FLORIDA SOLAR ENERGY CENTER®

Contract Report

Development of a Conceptual Design for a Non-Industry Dependent Warm-Water Refuge for Florida Manatees in Brevard County, Florida

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Final Report

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Table of Contents

List of Figures

List of Tables

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Executive Summary

Florida manatees (*Trichechus manatus latirostris*) are listed as endangered under the U.S. Endangered Species Act. Perhaps their greatest long-term threat is the potential loss of warm-water habitat essential for surviving winter. To survive periods of winter cold, most Florida manatees depend on thermal outfalls from power plants that may soon be retired or begin operating on unpredictable schedules. To prevent large numbers of manatees from dying due to cold-stress as aging power plants are closed, the Warm Water Task Force, part of the Florida Manatee Recovery Team, has recommended that steps be taken to determine if temporary solar heated warm-water refuges could be built to sustain manatees now using power plant outfalls during cold winter periods as plants close or their operating schedules become sporadic. If so, steps could then be taken over the next 20 to 30 years to gradually reduce the number of animals dependent on such refuges as the number of animals dependent on natural springs and thermal basins increase. Based on two earlier studies that concluded solar heated refuges should be technologically feasible (Goswami and Kearney 2002, Gu 2005), this project sought to develop detailed conceptual designs and cost estimates for building such a refuge at the Reliant Energy Indian River Generating Station in Brevard County, Florida.

The envisioned refuge would consist of two essential parts: (1) a 50 by 50-ft four-sided enclosure within which manatees could thermoregulate during cold winter periods, and (2) a land-based heat source composed of either a gas-fired boiler or pool-style solar water heating panels with a gas-fired water heater as a supplemental/back-up heating system. The refuge enclosure would be located in the Indian River about 100 ft from shore directly off the terminus of the power plant's cooling water discharge canal. It would be constructed of recycled plastic timbers bolted between steel H piles driven into the bottom. The boiler and solar array would be located on land owned by Reliant Energy immediately adjacent to the discharge canal about 180 ft from the enclosure. The refuge enclosure would have two openings to allow manatee access and might support up to 50 manatees on cold winter days. A closed circuit water-heating system would heat water within the enclosure. The system would circulate freshwater heated by the gas-fired boiler or array of solar collectors through pipes to the enclosure, where it would circulate through a heat exchanger attached to the inside of three enclosure walls before returning to the solar panels or boiler to be reheated. Thus, there would be no direct discharge of effluent into the refuge enclosure or the Indian River. Water temperatures within the enclosure would be maintained at 22ºC (72ºF) or above, which matches temperatures of natural warm-water springs known to support manatees through the winter.

To estimate the size of heating system components necessary to maintain temperatures at or above 22ºC, hourly ambient water temperatures for the Indian River were estimated for coldest winter on record (i.e., the winter of 1989–1990), when a large number of manatees died of cold-stress. That winter, inland coastal water temperatures apparently dipped to as low as 4ºC (39.2ºF) in parts of the Indian River in Brevard County, although temperatures of 16–20ºC (60–68ºF) are far more typical. Based on that information, a model was used to predict the heat energy required to maintain the refuge enclosure at a constant 22ºC. Those results were then used to calculate the size of the requisite gas-fired

water heater and solar array. Preliminary calculations concluded that the gas-fired water heater would need to have a 5.2 MMBtu/hr heating capacity and that the array would require 336 unglazed solar panels, each 4 ft by 12 ft.

From these calculations and advice on refuge design features provided by a project steering committee composed of representatives of the Warm Water Task Force, conceptual engineering plans and cost estimates were developed by an engineering firm hired by Reliant Energy (Washington Group International) for constructing a temporary refuge with a 25-year life span at the Reliant Energy plant. To minimize potential costs in the event that it was determined that manatees would not use such a refuge, it was recommended that the project proceed in two phases. Phase I would include construction of the refuge enclosure and a gas-fired water heating system. If, after two to five years, it was determined that manatees were using the refuge enclosure during cold winter periods when the adjacent power plant was not operating, a decision might be made to proceed with a Phase II construction project, which would involve adding a solar panel array that could become the primary heating source. The gas-fired boiler would then be used only as a supplemental heat source on exceptionally cold or cloudy winter days when the solar panels alone could not keep the refuge enclosure at 22ºC. Alternatively, a second gas-fired water heater might be installed to serve as a back-up or supplemental heat source in case the primary boiler experiences a system failure or is in sufficient to provide requisite heating needs.

Costs for constructing the refuge were estimated as follows:

<u>Phase I</u>	
Constructing an enclosure and associated heat exchanger	$1,225,447
Installing a gas-fired water heater	$329,489
Subtotal for Phase I	$1,554,946
<u>Phase II</u>	
Constructing a 336-panel solar array with pumps, piping, etc.	$2,431,654
<u>Total for Phases I & II</u>	$3,986,600

These estimates did not include sales tax, the cost of a geophysical survey to analyze substrate conditions for pile driving, the cost of preparing final construction plans, construction management, or costs for obtaining necessary permits. Construction of an optional cover about 3 ft above refuge surface was also considered to reduce heating requirements. Its estimated cost was $435,277, which would increase total estimated costs for both phases to $4,421,877. However, a subsequent reanalysis of heating requirements performed after other design features for the refuge enclosure were known in greater detail concluded that a roof would not be cost-effective for a refuge at this location and was not recommended for this project. That recalculation also estimated a slightly higher base case heating requirement of 5.44 to 5.78 MMBtu/hr, instead of 5.2 MMbtu/hr. The estimate of 5.44 MMBtu/hr would maintain the refuge at between 20–22ºC while a capacity of 5.78 would maintain temperatures at between 21–23ºC during all but the most extreme cold periods. If construction were to proceed, increasing boiler capacity to this range would provide greater assurance that needed temperatures could be maintained. This would increase the costs slightly, but probably not significantly. Based on market availability, a boiler with 5.52 MMBtu/hr is recommended.

Estimates of fuel costs over the expected 25-year life of the refuge suggest that fuel savings would do little to offset construction cost for installing a solar array in Phase II. Fuel savings in constant 2007 dollars assuming that the current price of natural gas remains unchanged over the life of the refuge would be approximately $81,000 to $105,000 compared to Washington International Group's estimated solar array construction cost of $2.4 million. Even with expected increases in fuel costs and perhaps somewhat lower construction costs, which might be realized through a competitive bidding process, construction of a Phase II solar array probably would not be cost effective relative to the use of a gas-fired boiler as the primary heat source. For back up purposes, however, it may be necessary to install a second gas-fired boiler with a comparable capacity to provide heat in case the primary boiler fails for some reason and to provide a supplemental heat source as needed on exceptionally cold days. This presumably would cost about the same as the boiler installed during Phase I (i.e., about $330,000 compared to $2.4 million for the solar array).

1. Introduction

West Indian manatees, including the Florida manatee (*Trichechus manatus latirostris*), are listed as endangered under the U.S. Endangered Species Act. They occur primarily in Florida and appear to be divided into at least four relatively distinct subpopulations (U.S. Fish and Wildlife Service 2001). Manatees are unable to survive extended periods of time in water colder than about 18 to 20ºC (64 to 68ºF). The distribution and cohesion of the four regional subpopulations may be determined in large part by their site-fidelity to specific warm-water refuges used during winter months (Laist and Reynolds 2005a). Most warm-water refuges are formed by localized discharges of warm water from natural or industrial sources. The two largest manatee subpopulations—the Atlantic coast and southwest Florida subpopulations—depend largely on thermal outfalls from power plants built before the 1970s. Together, those two subpopulations currently make up about 85 percent of all Florida manatees. The other two subpopulations (i.e., the upper St. Johns River and northwest Florida subpopulations) currently comprise about 15 percent of all Florida manatees and are the northernmost subpopulations. Those two subpopulations rely principally on discharges from natural warm-water springs that remain a constant 22ºC (72ºF) year-round and are the only two subpopulations increasing at a clear and significant rate.

The Atlantic coast subpopulation, which currently numbers about 1,500 animals, is the one most dependent on power plant outfalls. During a statewide manatee survey in January 2001, nearly 85 percent of all Atlantic coast manatees were counted at five East Coast power plants between Broward County in southeastern Florida, and Brevard County in east-central Florida. One-day counts of more than 100 manatees have been made at each of those five power plants and counts of more than 300 animals have been made at two of those plants. At one of the two plants in Brevard County, more than 500 animals have been seen in a single count (Laist and Reynolds 2005a). The southwest Florida subpopulation numbers perhaps 1,400 manatees and is somewhat less dependent on power plant outfalls; perhaps half of that subpopulation uses power plant outfalls during the coldest winter periods.

Although a few manatees in the Atlantic coast and southwest Florida subpopulations have been seen at natural warm-water springs in the upper St. Johns River and in northwestern Florida regions, respectively, the vast majority of animals in those two subpopulations have never been seen at warm-water refuges outside of their respective regions. It therefore is likely that most manatees in the two largest subpopulations are unfamiliar with the location or existence of springs outside their normal ranges and that animals accustomed to using power plant outfalls will not be able to relocate to natural warm-water habitats in other regions if power plant outfalls are eliminated. For example, an unusually large number of satellite tagged manatees using a small warm-water refuge at an industrial outfall in northeast Florida died or had to be rescued in the winter of 2000–2001 when that outfall was eliminated (Laist and Reynolds 2005b). It also is questionable whether alternative natural warm-water habitats alone (i.e., natural springs and passive thermal basins) within the Atlantic coast and southwest Florida regions would be adequate to support existing numbers of animals in those regional subpopulations. As a result, some scientists believe that manatees accustomed to using particular industrial outfalls in the Atlantic and southwestern Florida subpopulations during cold winter periods will be unable to find other suitable warm-water sites if those outfalls are shut down.

As noted above, all power plants used by manatees as warm-water refuges were built before the early 1970s. Given rising fuel costs, aging equipment, and new technology for generating electric power more efficiently, many aging plants may be retired within the next 10 to 20 years. Regulations under the Clean Water Act of 1972 prohibit new power plants from discharging thermal effluent at temperatures substantially higher than ambient water temperatures. As a result, any new power plants built to replace aging facilities will not be allowed to have comparable thermal outfalls. It therefore follows that many, if not most, of the power plant outfalls now used by two-thirds of all Florida manatees could be eliminated within the next 10 to 20 years. This could cause a large proportion of the Florida manatee population, particularly those in the Atlantic coast subpopulation, to suffer cold-related deaths during winter months as power plants are retired or begin operating sporadically.

To address this situation, a Warm Water Task Force (WWTF) within the Florida Manatee Recovery Team is considering management options to prevent large numbers of cold stress-related manatee deaths due to power plant closures, while at the same time taking steps to facilitate an increase in the proportion of Florida manatees that rely on natural warm-water springs and passive thermal basins. One possible approach under consideration is the development of solar-heated refuges that could temporarily (e.g. 20 to 25 years) support manatees at power plant outfalls if they are shut down. If such temporary refuges could be developed, they might be eliminated gradually over the long term as other manatee subpopulations using natural warm-water refuges increase in abundance. This could help avoid sudden and substantial declines in manatee abundance due to hard to predict power plant closures.

To assess the possibility of developing new warm-water refuges that could temporarily replace power plant discharges, Goswami and Kearny (2002) and Gu (2005) examined the technical feasibility of heating enclosed basins using solar panels and a closed-loop heat exchanger. Their analyses suggested that available solar water-heating technology is adequate to heat water in enclosed areas to temperatures that could support manatees even during most cold winter days. Based on those results, the WWTF, in cooperation with Reliant Energy, proposed that a pilot project be undertaken to develop a test solar heated warm-water refuge that could support manatees at Reliant Energy's Indian River power plant in Brevard County, Florida. The purpose of this study is to develop a detailed conceptual design and associated cost estimates that could be used to proceed with planning for the construction of a test refuge near the outfall of that power plant. The test refuge would help determine if manatees would use such a structure, and if so, whether it could support animals currently using the plant's outfall during winter periods when the plant is not operating or retired.

1.1 Project Objectives

To develop a detailed conceptual design and cost estimates for a constructing a test warm-water refuge for manatees at the Reliant Energy power plant in Brevard County, the following objectives were identified:

- Convene a project steering committee to identify key attributes for a solar-heated warm-water refuge for manatees;
- Review and, as necessary, revise previous estimates of thermal water heating requirements calculated by Gu (2005) for a warm-water refuge in Brevard County, Florida;
- Develop conceptual architectural drawings and cost estimates for building a manatee enclosure at least 2,500 sq ft in size in waters adjacent to the Reliant Energy power plant in Brevard County;
- Develop conceptual drawings and cost estimates for constructing a solar powered water heating system with a supplementary/backup gas-fired water heater to maintain water in the refuge enclosure at 22°C in winter; and
- Prepare a final report describing the results of the above tasks.

1.2 Project Organization

This project was carried out as a joint effort by the Florida Solar Energy Center (FSEC) and Reliant Energy, in close cooperation with the WWTF. FSEC was responsible for calculating thermal heating requirements necessary to maintain the refuge enclosure at levels adequate to support manatees during winter months, and for summarizing project results. Reliant Energy contracted with an engineering firm, Washington Group International, Inc, for conceptual drawings and cost estimates to construct the refuge enclosure and heating system. Representatives of the WWTF provided advice on refuge design parameters necessary to maintain and monitor manatees at the project site and reviewed the draft project report.

2. Refuge Design Specifications

To begin developing design specifications for a manatee refuge enclosure and heating system, FSEC convened a project steering committee to identify necessary refuge features. Members of the Committee are listed in Appendix A. FSEC also revised estimates of ambient water temperatures for the Indian River in Brevard County for the coldest year on record (i.e., the winter of 1989–1990) and calculated thermal heating requirements for the refuge enclosure based on a previous study (Gu 2005). Results of those efforts are described below.

2.1 Project Steering Committee Meetings

The project steering committee was convened on 16 November 2005 at the Reliant Energy power plant in Brevard County, Florida. During its initial meeting, the committee reviewed information on the purpose and concept for the refuge. As envisioned by the committee, the refuge would be composed of two major parts: a refuge enclosure and closed-circuit heating system that would warm ambient river water in the enclosure to levels that would support manatees during the winter. The refuge enclosure was to include a heat exchanger to transfer heat from a central heating system to enclosure waters. The heating source was to include an array of solar collectors and a backup gas-fired boiler. Advice provided by the committee focused on the following:

Project Life Span: Although the refuge would serve as a test facility, the steering committee noted that it could take perhaps five years to demonstrate its potential effectiveness. If successful, the refuge might require operation for an additional 20 years. Within that time frame, other manatee subpopulations dependent on natural warm water springs and thermal basins are expected to increase to levels where it might be appropriate to consider a phased elimination of refuges heated artificially (e.g., by solar heated refuges or industry outfalls) in areas where manatees could not otherwise survive winter. The committee therefore recommended that the refuge be designed with a 25-year life span.

Refuge Water Temperature: With regard to the water temperature to be maintained in the refuge enclosure, the steering committed considered options of 70º, 72º, and 74ºF (21.1º, 22.2º, and 23.3ºC). Based on the winter survival of manatees at natural warm water springs where water temperatures remain a constant 22ºC, it recommended that water temperatures within the refuge enclosure be maintained at or above 22ºC.

Refuge Depth: The committee considered options of 3.5, 6, and 8-ft depths for the refuge enclosure. Given water depths and a tidal range of 1 ft in waters off Reliant Energy's Indian River power plant, a desire to avoid dredging, and depths suitable to support resting manatees, the committee recommended that the refuge be 6 ft deep at mean sea level (i.e., the depth of the deepest area immediately off the existing power plant outfall).

Refuge Location: After reviewing available information on water depths around the plant outfall, the committee recommended that the refuge be located about 80 ft offshore in the path of the existing power plant cooling water outfall plume. This would place the enclosure within an existing no-entry area for boats to help protect animals, and within a short distance of shore to minimize heat loss from water circulating between land-based heating units and the refuge enclosure. It also would be in the same area where manatees now thermoregulate in winter. Thus, manatees would not have to learn to use a different site when the Reliant plant is not operating and there would be no need for establishing new regulatory protection measures. The site also is within a few miles of a Florida Power & Light Company power plant, which is also used by manatees overwintering at the Reliant plant. Thus, if manatees failed to use the new refuge enclosure to thermoregulate when the Reliant plant is not running, a convenient alternative location would be available to minimize the risk of cold stress for overwintering animals.

Refuge Dimensions: The Committee recommended that the refuge enclosure be 50 by 50 ft (i.e., 2,500 sq ft), a size that could accommodate perhaps 50 animals at a time.

Type of Wall Material: Given uncertainty about the thermal conductance of alternative materials that might be used to construct the walls of the refuge enclosure and their costs, the Committee recommended that the engineering firm hired to develop conceptual plans and cost estimates determine the thermal conductance of alternative materials (e.g. sheet piling, wood, recycled plastic planks, etc.) and make recommendations as to cost effective alternatives.

Refuge Cover: An earlier report analyzing the possible construction of non-industry dependent warm water refuges (Gu 2005) concluded that a cover placed a few feet above the surface of the refuge enclosure might significantly reduce heating requirements. Such a feature, however, could be expensive to install and maintain, and make it difficult to monitor animals using the enclosure. Given uncertainty as to the cost and effectiveness of a cover, the steering committee recommended that costs for installing a seasonal winter cover be estimated as an optional feature.

Openings for Manatee Access: Based on the size of openings between pools in marine aquaria that maintain manatees in captivity, the steering committee recommended that the wall openings to allow manatee access to the enclosure be 4 by 8 ft in size and that there be two openings. To minimize heat loss from water flowing through the refuge openings, it was recommended that the openings be placed 1 ft above the bottom on opposite walls in opposite corners. To prevent excessive flushing rates in winter, it was recommended that the openings be placed on walls that would not be directly exposed to prevailing northeasterly winter storm winds. To provide an option for further controlling flushing rates through the refuge, it was also recommended that the openings include fixtures for a panel that could be installed to close off one or the other opening should it be determined that both openings were not needed.

Heat Exchanger Design Considerations: To avoid the possibility of heat exchanger pipes being covered by accumulations of sediment or manatee feces, thereby reducing heat transfer to enclosure waters, the steering committee recommended that the heat exchanger be attached to the refuge walls, rather than being placed on the bottom of the enclosure. It also recommended that the heat exchanger be constructed of copper because of its high efficiency in transferring heat between the circulation water in the heating system and water in the refuge, and its résistance to corrosion in the marine environment. Because water circulating through heat exchanger pipes would not exceed about 35ºC (95ºF), it was believed that direct contact by manatees with the heat exchanger would pose no risk of burning the animals. However, to protect the heat exchanger from damage by manatees rubbing against the pipes and to prevent entrapment risks for manatees, it was recommended that the heat exchanger be placed no more than about 4 in from the wall and that it be covered by a protective grating.

Solar Panel Design Considerations: It was noted that the solar panels should be placed on land as close to the enclosure as possible to minimize the loss of heat from the water circulating between the heating source and the refuge enclosure. It also was noted that the solar array would need to withstand hurricane force winds and comply with relevant building codes. To ensure that the refuge could be heated in the event of exceptionally intense and long periods of cold, cloudy weather, the steering committee recommended that the heating system include a backup gas-fired boiler that could provide a supplemental heating source or an alternative heat source in the event of a failure in the solar heating array. From preliminary calculations of thermal heating requirements, it was estimated that an array with 336 unglazed commercial solar panels, each a standard 4 by 12 ft in size, would be needed.

Based on the above considerations, Reliant Energy prepared a statement of work (Appendix B) for developing conceptual drawings and cost estimates to construct a refuge enclosure with a heat exchanger, and an associated heating system composed of an array of solar panels and a back-up gas fired boiler, adjacent to their Brevard County power plant's thermal discharge outfall. Reliant Energy then contracted with an engineering firm, Washington Group International, Inc., to carry out the work.

Preliminary results of the engineering analysis concluded that construction costs for the solar panel array alone would exceed $2 million. FSEC therefore reconvened the project steering committee on 18 May 2006 to consider ways of reducing facility costs. At that meeting, the engineering contractor noted that, for the short-term (e.g., five years), the back-up gas-fired heater alone could be sufficient to meet heating requirements for the refuge enclosure. Therefore, to reduce initial construction costs, while allowing for a test to determine if manatees would use the heated refuge enclosure, the steering committee recommended that refuge construction proceed in two phases. Phase I would involve constructing the refuge enclosure and installing a gas-fired boiler that could mimic heating characteristics of a solar panel array. If, after a period of time (e.g. five years), manatees learned to use the enclosure, work could proceed on Phase II, which could involve constructing a solar panel array to replace the gas boiler as the primary heating source. Based on this advice, Reliant Energy amended its contract with the engineering firm to request an estimate for constructing a refuge with a gas boiler heating system alone as an initial project phase.

3. Design Features and Cost Estimates for the Refuge Enclosure

The location of the manatee refuge considered in this report would be immediately adjacent to the mouth of the cooling water discharge canal at the Reliant Energy Indian River power plant in Brevard County, Florida (Figure 3-1). The refuge enclosure would be constructed during Phase I and would be a four-sided structure located offshore in the Indian River about 140 ft from a security fence across the terminus of the plant's discharge canal in water 6 ft below mean sea level. This would place the refuge directly in the path of the plant's thermal effluent as it enters the Indian River. Manatees currently use this area to thermoregulate. This should ensure that manatees now using the plant to overwinter would be able to find the refuge when the plant is not operating. The enclosure would be about 100 ft from the nearest point of land and about 180 ft from the location of the landside gas boiler that would provide the heat source during Phase 1 of the project.

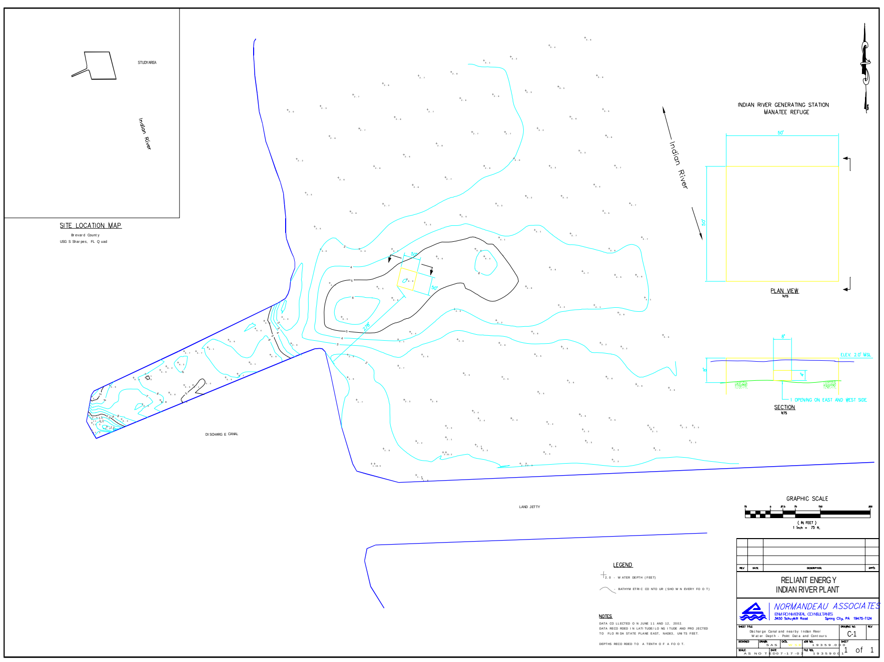

Figure 3-1. Site plan for the location of the enclosure showing site bathymetry (black line = 5 ft msl depth contour) and associated land-based heating source for a manatee refuge at the Reliant Energy Indian River power plant, Brevard County, Florida.

Based on design details developed by Washington Group International (Appendix 2), the structure would be a square enclosure with walls facing approximately northeast, northwest, southeast, and southwest. After considering vinyl sheet piling, concrete sheet pilings, solid 12 by 12-in wood timbers, and recycled plastic timbers as options for constructing the enclosure walls, the latter was determined to be the preferred material. This was based on its resistance to corrosion and marine borers, the lack of chemical treatments that could introduce hazardous pollutants to coastal waters, and thermal conductance characteristics. The recycled plastic timbers would be 12 in wide, 6 in thick, and up to 25 ft long. They would be stacked horizontally from the river bottom to a height of 3 ft above mean sea level (Figure 3-2). The plastic timber would be designed with interlocking machined grooves and laid with cement grouting between timbers to make the walls as leak proof as possible.

The plastic timber lagging would be secured with 4 by 4 in fiberglass angles and corrosion resistant bolts between the flanges of 30-ft- long steel soldier H piles driven into the sediment at each corner of the enclosure and at intervals along each wall. Two additional H piles would reinforce the northeast wall and one additional H pile would be placed at the center points of the northwest, southwest, and southeast walls. The two additional H piles along the northeast wall would ensure that the wall could withstand exposure to prevailing wind and wave forces hitting the enclosure from the northeast during winter. The H piles would be galvanized with zinc anodes and covered by coal tar epoxy to prevent corrosion. A small platform would be placed atop each corner pile for use by observers monitoring manatees inside the enclosure and in adjacent waters. A solid fiberglass plate extending 2 ft below the plastic timber walls into the sediment would be installed to prevent gaps from forming beneath the refuge walls due to erosion or burrowing manatees. The two openings for manatee access, each 4 by 8 ft in size, would be placed 1 ft above the bottom, one in the northwest wall and the other in southeast wall, at opposite corners. The northeast wall, which would face prevailing winter winds and waves, would have no openings to minimize water circulation through the enclosure due to wind driven currents in winter.

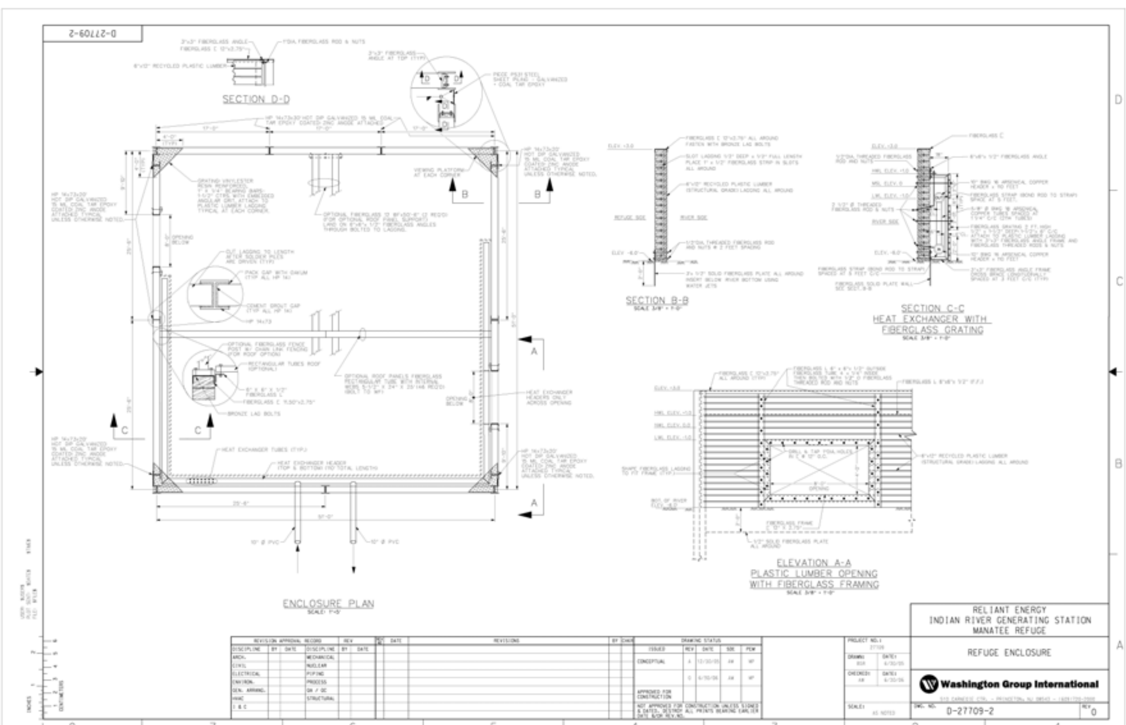

Figure 3-2. Conceptual plans for the enclosure and associated heat exchanger for a manatee refuge at the Reliant Energy Indian River power plant, Brevard County, Florida.

The heat exchanger for transferring heat from the circulation water to the enclosure water would be constructed of 5/8-in thick arsenical copper tubing installed on the inside of the entire southwest wall and parts of the northwest and southeast walls. Water would flow through the tubing at a rate of 1,347 gpm. The tubing would be supported a few inches from the wall facing to promote water circulation around the tubing and would be covered by a protective fiberglass grating designed to prevent the heat exchanger from being damaged or dislodged by a 2000-lb manatee attempting to rub against it. Tubing for the heat exchanger would be connected to the land-based heat source (i.e., the gas-fired boiler and array of solar panels) by an insulated 10-in PVC lower header 1 ft above the bottom, which would carry heated water to the exchanger, and a 10-in upper header carrying circulation water back to the heat source. Two insulated 10-in PVC pipes lying on the river bottom would carry the circulation water between the enclosure and the heat source. One would carry heated water to the refuge and the other would return cooled water to the heat source.

The refuge enclosure would be constructed to withstand 6 ft wave heights predicted to occur at the site as a result of a 3-mi fetch of open water to the northeast of the refuge and the possibility of 100 mph winds during a hurricane. Although located within a no entry zone for watercraft, an appropriate navigation warning light would paced on the refuge enclosure to comply with Coast Guard requirements for marking fixed structures located in navigable waters.

Based on an itemized list of equipment, material, and labor costs (Appendix 2), as well as applicable design and construction codes, Washington Group International estimated that the cost for constructing the refuge enclosure, including the heat exchanger, would be $1,225,447. This estimate includes a 10 percent contingency cost for unforeseen material and labor costs, and a 5 percent contingency for engineering modifications and assumes Reliant Energy would make the land on which the heating systems would be located available for this use at no cost. The estimate does not include sales taxes, the cost of collecting soil samples for analyzing substrate composition at the enclosure, the cost of preparing final construction plans and construction management, or costs for obtaining necessary permits. An optional cover supported by a central beam and fiberglass tubing, which would be capable of supporting up to 300 lbs, was estimated to cost an additional $435,571, including all materials, labor, and a 10 percent contingency for unforeseen costs.

4. Design Features and Costs Estimates for the Refuge Heat Source

To heat the refuge enclosure, this project considered a closed loop heating system that would rely on an array of solar panels and a gas-fired water heater (Figure 4-1). To calculate heating requirements for this system FSEC first had to estimate ambient water for the Indian River in Brevard County during the coldest year (i.e., the winter of 1989-90). It then used a model developed in a previous study (Gu 2005) to calculate the heat energy and the sizes of the gas-fired heater and solar array required for Phases I and II. Based on preliminary calculations of these sizes, Washington Group International prepared a site-specific conceptual design with itemized costs estimates for installing the heating system. The results of those efforts are described below.

4.1 Predictions of Minimum Ambient River Water Temperatures

In a previous study, Gu (2005) calculated thermal heating requirements for three possible solar heated refuges along Florida's Atlantic coast, including one site in Brevard County. These calculations require hourly ambient water temperatures during the coldest periods likely to be encountered at the refuge site. Such data was not available for the Indian River in Brevard County and therefore, the earlier study used temperature records collected by the National Oceanographic Data Center at two sites during the winter of 1989–1990. One site (an ocean buoy located 20 mi offshore of Cape Canaveral) recorded hourly air and surface water temperatures, while the other site (a station located

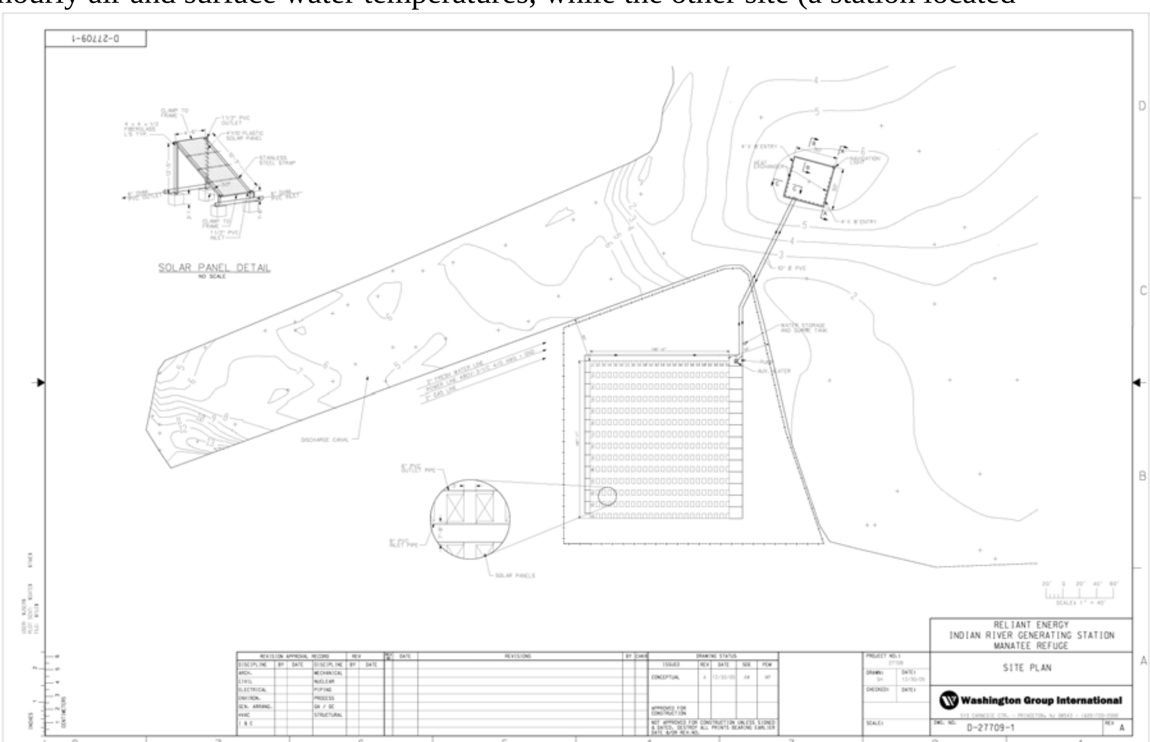

Figure 4-1. Conceptual flow diagram and plan view for a manatee warm-water refuge at the Reliant Energy Indian River generating station, Brevard, County, Florida.

on an ocean pier in Palm Beach County) recorded hourly surface water temperatures. Hourly inland water temperatures for Brevard County were estimated from those records by correlating them with inland water temperatures in Brevard County during other periods when such data were available for all locations. To do so, inland coastal water temperature was expressed as a bi-quadratic function of ocean air and water temperatures using the following regression:

$$T_{river} = a + b*T_{air} + c*T_{ocean} + d*T_{air}^{\ 2} + e*T_{ocean}^{\ 2} + f*T_{air}*T_{ocean}$$

where	T_{river}	River temperature [^{o}C]
	a,b,c,d,e,f	Regression coefficients
	T_{air}	Ocean air temperature [^{o}C]
	T_{ocean}	Ocean water temperature [^{o}C]

Although Gu (2005) found that the above equation predicted inland coastal water temperature well for West Palm Beach County, it could not catch the lowest water temperatures in Cape Canaveral during December 1989 (the coldest period in recent years). The main reason appears to be that ocean water temperatures are much warmer than inland coastal water temperatures during very cold periods. To accurately predict thermal heating requirements for a manatee refuge, inland coastal water temperatures are essential.

With the help of Cathy Beck, a wildlife biologist with the U.S. Geological Survey in Gainesville, Florida, water temperature records that were not available for the previous study were obtained for Banana Creek, Brevard County, during the period February 1988 to May 1995. Those data included daily mean, daily minimum, and daily maximum water temperatures. To convert those data to an hourly form suitable for simulating heating requirements in this study, Indian River water temperatures provided by Florida Power & Light Company from its Cape Canaveral power plant were examined for the period 1996 to 2003. Those data reported inland water temperatures at 4-hr intervals from the mouth of two cooling system intakes. After eliminating unreasonable data points and averaging temperatures from the two intakes, daily mean, minimum, and maximum temperatures were plotted for the period December 1998 through January 1999 (Figure 4-2). That plot indicates that daily minimum and maximum water temperatures during that period generally occur at about 6:00 AM and 6:00 PM, respectively.

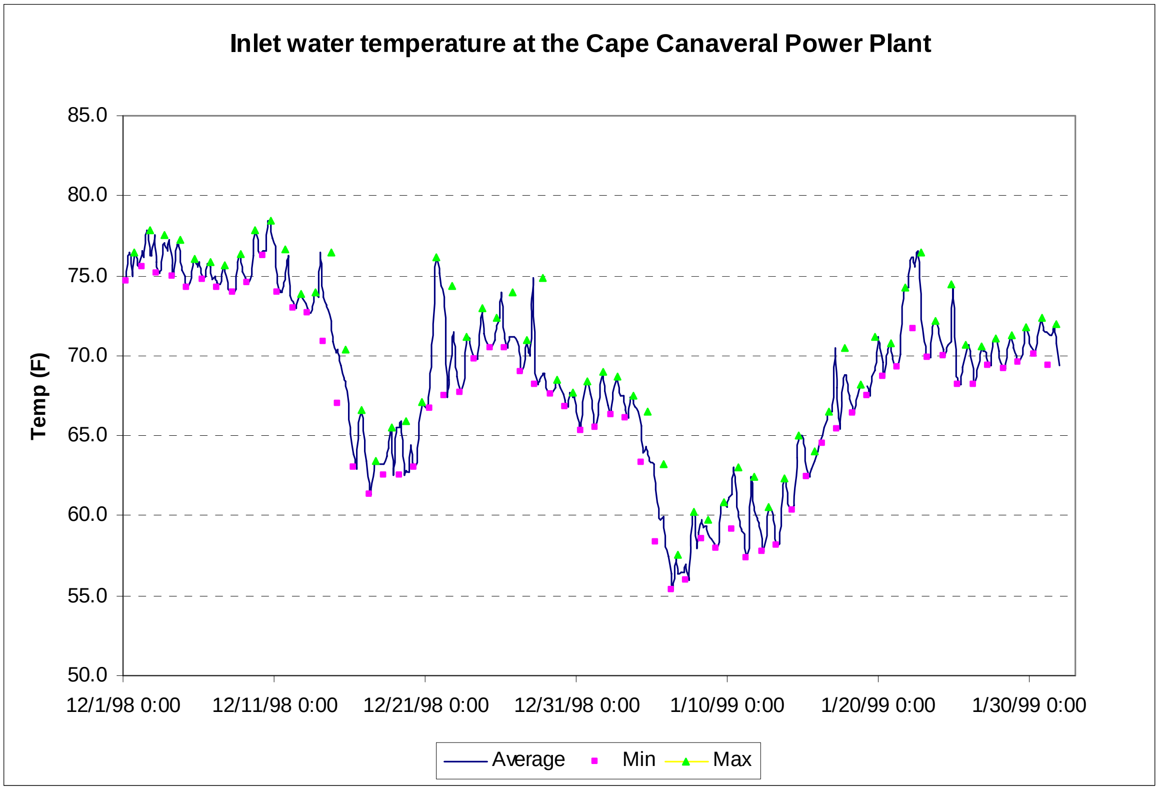

Figure 4-2. Inlet water temperatures measured at the FPL Cape Canaveral power plant cooling system intake between December 1998 and January 1990

Based on that observation, it was assumed that the minimum and maximum temperatures during the severe cold period in December 1989-January 1990 also occurred at 6:00 AM and 6:00 PM, respectively, and that hourly inland water temperatures would form a sine curve that could be used to estimate hourly inland coastal water temperatures. Therefore, to estimate hourly temperatures, the following two equations may be used:

For hours 1 to 12: $$T = T_{mean} - (T_{mean} - T_{\min}) * \sin(hour * \pi / 12)$$

For hours 13 to 24: $$T = T_{mean} + (T_{\max} - T_{mean}) * \sin(hour * \pi / 12)$$

Where
T_{mean} = Mean temperature on a day
T_{min} = Minimum temperature on a day
T_{max} = Maximum temperature on a day
Hour = Hour of a day

These equations assume that (1) the minimum and maximum temperatures always occur at 6 AM and 6 PM, respectively, and (2) the mean temperature always occurs at noon. Although these assumptions may not be valid on all days (e.g., on cloudy days), the above equations appear adequate for generating hourly temperature trends for this study. Figure 4-3 shows the predicted ambient hourly water temperatures based on those equations for the period between 1 December 1989 and 31 January 1990. The predicted hourly temperatures were substantially lower than those previously predicted by Gu (2005), which are also shown on Figure 4-3. The minimum temperature estimated for that period in this study was 8°C cooler than that estimated in the previous study (i.e., 4°C rather than 12°C). This would make a significant difference in the estimated size of the solar panel array and boiler needed to heat the refuge enclosure. By the same token, the data

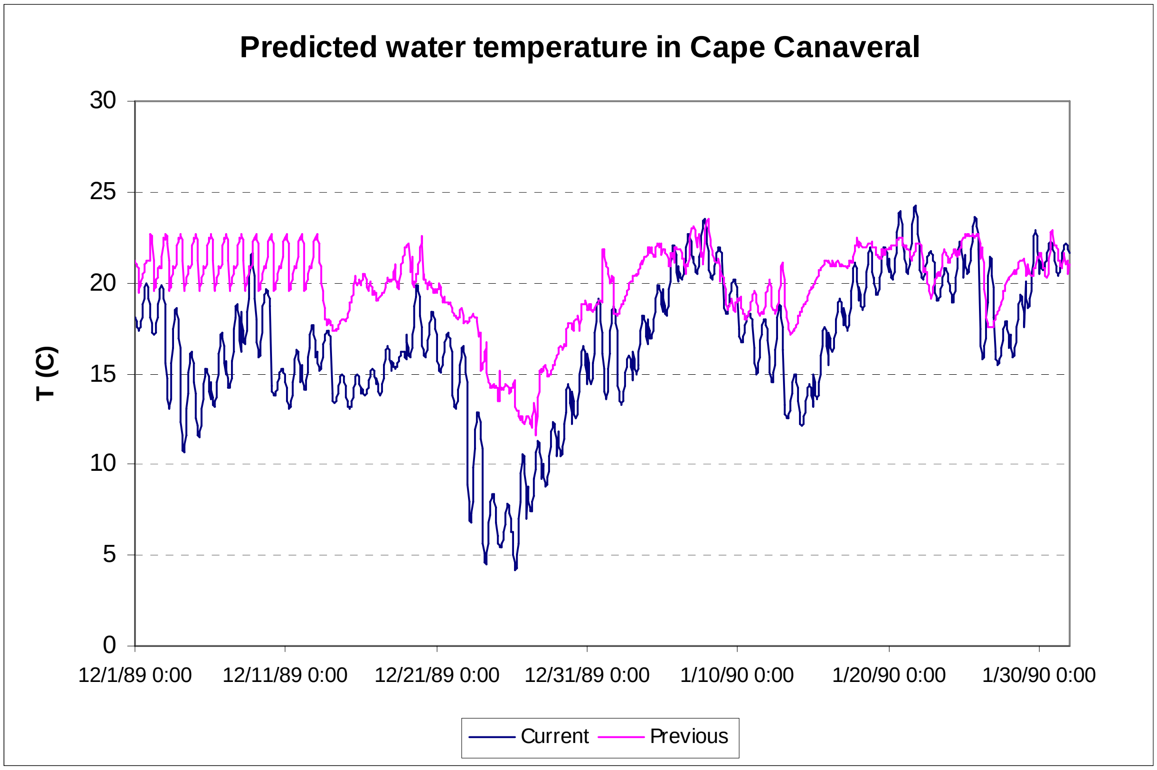

Figure 4-3. Predicted river water temperature profile for the period December 1989 through January 1990 based on previous analyses (Gu 2005) and analyses in this study.

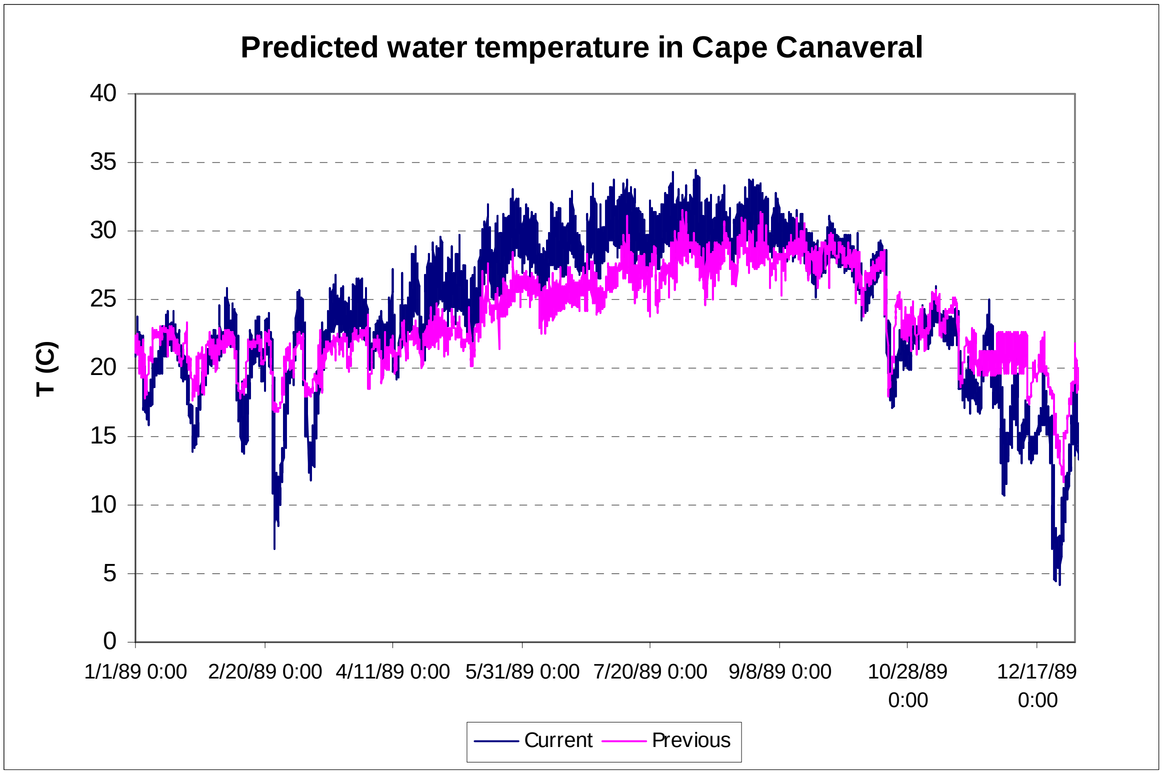

Figure 4-4. Predicted river water temperature profile for the year 1989 based on previous analyses (Gu 2005) and analyses in this study

suggest that the maximum summer temperatures were higher than previously predicted as shown in a plot of the estimated inland water temperatures for a full-year period from January 1989 through December 1989 (Figure 4-4).

4.2 Heat Energy Simulation Methods

The model used in this study to simulate thermal heating requirements (along with steps to validate it) is described in Gu (2005). Briefly, that model considers heat transfer across the following boundaries:

- heat from solar radiation entering the refuge embayment,
- heat transfer due to convection at the water surface through air movement;
- heat exchange between the water surface and sky temperatures due to night sky radiation,
- heat exchange between the ground and water within the refuge area,
- heat exchange due to tidal effects, and
- heat exchange between reheat water and the water in the refuge.

The general governing equation to calculate refuge heat losses may be written as:

$$\rho C_p V \frac{dT_w}{dt} = Q_{cond} + Q_{solar} + Q_{rad} + Q_{conv} + Q_{evap} + Q_{tide} + Q_{heat}$$

where
- ρ = Water density [1000 kg/m^3]
- C_p = Water specific heat [4180 J/kg.K]
- V = Refuge volume [m^3]
- T_w = Refuge water temperature [K]
- t = Time [s]
- Q_{cond} = Heat conduction loss from surrounding walls and ground [W]
- Q_{solar} = Heat gain from solar radiation [W]
- Q_{rad} = Heat loss from radiation between refuge water surface and sky temperature [W]
- Q_{conv} = Heat loss from surface convection [W]
- Q_{evap} = Heat loss from surface evaporation [W]
- Q_{tide} = Heat loss from water exchange between the refuge and surrounding [W]
- Q_{heat} = Heating energy [W], either from ideal heating or solar collectors

For ambient inland coastal water temperatures, the estimated hourly ambient water temperatures estimated for the period 1 December 1988 to 30 January 1990 were used. Other parameters used for simulations in this study included the following:

Ground temperature:

The ground temperature was calculated based on the following equation (Labs et al., 1986):

$$T_z = T_m - A_s e^{-z\Phi} \cos\left[\frac{360}{365}(t - t_o - zL)\right]$$

where
- T_z = Ground temperature at depth z on day (^{o}F)
- T_m = Mean annual or “deep” ground temperature (74^{o}F in central Florida)
- A_s = Amplitude of annual ground surface temperature (11^{o}F in central Florida)
- z = Depth below surface (feet)
- Φ = Logarithmic decrement = $(\pi/365\alpha)^{0.5}$ (feet^{-1})
- L = Lag time (days)
- T = Time, beginning midnight, December 31 (days)
- T_o = A phase constant (days)

Refuge wall insulation:

Since the manatee refuge would be a free-standing structure located in the Indian River, it was thought that wall insulation would be an important consideration for reducing heat losses. The range of wall insulation values considered possible for this study ranged from R=0 as the base case to R=6.

Tidal impact:

Tidal fluctuations will cause surrounding river water to flow into the refuge enclosure on rising tides and heated water in the enclosure to flow out on falling tides. The resulting water turnover will increase the heating requirements for the refuge enclosure on rising tides. Although the normal tidal range at the Reliant plant is less than 1 ft, wind-driven water movement in this part of the Indian River may magnify tidal fluctuations. Therefore, to account for effects of tidal flushing on heating requirements, 1-ft tidal range was assumed for the base case. There also may be a need to artificially increase water turnover rates within the enclosure to prevent the accumulations of fecal material. To assess the effects of variable tidal range and the possibility of increased flushing to minimize fecal accumulations, tidal variations/water turnover rates of 0.5 and 2 ft also were considered.

Refuge cover:

A cover over the refuge enclosure would reduce heat losses from surface convection and evaporation. Two types of refuge covers are available: opaque and transparent. An opaque cover would block solar radiation and be relatively inexpensive. A transparent cover would allow solar radiation pass through the cover and trap incoming solar heat, but would be more expensive and hard keep clean. For purposes of base calculations, the model assumed there would be no cover.

To evaluate the significance of certain variables that might be manipulated to alter refuge heating requirements, estimates of heat requirements were calculated for a base case set of values, as well as for possible differences in wall insulation, refuge water turnover rates, and use of a cover over the refuge. Table 4-1 lists all cases and associated parameter variations used in simulations for this study.

As mentioned above, the refuge would be heated solely by a gas-fired boiler during Phase I. In Phase II it would be heated by an array of solar panels, with the boiler installed in Phase I serving as a back-up system that also would supplement solar heating on exceptionally cold or cloudy days. For Phase I, the simulations conducted in this study sought to predict the heating requirements for maintaining the refuge water temperature at 22ºC. Although the project steering committee had suggested that the boiler operation during Phase I simulate the performance of a solar array, it was determined that doing so would significantly increase the required boiler capacity. In part, this is because of differences in the operating schedule of a boiler and a solar array. Whereas a boiler can operate 24 hr a day, solar panels must provide all their heat during daylight hours. As a result, the solar array would need to raise refuge water temperatures several degrees above 22ºC during the day so that nighttime cooling will not fall below the target temperature.

Table 4-1. Case Descriptions

Case	Description	Description
1	Base	All the multipliers are set to 1.0, with no wall insulation, and an enclosure depth of 6 ft deep at mean low tide
2	Wall R=2	Same conditions as the base case, except for wall insulation of R=2
3	Wall R=4	Same conditions as the base case, except for wall insulation of R=4
4	Wall R=6	Same conditions as the base case, except for wall insulation of R=6
5	1/2 ft. Tide	Assumes a 0.5 ft tidal range or ½ the base case
6	2 ft. Tide	Assumes a 2 ft tidal range or twice the base casepump would `increase water turnover rates to 2 times the volume of the refuge each day to prevent fecal accumulations
7	Opaque cover with 1m high	Assumes an opaque cover is placed 1m high over the refuge surface. The condition is equivalent to no direct solar input, no night sky radiation heat loss, ½ convection heat loss, and ½ evaporation heat loss.
8	Transparent cover with 1m high	Assumes a transparent cover is placed 1m high over the refuge surface. The condition is equivalent to ½ night sky radiation heat loss, ½ convection heat loss, and ½ evaporation heat loss.
9	Opaque cover + Wall R=2	Assumes an opaque cover is placed 1m high over the refuge surface and wall insulation is at R-2 level.
10	Opaque cover + Wall R=6	Assumes an opaque cover is placed 1m high over the refuge surface and wall insulation is at R-6 level.
11	Transparent cover + Wall R=2	Assumes a transparent cover is placed 1m high over the refuge surface and wall insulation is at R-2 level.
12	Transparent cover + Wall R=6	Assumes a transparent cover is placed 1m high over the refuge surface and wall insulation is at R-6 level.

The size of the heating system, however, is determined in large part by the extent to which the temperature of a given volume of water must be raised over a given time period to overcome heat loss due to cooling. For example, the capacity of a boiler to overcome a heat loss of one-tenth of a degree would be far lower than one required to overcome a heat loss of several degrees. As a result, the capacity of a boiler heating system that could operate both day and night, and thereby avoid large daily temperature declines, would be far lower than one which could not cycle on and off to prevent temperature declines of several degrees due to nighttime cooling. Based on preliminary calculations, it was determined that a boiler able to raise water temperatures in the refuge from 22 to 26ºC in daylight hours and not operate at night during the coldest periods on record would have to be an order of magnitude greater than one that could keep refuge temperatures at a near constant 22ºC both day and night. As a result, mimicking operation of a solar array during Phase I was determined to be ill-advised on economic grounds and was not considered to be a desirable heating strategy. Instead, three other heating strategies were considered.

The first heating strategy considered for Phase I was an ideal situation in which a gas-fired boiler would maintain a constant 22^{o}C 24 hr a day. In reality, however, a heating unit must cycle on and off as temperatures rise and fall around a target temperature. The range within which a unit cycles on and off is called the deadbend. To simulate a more realistic heating system, two other heating strategies were therefore simulated. Heating

Strategy 2 simulated a situation in which the boiler would cycle on when refuge temperatures fall to 20°C and cycle off when they increase to 22°C. Heating Strategy 3 would cycle on and off over a deadbend range of 21–23ºC. These alternatives would require a larger capacity boiler that, in most winter situations, would be able to maintain temperatures above 22°C, thereby providing an added measure of safety for manatees except in extreme cold periods or in the event of certain system failures (e.g., a portion of the heat exchanger becoming inoperable). Calculations of the thermal heating requirements and boiler costs based on these three heating strategies are presented below.

4.3 Predicted Thermal Heating Requirements and Cost Estimates

4.3.1 Phase I

Estimates of the size of the boiler required for Phase I were developed for each of the three heating strategies mentioned above using each of the 12 cases described above. Results of those calculations are provided in Table 4-2.

Table 4-2. Predicted boiler capacity (in both kW and MMBtu/hr) required to heat a 50 by 50 ft refuge enclosure in the Indian River near Cape Canaveral, Florida

Case	Description	Heating Strategy 1 (Constant 22ºC)		Heating Strategy 2 (between 20-22ºC)		Heating Strategy 3 (between 21-23ºC)	
		kW	MMBtu/h	kW	MMBtu/h	kW	MMBtu/h
1	Base	847	2.89	1,594	5.44	1,694	5.78
2	Wall R=2	770	2.63	1,546	5.27	1,620	5.53
3	Wall R=4	768	2.62	1,520	5.19	1,613	5.50
4	Wall R=6	767	2.62	1,517	5.18	1,611	5.50
5	Tidal Rnge = 0.5 ft	479	1.64	1,249	4.26	1,325	4.52
6	Tidal Rnge = 2 ft	2,491	8.50	3,120	10.65	3,503	11.95
7	Opaque Cover	770	2.63	1,551	5.29	1,588	5.42
8	Transparent Cover	777	2.65	1,611	5.50	1,575	5.38
9	Opaque Cover+ R=2	691	2.36	1,444	4.93	1,561	5.33
10	Opaque Cover + R=6	688	2.35	1,414	4.83	1,552	5.30
11	Transparent Cover + R=2	697	2.38	1,472	5.02	1,463	4.99
12	Transparent Cover + R=6	694	2.4	1,478	5.04	1,448	4.94

It should be pointed out that the four different wall insulation values (cases 1 through 4) had little effect on predicted heating requirements during periods of exceptional cold because most heat loss occurs through the surface, rather than the walls. However, during milder periods with more typical winter temperatures, heat loss through the walls is a greater proportion of the overall heat loss. Thus, while higher insulation levels are not very effective for conserving heat during extreme cold periods, they are more effective during more typical winter weather with milder temperatures. It is therefore recommended that the wall insulation rating be at a level of R-6 if possible.

Limiting water turnover rates and adding a cover would have far more impact than wall insulation values in reducing heating requirements. It is therefore recommended that water turnover rates be minimized to natural flushing rates (assumed to be one half the refuge volume per day) unless pollution concerns within the refuge require a higher water turnover rate. A cover would also significantly reduce heat loss during typical winter temperatures; however, the cost of a cover would be significant, add maintenance costs, and limit visibility for monitoring manatees within the refuge. Given these concerns and the ability of a reasonably priced boiler to maintain necessary temperatures without a cover, a cover is not recommended.

With the above estimates of required heating capacity, the cost for purchasing and installing a boiler of appropriate capacity can be estimated using the following regression equation from Means (2005).

$$TotalCost = 7900.821 + 3.693559 * Cap + 0.001224 * Cap^2$$

Where

Total Cost	=	Total boiler cost, including equipment and installation [$]
Cap	=	Boiler capacity [MBtu/h]

The regression equation is obtained using the least square method. The coefficient of determination of r^2 is used to evaluate how well the formula performs when comparing estimated and actual values within a range of 0 to 1, where 1 would be a perfect correlation and 0 would indicate no correlation between predicted and actual conditions. The value of r^2 for this regression equation is 0.948. Based on this equation, cost estimates for a suitable boiler for use in Phase I are provided in Table 4-3 for each of the 12 cases noted above and each of the three heating strategies.

Table 4-3. Estimated cost for purchasing and installing a boiler to heat a 50 by 50 ft refuge enclosure in Cape Canaveral

Case	Description	Strategy 1 (Constant 22ºC)	Strategy 2 (between 20-22ºC)	Strategy 3 (between 21-23ºC)
1	Base	$28,800	$64,188	$70,153
2	Wall R=2	26,054	61,425	65,727
3	Wall R=4	25,984	59,954	65,294
4	Wall R=6	25,960	59,826	65,176
5	Tidal Range = 0.5 ft	17,215	45,855	49,634
6	Tidal Range = 2 ft	127,711	185,931	226,872
7	Opaque Cover	26,064	61,709	63,855
8	Transparent Cover	26,280	65,209	63,121
9	Opaque Cover + R=2	23,399	55,828	62,287
10	Opaque Cover + R=6	23,308	54,234	61,802
11	Transparent Cover + R=2	23,600	57,316	56,847
12	Transparent Cover + R=6	23,509	57,627	56,004

Costs for the boiler system over the life of the project (i.e., present value) also can be estimated. Those costs would include the initial cost of the boiler and its installation (from table 4-3), as well as cumulative annual operating and maintenance costs and a depreciation rate over the life of the project. For purposes of estimating those costs, it was assumed that annual equipment and maintenance repair would equal 10 percent of annual initial costs and that the depreciation rate was 6 percent. To calculate fuel costs it was assumed that the efficiency of the boiler was 80 percent, which is the required minimum efficiency for large boilers (New Building Institute 1998), and that the cost of fuel would be $8.50 per MMBtu (i.e., the current cost for natural gas).

It should be pointed out that gas consumption rates estimated for this study are based on the coldest year on record, which will be higher than actual consumption rates in most years. The estimates also assume that the Reliant Energy power plant would not be operating during the winter and therefore would not be discharging any thermal effluent. When the plant is operating, water temperatures around the refuge enclosure would be several degrees higher than ambient temperatures elsewhere in the Indian River. Thus, estimated fuel consumption is likely to be far higher than it actually would be if the Reliant Plant continues to operate at least sporadically during winter months (which could include most winters over the entire five-year test period). However, the calculations also assume that the cost of natural gas does not change over the life of the refuge. Although fuel costs almost certainly will rise over the life of the project, it is impossible to predict how much they might increase. Thus, effects of fuel costs on operating expense over the life of the project are highly speculative.

To project total costs (i.e., the "present value") for boiler system over the life of the project, the life-cycle cost analysis (LCCA) was performed. The purpose of LCCA is to estimate the overall costs of project alternatives and to select the design that ensures the facility will provide the lowest overall cost of ownership. The present value is represented in the following equation:

$$PV = I + M\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

where	PV	= Present value
	I	= Initial investment
	M	= Annual operation and maintenance cost
	i	= Discount rate
	n	= Year of life

For this project, it was assumed that the boiler system would have a 25-year life span, there would be a 6 percent annual discount (i.e. depreciation) rate, and the boiler would have no salvage value at the end of the project. Tables 4-4, 4-5, and 4-6 provide cost estimates based on this formula under heating strategies 1, 2, and 3.

Table 4-1. Present value (in dollars) of a boiler heating system for a 50 by 50 ft refuge enclosure in Cape Canaveral under Strategy 1 (maintaining a constant 22ºC)

Case	Description	Initial Costs	Total Fuel Costs over the Life of the Refuge	Total Operating Costs over the Life of the Refuge	Present Value
1	Base	$28,800	$138,195	$36,816	$203,810
2	Wall R=2	26,054	110,438	33,305	169,797
3	Wall R=4	25,984	109,708	33,216	168,907
4	Wall R=6	25,960	109,465	33,186	168,611
5	Tidal Range = 0.5 ft	17,215	95,933	22,007	135,154
6	Tidal Range = 2 ft	127,711	304,234	163,258	595,204
7	Opaque Cover	26,064	138,870	33,319	198,254
8	Transparent Cover	26,280	108,348	33,595	168,223
9	Opaque Cover + R=2	23,399	111,412	29,911	164,722
10	Opaque Cover + R=6	23,308	110,453	29,796	163,557
11	Transparent Cover + R=2	23,600	81,035	30,168	134,803
12	Transparent Cover + R=6	23,509	80,086	30,053	133,648

Table 4-2. Present value (in dollars) of a boiler heating system for a 50 by 50 ft refuge enclosure in Cape Canaveral under Strategy 2 (20–22ºC deadbend)

Case	Description	Initial Costs	Total Fuel Costs over the Life of the Refuge	Total Maintenance Costs over the Life of the Refuge	Present Value
1	Base	$64,188	$103,771	$82,054	$250,013
2	Wall R=2	61,425	84,112	78,522	224,059
3	Wall R=4	59,954	83,470	76,641	220,065
4	Wall R=6	59,826	83,311	76,478	219,615
5	Tidal Range = 0.5 ft	45,855	73,126	58,618	177,598
6	Tidal Range = 2 ft	185,931	232,947	237,683	656,561
7	Opaque Cover	61,709	101,670	78,885	242,264
8	Transparent Cover	65,209	81,223	83,359	229,790
9	Opaque Cover + R=2	55,828	81548	71,366	208742
10	Opaque Cover + R=6	54,234	80,120	69,329	203,683
11	Transparent Cover + R=2	57,316	61,274	73,269	191,860
12	Transparent Cover + R=6	57,627	61,087	73,666	192,379

Table 4-6. Present value (in dollars) of a boiler heating system for a 50 by 50 ft refuge enclosure in Cape Canaveral under Strategy 3 (21–23°C deadbend)

Case	Description	Initial Costs	Total Fuel Costs over the Life of the Refuge	Total Maintenance Costs over the Life of the Refuge	Present Value
1	Base	$70,153	$135,208	$89,679	$295,040
2	Wall R=2	65,727	108,151	84,022	257,900
3	Wall R=4	65,294	106,802	83,467	255,564
4	Wall R=6	65,176	106,598	83,317	255,092
5	Tidal Range = 0.5 ft	49,634	94,236	63,449	207,320
6	Tidal Range = 2 ft	226,872	302,910	290,018	819,799
7	Opaque Cover	63,855	132,791	81,628	278,273
8	Transparent Cover	63,121	105,246	80,689	249,056
9	Opaque Cover + R=2	62,287	107,488	79,624	249,398
10	Opaque Cover + R=6	61,802	106,617	79,004	247,424
11	Transparent Cover + R=2	56,847	78,833	72,670	208,350
12	Transparent Cover + R=6	56,004	77,514	71,592	205,110

As indicated in Table 4-2, the estimated boiler sizes required to heat a 50 by 50 ft refuge vary from 2.89 MMBtu/hr (Strategy 1) to 5.78 MMBtu/hr (Strategy 3). Since boilers available on the current market have discrete preset capacities, and Means (2005) indicates that the size closest to the estimated sizes for heating strategies 2 and 3 would be a boiler with a 5.52 MMBtu/hr capacity, it is recommended that a 5.52 MMBtu/hr boiler be used as the heat source for manatee refuge envisioned at this location.

Washington Group International also calculated construction costs for Phase I based on site-specific design considerations and preliminary estimates for heating requirements (Appendix 2). They assumed that the gas-fired water heater required for Phase I would have a 5.2 MMBtu/hr capacity. This capacity was slightly below the 5.44 to 5.78 MMBtu/hr estimate for heating needs calculated for the base case scenarios analyzed above, which considered additional site design information available after the refuge location and design specifications had been developed by Washington Group. Based on the recommended location of refuge enclosure, they recommended that the boiler system be placed on the south side of the discharge canal on an earth mound 8 ft above the existing ground level to protect it from the 10-ft storm surge level defined for this site. The earth mound would be protected from erosion by a stone riprap facing. A horizontal pump immediately before the heater along with a small surge and storage tank upstream of the pump would maintain flow through the heating system. Control of the operation of the water heating system would be by means of a thermocouple placed in the enclosure that would start up the heating system whenever the water temperature in the refuge fell below 22°C (72°F). Based on an itemized list of equipment, material, and labor costs (Appendix 2), Washington Group International estimated the total cost for purchasing and installing the 5.2 MMBtu/hr gas-fired boiler, including site preparation, associated water, gas, and electric hookups, and cost contingencies for unforeseen material, labor and engineering design, would be $329,489.

4.3.2 Phase II

The difference between Phase I and II is that an array of solar panels would serve as the primary heat source in Phase II and the gas fired boiler installed during Phase I would serve only as a supplemental heat source on cold winter nights or cold cloudy days when the solar panels could not maintain the refuge at 22ºC. Because the same gas-fired boiler would be used in both phases, the difference between the two phases is in the role of the boiler system and the extent to which its heat energy would be replaced by the solar array. Thus, separate estimates are needed to predict heating requirements for the solar array and the boiler. To calculate heating requirements and the size of the solar array during Phase II, the following steps were taken:

- Calculating required heating energy to maintain an hourly refuge temperature of 22^{o}C (i.e., ideal heating);
- Calculating heat output from three different types of solar collectors in a unit area;
- Determining energy required to heat the refuge enclosure during the coldest winter period on record (i.e., December 1989);
- Calculating the size of the solar collector array necessary to provide the heat energy calculated by assuming the energy generated by solar collectors is equal to the energy required to heat the refuge at 22^{o}C; and
- Based on the size of the solar collector arrays for the three different types of solar panels, recalculating refuge water temperatures to determine the boiler size.

Table 4-7 provides estimates of the heat energy required to maintain temperatures at 22^{o}C 100 percent of the time. This means that the heating equipment would remain on whenever the refuge water temperature is below 22ºC. Energy requirements were calculated for a 12- month period based on ambient water temperatures between May 1989 and April 1990, the coldest month (i.e., December 1989), the coldest day of the year (i.e., peak day), and the coldest hour of the coldest day (i.e. peak hour). These calculations assumed that the Reliant Energy power plant would not produce any thermal outfall and that ambient inland water temperatures would equal that of the coldest year (i.e. May 1, 1989 to April 30, 1990). All estimates of required heating energy were in kilowatts (kWh).

For heating purposes, three types of solar collector were considered: unglazed, glazed and evacuated. The main purpose of this analysis was to identify the type of solar collector that would be the most cost effective. Table 4-8 provides estimates of the size of the solar array required to raise and maintain water temperatures in the refuge to a target level of 26ºC during the day 95 percent and 99 percent of time given water temperatures in December 1989 for each of the three types of solar collectors. The collector sizes are 4 by 12 ft for unglazed and glazed types, and 6 ft,8 in by 4 ft, 8in for evacuated type. As shown in that table, the smallest array would be possible with unglazed solar panels, which are recommended for use in this project.

Table 4-7. Heating energy requirements (in kWh) in Phase II based on estimated inland water temperatures from 1 May 1989 through 30 April 1990.

Case	Description	Total for Year	Total for Month of December	Total for Peak Day	Total for Peak Hour
1	Base	298,200.6	156,362.8	10,318	847.06
2	Wall R=2	238,305.6	124,805.4	8,288.5	770.02
3	Wall R=4	236,731.1	123,977.2	8,235.1	767.99
4	Wall R=6	236,206.3	123,701.1	8,217.3	767.31
5	Tidal Range = 0.5 ft	207,006.4	110,400.9	7,947.0	479.31
6	Tidal Range = 2 ft	656,485.7	335,261.4	19,618.6	2,491.08
7	Opaque Cover	299,658.6	146,543.6	9,022.4	770.33
8	Transparent Cover	233,796.8	132,593.6	8,428.6	776.55
9	Opaque Cover + R=2	240,407.2	114,853.4	6,992.8	690.56
10	Opaque Cover + R=6	238,338.4	113,741.5	6,921.6	687.76
11	Transparent Cover+ R=2	174,859.3	101,126.1	6,399.0	696.77
12	Transparent Cover + R=6	172,811.3	100,025.1	6,327.8	693.98

Table 4-8. The estimated size of solar array (in m^2) and number of solar collectors required to heat a 50 by 50 ft refuge enclosure to 22ºC 95 percent of the time given temperatures recorded in December 1989 in Cape Canaveral

Case	Description	Unglazed Collectors		Glazed Collectors		Evacuated Collectors	
		m^2	# of Panels	m^2	# of Panels	m^2	# of Panels
1	Base	1889.21	425	2069.45	466	2348.71	824
2	Wall R=2	1510.98	340	1653.43	372	1875.95	658
3	Wall R=4	1501.07	338	1642.52	370	1863.55	654
4	Wall R=6	1497.78	337	1638.89	369	1859.42	652
5	1/2 Daily TOR Tidal Range = 0.5 ft	1338.22	301	1463.33	330	1659.89	582
6	Tidal Range = 2 ft	4010.59	903	4416.92	995	5020.99	1762
7	Opaque Cover	1765.54	398	1937.51	436	2199.92	772
8	Transparent Cover	1604.92	361	1756.47	396	1992.9	699
9	Opaque Cover + R=2	1387.75	313	1520.6	342	1725.76	606
10	Opaque Cover + R=6	1374.46	310	1505.95	339	1709.11	600
11	Transparent Cover + R=2	1226.57	276	1340.98	302	1520.99	534
12	Transparent Cover + R=6	1213.37	273	1326.46	299	1504.49	528

When the solar system could not meet the total heating requirements, the backup gas-fired boiler would turn on to provide additional heat. Table 4-9 estimates the number of hours (principally nights during the coldest days) that the refuge water temperature would have been below 22ºC with the solar system alone in December 1989 for each of the 12 different cases and three different collector types**.** Total costs for the heating system components added in Phase II, which assume no additional cost for the boiler, can be calculated using the formula noted above. Table 4-10 presents estimates of the initial cost for purchasing the necessary unglazed solar collectors and water pumps, present values of operation and maintenance costs, and the present value over the 25-year life of the refuge assuming that the solar panels would provide 99 percent of the required heat energy in December. The present values of maintenance costs are assumed to be 10 percent of the initial investments, and the present values of operation costs are only the costs for natural gas used by the backup gas-fired boiler.

Table 4-9. Estimated number of hours when the solar system alone would not be able to maintain the refuge water temperature at 22ºC or above for a 50 by 50 ft refuge enclosure given temperatures recorded in December 1989 at Cape Canaveral

Case	Description	Unglazed Collectors (hours)	Glazed Collectors (hours)	Evacuated Collectors (hours)
1	Base	387	372	370
2	Wall R=2	377	363	368
3	Wall R=4	376	364	367
4	Wall R=6	376	365	367
5	Tidal Range = 0.5 ft	373	366	367
6	Tidal Range = 2 ft	406	380	378
7	Opaque Cover	381	370	370
8	Transparent Cover	379	370	370
9	Opaque Cover + R=2	372	368	367
10	Opaque Cover + R=6	372	368	368
11	Transparent Cover + R=2	374	368	367
12	Transparent Cover + R=6	387	372	370

Table 4-10. Estimated initial investment costs plus total maintenance and fuel costs in dollars over the 25-year life of the refuge for heating a 50 by 50 ft refuge with a solar array and a backup gas-fired heater in Cape Canaveral during Phase II

		Initial Investment			Operation and Maintenance Costs		
Case	Description	Array of Unglazed Solar Collectors	Water Pump	Total	Total Maintenance Costs	Total Fuel Cost (Operation)	Present Value
1	Base	$303,608	$19,060	$322,669	$348,236	$30,170	$746,629
2	Wall R=2	242,824	15,244	258,069	278,518	22,625	59,361
3	Wall R=4	241,232	15,144	256,376	27,6691	22,432	587,348
4	Wall R=6	240,703	15,111	255,814	276,084	22,368	586,015
5	Tidal Range = 0.5 ft	215,061	13,501	228,562	246,673	18,715	522,073
6	Tidal Range = 2 ft	644,528	40,463	684,991	739268	82,148	1,697,625
7	Opaque Cover + Base	283,734	17,813	301,547	325,440	23,932	688,505
8	Transparent Cover + Base	257,921	16,192	274,113	295,833	23,564	626,538
9	Opaque Cover + R=2	223,020	14,001	237,022	255,803	17,050	536,215
10	Opaque Cover + R=6	220,885	13,867	234,752	253,353	16,824	530,939
11	Transparent Cover + R=2	197,118	12,375	209,493	226,093	16,678	475,130
12	Transparent Cover + R=6	194,996	12,242	207,238	223,659	16,449	469,917

Table 4-11 compares estimated natural gas costs over the 25-year life of the refuge for (1) a heating system consisting of a boiler only and (2) a system composed of a solar array with a back-up boiler. The estimates assume that natural gas costs remain constant over that period. This table provides a basis for assessing how much money would be saved in fuel costs by adding the solar heating system in Phase II. Due to reduction of natural gas use, carbon emissions from natural gas combustion also would be reduced. Excluding possible tax credits available to encourage the use of solar heating systems), the results suggest that, in constant 2007 dollars, addition of the solar heating system would save between $81,168 (heating strategy 2) and $104,930 (heating strategy 3) in fuel costs over the 25-year life of the refuge under the base case scenario. This equates to an average annual savings of between about $3,250 and $4,200 per year.

Table 4-11. Comparison of estimated total fuel costs over 25 years for a 50 by 50 ft refuge enclosure for three heating strategies (Strategy 1 = ideal heating at a constant 22ºC, Strategy 2 = 20–22ºdeadbend and Strategy 3 = 21–23ºC deadbend) using a boiler only and a solar array with a boiler backup heater

		Boiler Only			Solar Array with Back-up Boiler		
Case	Description	Strategy 1	Strategy 2	Strategy 3	Strategy 1	Strategy 2	Strategy 3
1	Base	$138,195	$103,771	$135,208	$30,170	22,603	30,278
2	Wall R=2	110,438	84,112	108,151	22,625	16,668	21,789
3	Wall R=4	109,708	83,470	106,802	22,432	15,673	21,710
4	Wall R=6	109,465	83,311	106,598	22,368	15,641	21,667
5	Tidal Range = 0.5 ft	95,933	73,126	94,236	18,715	14,127	18,039
6	Tidal Range = 2 ft	304,234	232,947	302,910	82,148	64,912	85,625
7	Opaque Cover	138,870	101,670	132,791	23,932	17,669	23,785
8	Transparent Cover	108,348	81,223	105,246	23,564	17,891	23,707
9	Opaque Cover + R=2	111,412	81,548	107,488	17,050	12,824	17,154
10	Opaque Cover + R=6	110,453	80,120	106,617	16,824	12,787	16,851
11	Transparent Cover + R=2	81,035	61,274	78,833	16,678	12,416	16,544
12	Transparent Cover + R=6	80,086	61,087	77,514	16,449	11,741	16,251

Washington Group International also calculated costs for purchasing and installing the solar array based on site-specific considerations and preliminary estimates of the size of the solar array provided during the steering committee meetings. Their estimate assumed that the solar panel array would consist of 336 solar panels, each 4 ft by 12 ft in size, arranged in an array of 14 rows with 24 panels per row. The array would be located adjacent to the boiler installed in Phase I on the south side of the discharge canal 50 ft back from the shorelines of the plant discharge canal and Indian River (see Figure 3-1). The panels would be supported on racks constructed of 4 by 4 in fiberglass angles secured to a concrete foundation. The array would be capable of withstanding winds up to 100 mph. The panels would be arranged to avoid shading from adjacent panels at noontime with a north-south orientation and placed at an angle to maximize exposure to incoming solar radiation in winter.

Each panel would be fed fresh water through a series of 6-in insulated PVC pipe headers through individual tees at each panel. Valves would be installed allowing individual panels and individual rows of panels to be closed and isolated from other panels for maintenance and repair. The panels would discharge through an insulated 1.5-in PVC pipe to a 6-in insulated PVC pipe header that would lead to a 10-in pipe transporting the circulation water to the heat exchanger in the refuge. The portion of the circulation water loop supplying the solar panels would be parallel to the loop for the gas-fired water heater so that the boiler could be used as a supplemental heat source when refuge temperatures fall below target levels. The solar panel loop would have a separate pump.

To mimic operation of a solar array, Washington Group International recommended that water temperature inside the enclosure be monitored with a thermocouple. When temperatures fall below 72ºF (22.2ºC), a signal will be sent to a Programmable Logic Controller (PLC) to start the water heater and the circulating pump. The PLC would then check a solar cell to determine the amount of incoming solar radiation. If there was insufficient radiation to allow a solar panel array to supply adequate warm water, the PLC would start the gas-fired water heater and the circulating water pumps. If there was sufficient solar radiation the heater and pumps would not start. The PLC would also log data on ambient river water temperature, enclosure water temperature, operation of the gas-fired water heater, solar radiation, water heater inlet and discharge temperatures, and gas usage. As noted above it was determined that efforts to mimic a solar array would not be possible without significantly increasing the boiler's capacity and this approach is not recommended. Nevertheless, sensors for collecting data on the refuge temperature and solar radiation at the site would still be useful for verifying estimates of the size of the solar panel array prior to installing the solar panel array in Phase II and they would be needed with different settings to control operation of the boiler.

Based on this design and an itemized list of equipment, materials, and labor costs, Washington Group International estimated that the cost for installing the solar panel array, support structure, piping, pumps, pipe insulation, and controllers, including a 10 percent contingency for unforeseen costs and a 5 percent contingency for engineering design, would be $2,431,643.

5. Conclusions

This project developed detailed conceptual plans for constructing a warm-water refuge enclosure for maintaining manatees at the Reliant Energy Indian River power plant in Brevard County, Florida, during winter periods when the plant does not operate. The refuge would be heated with a closed-circuit water heating system that would circulate fresh water through a land-based heating system composed of either a gas-fired boiler or an array of solar panels with a backup gas-fired water heater and a heat exchanger located in an offshore refuge enclosure. Thus, there would be no direct discharge of heated effluent into the refuge enclosure or the Indian River. Although it is expected that manatees would use the enclosure during periods of cold weather and would be supported at the site when the power plant is not operating, those assumptions are undemonstrated. To determine if those assumptions are valid at a minimal cost, it is recommended that refuge development proceed in two phases. Phase I would involve construction of the refuge enclosure with a heat exchanger, and installation of a gas-fired water heating system that could maintain a refuge enclosure at 22ºC through the winter. If, within two to five years, it is determined that manatees use the enclosure during winter periods when the power plant is not operating and discharging a thermal plume, a decision could be made regarding whether to proceed with a Phase II construction project involving the installation of a solar panel array that could serve as the primary heat source for the refuge enclosure, or a second gas fired boiler that could serve as a back-up heat source. The operational life of the refuge is designed to be 25 years.

At the present time, Reliant Energy has announced no plans for retiring its Indian River Generating Station. However, there have been winter periods in recent years when the plant has operated “out of economics” solely for the purpose of producing warm-water effluent for manatees using the plant’s outfall. That is, during these periods, the plant would have been shut down except for the operator’s obligation to maintain a safe environment for manatees accustomed to using the plant’s heated effluent. Assuming similar periods will occur in the future, it should be possible to determine if manatees would use the heated refuge enclosure by allowing the plant to shut down and stop discharging thermal effluent when it was determined that plant operations were not economical. Based on recent experience, these periods would be relatively brief. Thus, thermal effluent likely would continue to be discharged for the next few years during most of the winter season. Even when the plant is operating, however, temperatures in the refuge could be maintained at temperatures slightly above the ambient discharge plume which could attract manatees to use the refuge.

Based on calculations of heating requirements and simulations of heating systems in this study, a boiler with 5.52 MMBtu/h capacity is recommended for heating a 50 by 50 ft refuge enclosure at the Reliant Energy plant’s location. Although simulations in this study suggested that required boiler capacities might range from about 5.2 to 5.8 MMBtu/hr, a 5.52 MMBtu/hr capacity boiler is recommended given that boilers available on the market have set capacities and the available size closest to this range is a 5.52 MMBtu/hr capacity unit. Such a boiler should be able to maintain refuge temperatures a degree or two above ambient thermal discharge temperatures while the plant is operating.

This elevated temperature would help manatees to learn to use the enclosure during winter periods even when the plant is operating. A boiler of this capacity also should be able to maintain a refuge temperature of at least 20ºC to 22ºC even when the plant is not be operating, except perhaps during an exceptionally cold period comparable to that experienced in the winter of 1989-90. In that event, manatees would have access to the thermal outfall at the Florida Power & Light Company power plant located about 2 mi south.

Based on site-specific design considerations and preliminary calculations indicating the need for a 5.2 MMBtu/hr boiler, Washington Group International estimated costs for the two Phases of construction as follows:

<u>Phase I</u>	
Constructing an enclosure and associated heat exchanger	$1,225,447
Purchasing & installing a 5.2 MMBtu/hr gas-fired boiler	$329,489
Subtotal	$1,554,946
<u>Phase II</u>	
Constructing a 336 panel solar array with pumps, piping, etc.	$2,431,654
<u>Optional Roof</u>	$435,277
<u>Total for Phases I and</u> II	
Without optional roof	$3,986,600
With optional roof	$4,421,877

These estimates do not include sales tax, the cost of drilling to collect soil samples for analyzing substrate composition at the enclosure site, the cost of preparing final construction plans and construction management, or costs for obtaining necessary permits. They also assume there would be no cost for the land on which the heating system would be built (i.e., Reliant Energy would make space available on its property for installing the heating system at no cost). A recalculation of heating requirements by FSEC based on design specifications and location of the refuge enclosure developed by Washington Group International concluded that a slightly larger capacity boiler (i.e., 5.44 to 5.78 MMBtu/hr) would be required for periods of exceptional cold comparable to those experienced in 1989. As noted above, based on those calculations a 5.52 MMBtu/hr boiler is recommended for heating the refuge enclosure based on those calculations. This slightly higher capacity boiler would increase cost estimates for Phase I slightly, but probably not significantly.

Although use of a solar heating system rather than a gas-fired boiler would have a number of advantages (e.g., reduced gas consumption and carbon emissions), cost savings do not appear to be among them based on installation cost estimates generated by Washington International. The principal savings from a solar array would be in reduced fuel costs. Assuming constant 2007 dollar and fuel prices set at current levels, use of a solar array would produce fuel savings of about $81,000 to $105,000 over the life of the refuge. Although a competitive bidding process might result in a lower cost construction cost, compared to Washington International's estimate $2.4 million for installing a solar array sufficient to heat the refuge enclosure, the fuel cost savings would be far less than the costs for material and labor to install a solar heating system. Thus, if proceeding with Phase II is deemed warranted based on manatee use of the refuge enclosure in Phase I, a more cost-effective means for providing a necessary backup water heating system would appear to be installing a second gas-fired water heating unit of comparable capacity.

Several possible design considerations not factored into cost estimates were identified during the study. The walls of the enclosure are designed to be as leak tight as possible and the entrances are staggered on opposite walls to minimize crosscurrents through the enclosure. However, the open entrances may create convection currents that could draw warm water out of the enclosure and thereby draw in cooler surrounding water from outside the refuge. It is recommended that the geometry of the entrances be studied to assess the need or possibility of reconfiguring their shape or size (including the addition of a hood or baffle system) to minimize convective loss.

Placing the enclosure near the mouth of the discharge canal may induce seabed erosion around the enclosure walls due to the canal discharge water flow. To better assess such effects, measurements should be taken of the actual current velocities at the site proposed for the enclosure. Computer Fluid Dynamics studies could then be performed to evaluate the probable current speeds and directions when the enclosure is constructed. The results could be used to judge the probability of seabed erosion. Measurements of the amount and rate of sand drifting along the shore from the north also should be pursued to determine if an accumulation of sand may occur at the northwest entrance and block it.

Depending upon the perceived criticality of the objectives of this construction, redundant equipment also may be desirable to prevent system failures due to a single component failure. For this project such items as the pumps, controls and valves would warrant investigation as to the value of providing redundant equipment.

6. References

Goswami, Y., and D.W. Kearney. 2002. Feasibility study on solar heating of a manatee refuge in southeast Florida. Report submitted by Kearney Associates to Florida Power & Light Company, Environmental Services Department, Juno Beach, FL. 9 pp + appendices.

Gu, L. 2005. Assessment of thermal heating requirements for non-industry dependent warm water refuges for Florida manatees. Report for contract # 20126025 submitted by the Florida Solar Energy Center to the Marine Mammal Commission, Bethesda, MD. 61 pp + appendices.

Labs, K., J. Carmody, R. Sterling, L. Shen, Y. J. Huang, and D. Parker, 1986. Building Foundation Design Handbook, ORNL/Sub/86-72143/1, Oak Ridge National Laboratory, Oak Ridge, TN.

Laist, D.W., and J. E. Reynolds III. 2005a. Influence of power plants and other warm-water refuges on Florida manatees. Marine Mammal Science 21(4):739–764.

Laist, D.W., and J. E. Reynolds III. 2005b. Florida manatees, warm-water refuges, and an uncertain future. Coastal Management 33:279–295.

Means, R.S. 2005. Mechanical Cost Data. 28th Annual Edition, Kingston, MA.

New Building Institute. 1998. Gas Boilers Guideline. November 1998, Fair Oaks, CA.

U.S. Fish and Wildlife Service. 2001. Florida Manatee Recovery Plan (*Trichechus manatus latirostris*). Third Revision, Atlanta, GA. 144 pp + appendices.

Appendix A: Members of the Project Steering Committee

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Appendix B: Statement of Work proposed by Reliant Energy Corp

This appendix encloses the Statement of Work written by Tim Brunett, Reliant Energy Corp. and was sent to Washington Global International (WGI) to start the work. The content was discussed during the kickoff meeting at the Indian River power plant of Reliant Energy on Nov. 16, 2005. The SOW was finalized based on the comments from team members.

Indian River Generating Station
Manatee Refuge Design Scope of Work

The scope of work includes the design of a solar heating system and a 4-sided heated enclosure that will be used as a thermal refuge for manatees in winter months. The manatee refuge solar heating system and enclosure design will include the following:

1. **Enclosure Location:** The location of the enclosure will be as indicated on the drawing entitled "Reliant Energy Indian River Plant. " The plant circulating water discharge flow should be calculated to determine scour potential to the enclosure. If possible, the enclosure location should be moved closer to the shoreline. In either case, the enclosure will be located in 6 ft of water at MSL. The tidal range is approximately 1 ft.

2. **Enclosure Design:** The enclosure will be a four-sided enclosure with interior dimensions of 50 by 50 by 8 ft high. The enclosure will be constructed of steel sheet piling, vinyl sheet piling, concrete or timber with a wall insulation level of approximately R-6. The design engineer will perform an enclosure material study and make a material recommendation based on installed material cost and insulating ability. The structure will be located in the water and the design should include allowance for as much assembly on land as possible. The enclosure design should include an option for a removable cover or roof to help reduce heat loss. The cover will be removed from April through November. The elevation of the top of the enclosure is 2.0 ft MSL.

3. **Enclosure Openings:** The enclosure will include 2 openings for the manatees to ingress and egress. One opening will be located on the southeast side and one on the northwest side. The opening size will be 4 ft high and 8 ft wide with no covers or doors. The edges of the opening shall be smooth so as to not cause bodily harm to the manatees. The bottom of the openings should be approximately 1 ft above the river bottom.

4. **Geotechnical Investigation:** Geotechnical information is not available. One soil boring will be performed and all testing will be as specified by the design engineer.

5. **Enclosure Heater Tubes:** Heater tubes will be copper and will be mounted on the enclosure walls such that there is no gap between the tubes and the walls. The

enclosure design will include details for connecting the tubes to the walls so as to prevent them from being dislodged or damaged as a result of a 2000-pound manatee attempting to rub against them. If deemed necessary by the engineer, the design may include a mesh grating over the tubes that will be adequate to prevent manatees from rubbing directly against the pipes. The total flow rate of the heat exchanger is 600 – 800 gpm and should be able to distribute heat quickly from the exchanger throughout the refuge enclosure. The enclosure heater tube design will include sizing the tubes and determining the tube length and layout.

6. **Foundation Design:** Foundation design will be needed for circulating water pump and motor supports, pipe supports, solar panel supports, and the auxiliary gas water heater support. All equipment will be located on shore as near as possible to the enclosure. The solar panels should be located such that there is no shading between 9 am and 4 pm from adjacent rows of collectors, trees, buildings or overhead power lines.

7. **Design Enclosure Temperature:** 72 degrees Fahrenheit

8. **Heating System:**

Panel Type:	4 by 10 ft unglazed solar collector (pool type)
Number of Panels:	150 to 200
Flow Rate/Panel:	4 gpm
Total Flow Rate:	600-800 gpm
Facing:	South
Panel Tilt:	50 degrees from horizontal (the maximum winter performance)
Panel Bottom Height:	18 to 24 in
Panel Height:	12 ft maximum

The circulating water pump and motor should be sized based on the above parameters with a closed loop systems. Provisions for makeup water are necessary. The solar system should have an opening for initially filling the system with potable water. No glycol or other solutions are required to prevent freezing.

The circulating water pipe from the pump to the solar panels and refuge shall be PVC pipe with a minimum insulation of R-3.

The heating system should include a back-up gas fired water heater.

9. **Utilities:** Electrical (underground or overhead) will be needed for the circulating water pump motor. Gas supply will be needed for the back-up gas fired water heater.

10. **Permits –** Provide technical support for obtaining the following permits:

- U.S. Army Corps of Engineers 404 Permit
- DEP Environmental Resource Permit
- U.S. Fish & Wildlife Marine Mammal Enhancement or Scientific Research Permit
- County Building Permit
- Modifications to the NPDES Permit
- Submerged Land Process
- Coast Guard Navigation Safety Permit

11. All work shall be in compliance with the following general standards:

- ASCE 7-2002 Minimum Design Loads for Buildings and Other Structures
- 1997 Uniform Building Code
- Applicable codes and standards for supply of materials, the manufactured products, and the mill and manufacturing tolerances
- Applicable codes and standards for fabrication practices, methods, and tolerances
- Applicable codes and standards for construction
- Applicable standards for testing of materials and building components
- Applicable codes and standards for erection/installation
- OSHA regulations
- Local building regulations as well as regulations of other agencies having jurisdiction over the work

Appendix C

Basis for Project Design

**Prepared by Washington Group International, Inc.
for Reliant Energy 30 June 2005**

1 General

1.1 Environmental Data

.01 Air Temperatures
Maximum: 100^0 F
Minimum: 32^0 F

.02 Depth of Frost: 0 inches

.03 Seismic Exposure: UBC 1997

.04 Wind Exposure: UBC 1997-Basic Wind Speed: 100 mph Exposure C

.05 Rainfall: Not Applicable to this design

.06 Snow: 100 year recurrence ground snow load = 0 psf

.07 Water Temperatures:
Indian River Maximum: 90^0F
Indian River Minimum: 41^0F
Enclosure Steady State: 72^0F

1.2 Elevations

.01 Plant Datum based upon Mean Sea Level

.02 Yard Grade High Point Elev. +5 feet (to be confirmed)

.03 Ground Water Elev. MSL

.04 Water Front

a. Maximum High Water Elev. +1 foot
b. Minimum Low Water Elev. –1 foot
c. Normal Water Elev. MSL
d. Tidal Range: ± 1 foot
e. Significant Wave Characteristics
Hs = 6 feet
Ts = 4.6 seconds
f. Storm Surge to elevation +10 feet

1.3 Physical Requirements for the Installation

The design shall adhere to the following:

.01 Enclosure Location - The location of the enclosure shall be as indicated on the drawing entitled Reliant Energy-Indian River Generating Station-Site Plan. The enclosure will be located in 6 feet of water at MSL.

.02 Enclosure Design – The enclosure will be a four-sided enclosure with interior dimensions of 50 feet X 50 feet X 9 feet high. The enclosure will be constructed of steel sheet piling, vinyl sheet piling, concrete, timber or recycled plastic lumber with a wall insulation level of R-6 or higher. Presently recycled plastic lumber (RPL) with steel soldier piles is the preferred construction. The structure will be located in the water and the design should provide for as much assembly on land as possible. The enclosure design shall include the capability to support an optional removable cover or roof to help reduce heat loss. The elevation of the top of the enclosure shall be +3.0 feet MSL.

.03 Enclosure Openings - The enclosure shall include 2 openings for the manatees to enter and leave. One opening shall be located on the southeast side and one on the northwest side. They shall not be opposite each other but staggered to minimize flow through. The opening size shall be 4 feet high and 8 feet wide with no covers or doors. The edges of the opening shall be smooth so as to not cause bodily harm to the manatees. The bottom of the openings shall be approximately 1 foot above the river bottom. Provision shall be made for bolting a cover over either opening in the future.

.04 Geotechnical Investigations - Geotechnical information is not available. One soil boring shall be performed at the location of the enclosure and all testing shall be as specified by the Engineer. The Engineer shall analyze the soils information and develop a foundation criteria document for the enclosure identifying all pertinent engineering properties.

.05 Enclosure Heater Tubes - Heater tubes shall be arsenical copper and be mounted on the enclosure walls such that there is a minimum gap between the tubes and the walls. The copper heat exchangers are to be separated sufficiently from the steel “H” piles and steel sheet piles pieces that a galvanic cell is not a possibility. The enclosure design shall include details for connecting the tubes to the walls so as to prevent them from being dislodged or damaged as a result of a 2000-pound manatee attempting to rub against them. The design shall include a grating over the tubes that will be adequate to prevent manatees from rubbing directly against the pipes. The grating design shall be such that heavy fouling of the grating by crustaceans, etc will not impede the convective flow of the water past the heat exchangers and into the enclosure water volume. The total flow rate to the heat exchanger shall be 1347 gpm and the heat exchanger shall be able to distribute heat quickly from the exchanger throughout the refuge enclosure. The enclosure heater tube design shall include sizing the tubes and determining the tube length and layout.

.06 Foundation Design - Foundation design shall be provided for the circulating water pump and motor supports, electrical control cabinets, water storage and surge tank and the gas water heater. All equipment is to be located on shore as near as possible to the enclosure. The future solar panels shall be located such that there is no shading between 9 am and 4 pm from adjacent rows of collectors, trees, buildings or overhead power lines.

.07 Design Enclosure Water Temperature – 72 degrees Fahrenheit

.08 Heating System

.081 Future Solar Heating System

Panel Type: 4'x10' unglazed plastic solar collector (swimming pool type)
Number of Panels: 336
Flow Rate/Panel: 4 gpm
Total Flow Rate: 1347 gpm
Facing: South
Panel Tilt: 50 degrees from horizontal (the maximum winter performance)
Panel Bottom Height: 18 inches above grade
Panel Height: 12 feet maximum above grade

.082 Gas Water Heater-Stage I

A gas fired water heater with a heating capability of 5.5MM Btu per hour will be required.

.083 Circulating Water System

The circulating water pump and motor shall be sized based on the above parameters with a closed loop fresh water system. Provisions for makeup water are necessary; a storage/surge tank is to be placed on the inlet pipe to the heaters. The system shall have provision for initially filling the system with potable water and the storage/surge tank shall have automatic fresh water makeup controlled by a float valve. No glycol or other solutions shall be added to prevent freezing.

The circulating water pipe from the pump to the water heater and refuge shall be PVC pipe insulated to achieve a minimum thermal insulation value of R-3. All pipe shall be placed directly on the ground or river bottom.

Control of the heating system, pumps, etc is to be done by means of a PLC (Programmable Logic Controller).

Operation of the heating system shall be controlled by a thermocouple in the enclosure and a photovoltaic cell. Motor operated valves shall be used, controlled by the control system, to route the water through the appropriate heater.

.09 Utilities – Electrical (underground or overhead) shall be provided for the circulating water pump motor and the controls and lighting. Gas supply shall be provided for the gas fired water heater. Water supply shall be provided for maintaining the circulating water storage /surge tank full. All utilities shall be routed from the plant to the site.

1.4 Design Codes

.01. AISC - Specification for Structural Steel Buildings, June 1, 1989.

.02. AISC - Code of Standard Practice for Steel Buildings and Bridges, March 7, 2000.

.03. RCSC - Specification for Structural Joints Using ASTM A325 or A490 Bolts, June 23, 2000.

.04. AWS D1.1 - Structural Welding Code, dated

.05. ACI 318 - Building Code Requirements for Reinforced Concrete.

.06 ASCE 7-2002 - Minimum Design Loads for Buildings and Other Structures

.07 Federal Occupational Safety and Health Administration (OSHA) - Regulation 29 CFR Part 1910

.08 Uniform Building Code/1997

.09 American Association of State Highway and Transportation Officials (AASHTO) - Standard Specification for Highway Bridges, dated

.10 Steel Structures Painting Council
SSPC-SP6 Commercial Blast Cleaning
SSPC-PS 12.01 One-Coat Zinc Rich Painting System

.11 State and Local Codes:

a – Florida Building Code

2 Site Design

No site preparation will be performed. The site shall be used “as is”.

3. Structural Loading Criteria

The loads that shall be considered in the design of the new project facilities are as follows:

3.1 Wind Load

a. UBC 100 mph basic wind speed Exposure C

3.2 Seismic Load:

UBC Seismic Zone 0

3.3 Soil Loads

.01 Soil dead weight 120 pounds per cubic foot

.02 Lateral pressure coefficients

a. Active K_a = 0.3 (Cohesionless soils)
K_a= 0.5 (Cohesive soils)
b. Passive K_p = 3.0 (Cohesionless soils)
K_p= 2.0 (Cohesive soils)
c. At Rest K_r = 0.5 (Cohesionless soils)
K_r= 0.75 (Cohesive soils)

.03 Slope Stability

a. Slopes shall be analyzed by a slip circle analysis.

b. Factors of Safety against Failure shall be as a minimum:
Static FS>1.4

3.4 Dead Loads

Dead loads shall include all vertical loads due to weight of permanent structural and nonstructural components, including permanently hung loads. Dead loads shall be in accordance with ASCE 7-2002 as a minimum.

3.5 Live Loads

Each platform shall be designed to sustain the live load listed below in addition to the equipment loads, piping loads and electrical loads supported by the floor.

Viewing platforms	100 psf
Optional Enclosure roof	300 pounds point load-roof is not to be designed at this time
Roof Handrails	50 lbs per foot at the top 200 lbs concentrated at any point along the top 50 lbs concentrated at any point on intermediate rails

Roof Handrails and Posts: 2-inch diameter fiberglass, round tube, with posts spaced not more than 4 feet on centers.

3.6 Equipment Loads

Weights and applied reaction forces of major equipment shall be obtained from certified manufacturer's drawings of the equipment purchased for this unit wherever possible, and when so obtained shall be used without any increases. Where structural design must proceed before manufacturer's certified drawings are obtained, the approximate weights may be obtained from the manufacturer or from known similar equipment or catalog data. All equipment loads shall include the effects of any piping or other appurtenances attached thereto, including pressure loads.

4. Materials of Construction

4.1 Concrete
28 day cylinder compressive strength = 4000 psi

4.2 Reinforcing Steel
ASTM A615 Grade 60 (60,000 psi yield strength)

4.3 Structural Steel

.01 Hot rolled sections:

a. “H” piles-ASTM A36
b. Sheet pile pieces- ASTM A572-Grade 50

.02 Field Connections

a. Steel Bolts: ASTM A325 High Strength galvanized bolts, 7/8 inch diameter, with heavy, galvanized, semi-finished hexagon nuts and one galvanized hardened washer per bolt.

b. Fiberglass bolting material: Fiber reinforced polymer threaded rods and nuts

c. Welding Electrodes

i. AWS-A5.1 low hydrogen Class E70 for manual shielded metal arc welding

ii. AWS-A5.17 Class F7X for submerged arc welding

4.4 Grating

.01 Viewing Platforms

Vinyl-Ester resin fiberglass, rectangular welded type; 1/4 inch bearing bars, 1 inch deep, spaced 1-1/2 inches on centers with embedded angular grit particles

.02 Heat Exchanger Protection

Vinyl-Ester resin fiberglass, rectangular welded type; 1/2 inch bearing bars, 1-1/2 inch deep x 1-1/2 x 6 inches on centers

4.5 Anchor Rods: Fiber reinforced polymer threaded rods and nuts

4.7 Coatings

Structural steel “H” piles to be hot dipped galvanized and then coated with one coat of coal tar epoxy, 15 mils dry film thickness. One zinc anode to be attached by bolting to each pile.

4.8 Fiberglass Structural Members

Fiberglass structural members, bolts, rod, nuts, etc shall be as manufactured by Creative Pultrusions, Inc under the trade name “Pultrex”.

4.9 Reinforced Plastic Lumber (RPL) shall be as defined by the short form specification attached to this document.

5. Superstructure Design

5.1 Future Solar Panel Support

Future solar panel supports shall use structural members composed of glass fiber reinforced polymer using vinyl ester resin with ultraviolet inhibitors.

Future solar panel supports shall use bolted construction utilizing fiber-reinforced nuts and bolts or use fully bonded joints.

Future solar panels are to be aligned north south and placed at an angle of 50^0 to the horizontal. They are to be aligned such that they do not shade each other from 9AM to 4PM and are not shaded by any other physical object

6. Foundation Design

6.1 Geotechnical Data

.01 Soil is assumed as medium to fine sand until geotechnical investigations are complete:

$Ø = 30^0$
C = 0 psf

6.2 Shallow Foundations

a. Depth of Foundations: minimum 2 feet

b. Allowable Bearing Pressure: 2 tons per square foot

c. Frost Protection Required: No

d. Elevation of gas fired water heater foundation shall be elevation +13 feet. Earth shall be mounded and compacted to achieve this. Slopes of earth mound to be protected from erosion by 12 inches of 9 inch (D_{50}) stone over a 3 inch gravel layer.

7. Hydraulic Design

7.1 Heating Water System

.01 Flow = 1347 gpm

.02 Temperature of water:

.001 Future solar panel/heater outlet: 85^0F
.002 Gas Fired Heat Exchanger outlet: 85^0F
.003 Enclosure Water: 72^0F
.004 Indian River minimum water temperature: 40^0F

8. Waterfront Facilities Design

8.1 Significant Wave: approaching from the north-east

a. Height: H_s= 6 feet
b. Period: T_s= 4.6 seconds
c. Storm Surge above MSL = 10 feet

SHORT FORM SPECIFICATION
STRUCTURAL PLASTIC LUMBER

DESCRIPTION:

Structural plastic lumber shall be manufactured with HDPE and fiberglass elements to act reinforcing with the HDPE. Lumber shall be molded in one piece per specified size. All materials will have UV additives to prevent deterioration of the plastic lumber from exposure to UV light. HDPE will be made up of no less than 80% recycled material; both post industrial and post consumer. Finished plastic lumber will not rot, split, crack or splinter for a minimum of 50 years. It shall be resistant to termites, marine borers, salt spray, oil, and fungus.

MECHANICAL PROPERTIES:

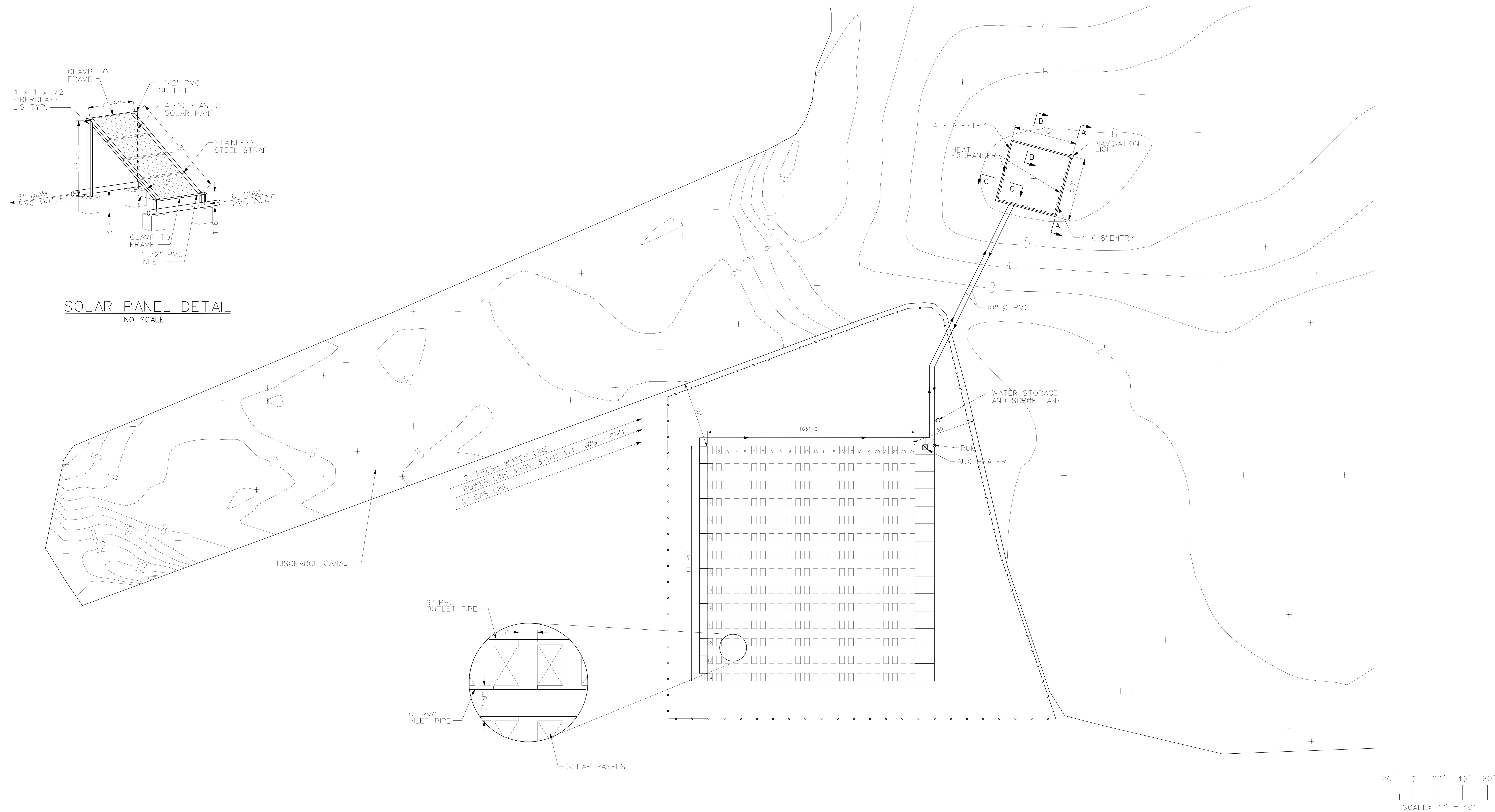
		English Units		**Metric Units**	
Test	**ASTM Test**	**Value**	**Units**	**Value**	**Units**
Flexural Strength	D6109-97	2750	PSI	193	Kg/cm^2
Flexural Modulus	D6109-97	306080	PSI	15503	Kg/cm^2
Compression Strength	D6108-97	2340	PSI	165	Kg/cm^2
Compression Modulus	D6108-97	114900	PSI	8077	Kg/cm^2
Specific Gravity	D6111-97	0.93	g/cc	0.93	g/cc
Flash point		644	Deg F	340	Deg C
Moisture Absorption		< 0.06	% by Weight	0.06	% by Weight
Thermal Expansion	D6341-98	0.000033	Inch/Inch/Deg F		
Average Nail pull out	D6117-97	504	Lbs		

DIMENSIONAL TOLERANCES:

CUP/BULDGE TOLERANCES – deviation in the face from a straight line from edge to edge of piece.

FACE WIDTH	**4″**	**6″**	**8″**	**10″**	**12″**
Tolerance (+/-)	3/32″	1/8″	3/16″	1/4″	1/4″

LENGTH TOLERANCE = + 3″ / - 0″ – Measured at 70 deg F.



RELIANT ENERGY
INDIAN RIVER GENERATING STATION
MANATEE REFUGE

SITE PLAN

Washington Group International
510 CARNEGIE CTR. - PRINCETON, NJ 08543 - (609)720-2000

PROJECT NO.: 27709
DRAWN: SH DATE: 12/30/05
CHECKED: DATE:
SCALE:
DWG. NO. D-27709-1 REV A

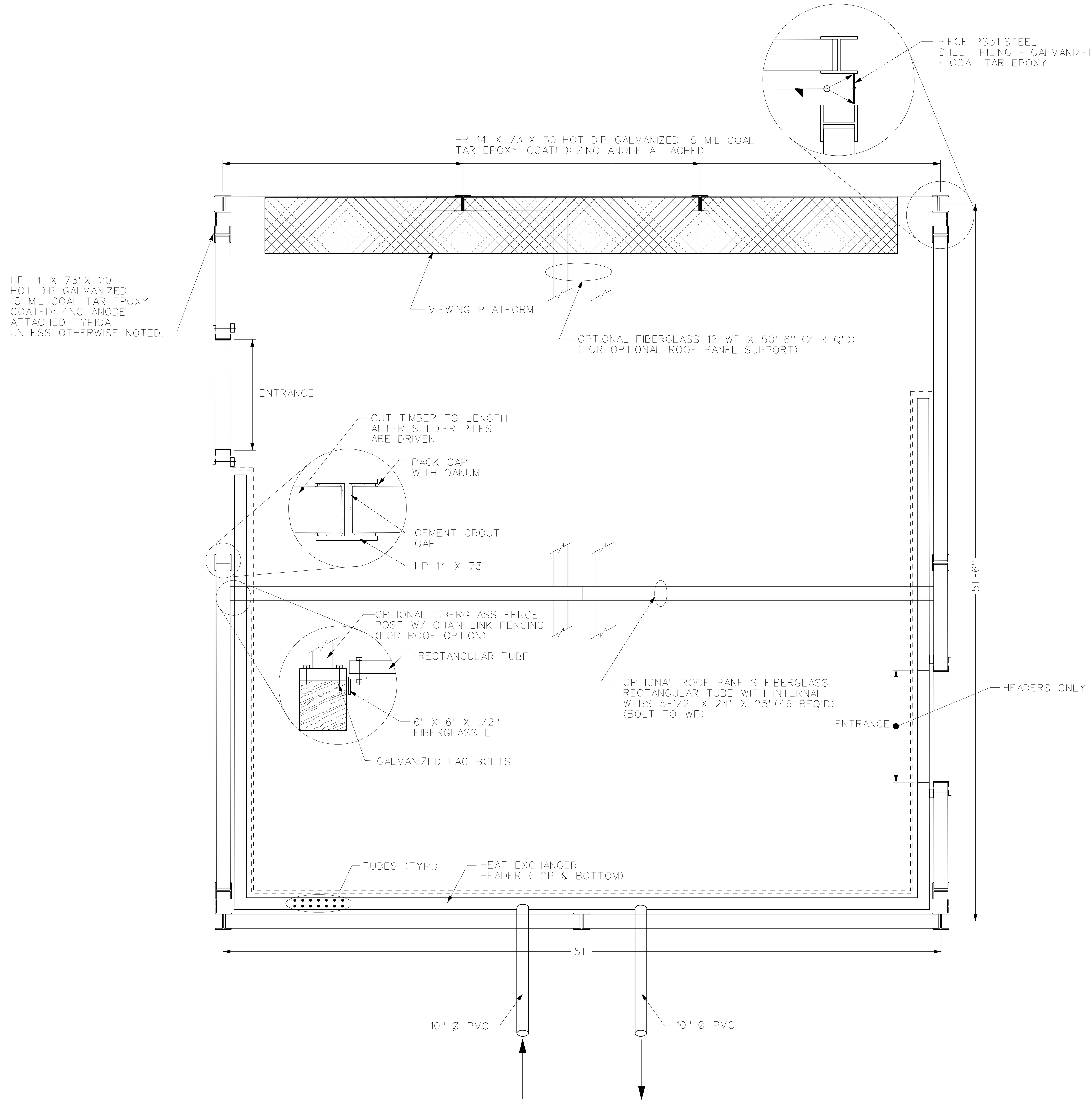
REVISION APPROVAL RECORD						REV NO	DATE	REVISIONS	BY	CHKR
DISCIPLINE	BY	DATE	DISCIPLINE	BY	DATE					
ARCH.			MECHANICAL							
CIVIL			NUCLEAR							
ELECTRICAL			PIPING							
ENVIRON.			PROCESS							
GEN. ARRANG.			QA / QC							
HVAC			STRUCTURAL							
I & C										

DRAWING STATUS				
ISSUED	REV	DATE	SDE	PEM
CONCEPTUAL	A	12/30/05	AW	MP
APPROVED FOR CONSTRUCTION				

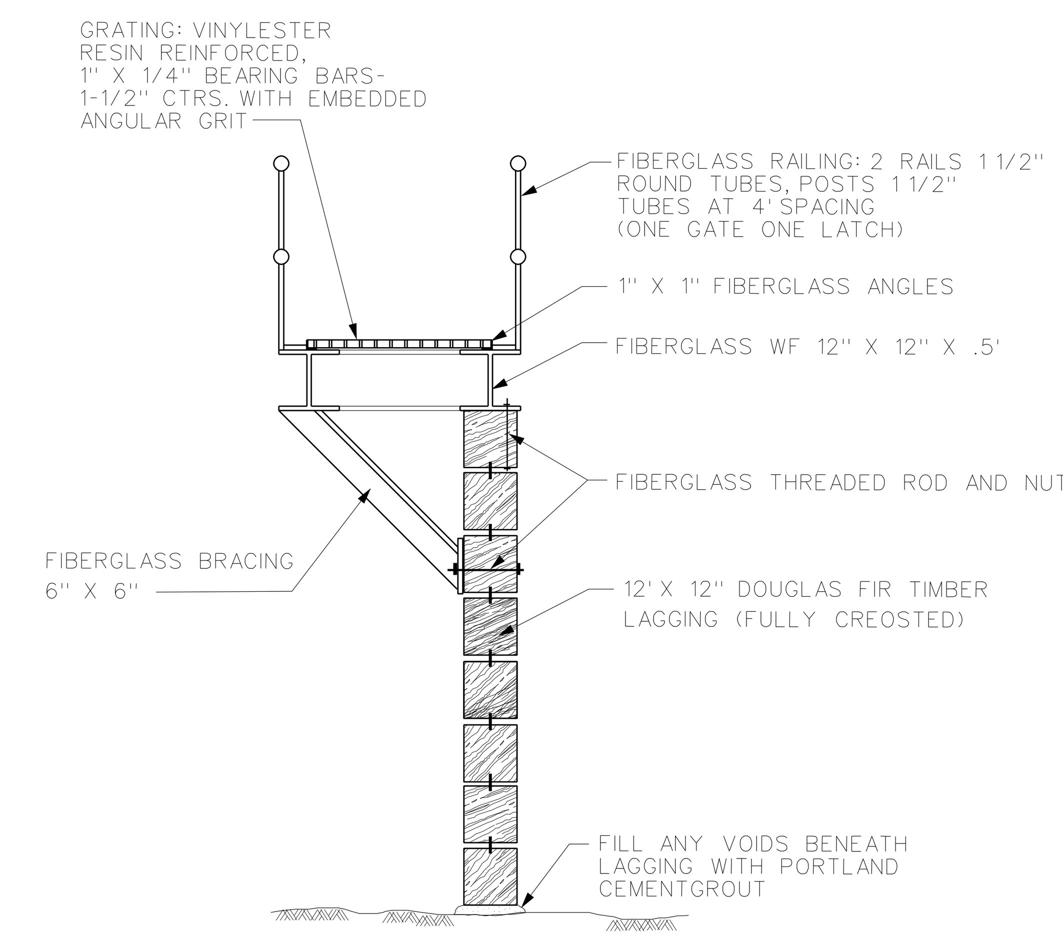
NOT APPROVED FOR CONSTRUCTION UNLESS SIGNED & DATED. DESTROY ALL PRINTS BEARING EARLIER DATE &/OR REV.NO.

USER: $USER$ PLOT SENT: $DATE$ $TIME$ FILE: $FILE$

D-27709-2

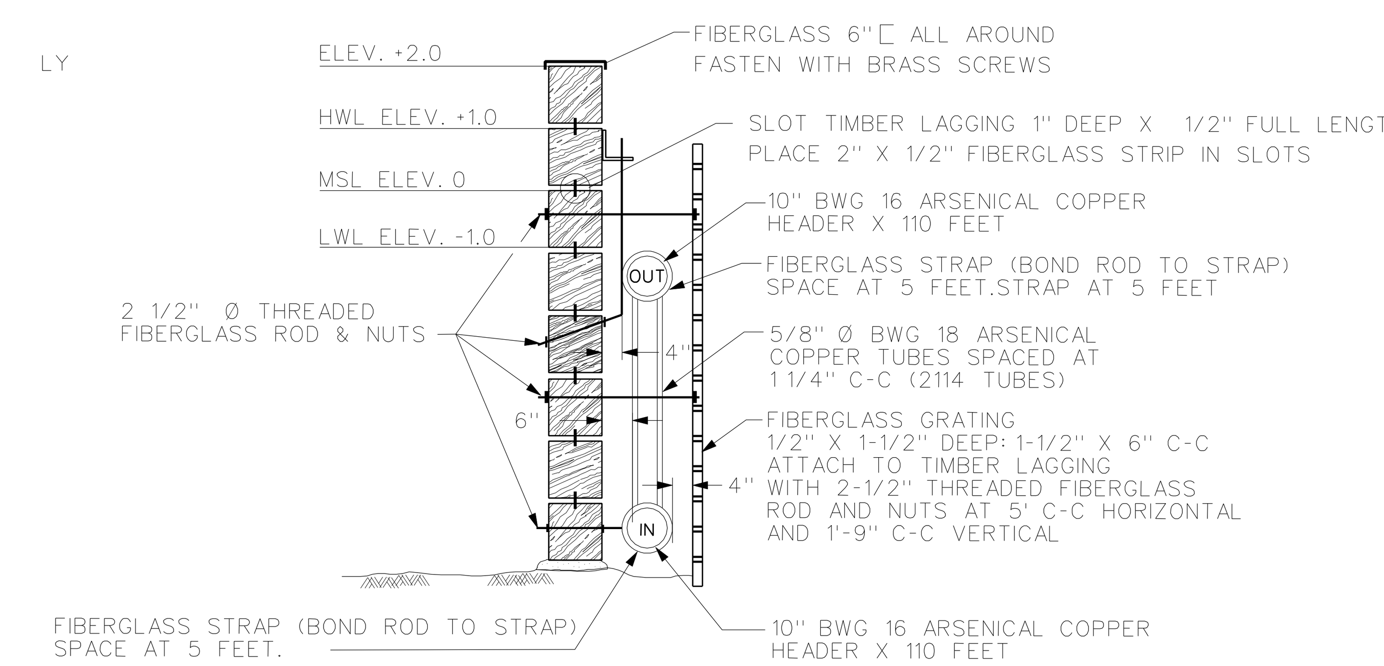


ENCLOSURE PLAN
SCALE: 1"=5'

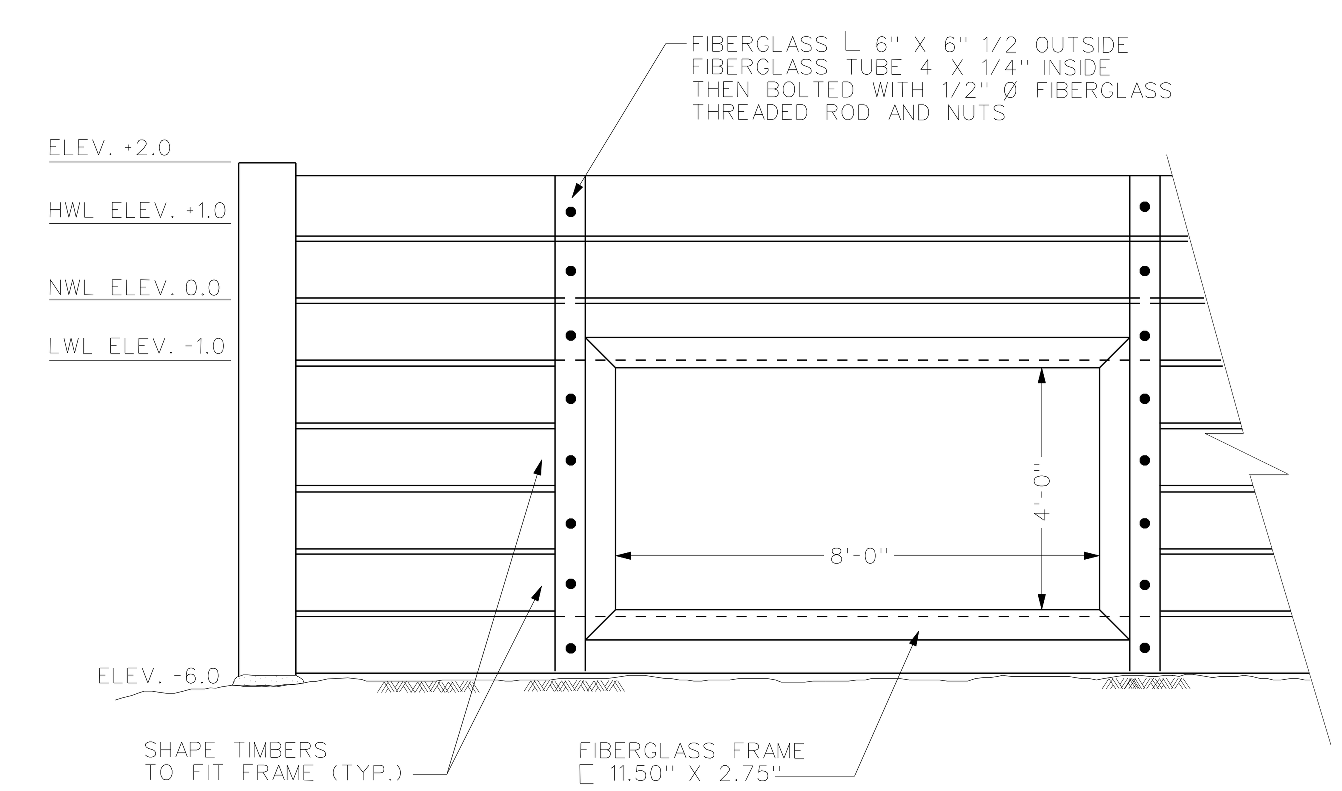


SECTION B-B
VIEWING PLATFORM.
SCALE 3/8" = 1'-0"

LY



SECTION C-C
HEAT EXCHANGER WITH
FIBERGLASS GRATING
SCALE 3/8" = 1'-0"



SECTION A-A
TIMBER OPENING WITH
FIBERGLASSFRAMING
SCALE 3/8" = 1'-0"

REVISION APPROVAL RECORD				REV	
DISCIPLINE	BY	DATE	DISCIPLINE	BY	DATE
ARCH.			MECHANICAL		
CIVIL			NUCLEAR		
ELECTRICAL			PIPING		
ENVIRON.			PROCESS		
GEN. ARRANG.			QA / QC		
HVAC			STRUCTURAL		
I & C					

REV NO	DATE	REVISIONS	BY	CHKR

DRAWING STATUS				
ISSUED	REV	DATE	SDE	PEM
CONCEPTUAL	A	12/30/05	AW	MP
APPROVED FOR CONSTRUCTION				

NOT APPROVED FOR CONSTRUCTION UNLESS SIGNED & DATED. DESTROY ALL PRINTS BEARING EARLIER DATE &/OR REV.NO.

PROJECT NO.: 27709	
DRAWN: SH	DATE: 12/30/05
CHECKED:	DATE:
SCALE: AS NOTED	

RELIANT ENERGY
INDIAN RIVER GENERATING STATION
MANATEE REFUGE

REFUGE ENCLOSURE

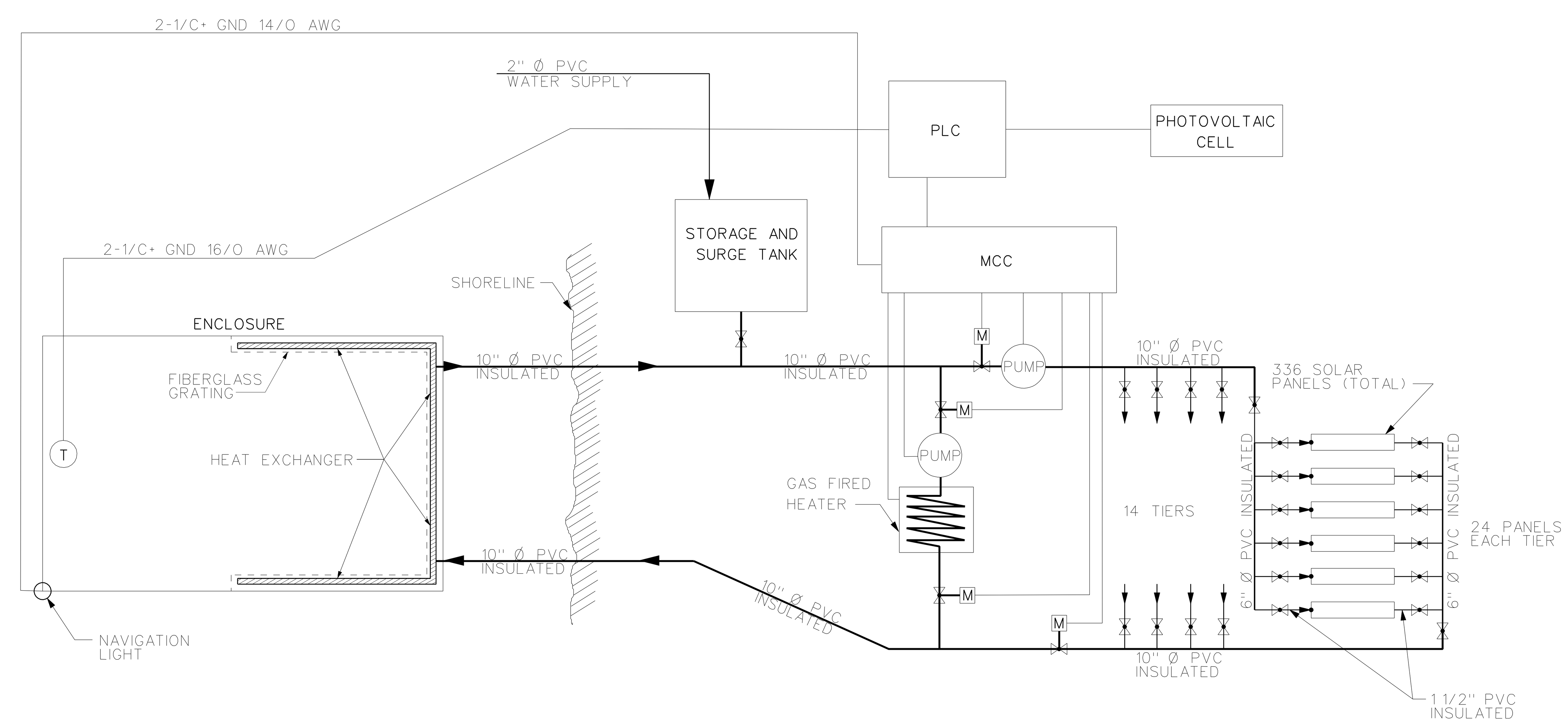
Washington Group International
510 CARNEGIE CTR. - PRINCETON, NJ 08543 - (609)720-2000

DWG. NO. D-27709-2 REV A

USER: $USER$ PLOT SENT: $DATE$ $TIME$ FILE: $FILE$

INCHES CENTIMETERS

D-27709-3



USER: $USER$
PLOT SENT: $DATE$ $TIME$
FILE: $FILE$

INCHES CENTIMETERS

REVISION APPROVAL RECORD				REV	
DISCIPLINE	BY	DATE	DISCIPLINE	BY	DATE
ARCH.			MECHANICAL		
CIVIL			NUCLEAR		
ELECTRICAL			PIPING		
ENVIRON.			PROCESS		
GEN. ARRANG.			QA / QC		
HVAC			STRUCTURAL		
I & C					

REV NO	DATE	REVISIONS	BY	CHKR

DRAWING STATUS				
ISSUED	REV	DATE	SDE	PEM
CONCEPTUAL	A	12/30/05	AW	MP
APPROVED FOR CONSTRUCTION				

NOT APPROVED FOR CONSTRUCTION UNLESS SIGNED & DATED. DESTROY ALL PRINTS BEARING EARLIER DATE &/OR REV.NO.

PROJECT NO.: 27709

DRAWN: SH DATE: 12/30/05

CHECKED: DATE:

SCALE: NO SCALE

RELIANT ENERGY
INDIAN RIVER GENERATING STATION
MANATEE REFUGE

FLOW DIAGRAM

Washington Group International

510 CARNEGIE CTR. - PRINCETON, NJ 08543 - (609)720-2000

DWG. NO. D-27709-3 REV A

Appendix D

Project Description

**Prepared by Washington Group International, Inc.
for Reliant Energy 30 June 2005**

1 Intent of the Project

It is planned, in compliance with the Multi-species Recovery Plan for South Florida (paragraph H 1.2.2), to construct and maintain a Manatee Refuge Station at the Reliant Energy Indian River Generating Station on the Indian River south of Titusville, Florida. This refuge will be experimental for a period of about five years and if successful will be made permanent.

Manatees gather and rest at the circulating water discharge canal at this station in colder weather. In case of a plant shutdown and the loss of the warm water discharge, the Manatees are in danger of suffering hypothermia with resulting fatal results. When water temperatures lower to 68^0F Manatees will search for and remain in areas with warmer temperatures. Water temperature at or below 61^0F can prove fatal to Manatees. At temperatures approaching 50^0F Manatees cease feeding and are in danger of starvation. The intent of this project is to provide a warm water refuge, during periods of cool ocean water and plant shutdown, to which Manatees can retreat.

It is planned to construct an enclosure in the water in the vicinity of the plant circulating water discharge canal with openings large enough to allow Manatees to enter and exit freely and to provide warm water to this chamber utilizing solar energy for the primary heating source with a backup gas-fired heater. For the present experimental installation, Stage I, only the gas-fired heater will be utilized for warming the water,

Primary design criteria for the system are:

a. Location: Titusville, Florida on the west bank of the Indian River about 7 miles north of the Route 1A crossing to Cape Canaveral. The chamber will be located in the vicinity of the circulating water system discharge canal.

b. Water depth in the area is about 6 feet.

c. Tidal range in the Indian River at Titusville is identified as negligible in the Tide Tables published by NOAA. Design will presume a tidal range of ± 1 foot (2 foot tide range).

d. The chamber will be 50 feet square.

e. Chamber to be constructed of steel, concrete or vinyl sheet piling or lumber. Thermal resistivity (R value) of the chamber walls to be at least 6.

f. Top of the chamber will be at elevation +3.0 feet MSL.

g. Enclosure will have 2 openings, each 4 feet high and 8 feet wide located on opposite sides of the enclosure and not directly opposite each other to minimize the through flow of water.

h. Edges of openings are to be smooth.

i. Structural design of the enclosure will be in accordance with:

- ASCE 7-2002
- 1997 Uniform Building Code
- Applicable codes and standards for supply of materials, manufactured products and mill and manufacturing tolerances
- Applicable codes and standards for fabrication practices, methods and tolerances
- Applicable codes and standards for construction
- Applicable standards for testing of materials and building components
- Applicable codes and standards for erection/installation
- OSHA regulations
- Local building regulations as well as regulations of other agencies having jurisdiction over the work

j. Geotechnical data is presently not available; for the purposes of this study the soil is assumed to be sands and to present no unusual geotechnical conditions.

k. A gas-fired heater is to be located near the future location of the solar collector array and utilized as the sole heating source for the Stage I installation. The heater will be connected to copper heat exchangers mounted on the inside face of the enclosure walls. Cooling medium is to be fresh water. The operation of the gas-fired heater is to mimic the operation of a solar collector heating system for the experimental period and then to become an auxiliary heater when the solar collectors are installed.

l. Future solar collectors, swimming pool plastic type, are to be located in the vicinity of the enclosure and are to consist of collectors each 4 feet by 10 feet. Cooling medium is to be fresh water. The solar collectors will be the primary heat source in the future and be connected in parallel into the Stage I heating system such that either heat source can be utilized for Stage II.

m. Heating system flow rate 1300 gallons per minute. Water within enclosure to be maintained at 22^{o}C (72^{o}F). Water temperature leaving gas-fired heater and future solar panels is 85^{0}F.

n. Enclosure to have capability of an optional removable cover.

o. No dredging of seabed material is to be done.

p. Life of the system 15 years.

q. Water pipes to be PVC with a thermal insulation value of R-3.

2 Description of the Project

The project consists of two component parts, the refuge enclosure and the water heating facilities.

Enclosure

The refuge enclosure consists of a 50 feet square enclosure located approximately 100 feet offshore of the discharge canal mouth, in the Indian River. It is a square structure aligned with one front wall facing northeast and one front wall facing southeast.

The top of the enclosure is set three feet above the mean water level in the Indian River and has a small platform at each corner for viewing capability. Access to the platforms will be by boat.

Water depth in the area is six feet below mean water level.

The enclosure is exposed to a three-mile fetch on the northeast side that can produce waves as high as six feet in the event of 100 miles per hour wind from that direction. 100 miles per hour is the UBC97 wind criteria for this region and considering the 15-year design life of the project is a reasonable expectation. The design of the northeast wall is intended to withstand such a wave impacting upon it. The other three walls are of similar design but with fewer soldier piles driven to less depth. Final design may want to explore making the three walls not exposed to the design wave less robust.

The enclosure is constructed of steel soldier “H” piles with recycled plastic lumber (RPL) lagging between them. The lagging is composed of 6 inch by 12 inch RPL extending between the piles and set within their flanges. The RPL lagging joints between stacked members are sealed by the use of fiberglass strips set in machined grooves in the surface between members and by cement grouting the small gap between the lagging and the “H” pile flanges The top of the RPL lagging is capped with a fiberglass channel coping and a fiberglass stop is placed at the top of the “H” piles to prevent any flotation of the RPL lagging. The bottom-lagging member has a sheet of fiberglass attached to it which extends down two feet below the river bottom to prevent Manatees from burrowing beneath the wall.

Two entrances, each 4 feet high and 8 feet long are to be placed in the walls of the enclosure, one on the northwest wall and one on the southeast wall, both about one foot above the sea bottom. The entrances will be surrounded with fiberglass channels into which the RPL wall members fit and provide a smooth surface so as not to injure a manatee that rubs against it. Fiberglass structural members will be added at the entrances to join the RPL lagging members.

The RPL lagging can be assembled into panels nine feet high on land and inserted between the piles or they can be assembled individually in the wet between the piles at the constructor’s option.

An appropriate navigation warning light will be placed on the enclosure.

Arsenical copper heat exchangers are attached to the interior of the enclosure walls with a minimum of clearance to the wall face but isolated from the steel soldier piles. The heat exchangers consist of copper lower and upper headers, one at the seabed and one at the low water level, -1.0 feet, connected by two rows of 5/8 inch copper tubes. The heat exchanger covers the entire southwest wall of the enclosure and part of the northwest and southeast walls. Fiberglass grating, attached to the walls, will be placed over the heat exchanger tubes to protect the tubes from damage from the manatees. The lower header is fed water from a 10-inch diameter PVC pipe extending from the discharge of the gas-fired water heater. The entire length of pipe is insulated. The upper header is connected to a 10-inch diameter PVC pipe, also insulated, that carries the return water back to the pump. All PVC pipe in the water is laid on the bottom. On land the pipes are laid on the ground.

An optional cover over the enclosure to minimize evaporative heat losses can be provided. Such a cover would be constructed of fiberglass tubes with a central wide flange beam spanning between walls for support. The tubes are capable of supporting one person, however, such a large flat surface may provide an enticement to boaters to land and walk on it. A fence would be provided around the enclosure perimeter to prevent such access. The cover would be designed to sit on fiberglass angles attached to the top of the RPL lagging and be bolted to them.

Heating Facilities

The water heating facilities consist of a gas fired water heater with provisions for a future solar panel array. The water heater is placed on an earth mound eight feet above the existing ground. This will provide protection from the defined ten-foot storm surge. The earth mound will be protected from erosion by a stone riprap facing. A horizontal pump immediately before the heater along with a small surge and storage tank upstream of the pump maintains flow in the system.

Control of the operation of the water heating system will be by means of a thermocouple in the enclosure that will start up the system whenever the temperature of the water falls below 72^0F. Future control of the loop that is being used for heating, solar panel array or auxiliary water heater, will be by means of a solar cell that will measure the solar radiation and that will operate motor operated valves to direct the flow to the appropriate heating device. A manual override of the control system will be provided. For the present experimental installation the gas-fired water heater will be programmed to mimic a solar panel operation, operating only when there is sufficient solar energy to operate the future solar panels. With a gas water heater sized to supply 5.5MM Btu/hour, and assuming that it operates 12 hours per day every day for 4 months during the experimental, Stage I, period and the cost of gas is $8.50/MM Btu, the fuel cost to operate the system will be $67,200 per year.

The future solar panel array consists of 336 plastic solar panels, each 4 feet by 10 feet, arranged in a pattern of 14 panels by 24 panels. The array is located on the south side of the discharge canal 50 feet back of the canal waterline and 50 feet back of the Indian River shoreline.

The panels are supported on racks constructed of 4-inch x 4-inch fiberglass angles firmly attached to concrete foundations and to the panels to prevent damage in event of high winds.

The panel array is arranged such that the entire panel is exposed to the sun with no shading from adjacent panels at noontime with sufficient space between panels for access for repair and maintenance. Each panel is oriented north south and raised and held at an angle of 50^0 to the horizontal to achieve maximum solar efficiency during the winter. The panels are fed fresh water through a series of 6-inch insulated PVC pipe headers that feed all of the panels through individual tees at each panel. Closing the valves connecting the tier to the main

10-inch piping loop can isolate each panel tier and each solar panel is further individually valved for maintenance and replacement capability.

The panels discharge through insulated 1-1/2 inch PVC pipes into 6 inch insulated PVC pipe headers that then lead to the 10-inch PVC pipe transporting the water from the panels to the heat exchangers on the enclosure walls.

The portion of the water loop supplying the future solar panels will be a parallel loop to the gas fired water heater. When the solar panels are installed the gas fired water heater will only be used at times when the water requires heating and there is insufficient solar input. This solar panel water loop will have a separate pump.

3 Judgments Leading to Material Selections and Design

The design of the refuge enclosure considered five materials, steel sheet piling, vinyl sheet piling, concrete sheet piling, timber and plastic lumber. The materials were evaluated against four criteria:

a. Thermal insulation value of R=6
b. Ability to support two entrances
c. Ability to support copper heat exchangers
d. Ability to withstand a 6 feet high wave approaching from the northeast.
e. Maximum assembly on land

Steel sheet piling can be driven in place with sufficient strength to withstand a 6 feet high wave from the northeast. It would require special details to accommodate one or two entrances but this can be reasonably accomplished. Steel sheet piling would require corrosion protection in the form of a coating and cathodic protection. The steel sheet piling is deficient in thermal properties and would require the addition of insulation to achieve a thermal R of 6. The insulation that would be used is styrofoam sheets attached by pins to the sheet piling. Such attachment would necessarily be accomplished after the sheet piling is in place, a difficult accomplishment and one requiring divers with the attendant expense. Once in place the styrofoam insulation would need to be securely fixed so that it could not loosen and float to the surface. Styrofoam is a delicate material and would not be capable of withstanding the possible intense abrasion of Manatees rubbing against it. The steel sheet piling is not compatible with the planned copper heat exchangers to be affixed to the walls. Severe corrosion would occur due to the electrochemical, galvanic, action that would occur in salt water between these two materials. A positive insulation between them would be required and the potential for failure of the insulation and consequent severe

6
corrosion makes this an unacceptable selection. All of the work for constructing the enclosure must be done in place.

Vinyl sheet piling can be designed to withstand a 6 feet high wave from the northeast and to accommodate two entrances, similar to steel sheet piling. Vinyl sheet piling is attractive as it is not susceptible to corrosion in salt water. Vinyl sheet piling is similar to steel sheet piling in thermal properties and would require insulation on the inside face similar to the steel sheet piling, for this reason it is not a desirable selection. All of the work for constructing the enclosure must be done in place.

Concrete sheet piling also has poor thermal qualities and would require insulation on the inside face to attain the required R-value of 6. All of the work for constructing the enclosure would be done in place. For these reasons it is not a desirable selection.

A timber enclosure can be designed to withstand a 6 feet high wave from the northeast. The design consists of soldier "H" piles driven into the underlying soil with horizontal timbers, "lagging", placed between the soldier piles. Special details will provide for the required two entrances. The insulation R-value for the timbers, 12 inches thick, is on the order of 12, which is in excess of the required thermal properties. Timber members must be treated with a preservative to protect them from marine borers. The preferred preservative is creosote with other pressure treatments available. All of the treatments utilize materials possibly harmful to manatees, particularly considering the confined nature of the refuge and the closeness of the manatees to the wall. Timber is therefore considered not acceptable.

An enclosure identical to the timber enclosure but utilizing recycled plastic lumber (RPL) can be designed and constructed. Recycled plastic lumber is comprised of recycled high-density polyethylene (HDPE) (milk containers, etc) and has the same basic properties as virgin HDPE and is available in member sizes slightly smaller than timber members. Being HDPE, RPL will not corrode and is not susceptible to damage from marine borers. The insulation value and strength of HDPE is similar to that of timber. As such this material and design was chosen as the preferred one. A short form specification for RPL is attached.

The copper heat exchangers will be attached to the RPL lagging and be kept sufficiently far from the steel H piles to avoid any galvanic action. "H" piles will have zinc anodes attached to provide cathodic protection in addition to being galvanized and coated with coal tar epoxy. The driving of the soldier piles and placing of the RPL lagging must be done in place. Shaping of the lagging members can be done on land as well as assembly of them into panels. The

6
lagging/"H" pile interface will be sealed with cement grout to provide as tight a seal as possible. A fiberglass plate will be set to penetrate two feet below the bottom-lagging member into the river bottom to prevent manatees from burrowing beneath the enclosure wall.

The RPL enclosure best meets all of the criteria and is selected as the preferred design.

4.0 Operation of the Experimental Installation

The experimental installation will be operated to mimic the operation of a solar panel installation. The water temperature inside of the enclosure will be monitored with a thermocouple and when it falls below 72^0F a signal will be sent to the PLC (Programmable Logic Controller) to start the water heater and the circulating pump. The PLC will inquire of the solar cell as to the amount of solar radiation. If there is sufficient (sufficient to be determined later) radiation to allow a solar panel array to supply adequate warm water the PLC starts the gas-fired water heater and the circulating water pumps. If there is insufficient solar radiation the heater and pumps do not start. The PLC will data log river water temperature, enclosure water temperature, operation of the gas-fired water heater, solar radiation, water heater inlet and discharge temperatures, and gas usage.

5.0 Possible Additional Designs

Prevention of Public Access

The enclosure and viewing platforms are open to access by anyone coming by boat. The risk that this poses to injury needs to be judged and if found to be great a fence can be erected around the perimeter of the enclosure, attached to the lagging.

Convective Loss of Heated Water Through the Entrances

The walls of the enclosure are designed to be as leak tight as possible and the entrances are staggered on opposite walls to minimize crosscurrents through the enclosure. However, the open entrances may create convection currents that result in warm water leaving the enclosure and being replaced by cold water from outside. Final design should study the geometry of the entrances and develop a geometry that minimizes such convective losses possibly by the use of a hood placed over the outside of the entrances to minimize vertical convection and a labyrinth placed at the entrance openings to minimize through flow.

Sea Bottom Erosion

Placing the enclosure near the mouth of the discharge canal may induce seabed erosion around the enclosure walls due to the canal discharge water flow. Measurements should be taken of the actual current velocities in the region proposed for the enclosure and Computer Fluid Dynamics studies performed to evaluate the probable current speeds and directions when the enclosure is constructed. Such evaluated velocities can be used to judge the probability of seabed erosion. Measurements of the amount and rate of sand drifting along the shore from the north should be pursued to determine if an accumulation of sand may occur at the northwest entrance and block it.

Redundancy of Equipment

Depending upon the perceived criticality of the objectives of this construction, redundant equipment may be desirable to prevent system failure due to a single component failure. For this project such items as the pumps, controls and valves would warrant investigation as to the value of providing redundant equipment.

Appendix E

Estimate of Construction Cost

**Prepared by Washington Group International, Inc.
for Reliant Energy 30 June 2005**

Summary

The cost has been estimated to construct Stage I of the Manatee Refuge at the Indian River Plant of Reliant Energy along with the cost for Stage II, construction of the solar panels array and the cost for the optional roof over the enclosure. Costs are based on 2006 pricing and are considered accurate to within about 20%.

Stage I consisting of constructing the enclosure in the Indian River about 100 feet offshore and in line with the circulating water discharge canal plus a gas fired water heater on shore close to the shoreline along with connecting piping, pump, storage/surge tank and control system and electrical, water and gas connections to the power plant will require the expenditure of about $1,554,936. This is a direct construction cost and does not include sales/use taxes, construction management, start up costs, permit costs or other owner costs. Engineering costs of 5% of the construction cost would amount to $77,748 additional.

If Stages I and II without the optional roof were constructed at this time the cost would be $3,986,579

Detail Estimate of Cost

Detailed Cost Estimates are attached for the various component parts of construction for Stage I and the future Stage II, the addition of a solar panel heating system to Stage I. Also included is the estimate of cost for adding a roof over the enclosure.

The various component costs are:

Stage I

Enclosure in the Indian River……………………….$1,225,447
Gas Water Heater System………………………….$ 329,489

Stage II

Solar Panel Installation incl piping, pumps………$2,431,643

Optional Enclosure Roof………………………………….$ 435,277

ATTACHMENTS

COST ESTIMATE DETAIL SHEETS

1. **REFUGE ENCLOSURE**
2. **GAS HEATER SITE**
3. **SOLAR PANEL SITE**
4. **OPTIONAL ENCLOSURE ROOF**
5. **ALL COMPONENT PARTS-ALL AREAS**

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Bill of Materials			Unit Costs			Estimated Present Day Construction Costs					
Location	Item	Quantity	Unit Mat'l Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Enclosure	Steel "H" Piles-HP14x73 x 30 feet long - Galvanized with 15 mil coal tar epoxy coating; 10 lb zinc anode bolted to each	2 each			6,150.00	$ -	-	$ 66.00	$ -	$ 12,300	$ 12,300
Enclosure	Steel "H" Piles-HP14x73 x 20 feet long - Galvanized with 15 mil coal tar epoxy coating; 10 lb zinc anode bolted to each	3 each			4,125.00	$ -	-	$ 66.00	$ -	$ 12,375	$ 12,375
Enclosure	Steel "H" Piles-HP14x73 x 30 feet long - piece of PS31 steel sheet piling welded to each for full length-Galvanized with 15 mil coal tar epoxy coating; 10 lb zinc anode bolted to each	2 each			9,850.00	$ -	-	$ 66.00	$ -	$ 19,700	$ 19,700
Enclosure	Steel "H" Piles - HP14x73 x 20 feet long- piece of PS31 steel sheet piling welded to each for full length-Galvanized with 15 mil coal tar epoxy coating; 10 lb zinc anode bolted to each	6 each			6,600.00	$ -	-	$ 66.00	$ -	$ 39,600	$ 39,600
Enclosure	Fiberglass Reinforced Plastic Lumber lagging; 12" x 06", 25 feet length	92 each	990.00	6.250		$ 91,080	575	$ 66.00	$ 37,950	$ -	$ 129,030
Enclosure	Fiberglass Reinforced Plastic Lumber lagging; 12" x 06", 16.67 feet length	54 each	660.00	5.000		$ 35,640	270	$ 66.00	$ 17,820	$ -	$ 53,460
Enclosure	Fiberglass Reinforced Plastic Lumber lagging; 12" x 06", 08.50 feet length	32 each	340.00	3.750		$ 10,880	120	$ 66.00	$ 7,920	$ -	$ 18,800
Enclosure	Cut horizontal slots in lagging, insert fiberglass flat strip in facing notches of Lagging		Included above in fiberglass lagging costs								
Enclosure	Solid Fiberglass Plate, 1/2" th x 3'-00" dp, attach to two lowest lagging sections w/ 1/2" fiberglass threaded rods and nuts	615 sqft	12.00	0.312		$ 7,380	192	$ 66.00	$ 12,672	$ -	$ 20,052
Enclosure	Water Jetting to enable setting of two lowest lagging sections w/ 1/2" x 3'-00" solid fiberglass plate attached, with allowance for manual backfill with indigenous material	205 lnft	-	0.390		$ -	80	$ 66.00	$ 5,280	$ -	$ 5,280
Enclosure	8 foot x 4 foot fiberglass entrance frame composed of 11.50 inch x 2.75 inch channels: total 28 feet of channel required - assembled	2 each	1,400.00	14.000		$ 2,800	28	$ 66.00	$ 1,848	$ -	$ 4,648
Enclosure	Secure Fiberglass Channel entrance framing to contiguous wall	52 each	11.00	1.250		$ 572	65	$ 66.00	$ 4,290	$ -	$ 4,862
Enclosure	Plastic Lumber lagging ties: {vertically flank 8'w x 4'h lagging openings} 6" x 6" x 1/2" x 9 feet Fiberglass Angles outside of enclosure plus 4" x 1/4" x 9 feet Fiberglass Square Tubes - angles and tubes through bolted with 1/2" fiberglass threaded rods and nuts	4 locs									

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Bill of Materials			Unit Costs			Estimated Present Day Construction Costs					
Location	Item	Quantity	Unit Matl Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Enclosure	Fiberglass Angles 6" x 6" x 1/2" x 9 feet which vertically flank 8'w x 4'h lagging openings	36 lnft	33.00	0.333		$ 1,188	12	$ 66.00	$ 792	$ -	$ 1,980
Enclosure	Fiberglass Tubes 4" x 1/4" x 9 feet which vertically flank 8'w x 4'h lagging openings	36 lnft	21.00	0.333		$ 756	12	$ 66.00	$ 792	$ -	$ 1,548
Enclosure	Secure fiberglass angles and tubes which vertically flank 8'w x 4'h lagging openings with 1/2" Fiberglass Threaded Through Rods and Fiberglass End Fasteners	40 each	8.80	1.250		$ 352	50	$ 66.00	$ 3,300	$ -	$ 3,652
Enclosure	Triangular grating platform: vinyl ester resin fiberglass grating; 1/4 inch bearing bars, 1 inch deep, 1-1/2 inches on center with embedded angular grit, attach with bronze lag bolts	32 sqft	52.00	1.000		$ 1,664	32	$ 66.00	$ 2,112	$ -	$ 3,776
Enclosure	Heat Exchanger Support Angles: Fiberglass Angle, 6 inch x 6 inch x 1/2 inch, bolted to lagging with 1/2" diam fiberglass threaded rods and nuts	118 lnft	33.50	0.220		$ 3,953	26	$ 66.00	$ 1,716	$ -	$ 5,669
Enclosure	Fiberglass Fastener Sets, 1/2" diam, top row lagging to heat exchanger support angles	120 each	7.70	1.000		$ 924	120	$ 66.00	$ 7,920	$ -	$ 8,844
Enclosure	Fiberglass Fastener Sets, heat exchanger support angle to heat exchanger top header strap support	26 each	66.00	1.000		$ 1,716	26	$ 66.00	$ 1,716	$ -	$ 3,432
Enclosure	Fiberglass Fastener Sets, lagging laterally to heat exchanger top header	26 each	66.00	1.500		$ 1,716	39	$ 66.00	$ 2,574	$ -	$ 4,290
Enclosure	Fiberglass Fastener Sets, lagging tie to heat exchanger protective vertical grating	52 each	88.00	2.000		$ 4,576	104	$ 66.00	$ 6,864	$ -	$ 11,440
Enclosure	Fiberglass Fastener Sets, lagging laterally to heat exchanger bottom header	26 each	66.00	1.500		$ 1,716	39	$ 66.00	$ 2,574	$ -	$ 4,290
Enclosure	Heat exchanger protective grating - vinyl ester resin fiberglass grating; 1/2 inch bearing bars, 1.5 inch deep, 1-1/2 x 6 inches on center-attached to fiberglass 3 x 3 angle structure @ 3 ft ctrs and to lagging with 2-1/2 inch diam fiberglass threaded rods/nuts @ 5 ft ctrs	660 sqft	28.50	0.097		$ 18,810	64	$ 66.00	$ 4,224	$ -	$ 23,034
Enclosure	Fiberglass 3 x 3 Angle Structure to support Heat Exchanger Protective Grating, spaced @ 3 ft ctrs with logitudinal bracing and connected to lagging with 1/2 inch diam fiberglass threaded rods/nuts at top and bottom elevations	600 lnft	19.00	0.640		$ 11,400	384	$ 66.00	$ 25,344	$ -	$ 36,744
Enclosure	Fiber Reinforced Polymer Coping encompassing top elevation perimeter of lagging members, attached with brass lag screws	200 lnft	52.75	1.200		$ 10,550	240	$ 66.00	$ 15,840	$ -	$ 26,390

RELIANT ENERGY - INDIAN RIVER STATION - MANATEE REFUGE ... REFUGE ENCLOSURE

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Location	Item	Quantity	Unit Mat'l Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Enclosure	Cement Grout Fill Voids where required along Vertical Joints where lagging meets HP web	50 cuft	33.00	0.960		$ 1,650	48	$ 66.00	$ 3,168	$ -	$ 4,818
Enclosure	Oakum Caulk 1 side of vertical joints where Lagging meets HP web	180 lnft	2.75	0.333		$ 495	60	$ 66.00	$ 3,960	$ -	$ 4,455
Enclosure	Trenching in water: 10" Hot Water Supply to and Return from Refuge Heat Exchanger	0 cuyd	13.20	0.400		$ -	-	$ 66.00	$ -	$ -	$ -
Enclosure	Heat exchanger: copper materials of construction	1 each	550,000.00	400.000		$ 550,000	400	$ 66.00	$ 26,400	$ -	$ 576,400
Enclosure	10 inch diameter PVC Schedule 40 waterside	250 lnft	28.50	0.600		$ 7,125	150	$ 66.00	$ 9,900	$ -	$ 17,025
Enclosure	10 inch diameter PVC Insulation 2" FBG w/ cover waterside	250 lnft	7.00	0.240		$ 1,750	60	$ 66.00	$ 3,960	$ -	$ 5,710
Enclosure	16 inch diameter Cover Pipe encapsulating insulated 10 inch diameter PVC Schedule 40 Hot Water Supply to and Return from Refuge Heat Exchanger (Cu matls of constr)	250 lnft	52.75	0.400		$ 13,188	100	$ 66.00	$ 6,600	$ -	$ 19,788
Enclosure	Power supply to navigation light 2 1/c + ground - 4/0 AWG	400 lnft	2.60	0.042		$ 1,040	17	$ 66.00	$ 1,122	$ -	$ 2,162
Enclosure	Power supply cable conduit RGS in Trench	400 lnft	5.50	0.400		$ 2,200	160	$ 66.00	$ 10,560	$ -	$ 12,760
Enclosure	Terminations	6 each	9.20	0.700		$ 55	4	$ 66.00	$ 264	$ -	$ 319
Enclosure	Pull Box	1 each	425.00	1.500		$ 425	2	$ 66.00	$ 132	$ -	$ 557
Enclosure	Thermocouple at enclosure	1 each	550.00	4.000		$ 550	4	$ 66.00	$ 264	$ -	$ 814
Enclosure	Instrumentation wiring to thermocouple 2 1/c 16 AWG	400 lnft	0.25	0.020		$ 100	8	$ 66.00	$ 528	$ -	$ 628
Enclosure	Thermocouple wire conduit RGS in Trench	400 lnft	5.50	0.400		$ 2,200	160	$ 66.00	$ 10,560	$ -	$ 12,760
Enclosure	Terminations	4 each	5.80	0.130		$ 23	1	$ 66.00	$ 66	$ -	$ 89
Enclosure	Pull Box	1 each	11.00	1.000		$ 11	1	$ 66.00	$ 66	$ -	$ 77
Enclosure	Navigation light	1 each	220.00	4.000		$ 220	4	$ 66.00	$ 264	$ -	$ 484
	SUBTOTALS - Enclosure - Present Day Costs					$ 788,705	3,657		$ 241,362	$ 83,975	$ 1,114,042
	CONTINGENCY									10.0%	$ 111,405
	SUBCONTRACT CONSTRUCTION COST										$ 1,225,447
	SALES/USE TAXES										NOT INCLUDED
	ENGINEERING - Enclosure									5.0%	$ 61,273
	CONSTRUCTION MANAGEMENT										BY OWNER
											NOT INCLUDED
	PERMITS										BY OWNER
	OTHER OWNER COSTS										BY OWNER

RELIANT ENERGY - INDIAN RIVER STATION - MANATEE REFUGE ... GAS HEATER SITE

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Location	Item	Quantity	Unit Matl Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Gas Heater Site	Gas Heater Embankment (compacted soil)	220 cuyd	16.50	0.218		$ 3,630	48	$ 66.00	$ 3,168	$ -	$ 6,798
Gas Heater Site	Gravel Fill, 3" dp layer	108 sqyd	1.65	0.037		$ 178	4	$ 66.00	$ 264	$ -	$ 442
Gas Heater Site	Rip Rap, 12" dp layer, 9" D50 Stone	108 sqyd	11.00	0.222		$ 1,188	24	$ 66.00	$ 1,584	$ -	$ 2,772
Gas Heater Site	Concrete foundations: 4000 psi reinforced concrete	10 cuyd	230.00	10.000		$ 2,300	100	$ 66.00	$ 6,600	$ -	$ 8,900
Gas Heater Site	Trenching: Gas line + Water Supply line + Power line: 3 feet wide x 3 feet deep x 1000 feet each	1,000 cuyd	6.60	0.280		$ 6,600	280	$ 66.00	$ 18,480	$ -	$ 25,080
Gas Heater Site	Gas Heater Pump - 1,300 gpm / 15 psi, 15 HP horizontal	1 each	13,200.00	12.000		$ 13,200	12	$ 66.00	$ 792	$ -	$ 13,992
Gas Heater Site	Storage/Surge Tank: 3 feet diameter x 15 feet high fiberglass vented tank	1 each	2,200.00	8.000		$ 2,200	8	$ 66.00	$ 528	$ -	$ 2,728
Gas Heater Site	Auxiliary Heater - Gas fired, 5,200,000 BTU/hr	1 each	66,000.00	200.000		$ 66,000	200	$ 66.00	$ 13,200	$ -	$ 79,200
Gas Heater Site	Gas pipe: 2 inch plastic	1,000 lnft	11.00	0.240		$ 11,000	240	$ 66.00	$ 15,840	$ -	$ 26,840
Gas Heater Site	Water Supply pipe: 2 inch diameter PVC Schedule 40	1,000 lnft	2.55	0.240		$ 2,550	240	$ 66.00	$ 15,840	$ -	$ 18,390
Gas Heater Site	10 inch diameter PVC Schedule 40 landside	200 lnft	28.50	0.600		$ 5,700	120	$ 66.00	$ 7,920	$ -	$ 13,620
Gas Heater Site	10 inch diameter PVC Insulation 2" FBG w/ cover landside	200 lnft	7.00	0.240		$ 1,400	48	$ 66.00	$ 3,168	$ -	$ 4,568
Gas Heater Site	10 inch diameter PVC Schedule 40 motor operated globe valves	2 each	4,400.00	10.000		$ 8,800	20	$ 66.00	$ 1,320	$ -	$ 10,120
Gas Heater Site	Power supply cable 480v: 3-1/c-4/0 AWG + Ground	1,000 lnft	3.50	0.056		$ 3,500	56	$ 66.00	$ 3,696	$ -	$ 7,196
Gas Heater Site	Terminations	16 each	9.20	0.700		$ 147	11	$ 66.00	$ 726	$ -	$ 873
Gas Heater Site	Pull Box	2 each	425.00	1.500		$ 850	3	$ 66.00	$ 198	$ -	$ 1,048
Gas Heater Site	Power supply cable conduit RGS in Trench	1,000 lnft	5.50	0.400		$ 5,500	400	$ 66.00	$ 26,400	$ -	$ 31,900
Gas Heater Site	Trenching: Conduit ... included in Trenching: Gas line + Water Supply line + Power line										
Gas Heater Site	Photovoltaic cell	1 each	138.00	6.000		$ 138	6	$ 66.00	$ 396	$ -	$ 534
Gas Heater Site	480v Motor Control Center: 2 vertical stacks - NEMA 3 enclosure, 4 - size 1 reversing starters, 1 - size 1 nonreversing starter, 1 - size 2 nonreversing starter, 1 - single phase 480/120v 5 KVA transformer, 1 - 120v distribution panel - 12 circuits	1 each	11,000.00	32.000		$ 11,000	32	$ 66.00	$ 2,112	$ -	$ 13,112

RELIANT ENERGY - INDIAN RIVER STATION - MANATEE REFUGE ... GAS HEATER SITE

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Bill of Materials			Unit Costs			Estimated Present Day Construction Costs					
Location	Item	Quantity	Unit Mat'l Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Gas Heater Site	Single phase 480/120v 5 KVA transformer	1 each	457.00	8.000		$ 457	8	$ 66.00	$ 528	$ -	$ 985
Gas Heater Site	120v distribution panel - 12 circuits	1 each	517.00	10.000		$ 517	10	$ 66.00	$ 660	$ -	$ 1,177
Gas Heater Site	Lighting and Grounding	1 lot	2,200.00	40.000		$ 2,200	40	$ 66.00	$ 2,640	$ -	$ 4,840
Gas Heater Site	Misc Instrumentation, e.g. pressure gauges	1 lot	11,000.00	80.000		$ 11,000	80	$ 66.00	$ 5,280	$ -	$ 16,280
Gas Heater Site	PLC	1 each	5,500.00	40.000		$ 5,500	40	$ 66.00	$ 2,640	$ -	$ 8,140
	SUBTOTALS - Gas Heater Site - Present Day Costs					$ 165,555	2,030		$ 133,980	$ -	$ 299,535
	CONTINGENCY									10.0%	$ 29,954
	SUBCONTRACT CONSTRUCTION COST										$ 329,489
	SALES/USE TAXES										NOT INCLUDED
	ENGINEERING - Gas Heater Site									5.0%	$ 16,475
	CONSTRUCTION MANAGEMENT										BY OWNER
	START UP COSTS										NOT INCLUDED
	PERMITS										BY OWNER
	OTHER OWNER COSTS										BY OWNER

RELIANT ENERGY - INDIAN RIVER STATION - MANATEE REFUGE ... SOLAR PANEL SITE

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Bill of Materials			Unit Costs			Estimated Present Day Construction Costs					
Location	Item	Quantity	Unit Mat'l Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Solar Panel Site	Concrete foundations: 4000 psi reinforced concrete	40 cuyd	230.00	10.000		$ 9,200	400	$ 66.00	$ 26,400	$ -	$ 35,600
Solar Panel Site	Solar panel support frames: constructed of 4 inch x 4 inch x 1/2 inch thick fiberglass angles-92 feet of angle required for each frame-assembled	30,912 lnft	18.85	0.043		$ 582,691	1,344	$ 66.00	$ 88,704	$ -	$ 671,395
Solar Panel Site	Pipe sleepers - 9 inch x 6 inch x 6 inches deep concrete pads with strap anchors for pipes	1,424 each	55.00	1.500		$ 78,320	2,136	$ 66.00	$ 140,976	$ -	$ 219,296
Solar Panel Site	10 inch diameter PVC Schedule 40 landside	600 lnft	28.50	0.600		$ 17,100	360	$ 66.00	$ 23,760	$ -	$ 40,860
Solar Panel Site	10 inch diameter PVC Insulation 2" FBG w/ cover landside	600 lnft	7.00	0.240		$ 4,200	144	$ 66.00	$ 9,504	$ -	$ 13,704
Solar Panel Site	6 inch diameter PVC Schedule 40 pipe insulated - landside	5,600 lnft	9.00	0.400		$ 50,400	2,240	$ 66.00	$ 147,840	$ -	$ 198,240
Solar Panel Site	6 inch diameter PVC Insulation 2" FBG w/ cover - landside	5,600 lnft	4.80	0.160		$ 26,880	896	$ 66.00	$ 59,136	$ -	$ 86,016
Solar Panel Site	6 inch diameter PVC Schedule 40 tees	800 each	60.50	2.160		$ 48,400	1,728	$ 66.00	$ 114,048	$ -	$ 162,448
Solar Panel Site	1-1/2 inch diameter PVC Schedule 40 reducer inserts	800 each	18.00	1.310		$ 14,400	1,048	$ 66.00	$ 69,168	$ -	$ 83,568
Solar Panel Site	6 inch diameter PVC Schedule 40 globe valves	28 each	770.00	4.000		$ 21,560	112	$ 66.00	$ 7,392	$ -	$ 28,952
Solar Panel Site	10 inch diameter PVC Schedule 40 motor operated globe valves	2 each	4,400.00	10.000		$ 8,800	20	$ 66.00	$ 1,320	$ -	$ 10,120
Solar Panel Site	1-1/2 inch diameter PVC Schedule 40 pipe	4,100 lnft	3.30	0.300		$ 13,530	1,230	$ 66.00	$ 81,180	$ -	$ 94,710
Solar Panel Site	1-1/2 inch diameter PVC Insulation 2" FBG w/ cover - landside	4,100 lnft	3.05	0.140		$ 12,505	574	$ 66.00	$ 37,884	$ -	$ 50,389
Solar Panel Site	1-1/2 inch diameter PVC Schedule 40 globe valves	672 each	88.00	0.400		$ 59,136	269	$ 66.00	$ 17,754	$ -	$ 76,890
Solar Panel Site	Solar Panel Pump- 1300 gpm/4 psi: 5 HP horizontal	1 each	5,500.00	12.000		$ 5,500	12	$ 66.00	$ 792	$ -	$ 6,292
Solar Panel Site	4 foot x 10 foot plastic solar panels	336 each	950.00	4.000		$ 319,200	1,344	$ 66.00	$ 88,704	$ -	$ 407,904
Solar Panel Site	Lighting and Grounding	1 lot	11,000.00	200.000		$ 11,000	200	$ 66.00	$ 13,200	$ -	$ 24,200

RELIANT ENERGY - INDIAN RIVER STATION - MANATEE REFUGE ... SOLAR PANEL SITE

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Location	Bill of Materials Item	Quantity	Unit Costs Unit Mat'l Cost	Unit WHs	Unit SubContr Specialty Cost	Estimated Present Day Construction Costs Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
	SUBTOTALS - Solar Panel Site - Present Day Costs					$ 1,282,822	14,057		$ 927,762	$ -	$ 2,210,584
	CONTINGENCY									10.0%	$ 221,059
	SUBCONTRACT CONSTRUCTION COST										$ 2,431,643
	SALES/USE TAXES										NOT INCLUDED
	ENGINEERING - Solar Panel Site									5.0%	$ 121,583
	CONSTRUCTION MANAGEMENT										BY OWNER
	START UP COSTS										NOT INCLUDED
	PERMITS										BY OWNER
	OTHER OWNER COSTS										BY OWNER

RELIANT ENERGY - INDIAN RIVER STATION - MANATEE REFUGE ... OPTIONAL ENCLOSURE ROOF

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Location	Item	Quantity	Unit Matl Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Enclosure Optional	Fiberglass Rectangular Tubes: 5-1/2" x 24" x 25 feet long	46 reqd	7,425.00	8.000		$ 341,550	368	$ 66.00	$ 24,288	$ -	$ 365,838
Enclosure Optional	12 WF Fiberglass x 50'-06" feet long	2 reqd	4,890.00	12.000		$ 9,780	24	$ 66.00	$ 1,584	$ -	$ 11,364
Enclosure Optional	Fiberglass Angles 6" x 6" x 50'-06" feet long	2 reqd	1,780.00	12.000		$ 3,560	24	$ 66.00	$ 1,584	$ -	$ 5,144
Enclosure Optional	Chain link fencing: 8' high with fiberglass fence posts and fiberglass plate post base plates	200 lnft	47.00	0.300		$ 9,400	60	$ 66.00	$ 3,960	$ -	$ 13,360
	SUBTOTALS - Enclosure Roof Option - Present Day Costs					$ 364,290	476		$ 31,416	$ -	$ 395,706
	CONTINGENCY									10.0%	$ 39,571
	SUBCONTRACT CONSTRUCTION COST										$ 435,277
	SALES/USE TAXES										NOT INCLUDED
	ENGINEERING - Enclosure Roof Option									5.0%	$ 21,764
	CONSTRUCTION MANAGEMENT										BY OWNER
											NOT INCLUDED
	PERMITS										BY OWNER
	OTHER OWNER COSTS										BY OWNER

Reliant Energy Indian River Station -
Manatee Refuge ... All Areas

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Bill of Materials			Unit Costs			Estimated Present Day Construction Costs					
Location	Item	Quantity	Unit Matl Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Enclosure	Steel "H" Piles-HP14x73 x 30 feet long - Galvanized with 15 mil coal tar epoxy coating: 10 lb zinc anode bolted to each	2 each			6,150.00	$ -	-	$ 66.00	$ -	$ 12,300	$ 12,300
Enclosure	Steel "H" Piles-HP14x73 x 20 feet long - Galvanized with 15 mil coal tar epoxy coating: 10 lb zinc anode bolted to each	3 each			4,125.00	$ -	-	$ 66.00	$ -	$ 12,375	$ 12,375
Enclosure	Steel "H" Piles-HP14x73 x 30 feet long - piece of PS31 steel sheet piling welded to each for full length-Galvanized with 15 mil coal tar epoxy coating: 10 lb zinc anode bolted to each	2 each			9,850.00	$ -	-	$ 66.00	$ -	$ 19,700	$ 19,700
Enclosure	Steel "H" Piles - HP14x73 x 20 feet long- piece of PS31 steel sheet piling welded to each for full length-Galvanized with 15 mil coal tar epoxy coating: 10 lb zinc anode bolted to each	6 each			6,600.00	$ -	-	$ 66.00	$ -	$ 39,600	$ 39,600
Enclosure	Fiberglass Reinforced Plastic Lumber lagging: 12" x 06", 25 feet length	92 each	990.00	6.250		$ 91,080	575	$ 66.00	$ 37,950	$ -	$ 129,030
Enclosure	Fiberglass Reinforced Plastic Lumber lagging: 12" x 06", 16.67 feet length	54 each	660.00	5.000		$ 35,640	270	$ 66.00	$ 17,820	$ -	$ 53,460
Enclosure	Fiberglass Reinforced Plastic Lumber lagging: 12" x 06", 08.50 feet length	32 each	340.00	3.750		$ 10,880	120	$ 66.00	$ 7,920	$ -	$ 18,800
Enclosure	Cut horizontal slots in lagging, insert fiberglass flat strip in facing notches of Lagging		included above in fiberglass lagging costs								
Enclosure	Solid Fiberglass Plate, 1/2" th x 3'-00" dp, attach to two lowest lagging sections w/ 1/2" fiberglass threaded rods and nuts	615 sqft	12.00	0.312		$ 7,380	192	$ 66.00	$ 12,672	$ -	$ 20,052
Enclosure	Water Jetting to enable setting of two lowest lagging sections w/ 1/2" x 3'-00" solid fiberglass plate attached, with allowance for manual backfill with indigenous material	205 lnft	-	0.390		$ -	80	$ 66.00	$ 5,280	$ -	$ 5,280
Enclosure	8 foot x 4 foot fiberglass entrance frame composed of 11.50 inch x 2.75 inch channels: total 28 feet of channel required - assembled	2 each	1,400.00	14.000		$ 2,800	28	$ 66.00	$ 1,848	$ -	$ 4,648
Enclosure	Secure Fiberglass Channel entrance framing to contiguous wall	52 each	11.00	1.250		$ 572	65	$ 66.00	$ 4,290	$ -	$ 4,862
Enclosure	Timber lagging ties: (vertically flank 8'w x 4'h lagging openings) 6" x 6" x 1/2" x 9 feet Fiberglass Angles outside of enclosure plus 4" x 1/4" x 9 feet Fiberglass Square Tubes - angles and tubes through bolted with 1/2" fiberglass threaded rods and nuts	4 locs									

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Enclosure	Fiberglass Angles 6" x 6" x 1/2" x 9 feet which vertically flank 8'w x 4'h lagging openings	36 lnft	33.00	0.333		$ 1,188	12	$ 66.00	$ 792	$ -	$ 1,980
Enclosure	Fiberglass Tubes 4" x 1/4" x 9 feet which vertically flank 8'w x 4'h lagging openings	36 lnft	21.00	0.333		$ 756	12	$ 66.00	$ 792	$ -	$ 1,548
Enclosure	Secure fiberglass angles and tubes which vertically flank 8'w x 4'h lagging openings with 1/2" Fiberglass Threaded Through Rods and Fiberglass End Fasteners	40 each	8.80	1.250		$ 352	50	$ 66.00	$ 3,300	$ -	$ 3,652
Enclosure	Triangular grating platform: vinyl ester resin fiberglass grating; 1/4 inch bearing bars, 1 inch deep, 1-1/2 inches on center with embedded angular grit, attach with bronze lag bolts	32 sqft	52.00	1.000		$ 1,664	32	$ 66.00	$ 2,112	$ -	$ 3,776
Enclosure	Heat Exchanger Support Angles: Fiberglass Angle, 6 inch x 6 inch x 1/2 inch, bolted to lagging with 1/2" diam fiberglass threaded rods and nuts	118 lnft	33.50	0.220		$ 3,953	26	$ 66.00	$ 1,716	$ -	$ 5,669
Enclosure	Fiberglass Fastener Sets, 1/2" diam, top row lagging to heat exchanger support angles	120 each	7.70	1.000		$ 924	120	$ 66.00	$ 7,920	$ -	$ 8,844
Enclosure	Fiberglass Fastener Sets, heat exchanger support angle to heat exchanger top header strap support	26 each	66.00	1.000		$ 1,716	26	$ 66.00	$ 1,716	$ -	$ 3,432
Enclosure	Fiberglass Fastener Sets, lagging laterally to heat exchanger top header	26 each	66.00	1.500		$ 1,716	39	$ 66.00	$ 2,574	$ -	$ 4,290
Enclosure	Fiberglass Fastener Sets, lagging tie to heat exchanger protective vertical grating	52 each	88.00	2.000		$ 4,576	104	$ 66.00	$ 6,864	$ -	$ 11,440
Enclosure	Fiberglass Fastener Sets, lagging laterally to heat exchanger bottom header	26 each	66.00	1.500		$ 1,716	39	$ 66.00	$ 2,574	$ -	$ 4,290
Enclosure	Heat exchanger protective grating - vinyl ester resin fiberglass grating; 1/2 inch bearing bars, 1.5 inch deep, 1-1/2 x 6 inches on center-attached to fiberglass 3 x 3 angle structure @ 3 ft ctrs and to lagging with 2-1/2 inch diam fiberglass threaded rods/nuts @ 5 ft ctrs	660 sqft	28.50	0.097		$ 18,810	64	$ 66.00	$ 4,224	$ -	$ 23,034
Enclosure	Fiberglass 3 x 3 Angle Structure to support Heat Exchanger Protective Grating, spaced @ 3 ft ctrs with logitudinal bracing and connected to lagging with 1/2 inch diam fiberglass threaded rods/nuts at top and bottom elevations	600 lnft	19.00	0.640		$ 11,400	384	$ 66.00	$ 25,344	$ -	$ 36,744
Enclosure	Fiber Reinforced Polymer Coping encompassing top elevation perimeter of lagging members, attached with brass lag screws	200 lnft	52.75	1.200		$ 10,550	240	$ 66.00	$ 15,840	$ -	$ 26,390

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Enclosure	Cement Grout Fill Voids where required along Vertical Joints where lagging meets HP web	50 cuft	33.00	0.960		$ 1,650	48	$ 66.00	$ 3,168	$ -	$ 4,818
Enclosure	Oakum Caulk 1 side of vertical joints where Lagging meets HP web	180 lnft	2.75	0.333		$ 495	60	$ 66.00	$ 3,960	$ -	$ 4,455
Gas Heater Site	Gas Heater Embankment (compacted soil)	220 cuyd	16.50	0.218		$ 3,630	48	$ 66.00	$ 3,168	$ -	$ 6,798
Gas Heater Site	Gravel Fill, 3" dp layer	108 sqyd	1.65	0.037		$ 178	4	$ 66.00	$ 264	$ -	$ 442
Gas Heater Site	Rip Rap, 12" dp layer, 9" D50 Stone	108 sqyd	11.00	0.222		$ 1,188	24	$ 66.00	$ 1,584	$ -	$ 2,772
Gas Heater Site	Concrete foundations: 4000 psi reinforced concrete	10 cuyd	230.00	10.000		$ 2,300	100	$ 66.00	$ 6,600	$ -	$ 8,900
Solar Panel Site	Concrete foundations: 4000 psi reinforced concrete	40 cuyd	230.00	10.000		$ 9,200	400	$ 66.00	$ 26,400	$ -	$ 35,600
Solar Panel Site	Solar panel support frames: constructed of 4 inch x 4 inch x 1/2 inch thick fiberglass angles-92 feet of angle required for each frame-assembled	30,912 lnft	18.85	0.043		$ 582,691	1,344	$ 66.00	$ 88,704	$ -	$ 671,395
Solar Panel Site	Pipe sleepers - 9 inch x 6 inch x 6 inches deep concrete pads with strap anchors for pipes	1,424 each	55.00	1.500		$ 78,320	2,136	$ 66.00	$ 140,976	$ -	$ 219,296
Gas Heater Site	Trenching: Gas line + Water Supply line + Power line: 3 feet wide x 3 feet deep x 1000 feet each	1,000 cuyd	6.60	0.280		$ 6,600	280	$ 66.00	$ 18,480	$ -	$ 25,080
Enclosure	Trenching in water: 10" Hot Water Supply to and Return from Refuge Heat Exchanger	0 cuyd	13.20	0.400		$ -	-	$ 66.00	$ -	$ -	$ -
Solar Panel Site	10 inch diameter PVC Schedule 40 landside	600 lnft	28.50	0.600		$ 17,100	360	$ 66.00	$ 23,760	$ -	$ 40,860
Solar Panel Site	10 inch diameter PVC Insulation 2" FBG w/ cover landside	600 lnft	7.00	0.240		$ 4,200	144	$ 66.00	$ 9,504	$ -	$ 13,704
Solar Panel Site	6 inch diameter PVC Schedule 40 pipe insulated - landside	5,600 lnft	9.00	0.400		$ 50,400	2,240	$ 66.00	$ 147,840	$ -	$ 198,240
Solar Panel Site	6 inch diameter PVC Insulation 2" FBG w/ cover - landside	5,600 lnft	4.80	0.160		$ 26,880	896	$ 66.00	$ 59,136	$ -	$ 86,016
Solar Panel Site	6 inch diameter PVC Schedule 40 tees	800 each	60.50	2.160		$ 48,400	1,728	$ 66.00	$ 114,048	$ -	$ 162,448
Solar Panel Site	1-1/2 inch diameter PVC Schedule 40 reducer inserts	800 each	18.00	1.310		$ 14,400	1,048	$ 66.00	$ 69,168	$ -	$ 83,568
Solar Panel Site	6 inch diameter PVC Schedule 40 globe valves	28 each	770.00	4.000		$ 21,560	112	$ 66.00	$ 7,392	$ -	$ 28,952
Solar Panel Site	10 inch diameter PVC Schedule 40 motor operated globe valves	2 each	4,400.00	10.000		$ 8,800	20	$ 66.00	$ 1,320	$ -	$ 10,120

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Location	Item	Quantity	Unit Matl Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Solar Panel Site	1-1/2 inch diameter PVC Schedule 40 pipe	4,100 lnft	3.30	0.300		$ 13,530	1,230	$ 66.00	$ 81,180	$ -	$ 94,710
Solar Panel Site	1-1/2 inch diameter PVC Insulation 2" FBG w/ cover - landside	4,100 lnft	3.05	0.140		$ 12,505	574	$ 66.00	$ 37,884	$ -	$ 50,389
Solar Panel Site	1-1/2 inch diameter PVC Schedule 40 globe valves	672 each	88.00	0.400		$ 59,136	269	$ 66.00	$ 17,754	$ -	$ 76,890
Solar Panel Site	Solar Panel Pump- 1300 gpm/4 psi: 5 HP horizontal	1 each	5,500.00	12.000		$ 5,500	12	$ 66.00	$ 792	$ -	$ 6,292
Gas Heater Site	Gas Heater Pump - 1,300 gpm / 15 psi, 15 HP horizontal	1 each	13,200.00	12.000		$ 13,200	12	$ 66.00	$ 792	$ -	$ 13,992
Solar Panel Site	4 foot x 10 foot plastic solar panels	336 each	950.00	4.000		$ 319,200	1,344	$ 66.00	$ 88,704	$ -	$ 407,904
Solar Panel Site	Lighting and Grounding	1 lot	11,000.00	200.000		$ 11,000	200	$ 66.00	$ 13,200	$ -	$ 24,200
Gas Heater Site	Storage/Surge Tank: 3 feet diameter x 15 feet high fiberglass vented tank	1 each	2,200.00	8.000		$ 2,200	8	$ 66.00	$ 528	$ -	$ 2,728
Gas Heater Site	Auxiliary Heater - Gas fired, 5,200,000 BTU/hr	1 each	66,000.00	200.000		$ 66,000	200	$ 66.00	$ 13,200	$ -	$ 79,200
Gas Heater Site	Gas pipe: 2 inch plastic	1,000 lnft	11.00	0.240		$ 11,000	240	$ 66.00	$ 15,840	$ -	$ 26,840
Gas Heater Site	Water Supply pipe: 2 inch diameter PVC Schedule 40	1,000 lnft	2.55	0.240		$ 2,550	240	$ 66.00	$ 15,840	$ -	$ 18,390
Gas Heater Site	10 inch diameter PVC Schedule 40 landside	200 lnft	28.50	0.600		$ 5,700	120	$ 66.00	$ 7,920	$ -	$ 13,620
Gas Heater Site	10 inch diameter PVC Insulation 2" FBG w/ cover landside	200 lnft	7.00	0.240		$ 1,400	48	$ 66.00	$ 3,168	$ -	$ 4,568
Gas Heater Site	10 inch diameter PVC Schedule 40 motor operated globe valves	2 each	4,400.00	10.000		$ 8,800	20	$ 66.00	$ 1,320	$ -	$ 10,120
Enclosure	Heat exchanger: copper materials of construction	1 each	550,000.00	400.000		$ 550,000	400	$ 66.00	$ 26,400	$ -	$ 576,400
Enclosure	10 inch diameter PVC Schedule 40 waterside	250 lnft	28.50	0.600		$ 7,125	150	$ 66.00	$ 9,900	$ -	$ 17,025
Enclosure	10 inch diameter PVC Insulation 2" FBG w/ cover waterside	250 lnft	7.00	0.240		$ 1,750	60	$ 66.00	$ 3,960	$ -	$ 5,710
Enclosure	16 inch diameter Cover Pipe encapsulating insulated 10 inch diameter PVC Schedule 40 Hot Water Supply to and Return from Refuge Heat Exchanger (Cu matls of constr)	250 lnft	52.75	0.400		$ 13,188	100	$ 66.00	$ 6,600	$ -	$ 19,788

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Bill of Materials			Unit Costs			Estimated Present Day Construction Costs					
Location	Item	Quantity	Unit Matl Cost	Unit WHs	Unit SubContr Specialty Cost	Materials	Work Hours	Composite Craft Wage Rate	Direct Labor	Specialty SubContract	Total
Gas Heater Site	Power supply cable 480v: 3-1/c-4/0 AWG + Ground	1,000 lnft	3.50	0.056		$ 3,500	56	$ 66.00	$ 3,696	$ -	$ 7,196
Gas Heater Site	Terminations	16 each	9.20	0.700		$ 147	11	$ 66.00	$ 726	$ -	$ 873
Gas Heater Site	Pull Box	2 each	425.00	1.600		$ 850	3	$ 66.00	$ 198	$ -	$ 1,048
Gas Heater Site	Power supply cable conduit RGS in Trench	1,000 lnft	5.50	0.400		$ 5,500	400	$ 66.00	$ 26,400	$ -	$ 31,900
Gas Heater Site	Trenching: Conduit ... included in Trenching: Gas line + Water Supply line + Power line										
Gas Heater Site	Photovoltaic cell	1 each	138.00	6.000		$ 138	6	$ 66.00	$ 396	$ -	$ 534
Gas Heater Site	480v Motor Control Center: 2 vertical stacks - NEMA 3 enclosure, 4 - size 1 reversing starters, 1 - size 1 nonreversing starter, 1 - size 2 nonreversing starter, 1 - single phase 480/120v 5 KVA transformer, 1 - 120v distribution panel - 12 circuits	1 each	11,000.00	32.000		$ 11,000	32	$ 66.00	$ 2,112	$ -	$ 13,112
Gas Heater Site	Single phase 480/120v 5 KVA transformer	1 each	457.00	8.000		$ 457	8	$ 66.00	$ 528	$ -	$ 985
Gas Heater Site	120v distribution panel - 12 circuits	1 each	517.00	10.000		$ 517	10	$ 66.00	$ 660	$ -	$ 1,177
Gas Heater Site	Lighting and Grounding	1 lot	2,200.00	40.000		$ 2,200	40	$ 66.00	$ 2,640	$ -	$ 4,840
Enclosure	Power supply to navigation light 2:1/c + ground - 4/0 AWG	400 lnft	2.60	0.042		$ 1,040	17	$ 66.00	$ 1,122	$ -	$ 2,162
Enclosure	Power supply cable conduit RGS in Trench	400 lnft	5.50	0.400		$ 2,200	160	$ 66.00	$ 10,560	$ -	$ 12,760
Enclosure	Terminations	6 each	9.20	0.700		$ 55	4	$ 66.00	$ 264	$ -	$ 319
Enclosure	Pull Box	1 each	425.00	1.600		$ 425	2	$ 66.00	$ 132	$ -	$ 557
Enclosure	Thermocouple at enclosure	1 each	550.00	4.000		$ 550	4	$ 66.00	$ 264	$ -	$ 814
Enclosure	Instrumentation wiring to thermocouple 2:1/c 16 AWG	400 lnft	0.25	0.020		$ 100	8	$ 66.00	$ 528	$ -	$ 628
Enclosure	Thermocouple wire conduit RGS in Trench	400 lnft	5.50	0.400		$ 2,200	160	$ 66.00	$ 10,560	$ -	$ 12,760
Enclosure	Terminations	4 each	5.80	0.130		$ 23	1	$ 66.00	$ 66	$ -	$ 89
Enclosure	Pull Box	1 each	11.00	1.000		$ 11	1	$ 66.00	$ 66	$ -	$ 77

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Gas Heater Site	Misc Instrumentation, e.g. pressure gauges	1 lot	11,000.00	80.000		$ 11,000	80	$ 66.00	$ 5,280	$ -	$ 16,280
Gas Heater Site	PLC	1 each	5,500.00	40.000		$ 5,500	40	$ 66.00	$ 2,640	$ -	$ 8,140
Enclosure	Navigation light	1 each	220.00	4.000		$ 220	4	$ 66.00	$ 264	$ -	$ 484
	SUBTOTALS - Enclosure, Gas Heater Site, Solar Panel Site - Present Day Costs					$ 2,237,082	19,744		$ 1,303,104	$ 83,975	$ 3,624,161
	CONTINGENCY									10.0%	$ 362,418
	SUBCONTRACT CONSTRUCTION COST										$ 3,986,579
	SALES/USE TAXES										NOT INCLUDED
	ENGINEERING - Enclosure, Gas Heater Site, Solar Panel Site									5.0%	$ 199,331
	CONSTRUCTION MANAGEMENT										BY OWNER
	START UP COSTS										NOT INCLUDED
	PERMITS										BY OWNER
	OTHER OWNER COSTS										BY OWNER

Appendix F

Recommended Project Design Scope of Work
For Preparing Engineering Plans

Prepared by Washington Group International, Inc.
for Reliant Energy 30 June 2005

The Engineer's scope of work shall consist of the design of a square enclosure in the Indian River that will be used as a thermal refuge for manatees in winter months, a gas fired heating system, with provision for adding a solar heating system in the future, along with all controls and utility connections and all supports and foundations for the system components. Assistance in the licensing of the project and procurement of the major pieces of equipment, assistance in securing firm price bids for construction and support during construction will also be required.

The manatee refuge water heating system and enclosure design will include the following:

1. A 50 foot square enclosure including a viewing platform and two entrances
2. A copper heat exchanger within the enclosure with protective grating
3. A gas fired heater
4. All interconnecting piping and valving between the heater and heat exchanger
5. All necessary controls for automatic operation of the system
6. All necessary foundations
7. Utility connections to provide electric, gas and fresh water
8. Provisions for a future solar panel heating array to be connected in parallel with the gas fired heater
9. Provision to allow the installation of a removable roof in the future

All of the above shall be designed in accordance with the Manatee Refuge Design Basis.

Engineer shall direct the drilling of one borehole in the Indian River for the purposes of geotechnical investigation and analyze the boring log and subsequent laboratory studies to develop the foundation requirements for the refuge enclosure.

Engineer shall perform a material study in detail of the enclosure material possibilities identified in the Design Basis and make a recommendation either confirming the material and construction presently presented or recommending another material and design based on material costs, installation costs and insulation value.

Engineer shall prepare scaled drawings defining the complete project in detail sufficient for securing firm price proposals for the construction of the project and for proceeding with the construction. Drawings shall be in MicroStation or AutoCAD. Engineer shall deliver an electronic copy of all drawings at the completion of design along with 12 hardcopy sets ready for bidding.

Engineer shall prepare specifications for the following:

1. Heat exchanger
2. Pump(s)
3. Gas fired heater
4. Piping
5. Mechanical installation
6. Motor(s)
7. Motor control center
8. Electrical installation
9. PLC
10. Geotechnical investigation
11. Piling
12. Recycled Plastic Lumber lagging
13. Concrete construction
14. Fiberglass structural members
15. Other specifications as required by the final design

Specifications shall be prepared in Microsoft Word format and an electronic copy of all specifications shall be delivered at the completion of design along with 12 hardcopy sets ready for bidding.

All drawings and specifications shall be prepared under the supervision of a Registered Professional Engineer in the State of Florida and shall be signed and sealed by that Professional Engineer.

Engineer shall evaluate the scour potential from the plant circulating water discharge from the canal around the enclosure. Engineer shall also evaluate the deposition potential from longshore drift along the shore of the Indian River. Recommendations on protection from scour and deposition, if found to be severe, shall be made by the Engineer.

Engineer shall provide technical support, including preparation of necessary drawings and text, in securing the following permits:

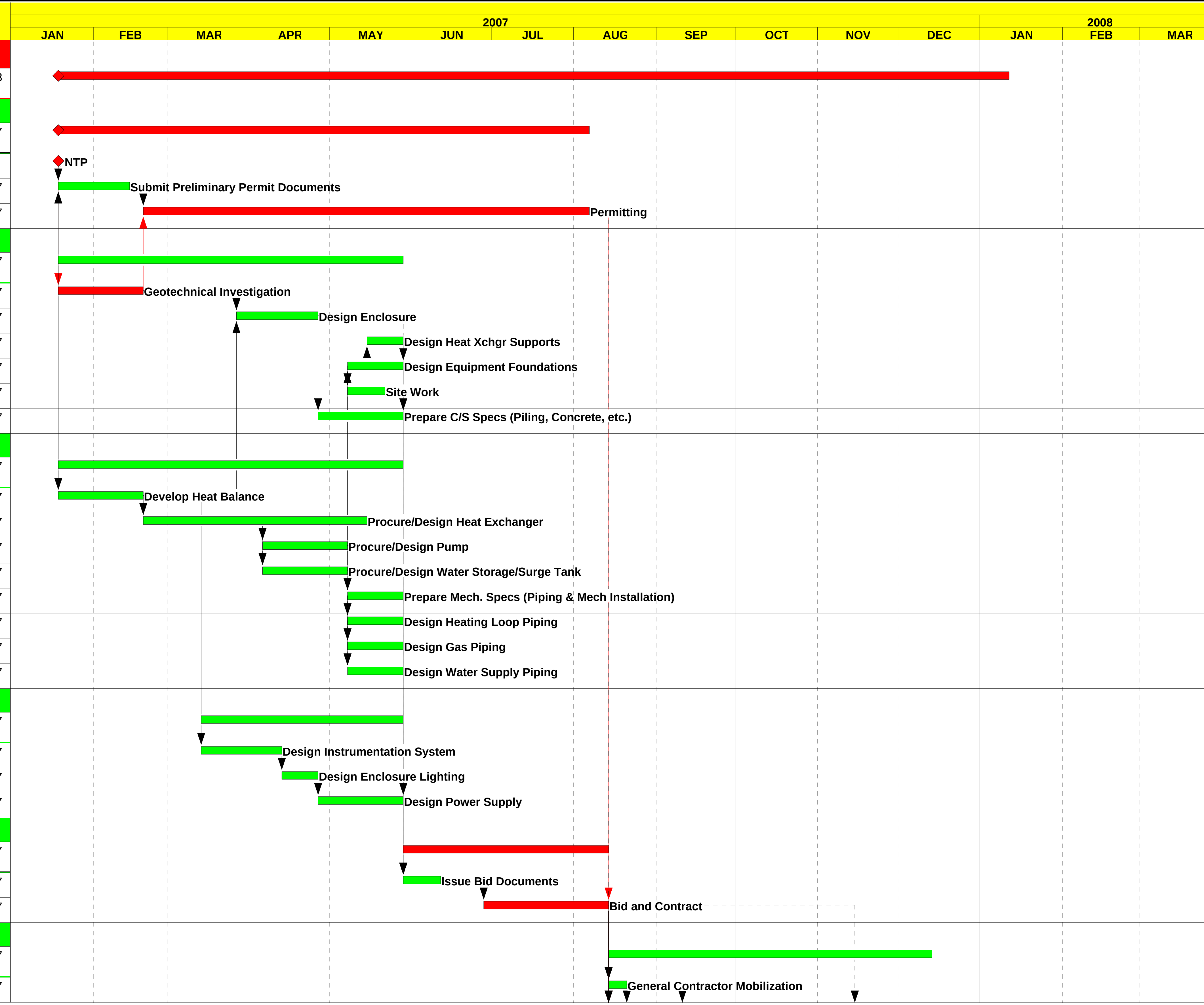
- U.S. Army Corp of Engineers 404 Permit
- DEP Environmental Resource Permit
- U.S. Fish & Wildlife Marine Mammal Enhancement or Scientific Research Permit
- County Building Permit
- Modifications to the NPDES Permit
- Submerged Land Process
- Coast Guard Navigation Safety Permit

Engineer shall provide support during construction by answering questions from the construction contractor and providing clarification of the drawings and specifications as necessary. Engineer shall periodically inspect the construction work to assure conformance with the drawings and specifications.

The design shall be as defined in the Project Description, in the Design Basis and on the three drawings:

27709-1	Site Plan
27709-2	Refuge Enclosure
27709-3	Flow Diagram

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
Indian River Manatee Refuge Design				
Total		256	01/19/07	01/11/08
Permitting				
Subtotal		142	01/19/07	08/06/07
MR1000	NTP	0	01/19/07*	
MR1010	Submit Preliminary Permit Documents	19	01/19/07*	02/14/07
MR1020	Permitting	120	02/20/07	08/06/07
Civil/Structural Design				
Subtotal		92	01/19/07	05/28/07
MR2015	Geotechnical Investigation	22	01/19/07	02/19/07
MR2020	Design Enclosure	23	03/27/07	04/26/07
MR2030	Design Heat Xchgr Supports	10	05/15/07	05/28/07
MR2050	Design Equipment Foundations	15	05/08/07	05/28/07
MR2060	Site Work	10	05/08/07	05/21/07
MR2070	Prepare C/S Specs (Piling, Concrete, etc.)	22	04/27/07	05/28/07
Mechanical Design				
Subtotal		92	01/19/07	05/28/07
MR2120	Develop Heat Balance	22	01/19/07	02/19/07
MR2140	Procure/Design Heat Exchanger	60	02/20/07	05/14/07
MR2160	Procure/Design Pump	22	04/06/07	05/07/07
MR2170	Procure/Design Water Storage/Surge Tank	22	04/06/07	05/07/07
MR2180	Prepare Mech. Specs (Piping & Mech Installation)	15	05/08/07	05/28/07
MR2185	Design Heating Loop Piping	15	05/08/07	05/28/07
MR2190	Design Gas Piping	15	05/08/07	05/28/07
MR2195	Design Water Supply Piping	15	05/08/07	05/28/07
Electrical Design				
Subtotal		54	03/14/07	05/28/07
MR2330	Design Instrumentation System	22	03/14/07	04/12/07
MR2340	Design Enclosure Lighting	10	04/13/07	04/26/07
MR2350	Design Power Supply	22	04/27/07	05/28/07
Contractor Bid Package				
Subtotal		55	05/29/07	08/13/07
MR2410	Issue Bid Documents	10	05/29/07*	06/11/07
MR2420	Bid and Contract	33	06/28/07	08/13/07
Procurement/Fabrication of Equipment/Materials				
Subtotal		88	08/14/07	12/13/07
MR2510	General Contractor Mobilization	5	08/14/07	08/20/07



Start Date	12/14/05
Finish Date	01/11/08
Data Date	06/26/06
Run Date	06/27/06 13:21

Early Bar
Progress Bar
Critical Activity

MRDC

Sheet 1 of 2

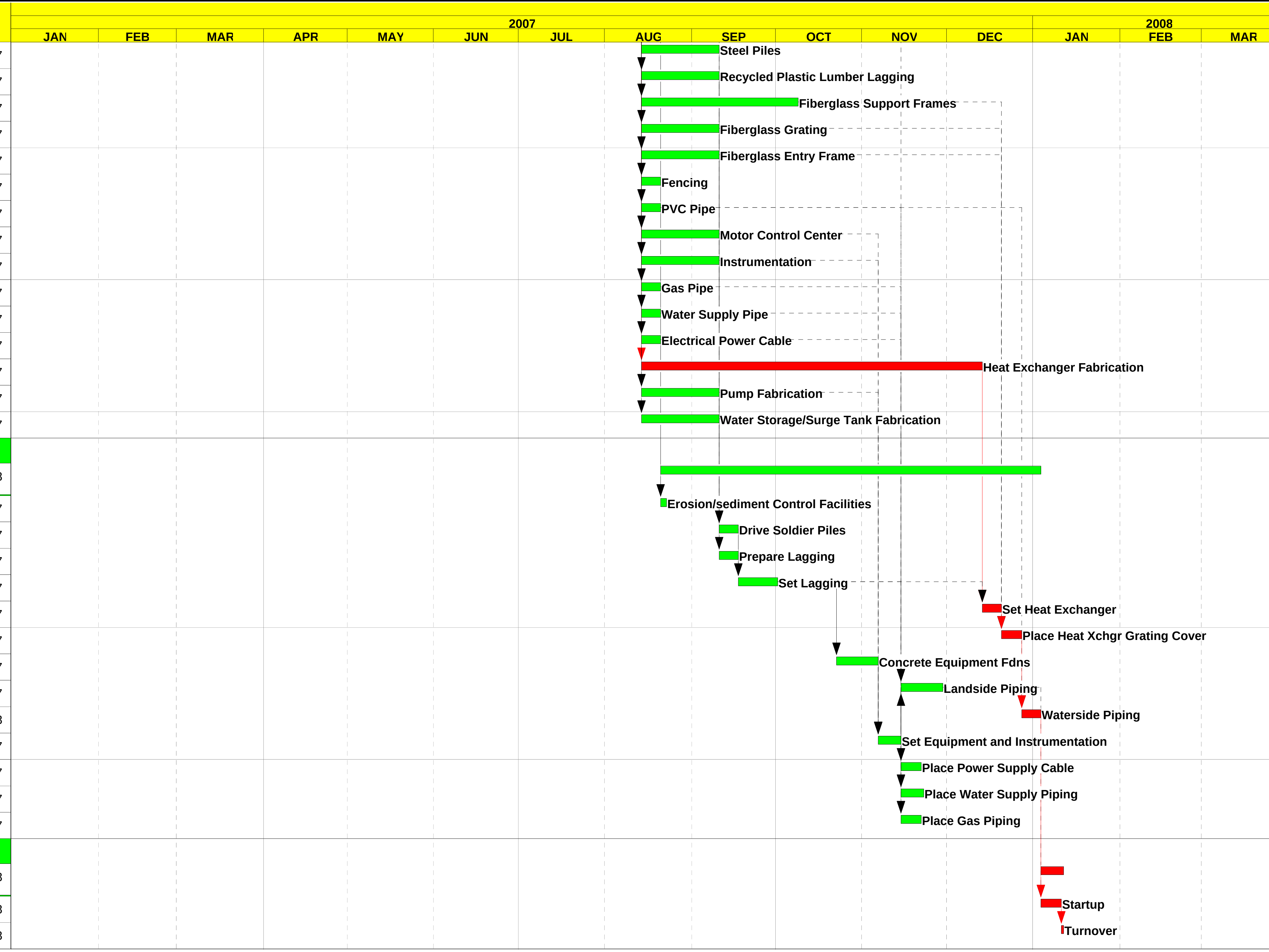
Reliant Energy

Indian River Station - Manatee Refuge - Stage I
Design/Construction Schedule

Date	Revision	Checked	Approved
06/26/06	Revised Schedule		

Washington Group International
Integrated Engineering, Construction, and Management Solutions

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
MR2520	Steel Piles	20	08/14/07	09/10/07
MR2530	Recycled Plastic Lumber Lagging	20	08/14/07	09/10/07
MR2540	Fiberglass Support Frames	40	08/14/07	10/08/07
MR2550	Fiberglass Grating	20	08/14/07	09/10/07
MR2560	Fiberglass Entry Frame	20	08/14/07	09/10/07
MR2570	Fencing	5	08/14/07	08/20/07
MR2590	PVC Pipe	5	08/14/07	08/20/07
MR2610	Motor Control Center	20	08/14/07	09/10/07
MR2620	Instrumentation	20	08/14/07	09/10/07
MR2630	Gas Pipe	5	08/14/07	08/20/07
MR2640	Water Supply Pipe	5	08/14/07	08/20/07
MR2650	Electrical Power Cable	5	08/14/07	08/20/07
MR2660	Heat Exchanger Fabrication	88	08/14/07	12/13/07
MR2670	Pump Fabrication	20	08/14/07	09/10/07
MR2680	Water Storage/Surge Tank Fabrication	20	08/14/07	09/10/07
Construction Execution				
Subtotal		98	08/21/07	01/03/08
MR2720	Erosion/sediment Control Facilities	2	08/21/07	08/22/07
MR2730	Drive Soldier Piles	5	09/11/07	09/17/07
MR2740	Prepare Lagging	5	09/11/07	09/17/07
MR2750	Set Lagging	10	09/18/07	10/01/07
MR2760	Set Heat Exchanger	5	12/14/07	12/20/07
MR2770	Place Heat Xchgr Grating Cover	5	12/21/07	12/27/07
MR2810	Concrete Equipment Fdns	11	10/23/07	11/06/07
MR2830	Landside Piping	11	11/15/07	11/29/07
MR2840	Waterside Piping	5	12/28/07	01/03/08
MR2850	Set Equipment and Instrumentation	6	11/07/07	11/14/07
MR2860	Place Power Supply Cable	5	11/15/07	11/21/07
MR2870	Place Water Supply Piping	6	11/15/07	11/22/07
MR2880	Place Gas Piping	5	11/15/07	11/21/07
Commissioning				
Subtotal		6	01/04/08	01/11/08
MR2910	Startup	5	01/04/08	01/10/08
MR2920	Turnover	1	01/11/08	01/11/08



Start Date	12/14/05
Finish Date	01/11/08
Data Date	06/26/06
Run Date	06/27/06 13:21

Early Bar
Progress Bar
Critical Activity

MRDC

Sheet 2 of 2

Reliant Energy

Indian River Station - Manatee Refuge - Stage I
Design/Construction Schedule

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