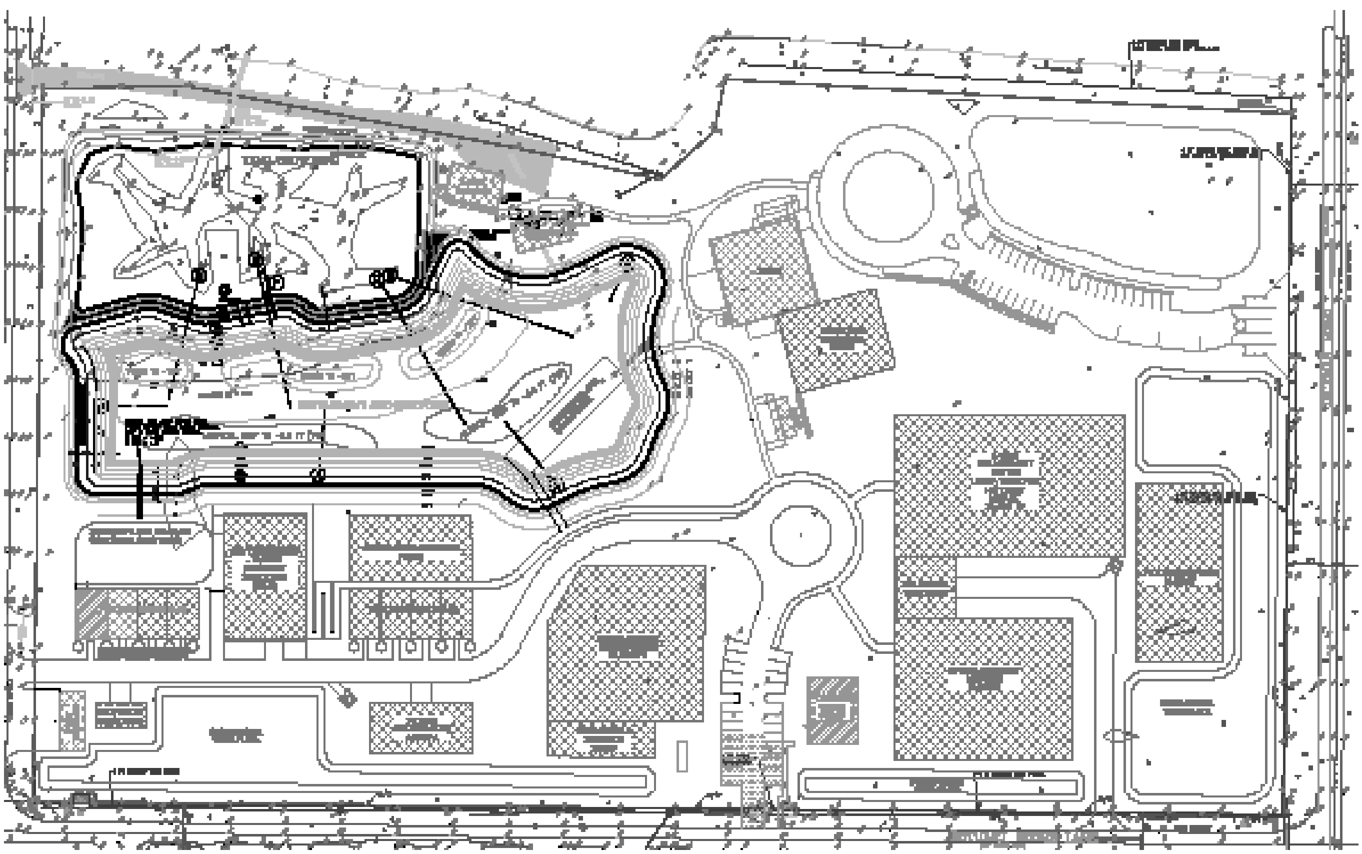

Creating Self-Sustaining Ecosystems
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Note: All photos in this document were taken by the author.

COURSE DESCRIPTION & INTRODUCTION

The intent of this course is to provide insight into the design and construction criteria used to design, permit, and construct a manmade, self-sustaining, tidal saltwater marsh, and a tidal saltwater pond that can be artificially controlled and monitored by marine biologists and scientists. See Figure 1 below. Additionally, the marsh and pond were designed to use only natural recruitment of saltwater species of fish and crustaceans which would provide an endless supply of fish and crustaceans… *for free!* There is no need to purchase, ship, or stock any of the fish species found in the saltwater marsh and pond today.

Figure 1 – The Tidal Saltwater Creek (top of photo), Tidal Saltwater Marsh (center of photo), and part of the Tidal Saltwater Pond (bottom of photo)

Course Applications

Over the past 250 years of development in this country, most of the better lands have been developed or turned into parks. New development projects are now frequently dealing with wetlands, especially along coastal regions. Regulatory agencies are requiring mitigation of the impacts to any wetlands and/or to endangered species for the construction of roads, utilities, and housing. The creation of, or enhancement of, saltwater ecosystems is an excellent way to mitigate for these impacts. Knowing what can be accomplished and what can be done to minimize mitigation costs will go a long way in your discussions with potential clients. Even local governments can benefit from these types of ecosystems for mitigation and community education and uses. Just take a moment to consider the possibilities….

What is in this course?

The course will discuss the research, preliminary concepts, regulatory agency involvement, engineering designs, and the regulatory permits that were required to obtain the construction permits for the Suncoast Conservation Center project. We will also discuss some of the construction challenges encountered due to preserving the existing environment during all of the construction activities.

This course will present the design criteria that evolved over time and was finally used for the development of new saltwater ecosystems adjacent to a tidal brackish water creek that emptied into Tampa Bay. The ecosystems consisted of a new manmade tidal saltwater marsh and a new manmade tidal saltwater pond that would be self-sustaining. *At least, that was our goal.*

SUNCOAST CONSERVATION CENTER PURPOSE

Purpose of the Suncoast Conservation Center

The Conservation Center’s purpose was to provide educational and scientific opportunities for both the public and scientists in the areas of conservation, marine biology, marine animal care, green energy, and potential careers.

Why Pursue a Tidal Saltwater Ecosystem?

There are many good museums, aquariums, and zoos throughout the world but they provide only an artificial presentation of life in the natural environment. Consider how much better it would be to take the artificial presentation and make it real… take people and safely place them in the actual environment? So, the idea was hatched to create a real-world natural habitat that the public could safely experience and learn from. A site became available from Tampa Electric (TECO) to provide this environment in a 19.46-acre (7.88 hectares) site adjacent to an existing saltwater creek. Additionally, the site would provide an opportunity to receive electrical power produced by nearby solar photoelectric panels for the facilities and solar-powered charging stations for cell phones at strategically placed locations. *How neat is that?*

From an ecological perspective, the conservation and engineering experience gained during the design, permitting, construction, and operation of a self-sustaining ecosystem could be used in developing similar ecosystems in other areas of the country or even in other parts of the world. This course will discuss the challenges and solutions used to create successful saltwater ecosystems. These methods can also be used to help with the repair or enhancement of damaged ecosystems in similar environments.

Hopefully, other development projects will benefit by creating new ecosystems to obtain the credits their project needs for wetland impacts caused by their construction. Perhaps in some instances, as mentioned previously, environmental credits may be obtained for repairing or enhancing existing distressed wetlands or ecosystems using some of the techniques used in this project. Each completed project would then provide additional visibility and consideration by media, developers, and local governments. This could become an incentive for public education and could be used to obtain their buy-in for funding these ecosystems.

BACKGROUND INFORMATION

How do you take an old tomato and palm tree farm located in uplands and convert it into a thriving self-sustaining tidal saltwater marsh and a tidal saltwater pond with many different species of plants, fish, and crustaceans using only natural recruitment? This was the challenge presented to Tampa Electric Company (TECO), Florida Fish and

Wildlife Conservation Commission (FWC), and the Florida Aquarium (FLAQ). These three entities were the Stakeholders. After much research for a similar saltwater ecosystem project, an existing project like this could not be found anywhere in the world. This effort would be a first. And what a challenge it would be!

Figure 2 – Aerial of Saltwater Creek, Saltwater Marsh, Saltwater Pond, & Campus

The site for this endeavor was located south of Tampa on property owned by TECO, and it consisted of a former farm and palm nursery. The project began in earnest in 2012. Multiple planning and engineering firms were interviewed and some were selected to start the development concept for the project. However, professionals with experience in converting uplands into a saltwater marsh and saltwater pond could not be found. Then in 2014, the author of this course, working for FWC at the time, was tasked with developing a workable concept and making it real. The author eventually became the Project Manager, the Design Engineer for the marsh and pond, and the Construction Engineer… not because of any prior experience with saltwater ecosystems, but because of prior experience in designing and constructing freshwater fish ponds with their required habitats. However, freshwater species have different requirements from saltwater species. Fortunately, the FWC's fisheries staff had that knowledge and they were able to assist with design guidance. Additionally, the FLAQ staff provided much needed input and design guidance for the marine animals. And, finally, other scientists and universities were able to provide additional recommendations, suggestions, and comments as well. It then took many more months to significantly rework the previous concepts by including the scientific community and regulatory agencies to assist in the development of a concept that could be presented to the Stakeholders, and with their approval, to the multitude of regulatory agencies. Eventually, a concept layout was developed and work began on developing the preliminary construction plans.

Designing the buildings, parking lots, utilities (electric, water, and sewer) was the "easy" part since the local architectural and engineering consultants had years of experience designing commercial and educational projects. However, the tidal marsh and tidal pond designs were another matter altogether.

During the events listed above, a "test marsh" was sized, shaped, constructed, and planted. The test marsh provided much of the critical information for determining the final marsh size, bottom elevations, channels, and vegetation. These results were then used to frequently update the preliminary design plans being reviewed by the regulatory agencies.

As with many developments, the list of wishes exceeded the land area and funding available. Then… additional meetings were required for the Stakeholder staff, consultants, and development staff to continue narrowing the project scope and priorities that could meet the allowable funding.

Working with the Stakeholders, a revised master plan was developed and finally approved to include the following facilities for each Stakeholder:

TECO: 1) Provided the land for the Center
2) A Field Operations facility (this would later become a research office for visiting scientists, marine biologists, and staff from various universities)
3) Electrical power produced from photoelectric cells with examples throughout the campus site

FWC: 1) A Youth Conservation Center for educational experiences and classes
2) A Marine Fisheries Enhancement Center for research and production
3) Support facilities (Outdoor classroom, Kayak storage building)

FLAQ: 1) A Turtle Care Center
2) A Coral Nursery & Research Lab
3) A future Mangrove Research Lab
4) A future Marine Animal Care Center
5) A future Shark and Fish Reproduction facility
6) Support facilities (Turtle and Coral equipment storage)

Public: 1) A public restroom facility for visitors and events
2) A transportation hub for a remote public parking location

The Tidal Saltwater Marsh was confirmed as an element of the site that would remain, as it would provide harvesting opportunities of the marsh vegetation for donations to conservation groups or for commercial sale.

A Tidal Saltwater Fish Pond was to be added adjacent to the saltwater marsh and would be “fed” by the marsh. This pond would provide unique research opportunities for the scientists and biologists while also simultaneously providing educational opportunities for fishing and kayaking for the FWC youth programs.

All of these facilities were to include both educational and research opportunities for the public, students, educators, scientists, marine biologists, and researchers. At long last, the concept plan was agreed upon and the final designs could be completed, permitted, and constructed.

DESIGN PROCESS AND CONTROLS

Some perplexing questions… How do you design something that no one has designed or constructed before? Where do you start? How much time would it take? How much would it cost? Think about it for a minute. If a client came to your office and proposed this project to you, *how would you respond to these questions?*

Coordination and input from Regulatory agencies

Similar questions arose when it came to the regulatory agencies. How do you permit something that no one has designed or permitted previously or even attempted to permit?

Additionally, do you know ALL of the agencies that regulate or might regulate this type of project you are proposing at the local, state, and federal levels? And… do you know all of the codes of each regulatory agency and department? And… would you be surprised to learn that some requirements of one agency conflict with one or more other agencies? If you have previously been involved with large projects involving environmentally regulated lands, this probably does not surprise you.

For us, we began by setting up meetings with the multitude of regulatory agencies at the local, state, and federal levels. Whenever possible, we invited one or two of the Stakeholders to attend these meetings to give the Stakeholders firsthand knowledge of the regulatory challenges and… give the regulators a sense that this project was going to be funded and constructed. Some of the agencies required multiple meetings because our initial meeting with an agency would be with a lower-level reviewer. That reviewer would quickly realize this project approval process was above his/her paygrade and refer us to a superior. And, of course, we would have to reschedule the meeting for another date to meet with the correct staff for this type of project. This process often required multiple delays just to work our way up the ladder to get to the correct person with the required authority to approve the project.

Several of the agencies we met with admitted to not having ANY regulations governing the *creation* of tidal saltwater marshes or tidal saltwater ponds. After having scheduled multiple meetings at each agency to finally reach the right person, many of these agencies ended up referring us to other state or federal agencies. On rare occasions, the agency's senior reviewer would refer us to another agency but would actually place a call on our behalf to the "correct" person to meet with, and introduced us, and set a meeting date. Some agencies had exemptions for aquaculture projects but didn't have any specific regulations for tidal saltwater marshes or tidal saltwater ponds.

Surprisingly, the US Department of Agriculture was the most receptive to this project, became interested in the project, and would provide us with letters of approval at the appropriate time. However, for them to become the lead regulatory agency, the project had to include farming or growing of livestock. Fortunately, the project included farming of sea grasses for donation or sale. Also, the project included the farming/growing of saltwater fish and crustaceans for educational purposes. They would ultimately take the lead and issue us a permit for an aquaculture project which superseded other local and state permit requirements, but only for the specific aquaculture developed areas. They also wanted to closely follow the development process of our designs, modifications, and construction especially since these 3 ecosystems (tidal creek, marsh, and pond) would all interact with each other once completed. The remaining areas (i.e., the buildings, drives, parking, sidewalks, utilities, and stormwater management) would still require the normal development permits from the usual regulatory agencies.

Could the project have been permitted without the Department of Agriculture? Absolutely, but their department involvement expedited the permitting processing to allow an earlier start of construction for the tidal saltwater marsh and saltwater pond.

Master Plan Concept Development

The development of the Master Plan Concept was a long and tedious process exacerbated by the fact it had never been attempted. The process involved collaboration between the Stakeholders on each of the elements being proposed for the development and providing answers to the following questions.

1. **What should be included?** This question would be somewhat determined by the total area available for the project and which elements were priorities. It would include evaluating the staffing required, yearly maintenance, purpose or function of the element, and the existing site conditions.
2. **How large should it be?** The size of each element would largely be determined by the answer to question 1 and discussions with experts that would be operating and maintaining each element. Some elements would be dropped from further consideration after what the experts said would be required.
3. **Where should it be located?** This question would evaluate the existing topography, vegetation, prevailing weather, access, and compatible uses of the proposed adjacent landowner activities and elements.
4. **How would it interact with the other elements being constructed?** Once the adjacent elements were considered, opportunities for points of access from the adjacent elements, availability of any required utilities (water, sewer,

power, communication), required security, noise levels, drives, paths and sidewalks, and other aspects could be made.

5. **What impact… positive or negative… could it have on the ecosystem?** This would include stormwater runoff & management and use of any pesticides, insecticides, fertilizers that must be evaluated and resolved. Additionally, area lighting would need to be addressed to avoid light pollution.
6. **When should it be started?** Would this be part of a phased development? What about weather considerations from a rainy season or hurricane/cyclone, fire hazards from a dry season, potential for freezing temperatures, and other considerations?
7. **How much would it cost?** A final consideration, but equally important in the consideration of any large project, was the development, construction, and maintenance budget for each element. Of similar importance, was providing a contingency budget for inflation of material costs and labor, unknown surprises discovered during construction, schedule delays, and more.

Reviews by Stakeholders

Having reached an agreement on the proposed project, the Stakeholders followed the progress being made at the regulatory meetings by the local, state, and federal agencies, the information being obtained from the experts in each of their fields, the input being received from each of the agencies, and the many revisions of the proposed Master Site Plan as the project evolved. Initially, the Stakeholders were meeting monthly to review, comment, and provide guidance to the design team. As the project evolved, the frequency of their meetings was reduced and were sometimes replaced by teleconferences to discuss special conditions and situations.

Predesign Input from Regulatory Agencies

During the introductory meetings with each regulatory agency, there was an initial hesitancy by their staff to discuss the technical aspects of the project with us. To resolve the hesitancy, we made a presentation to each agency's management staff that would be involved in the issuance of a permit for the development. During this presentation, we emphasized our desire to have the regulatory staff become "part of our design team" and provide suggestions, recommends, references, and contacts during the actual project design. This caught them by surprise and raised some eyebrows by their leadership. But it paid off big time by actually reducing the design time of the final construction documents. It was especially helpful when there were conflicting requirements from different agencies. Several times, the regulators from one agency would actually phone or meet with another agency to discuss the project and reach an acceptable design aspect that could resolve the permit conflicts and be approved! They liked the developmental concept and our willingness to bring them into the design process, and… looked forward to seeing it become a reality. Since the permitting of a new ecosystem project had never occurred before, the coordination and cooperation of these regulatory agencies were essential in expediting the development's construction permits.

Development of Architectural & Site Development Construction Plans

The architectural and site development plans for the campus were contracted out to local architectural and engineering firms since these firms were familiar with the regulatory agencies that had jurisdiction over the project location. They were managed by the FWC Project Manager and staff. This was a wise decision since the reduced amount of time required to manage these firms would provide additional time to research and develop the plans for the new ecosystems.

The architects focused on the Youth Conservation Center and the Turtle Care Center plans, and the engineers focused on the campus site development. The two largest challenges were: 1) isolating the stormwater runoff of the campus from the saltwater marsh and pond; and, 2) maintaining a net zero import / export of site earthwork (meaning no soil could be imported to the site from offsite sources and no soil could be exported from the site to other areas.) So, the cut, fill, and final grading for the total site had to be balanced… exactly! This meant that only the material excavated from the marsh, the saltwater pond, and the stormwater treatment ponds could be used for the final grades established for the entire site. This complicated the design efforts of the architects and engineers, because each time the site layout changed to meet new permitting or design requirements, the architects and engineers had to redesign the grading, which changed the finish floor elevations, underground piping grades, and all of the surface grading. Additionally, the excavated material had to be stored somewhere on the site until it could be used. This often required storing at one location for a short time and then moving it to another location for another period of time. How challenging was this, you ask? There were *31 master plans* prepared as the project evolved to meet the permitting requirements and the requests by contributing scientists, researchers, and Stakeholders! And the approved Master Plan for Development had to include all future phases of the ultimate build out. *Yikes!*

Obviously, these were busy times that required a LOT of coordination of the many efforts occurring simultaneously. This course is focused on the ecosystem being designed and constructed, so we will leave the development of the educational and research campus at this point and jump to the design and permitting challenges of the saltwater ecosystem.

ECOSYSTEM REGULATORY PROCESS

Permitting Agencies

As mentioned briefly before, we were able to eliminate some of the regulatory agencies simply by them deferring their reviews to other agencies. For example, the Water Management District (WMD) deferred their reviews to the Florida Department of Environmental Protection (FDEP). This deferral did not eliminate any regulation requirements, but it did eliminate the additional meetings with each agency along with the paperwork and fees for them to process a WMD permit approval from them. Likewise, the FDEP and the US Army of Corps of Engineers deferred to the US Department of Agriculture since the project was creating new ecosystems in uplands using the Federal Aquaculture exemptions and would not impact any of the existing ecosystems.

The County governmental departments did not defer their review and had many departments that required permit approvals. Some of these departments regulated the campus improvements for buildings, paving, traffic control, utilities (potable water, sanitary sewer, electrical power, data, and communications), and stormwater management. This course will not… for the most part… discuss the campus development except for those specific interactions with the new ecosystems.

The County staff that we did spend a lot of time and effort with were the Development Services Director, the Environmental department, the Historical Resources department, the Natural Resources department, and the Building Department (for coordination purposes of the proposed facilities to be constructed). Fortunately, the Development Services Director scheduled an initial meeting with staff from all of their departments just to ensure all departments would be informed of the project, and they could ask questions to determine if their specific departments needed to be involved.

Our meetings with the County departments occurred monthly, primarily to give them an update on the design and permitting progress being made with the Department of Agriculture and the designs of the campus development of the site. They also wanted to ensure there were no design issues that would conflict with the County regulations. And, of course, they wanted to follow the design for their own edification to use with any other developments desiring to construct a similar project.

DESIGN ISSUES

The FWC Project Manager solicited and hired architectural and site engineering consultants to handle the architectural and civil engineering plans, permits, and construction documents of the educational campus. The marine ecosystems were intentionally excluded from the consultants' designs since FWC would be responsible for all of the ecosystems' designs.

Some of the challenges the project faced were:

1) The existing ecosystems could not be negatively impacted. This applied to all stormwater runoff, erosion prevention, construction work, and protection of native species.
2) No soil was to be imported to the site or exported from the site. All site grading had to be a net-zero excavation-fill calculation. This was particularly challenging since much of the proposed site was subject to seasonal flooding.
3) All of the campus buildings and their supporting electrical equipment… emergency generators, air conditioners, transformers, and more… had to be above the 100-year flood elevation. This required raising the existing grades and raising the building finish floor elevations above the flood elevation, while still maintaining the net-zero fill requirements.
4) Only staff parking was to be provided. No public parking was to be provided, which was a particularly challenging requirement that conflicted with the County

parking codes. The requirement was finally resolved by providing public parking about a half mile (0.8 km) away from the campus and constructing a private gravel drive for shuttles to transport the public to and from the campus.

5) During soil borings, an ancient salt water aquifer was discovered deep below the site that could be used for the Marine Fisheries Enhancement Center and Turtle Care Center needs. Using the saltwater well would eliminate the expense of shipping saltwater from the Gulf of Mexico to the Tampa port and trucking it to the campus. However, the aquifer had its own challenges.
    a. The aquifer had different salinity levels and alkaline levels than is found in the Gulf of Mexico today.
    b. To be useful, the saltwater had to be *economically* altered to match the existing salt water properties of the Gulf.
    c. The saltwater well could not contaminate fresh groundwater sources.
6) The subsurface soils were primarily coastal sands, which are easily eroded by stormwater runoff or wave action. This presented multiple problems for the pond side-bank construction and stabilization.
7) Due to the types of research, educational, and marine animal care facilities, the access to the site was restricted to three 24-hour controlled security gates with monitored security cameras.

DESIGN OF THE SALTWATER MARSH

Now, at last, we can get to the fun stuff… the technical design challenges, design details, and construction issues of the saltwater ecosystems, and how they were resolved. This section of the course will not be a straight-forward design process for the simple reason that the saltwater marsh and pond have different development criteria, vegetation, marine species, and controls for sustainment and for research opportunities. So, if you need to… go get a big mug of heavily caffeinated coffee, stretch your legs, and when you're ready, we'll begin!

Okay… the break is over. Let's begin….

Figure 3 – Aerial view of the tidal creek (A), tidal marsh (B), and tidal pond (C)

Establishing High and Low Water Elevations in the Tidal Creek

First, let's begin with the existing tidal saltwater creek that the marsh would connect to. Without the saltwater creek, this project would not work at this location. The saltwater creek drains into the Tampa Bay which is connected to the Gulf of Mexico. But because of its creek bottom elevations, it is a tidal creek. At low tide, the creek drains into Tampa Bay. At high tide, the Bay surcharges the creek, raising its water level as it does so. The creek is located within a large mangrove system that provides marine species the ability to navigate the creek upstream and downstream 24 hours a day.

To support the commercial port of Tampa, there are tide gauges established to assist the cargo ships with determining the depths of water at their arrival and departure times. Unfortunately, the nearest tide gauge is many miles from the creek channel. As the tide changes, there is a time lag as the Bay water levels force the water up the creek channel and then back again. So high tide in the Bay does not occur at the same time as high tide in the creek. The Bay high tide occurs earlier… but, how much earlier? Likewise, the Bay's low tide occurs earlier than the creek low tide, but how much earlier? Is it the same lag time, or is it different? Also, how does the high tide water elevation of the Bay compare with the high tide water elevations of the creek? And, how do the low tide water elevations compare?

Then, to complicate matters even more, the water control structure between the tidal creek and the tidal marsh… which allows scientists to isolate or alter the flow rates to the marsh from the creek for research purposes and environmental precautions… caused a time lag of the high and low tides due to the amount of restriction of the water flow through the control structure. To complicate the calculations even more, the water flow restrictions from the tidal marsh into the tidal pond caused another time lag of the high and low tides in the pond. *It seemed never ending! The challenges just kept mounting!!!*

To help resolve some of these questions, we were fortunate to get some volunteers to gather the data we needed for the time and the water elevations of the creek's high and low tides… which meant they had to be present in the creek at the precise time these occurred. *Well… most of the time! We found we could not get any volunteers to go into a remote mangrove area inhabited by snakes and alligators to collect data in the middle of the night or during thunderstorms. It's so hard to get good help these days!* But… the volunteers were able to collect a lot of data over a period of about 3 months. We were then able to refer to the Tampa Bay's local tide charts to compare that data with our collected data and to develop some relationships.

With this data in hand, we were able to make some fairly accurate determinations as to what our expected high and low water elevations *might be* and the times that they would *probably* occur. We finally had our first usable data to start our initial designs. *You can cheer if you want… we did!*

A Trial Saltwater Marsh is Constructed

Using the USDA Aquaculture Exemption, a quarter acre site adjacent to the tidal creek was used to construct a "trial" marsh during the time that the permitting discussions with the regulatory agencies were ongoing. Note that this trial marsh would not have a connection to the pond since the pond had not been designed or constructed yet. Using tidal data from an existing tide gauge, the test marsh was constructed adjacent to the tidal creek with a 20ft wide isolation berm to separate the marsh from the creek, and then a water control structure was installed to manage the flow of water between the tidal creek and the test marsh. See Figure 4 below.

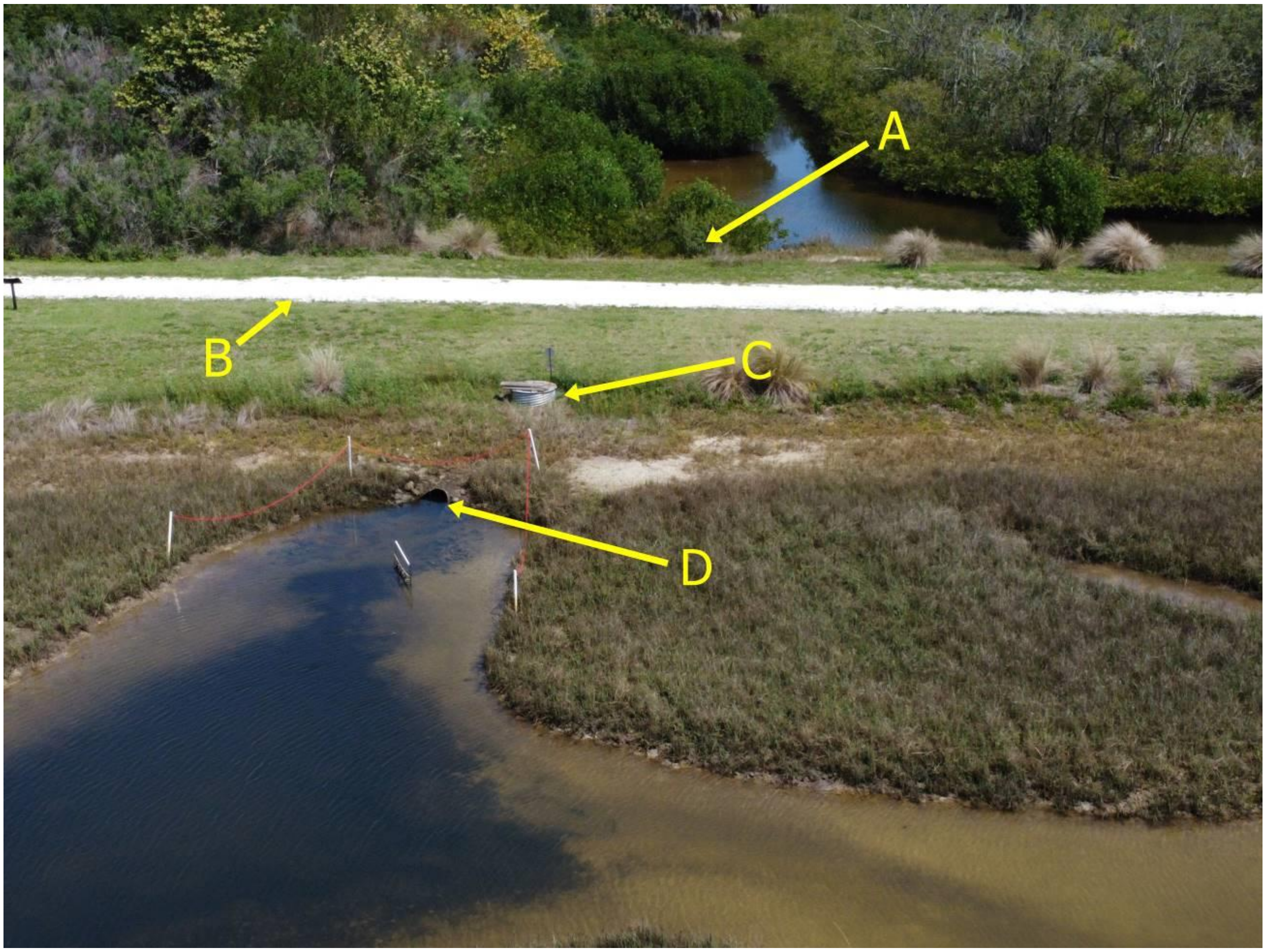

Figure 4 – Tidal Creek connection (A), Isolation Berm (B), Water Control Structure (C), Tidal Marsh connection (D)

The isolation berm and water control structure would also be used to isolate the marsh water levels, control erosion and turbidity issues during construction, and later provide opportunities for scientists and marine biologists to conduct research and tests on the vegetation and marine life within the marsh by controlling water levels and tidal flows.

The Water Control Structure

The water control structure consisted of a 48" diameter corrugated metal culvert installed vertically at the edge of the marsh. Two 30" diameter corrugated metal culverts were attached to the 48" diameter vertical culvert with one culvert connecting to the tidal creek and the other culvert discharging into the marsh. In the vertical culvert, a solid metal gate was connected to lift cables which allowed the gate to be raised to allow the flow of water between the creek and the marsh, or dropped to the bottom to block the flow of water. With this water control structure installed, the water flows could be increased or decreased as may be desired, and marine life could be monitored, research conducted, and the marsh/creek could be isolated from the other if ever needed.

Months after the trial tidal marsh was constructed, the marsh was found to be struggling. Upon closer evaluation, it was determined the problems were due to the marsh being constructed using the tidal information of the nearest tide gauge which, as you may remember, was miles away. Now that more specific tidal elevation data was available, it was easy to understand why the marsh was not thriving. Much of the marsh had been constructed at an elevation that was too high to stay hydrated even during the high tides. Additionally, the test marsh was constructed much larger than the staff could maintain or even potentially harvest once it was functioning properly. The original intent was to harvest the sea grasses for donations to other sites, and also, possibly be sold to minimize the ongoing maintenance costs. So, changes in the original design and construction were needed.

The Final Saltwater Marsh Design

Working with input from the FWC staff, marine scientists, and the regulators, the tidal marsh was redesigned for the proper elevations and proper size. As a result, the test marsh was reduced approximately 25% in size and then regraded to lower elevations with gentle slopes of about 16:1 to about a foot (0.3 m) above the normal high tide elevation. See Figure 5 below. At that point, the slope was increased to an elevation of 2 feet (0.6 m) above the normal high tide elevation which created a berm between the new tidal marsh and the proposed saltwater pond still to be designed. Reducing the marsh size also provided more soil to raise the campus grades by enlarging the pond.

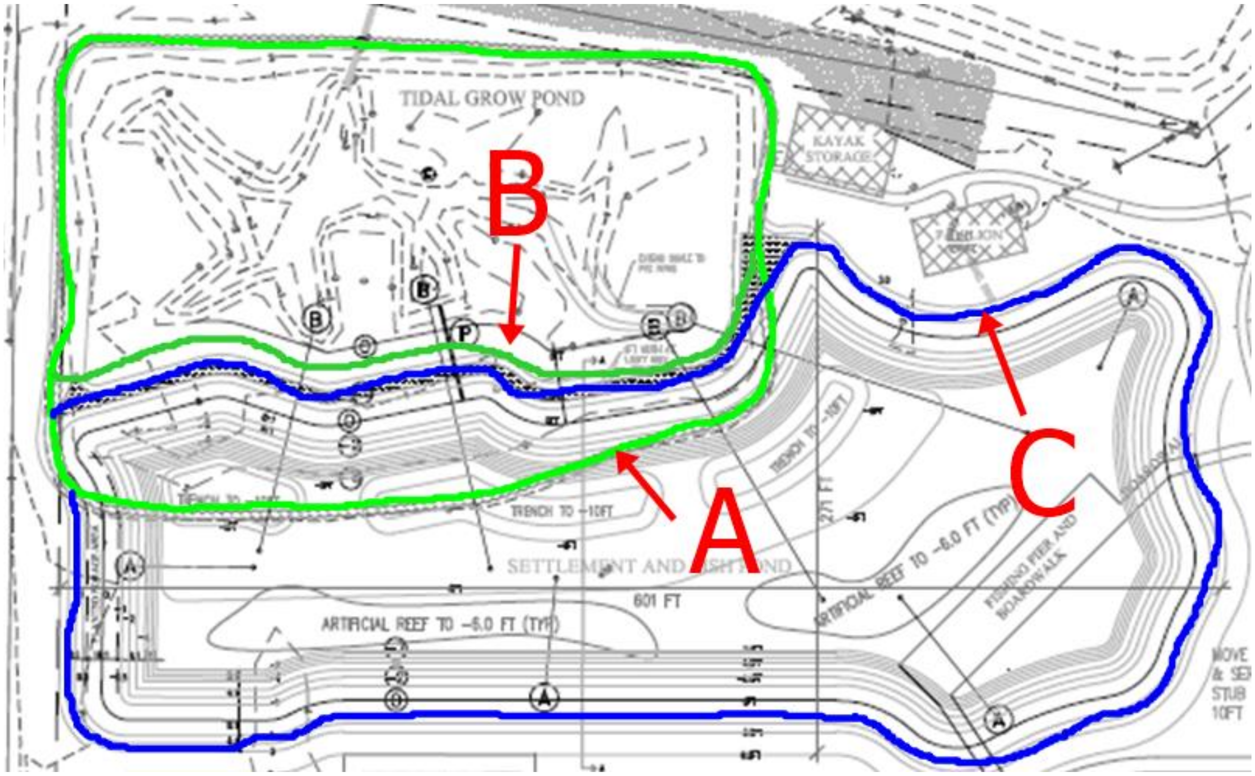

Figure 5 – The original Test Marsh area (green 'A' line) and final Marsh area (green 'B' line) with the final Saltwater Pond area (blue 'C' line)

Finally, the newly graded areas were primarily planted with marsh grasses (spartina alterniflora) transplanted from the existing marsh area that had remained untouched during the regrading process. Other sources offsite provided smooth cordgrass planted at elevations of 1.0-2.0 ft (0.3–0.6 m), seashore dropseed (*Sporobolus virginicus)* planted at 2.0-2.5 ft (0.6–0.8 m), saltmeadow cordgrass *(Spartina patens)* planted at 2.5-3.0 ft (0.8–0.9 m), seashore paspalum *(Paspalum vaginatum)* planted at 3.0-4.0 ft (0.9–1.0 m), and sand cordgrass *(Spartina bakeri)* planted at 3.3-4.0 ft (1.0–1.2 m). With the revised grading, the marsh grasses quickly spread into their new habitat. (Disclaimer: *Please note that the author is not a botanist or a marine biologist so these plant species were obtained from others that are.)* As the new tidal marsh began to establish itself, other wildlife consisting of birds, fish, and crustaceans were observed to be increasing their use of this redesigned marsh as well. *Success is always so sweet and should be celebrated… and in this case by humans and wildlife!*

On a side note, volunteers continued monitoring the tidal water elevations within the creek and within the tidal marsh, while they also monitored the health of the marsh. This additional data continued to substantiate the design elevations used in the marsh construction plans and which would also be used in the design of the tidal pond.

DESIGN OF THE TIDAL SALTWATER POND

With the Water Control Structure in place and the Tidal Salt Water Marsh established, the Tidal Saltwater Pond design could be completed and the construction commenced. Exciting times were ahead but so were the problems and the challenges!

In nature, saltwater habitats depend on moving water… the flow of tides, the movement caused by wind and waves, or the flow of currents along the shoreline. How do you provide this movement of water when you construct a pond… which is in essence a hole in the ground? How do you provide natural self-sustaining fish and vegetative habitats? Some fish want deep water while others need shallow waters to survive. How do you get the nutrients that the vegetation and marine life need for a flourishing life when the entire pond is surrounded by land or berms? Without water movement or circulation, you can end up with dead zones from a lack of required oxygen. Water movement at the surface is relatively easy to obtain but what about at the lower depths of a pond? Like I said… *challenges*… and they all had to be overcome.

Let us begin with the challenge of providing for the movement of water in a pond. A hole in the ground has very little natural movement except for an occasional ripple in the surface when something is dropped into it like a stick or raindrops or wind. To generate the required water movement in the saltwater pond, the design incorporated a 24” (61 cm) concrete culvert connection, and four (4) bi-directional PVC pipes to multiple discharge locations in the pond bottom, four (4) air lifts, and lastly, a concrete spillway. Refer to Figure 6 below for the pipe locations.

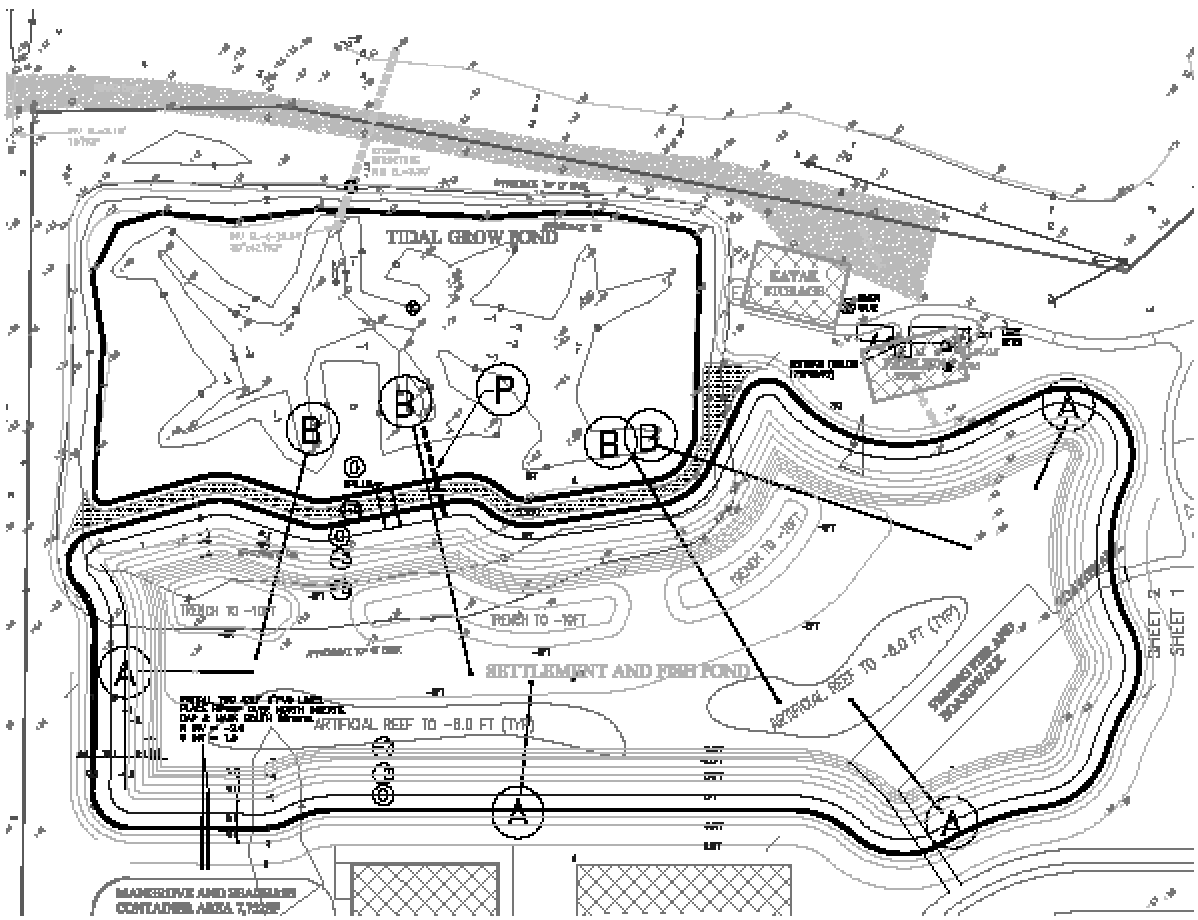

Figure 6 – Tidal Pond Piping – 24" Culvert (P), Bi-directional flow pipes (B), Air Lifts (A)

The **24" (61 cm) concrete culvert** would solve three (3) critical needs of the pond. First, the culvert would provide a substantial velocity of water into the pond to generate movement within the pond. Secondly, it would provide a critical source of nutrients needed to sustain the sea grasses and marine life. And, thirdly, it provided for the natural recruitment of different species of fish and crustaceans. See Figures 7 and 8 for the pipe cross-section detail and the photo of the pipe installed during construction below. The culvert had about 18" (46 cm) of stabilized soil placed over it to secure it in place and to protect it from maintenance vehicle traffic.

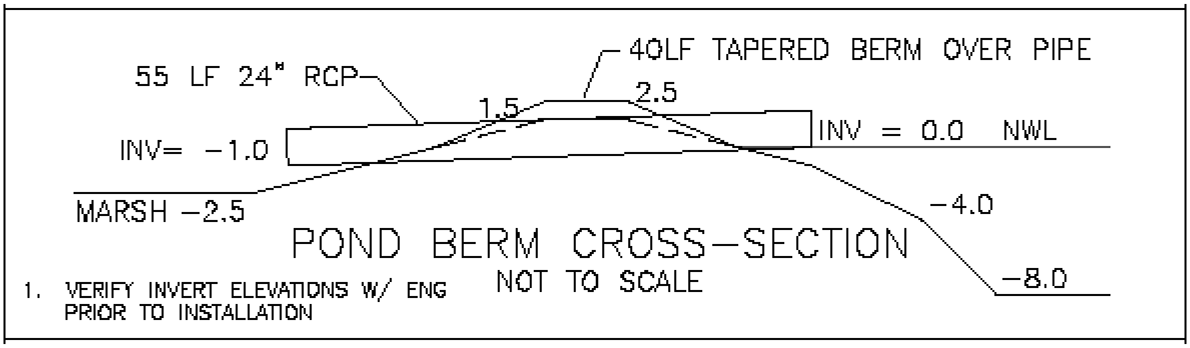

Figure 7 – Pond cross-section at culvert crossing

Figure 8 – Concrete culvert connection through berm to pond (the Spillway over the berm and into the Pond is in the background)

Four (4) bi-directional flow 6-inch (15 cm) PVC pipes were designed to flow directly into / from the pond bottom depending on the tidal creek water elevations. The pond piping would be installed underground from the marsh, under the berm, under the pond side slopes, to the intended discharge location, and then extend upwards to a point 12-inches (30 cm) above the pond bottom. The piping would allow for the discharge of pond water during a low tide cycle and the inflow of fresh seawater directly into the pond during a high tide cycle.

Following a low tide event, as the seawater began to flow into the saltwater marsh, the water level would rise to an elevation of 0.0 ft that would allow the water to enter these PVC pipes and flow through the pipes to be discharged into the pond. Following a high tide event, the tide would start flowing out of the marsh causing the pipes to reverse the flow and pull water out of the pond and discharge it back into the saltwater marsh until the pond reached elevation 0.0 ft. The saltwater marsh would gradually discharge the water back into the tidal creek. Simple but effective, right? See Figures 9 and 10 below. The 12" baffle was to keep floating debris in the marsh from entering the 6" PVC pipe.

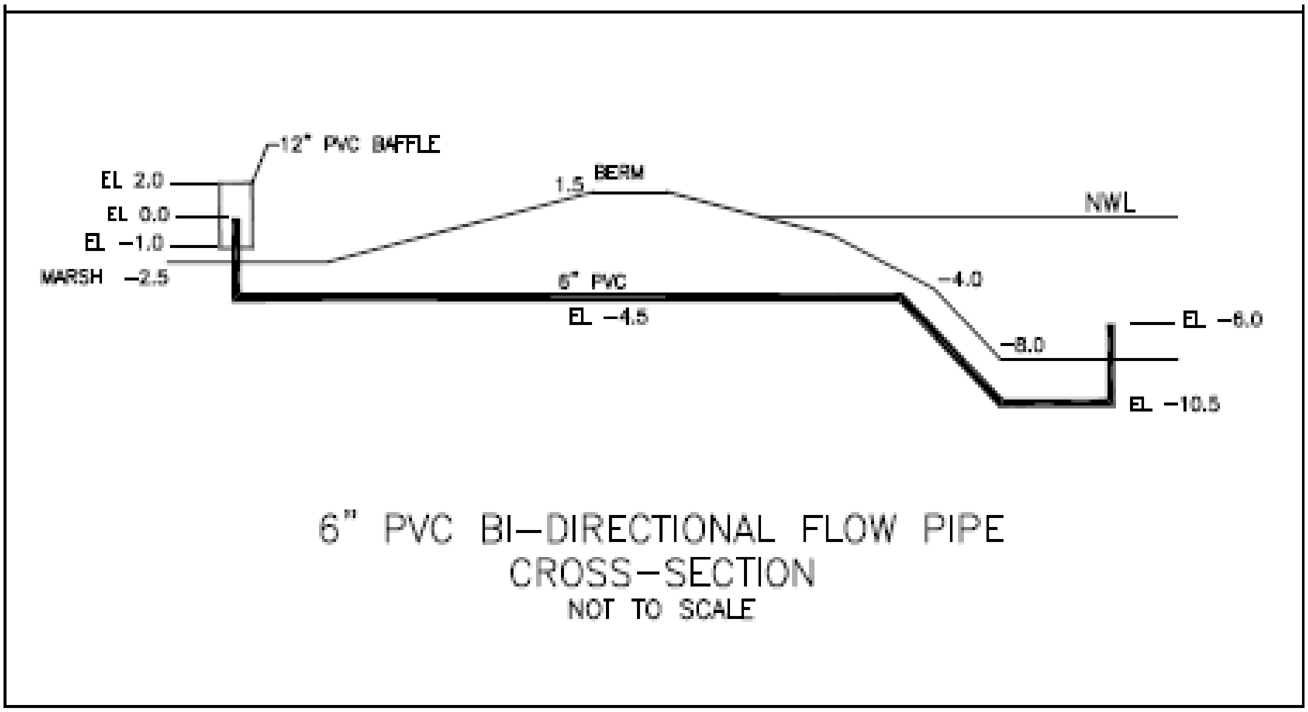

Figure 9 – Bi-directional flow pipes detail

Figure 10 – Two of the 4 Bi-directional Flow Pipes shown when discharging from the Pond into the Marsh. The brown stains indicate the various high tide elevations.

The four (4) airlifts were designed to be of 4-inch (10 cm) PVC pipes installed on the pond banks near the shoreline and extending to the bottom of the pond, and then once again extending 12-inches (30 cm) above the pond bottom. *A future shore-based electric air pump would be connected to the 4" (10 cm) PVC pipe to force air through the airlift pipe to its discharge point located at the pond bottom.* The airlifts would provide additional water circulation and add oxygen to the seawater, if ever needed. Fortunately, to-date, there has been no need to install the air pump or use the airlifts. See Figure 11 below.

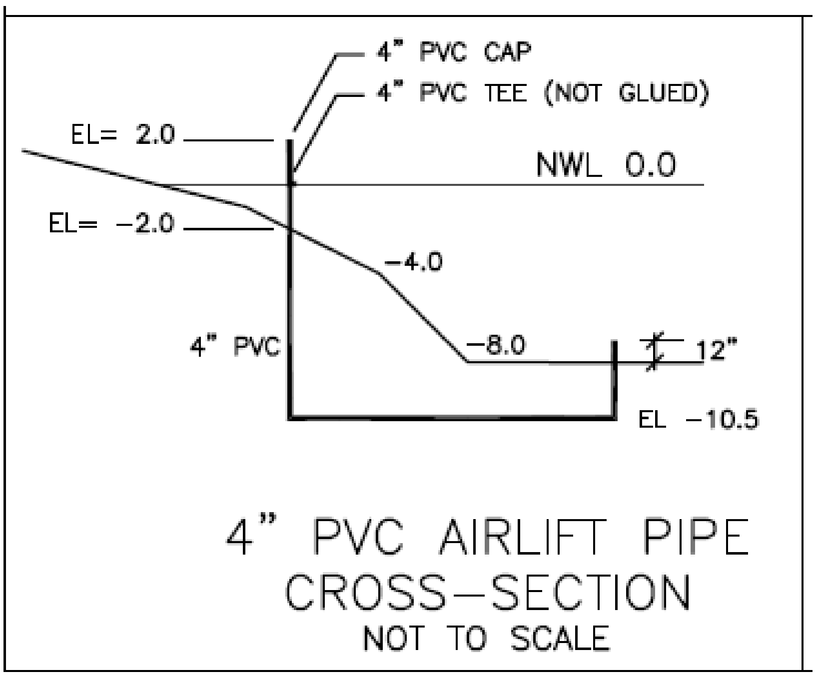

Figure 11 – Tidal Pond Air Lifts

A Concrete Spillway is Added

A concrete spillway was installed in the berm separating the saltwater marsh from the saltwater pond after two tropical storm events occurred that over-topped that berm, submerging the spillway and resulting in several berm washouts each time. The spillway now provides a relief point for those higher-than-normal tides that raise the water levels up to the berm elevation. The spillway also helps to protect the berm from suffering some storm erosion issues. *Since the pond and creek are tidal, they are obviously subject to extreme high tides caused by tropical storms and hurricanes… however, the fish don't seem to mind.* See Figure 12 below.

Figure 12 – Concrete Spillway being installed between the marsh and the pond

Interestingly, some of the fish have learned to gather at the spillway and the 24" culvert as the tide is coming in for their version of a buffet line… since each high tide brings in "new meals and new residents".

Design of the Marine Habitat

With the water flow issue resolved, other challenges had to resolved to address the marine habitat requirements in the pond. These challenges deal with the pond shape, size, depths, underwater side slopes, water movement along the bottom, and vegetation. Let's look at how these aspects were addressed in the pond design.

Pond Shape

For fish, the pond layout should provide a shoreline with natural turns to force the larger fish to make turns both to the right and to the left. It is not natural for fish to always turn to the right simply because an engineer designed their world to consist of a circular hole in the ground. As you will notice in Figure 13, the pond is not a circle but has opposing turns built into the shoreline. As a result, the larger fish are forced to make turns left and right regardless of which direction they prefer to travel around the pond. See Figure 13 below.

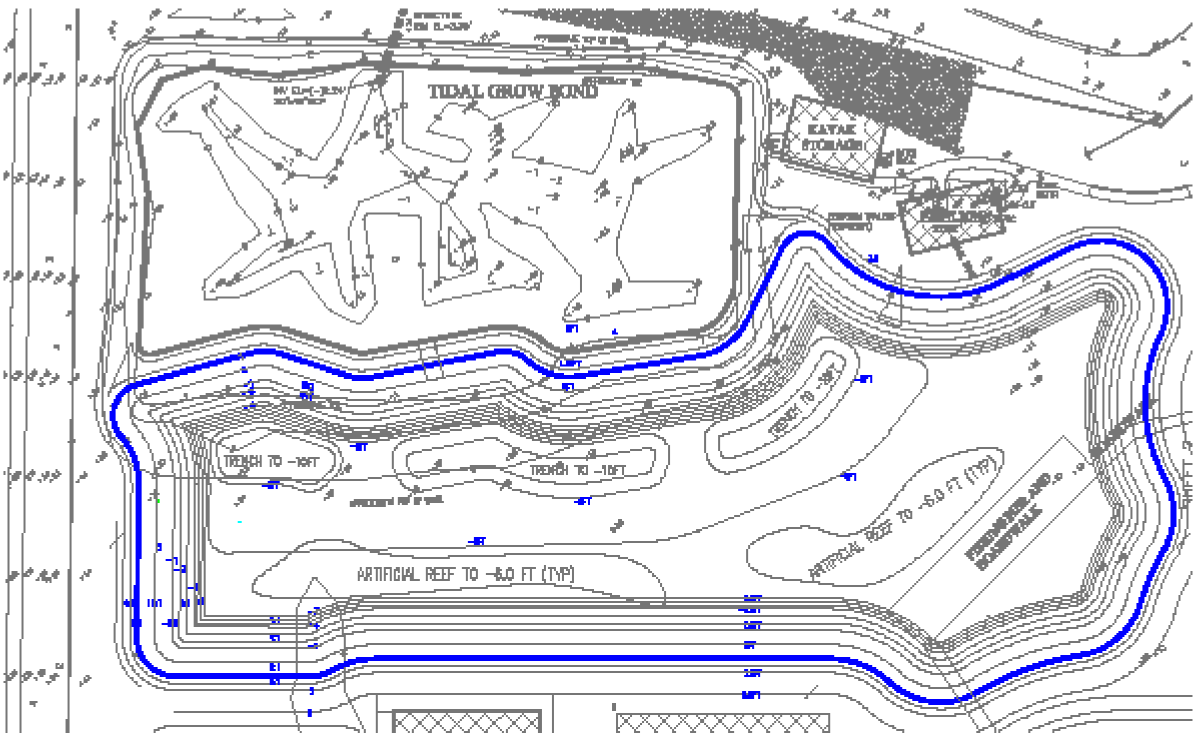

Figure 13 – Saltwater Fish Pond outlined in blue

Pond Size

The pond size is a critical component of a sustainable marine environment and must be sized for the marine species and the pond's intended uses. For this pond, the species were determined by the existing species found in the tidal creek and mangroves. The intended uses for the pond were for public education including catch-and-release fishing, boating and kayaking safety, scientific research, marine turtle care, and a Marine Enhancement Center. After speaking with the directors of each of these facilities and with marine biologists, it was agreed that the pond size at the High Water Level (HWL) would be about 2.74 acres (1.11 hectares). At the Normal Water Level (NWL) the area would be about 2.36 acres (0.96 hectares). At the pond bottom the area would be about 1.5 acres (0.61 hectares).

There is no magic formula to make this sizing determination so it must be made based on the marine species, the intended uses, and the water sources. A client's normal tendency is to undersize the pond area to reduce the construction costs or to minimize it in favor of other desired land uses. If your pond is to be successfully sustained, fight for the largest size you can get and caution the client about the consequences of constructing one too small. There is no harm in constructing a pond "too big" but you can construct a pond "too small".

Pond Depth

The preferred water depth is dependent on the different species that are to inhabit the pond. Small fish prefer shallow water with vegetation to protect them from becoming a tasty meal of larger fish and a place to hide from birds, snakes, and other predators. As a fish grows in size, the more depth it will need to survive. Some larger species want to hang out in the deeper water found at the pond's bottom or trenches or other deeper irregular pockets in the pond bottom.

All of the species need "safe" areas for reproduction. Ponds with gently sloping sides with plenty of sunlight are ideal for fish beds and reproduction. Having grasses and vegetation nearby provide safe habitat and food sources for their young. Other fish prefer steeper sides with more open water but with the opportunity to make a quick exit to shallow waters to escape a larger hungry fish pursuing them.

This pond was designed with a depth of 9.5 ft (2.9 m) at the high tide and a depth of 7.5 ft (2.3 m) at low tide, which was based on the normal existing tides found in the tidal creek. The pond's tidal water elevations lagged the tidal elevations that occurred in the marsh, which lagged the tidal elevations that occurred in the creek. For the marsh, the lag was due to the restricted water flows through the water control structure. For the pond, it was due to the bi-directional piping, culvert, and spillway sizing. Consequently, the water elevations of the marsh and the pond never reached the High Water or Low Water elevations of the tidal creek. Note that a tidal pond constructed in an area with large tide changes could be modified to have smaller tide changes simply by restricting the tidal flows through a water control structure.

Design of Pond Side Slopes

The Pond's side slopes are a critical element of the overall size, volume, and function of a tidal pond. As you can see in Figure 14, we used a side slope of 4 ft (1.2 m) horizontal to 1 ft (0.3 m) vertical (4:1) from the Top of Bank to a point approaching the HWL of the pond. We then changed the slope to 8:1 for 16 feet (4.9 m) which was the vegetative area. (In the marine forage area and fish bedding areas, we used a 16:1 slope as you can see in Figure 15.) At that point, the slope transitioned to 4:1 for 12 feet (3.7 m) for bank stabilization from wave action before changing to 2:1 for 6 feet (1.8 m) for increased depth and water volume. Finally, at the pond bottom the slope varied to create an undulating bottom with random linear trenches and "potholes" for fish habit and water circulation. This was the design we used and it has worked well for this system. Yours may be significantly different based on your soil conditions… rock vs sand and desired habitat preferences. I strongly encourage you to use all available expert sources to design your pond for the vegetative and marine species in your area.

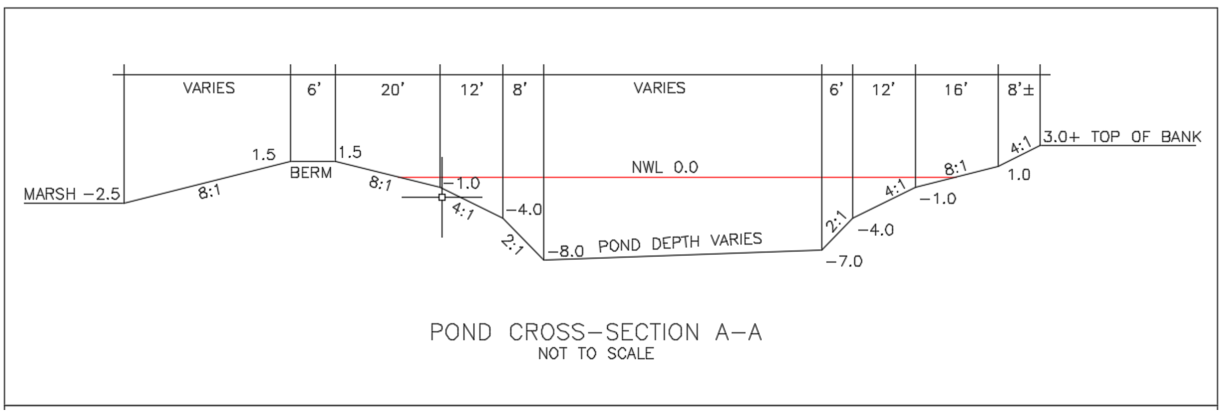

Figure 14 - Cross-section of Pond Side Slopes

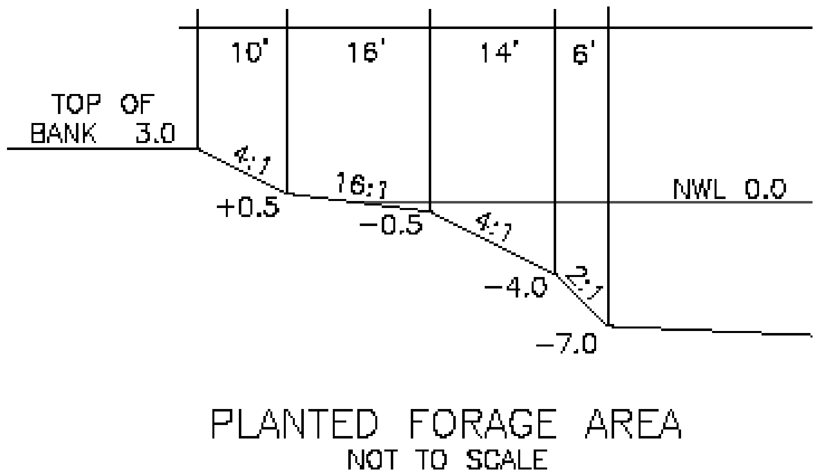

Figure 15 – Side Slopes of the Planted Forage Area

Design of Water Movement in the Pond

Rather than repeat what has already been provided about the water movement, you may want to review the information beginning on page 21 again. The bi-directional flow 6-inch (15 cm) PVC pipes, the 24" (61 cm) culvert, and the spillway have performed well for this system for more than 6 years. Your pond size and depth will probably require something different due to the elevations, soil profiles, and vegetation at your location.

Design of the Pond Vegetation

Since the pond provides habitat for the same species as found in the Saltwater Marsh, the vegetation needs to be capable of sustaining the larger population of marine species as well as new marine species that may be introduced to the pond, like the marine corals. So, the same marsh vegetation species were planted around the shoreline of the pond but in much different quantities, obviously. In addition, "artificial reefs" were constructed using oyster shells, concrete rubble, and concrete reef balls. These artificial reefs were dispersed in different areas of the pond bottom to create some diversity in the marine environment and, possibly, future habitat for the corals. See Figure 16 for the location of the artificial reefs.

Figure 16 – Some of the concrete Reef Balls located on the pond bottom during construction

While the marsh and pond vegetation are critical elements of the pond design, please note that their initial installation is a very labor-intensive effort. I recommend recruiting a lot of volunteers for this effort… from schools, conservation groups, clubs, etc.

EDUCATIONAL AND RESEARCH FACILITIES

The successes at the site have been in many areas, and we will briefly discuss some of the activities at the major facilities. See Figure 17 below for the facilities and their locations:

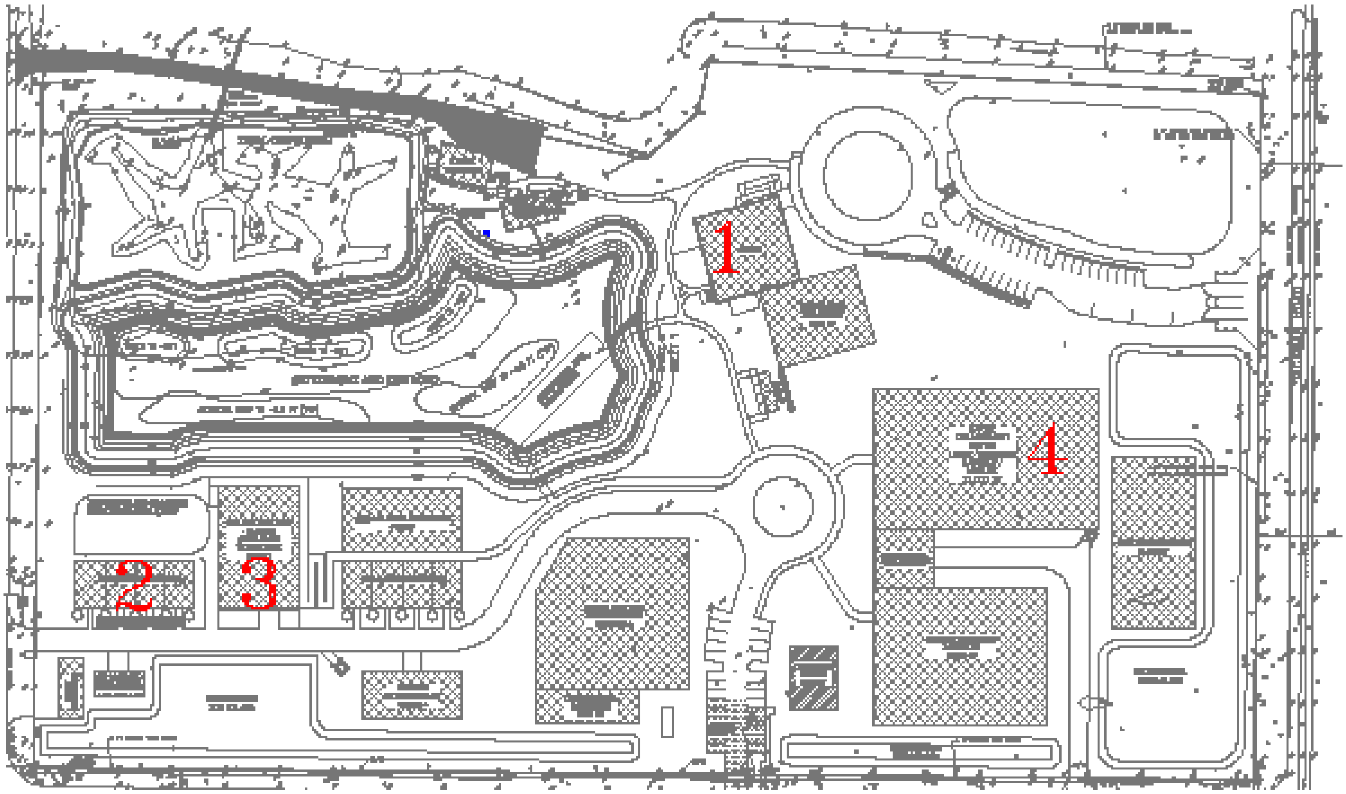

Figure 17 – Plan & Aerial of Suncoast Conservation Center Campus and locations

Florida Youth Conservation Center

The completion of a FWC Youth Conservation Center with 14,600 ft^2 (1,356 m^2), and operated year-round, was the first major facility completed on the campus. Here youth and youth leaders are taught about conservation, fishing, kayaking, nature hikes, and safety. The Youth Conservation Center location is shown on Figure 17 above and is identified as "1". A photo of it is shown in Figure 18 below.

Figure 18 - FWC Youth Conservation Center

Coral Nursery and Research Facilities

The FLAQ Coral Nursery and Research laboratories were constructed on site and are used not only for research of coral growth, but they are also growing different types of coral. The FLAQ facilities currently consist of 3 research laboratories. The Coral Nursery and Research facilities' location is shown on Figure 17 above and is identified as "2". A photo of it is shown in Figure 19 below.

Figure 19 - Coral Nursery & Research Labs

Turtle Care Center

FLAQ's ever-popular Turtle Care Center facility with 19,000 ft^2 (1,765 m^2) takes in injured sea turtles to provide care and rehabilitation for them, while also providing opportunities for the public to use large viewing windows to observe their various surgeries and their rehab care. The Turtle Care Center is a very popular attraction and the location is shown on Figure 17 above and is identified as "3". A photo of it is shown in Figure 20 below.

Figure 20 – Turtle Care Center

Marine Fisheries Enhancement Center

A third major facility constructed was the FWC Marine Fisheries Enhancement Center. The Marine Fisheries Enhancement Center location is shown on Figure 17 above and is identified as "4". A photo of it is shown in Figure 21 below. The current effort is to determine the impacts of stocking hatchery-grown sportfish (specifically spotted seatrout and redfish) into the wild to sustain or increase fishing opportunities, while also maintaining healthy wild spawning populations.

Figure 21 – FWC Marine Fisheries Enhancement Center

EDUCATIONAL AND RESEARCH OPPORTUNITIES

The Suncoast Conservation Center site provides exceptional educational opportunities for younger and older generations. The site also has unique research opportunities for scientists, marine biologists, academia, and professionals.

The Florida Youth Conservation Center currently offers introductory presentations and structured training courses for the general public, teachers, media reporters, and for other groups. Additionally, the Center runs weekly summer camp programs June through August and usually has a lengthy waiting list for each week.

Educational tours are also provided by the Coral Nursery and Research facilities, the Turtle Care Center, and by the Saltwater Marine Fisheries Enhancement Center for the general public, teachers, and for small groups.

The Suncoast Conservation Center has many research opportunities for marine biologists, scientists, ecologists, and botanists, too. Since the onsite ecosystems can be isolated from the offsite ecosystems, the researchers are able to conduct specialized studies by altering the water chemistry, vegetation, or marine habitat to determine the positive or negative impacts caused by specific actions… with one big IF. That being "IF" the study's expected impacts are approved by the Suncoast Conservation Center. Regardless, the researchers can meet with the onsite scientists and biologists to discuss their various theories and proposed activities.

In addition, the Suncoast Conservation Center sometimes has vacant offices or lab spaces that might be available to visiting scientists. It never hurts to ask….

LESSONS LEARNED DURING CONSTRUCTION

There were many minor modifications made to the design during construction (sidewalk locations, minor grading changes, staff parking, building configurations, etc.) that were not discussed in this course, but the Master Plan that was originally approved remained essentially the same as the original plan.

The **Test Saltwater Marsh** proved that there was insufficient staff to keep out invasive plant species, and the marsh grasses were too many to harvest for transplanting. The number of staff required to maintain the tidal marsh dictated a smaller marsh area. *A larger marsh is not always better.*

The **Test Saltwater Marsh** also proved the constructed marsh elevations were too high for the vegetation to survive at the tidal low water elevations. Consequently, the marsh elevations were regraded to lower the elevations to properly hydrate the grasses and have them flourish.

The **Tidal Saltwater Pond** design initially was determined to be too small for the planned activities of catch-and-release fishing and kayak/canoe training. While there were many discussions by the various Stakeholders about the size of the tidal pond, an agreement was reached. The pond size was to be enlarged enough to function properly by reducing the tidal marsh size and by reshaping the pond shoreline. *If ever in doubt about the pond being the correct size, go larger rather than smaller!*

The **side-bank stabilization** of the Tidal Saltwater Pond was an issue multiple times during construction due to the existing sandy soils. Since bringing in suitable soil for stabilization from offsite sources was prohibited by the regulatory agencies, more vegetation needed to be established as quickly as possible to prevent side-bank soil erosion during storms. An engineer needs to closely review the soil geotechnical reports and address the potential for erosion issues early to avoid these problems. The use of structural soils, geo-web fabric, or different vegetative species may provide workable solutions… if allowable.

Similarly, **berm stabilization** of the berm between the marsh and the pond may require a spillway to be constructed at the proper elevation and size to prevent storm surges from overtopping the berm and causing severe washouts. This specific issue had to be addressed during the early stages of the pond construction. We had to go back to the regulatory agencies to explain the issue and obtain a permit modification to construct a spillway. This caused delays which had a direct impact to the contractor's schedule and costs. So, watch for these issues during the engineering design. The author recommends constructing a berm using structural soils or even a concrete dam with a spillway… if necessary, and if possible. Again, consult a geotechnical engineer early if there are any doubts.

Invasive Species were another issue not really addressed during the design phase but which became apparent after construction. The frequent "Catch and Release" fishing events have been very effective in the removal of invasive fish species. However, the mangroves adjacent to the Tidal Saltwater Marsh are constantly trying to get established in the marsh. Fortunately, the mangroves do not grow that fast so they are effectively removed by some of the youth and staff of the Youth Conservation Center during their workshops and summer programs. Invasive species will likely be found in any new ecosystem and the effort to control them should be considered and addressed during the design phase.

Communication and Construction

The conceptual planning, design, permitting, and contract negotiation took years to complete due to the complexity of developing an educational campus with multiple Stakeholders, while also trying to permit new ecosystems *that had never been attempted previously*. And, it did not get any easier once construction began! During construction, weekly meetings were held to coordinate the activities of the multiple contractors that were on site simultaneously, each trying to complete their portion of the campus with those working on the ecosystems. This often required some brainstorming sessions at the meetings to find a means and schedule that kept everyone moving forward without running into each other… *literally!*

The pond construction in itself was an amazing feat since the contractor was digging a 12-foot (3.7 m) deep "hole" in sandy soil adjacent to a tidal basin! Plus, no one was able to successfully delay the tropical storms or the multiple thunderstorms that hit the construction site. However, in the end these meetings with the contractors, design team, and owners proved to save all a lot of time, money, and… *headaches*.

FUTURE GROWTH OPPORTUNITIES

The future is never certain, but possibilities and expansions should be included in the master plan. Some of the possibilities may not happen or they might be repurposed for a use no one foresaw. For the Suncoast Conservation Center, some future possibilities include the following:

1. FWC Youth Conservation Center plan for an 8,000 sf expansion for additional classrooms and labs.
2. FLAQ research on the viability of coral growth in a tidal saltwater pond. This will definitely be an interesting research project.
3. FLAQ research on mangrove development, growth, and propagation, which will require a new containment structure for the mangrove species being tested.
4. A new FLAQ Animal Care Center for species found in coastal areas that have been injured or are diseased.
5. An addition of a FLAQ Shark and Fish Reproduction facility.
6. Expansion of the FWC Marine Fisheries Enhancement Center to include additional species, additional lab spaces, and storage spaces.

SUMMARY

As all types of development continue to expand, the natural environment ecosystems continue to be impacted. As engineers and conservationists, we need to develop new ideas on how to minimize those impacts through new processes, techniques, and regulatory permits. The Suncoast Conservation Center was intended to provide educational opportunities and scientific research opportunities. Though not an intended goal, the project also provided environmental concepts for developers to consider, guidance for engineers to possibly incorporate into their preliminary conceptual designs, and even precedence for regulatory agencies to use to expedite permit reviews and approvals.

In this course, we began by introducing the Stakeholders as being Tampa Electric Company (TECO), Florida Fish and Wildlife Conservation Commission (FWC), and the Florida Aquarium (FLAQ) and then discussing some of the existing site conditions at the start of the project. While the environmental and engineering consultants were hard at work to develop some rough concepts, the Stakeholders' staffs were developing their wish lists as to what could be included in each of their facilities. The staff and consultants would then meet monthly to discuss the land areas needed, the locations for each of their facilities, and the common use areas on the site. At each Stakeholder meeting, the design progress would be presented and the staff would make their presentations. As normal, the list of wishes exceeded the land area and funding available. Then… it was back to the drawing board for all to continue narrowing the project scope to the priorities that could meet the allowable funding.

Next, we discussed what was needed to develop the Master Plan. As with all developments, the essential questions were: 1) What should be included? 2) How large should each element be? 3) Where should each element be located on the site? 4) How will each element interact with the other elements being constructed? 5) What impact… positive or negative… could each element have on the ecosystem? 6) When should each element be started? 7) How much will each element cost?

We then discussed the critical aspect of setting up meetings with each of the regulatory departments and agencies. These meetings brought the designers, engineers, and regulatory reviewers together to make specific technical determinations for the required permit approvals. As you will remember, involving the regulatory staff to obtain their suggestions and allowing them to become “part of the team” helped expedite the permit approval process and minimized the time and money spent on designs that the regulatory staff would not even consider. We had many brainstorming sessions with all parties that proved invaluable… to them and to us!

We also discussed the seven (7) design issues that were established for the site: 1) No impacts to the existing ecosystems; 2) No soil imported or exported from the site; 3) All structures to comply with the 100-year flood plain elevation; 4) Staff parking but no public parking; 5) The saltwater well water must match the existing Gulf of Mexico water chemistry; 6) The sandy soils needed to be stabilized to avoid erosion; and 7) The 24-hour site security requirements.

The technical aspects of developing the Saltwater Marsh were then discussed. A Test Saltwater Marsh was constructed using the High and Low Water elevations from the closest NOAA tide gauge. This Test Marsh proved the tide elevations we used were not functional for our site. The problem was the closest NOAA tide gauge was miles from the site and our observed elevations were different from that NOAA tide gauge. This required collection of the High and Low Water elevations in the Tidal Creek *at the site*. Using the tide data obtained at the site, a new Saltwater Marsh was designed. Additionally, the marsh size was reduced since the onsite staff couldn’t properly manage the marsh vegetation with limited staff at its original size. The Saltwater Marsh was re-constructed and planted again with the saltwater grasses. The marsh quickly flourished and our focus turned to the Saltwater Pond design.

As we learned, natural saltwater habitats depend on moving water and since a Tidal Saltwater Pond was to be created, the design needed to include mechanisms to cause water movement in the pond. The final design incorporated a 24" (61 cm) concrete culvert connection, four (4) bi-directional PVC pipes to multiple discharge locations in the pond bottom, four (4) air lifts, and lastly, a concrete spillway. The culvert was effective at creating water movement while at the same time providing a one-way trip for fish to enter the pond yet difficult to exit. The four bi-directional PVC pipes caused additional water flow at the pond bottom during both high tides and low tides. As a precautionary effort, PVC piping for four (4) air lifts were installed for future use, if ever the need arose. These would provide additional circulation in various areas of the pond. And, lastly, a spillway was constructed in the berm between the marsh and the pond to provide additional movement during the surge of water at high tides. The spillway also helped minimize the erosion of the side slopes caused when tides overtop the berm during storm events.

The pond vegetation was also critical for the pond since it provided habitat and food sources for the various marine fish and crustaceans, and it provided soil stabilization for the pond and berm side slopes. Additionally, oyster shells, concrete reef balls, and concrete debris were added to provide a variety of marine habitats.

The section on Education and Research was provided for those of you that might get involved in a similar development project. Your client may… or may not… be interested in any educational or research opportunities. But the popularity of these opportunities may entice the regulatory agencies to approve environmental credits simply due to the public education and research opportunities being made for the local schools and universities. You do not necessarily need to construct any buildings for educational uses because the ecosystems may provide the only educational opportunities that can be found anywhere in your region. The students and researchers could always observe and collect the data they need to take back to the classroom or their laboratories.

Please note that inclusion of educational opportunities is not required to develop one, or both, of these types of ecosystems. The developer's main incentive will probably be for the environmental credits… while the regulatory agencies incentive will be the development or restoration of the ecosystems.

Please do your own research. And talk to professionals to see if this type of project is right for you and your client. I'm not suggesting it is for all! But I strongly recommend you research these opportunities. If nothing else, you'll know what everyone is talking about if they mention these "hot new ecosystem designs!"

Also, note that the Lessons Learned section was provided to help some of you who prefer to avoid some of the problems that were encountered during the construction of this project. If you are one who prefers to learn from your own mistakes the hard way, you can forget everything in this section.