SOUTH LAKE WORTH INLET:
INLET MODIFICATION FEASIBILITY STUDY

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ABSTRACT

This paper highlights the results of the recent feasibility study of South Lake Worth Inlet in Palm Beach County, Florida. This study was initiated to assess two major issues; whether changes to the inlet could be made to improve the lagoon environment through increased flushing and whether changes to the inlet could be made to improve boater/public safety.

This effort involved multiple tasks including stakeholder input on inlet conditions, review of historic studies and accident records, engineering evaluation and modeling of alternatives and the development of an alternatives matrix which ranked each alternative based on various technical, environmental and permitting criteria.

South Lake Worth Inlet (also known as Boynton Inlet) was initially cut in the 1930's in an attempt to improve water quality in Lake Worth Lagoon. The inlet cut was made through the barrier island between Lake Worth Inlet (to the north) and Boca Inlet (to the south). Ongoing concerns about degrading water quality in Lake Worth Lagoon and navigation safety have led to an investigation into potential structural and non-structural modifications to the inlet.

This paper focuses on elements relating to littoral processes (i.e., potential changes to tidal prism, subsequent alterations to shoal formations, interruption of sediment transports, etc.) while briefly touching upon water quality and navigation safety issues (tidal exchange and flushing, inlet current velocity fields, etc.). Hydrodynamic models, including ADCIRC and EFDC were developed to evaluate flushing and tidal current changes. The resultant tidal current fields from ADCIRC were then fed into a 2-D Boussinesq model to evaluate changes to wave fields and current/wave interaction.

The results of the study are highlighted along with discussion of viable alternatives and recommendations for a future path forward.

INTRODUCTION

Applied Technology & Management (ATM) was contracted by the City of Boynton Beach (City) to assess the current conditions of the South Lake Worth Inlet with respect to improving boater safety and water quality in the Lake Worth Lagoon. The intent of this study was to determine possible inlet modifications to address these two concerns.

Key assessment parameters used to rank alternatives included: 1) Improvements to Navigation Safety; 2) Improvements to Lagoon Water Quality; 3) Permit-ability; 4) Environmental Impacts; 5) Other Secondary Impacts; 6) Construction Cost and Timeline; and, 7) Overall Effectiveness of Achieving Goals.

In addition to ATM's work and evaluations, public stakeholder feedback was solicited as a part of the study process. Prior to initiating field work and engineering assessments, a public workshop was held on August 8, 2007 during which the purpose and scope of the study was outlined and a question and answer session was held to solicit feedback and concerns about the inlet's existing condition and proposed changes. A survey form was provided to all attendees and posted on the internet for additional public input.

In general, this study looked at a full range of potential inlet modifications, ranging from small to large in scale, complexity, and cost. Five structural changes and a number of non-structural (management and operational) changes were evaluated. Each alternative was developed with one of two key goals in mind: 1) improve lagoon flushing and water quality; and, 2) improve navigation safety through the inlet.

As part of this work, ATM performed an extensive review of the inlet's history and current inlet and beach management programs. Additionally, numerous local resources were interviewed with data collected from the Palm Beach County's Department of Environmental Resource Management, Sheriff's Office, and Ocean Rescue to name a few. ATM collected additional field data and developed a numerical flushing model that included nearshore ocean waters and intracoastal waters from Palm Beach Inlet to Boca Inlet. Engineering efforts included limited design evaluations, construction cost estimates, as well as anticipated construction methods and time requirements. Coupled with assessments of the existing marine resources, ATM was able to build a ranking matrix suitable for comparison of the proposed inlet modifications.

Inlet History and Current Inlet Conditions

South Lake Worth Inlet was originally constructed primarily as a measure to improve the declining water quality in the Lake Worth Lagoon. At that time it was not deemed necessary for shipping and transportation. Prior to construction

of the South Lake Worth Inlet, the Legislature of Florida created a special taxing district (the South Lake Worth Inlet District) whose Board of Commissioners was authorized to construct and maintain an inlet.

The U.S. Army Corps of Engineers issued a permit for construction of the inlet in 1924 and construction commenced in 1925. After completion of the jetties and the channel bulkhead, the final cut opening the lagoon to the ocean was made in March 1927. The original channel was approximately 130 feet wide and averaged 8 feet deep. Soon after the initial opening of the inlet, sand impounded on the north jetty began to spill into the channel and form a large flood shoal inside the lagoon. The impounded sand along the north jetty and the formation of the flood shoal led to erosion on the south side of the inlet and consequently the construction of a 2,000-foot long seawall known as the "McCormick wall" in 1932. Soon after, a series of groins were built in front of the seawall by the same property owner in an attempt to protect the seawall from undermining.

The volume of sand entering the lagoon was high enough to necessitate raising the elevation of the jetties from +5 feet Mean Low Water (MLW) to +12 feet MLW and installing a fixed sand bypassing plant, accomplished in 1936 and 1937, respectively. Despite these modifications, interior shoaling remained a problem causing decreases in tidal flow and hazardous navigation conditions and requiring continuous maintenance dredging.

To help reduce the interior shoaling along the north side of the inlet, a training wall and weir were constructed in 1953. The University of Florida performed an engineering study of the inlet that resulted in the extension of the north and south jetties, the relocation and upsizing of the fixed sand transfer plant, and the construction of the south training wall in 1967. These modifications would improve the hydraulic efficiency of the inlet and decrease interior shoaling rates. The jetty extensions added 410 feet to the north jetty and 68 feet to the south jetty. The ends of the jetties were constructed with a deck elevation of around +7 ft referenced to the National Geodetic Vertical Datum (NGVD).

Since then, only minor modifications such as the construction of a small spur and sealing of portions of the north jetty (1971) have been made. According to the County's inlet summary report, the existing A1A fixed span bridge over the inlet was reconstructed in 1974. Additional communications with FDOT and their construction contractor indicate no plans for major rehabilitation or replacement of the bridge in the near future. Improvements to the bridge's eastern handrail system are underway and will not have any impact on the clearance or function of the bridge.

It is known through personal communications with the County that the original excavation and several maintenance dredging events of the inlet were

difficult and required blasting of base rock to complete. Since the original cut was made there has been only one attempt to remove more of the base rock resulting in removal of only a small but problematic high spot near the inlet mouth.

In 1996 the South Lake Worth Inlet District was abolished and the County now operates the sand transfer plant and manages the inlet. The latest inlet construction project occurred in 1998 when 8 “t-head” groins were installed south of the inlet to help retain a minimum beach section immediately downdrift of the inlet. The shoreline to the south of the inlet is maintained as a Federal Beach Nourishment project with the County serving as the local sponsor.

Today South Lake Worth Inlet remains close to its original configuration (Figure1). The inlet is stabilized by two rock and rock-filled crib jetties. The south jetty was 370 feet long, but lost ~10 ft of the outer end after the hurricane season of 2004. The north jetty is around 770 feet long and also suffered damage and loss of around 10 ft of the outer end during the 2004 hurricane season.

The navigable channel width varies from 125 feet wide west of the bridge to around 110 feet wide at the bridge, then down to less than 100 feet wide near the mouth of the inlet east of the bridge (Figure 2). Both sides of the channel passing through the barrier island are protected by vertical sheetpile walls. Bird Island is located inside the Lake Worth Lagoon and immediately adjacent to the north side of the channel and is protected by 840 feet of vertical wall. Opposite Bird Island is the 615-foot long training wall (also a vertical structure).

Because of the continuous lengths of vertical structures that line this relatively narrow channel, vessel wake reflection becomes problematic especially during peak usage. Multiple inbound and outbound vessels over a short period of time set up a series of reflected waves whose peaks and troughs merge across the full width of the channel. This creates difficult navigation conditions that force boaters to perform constant steering corrections to counter wave (and current) forces.

As can be seen in Figure 3, the depths within the channel also vary appreciably. The controlling water depth is between 8 and 10 feet. Average bottom elevations are around -11 feet NGVD west of the bridge. Near the mouth of the inlet there are deep pockets greater than 20 feet deep and remnant submerged ledges of -8 feet NGVD or less in the center of the channel. Along the south side of the inlet east of the bridge and roughly 15 feet from the north side of the south jetty structure, there is a near vertical ledge with less than 4 feet of water. This submerged ledge effectively reduces the navigable width of this section of the channel to less than 100 feet.

Figure 1 - Current Inlet Configuration

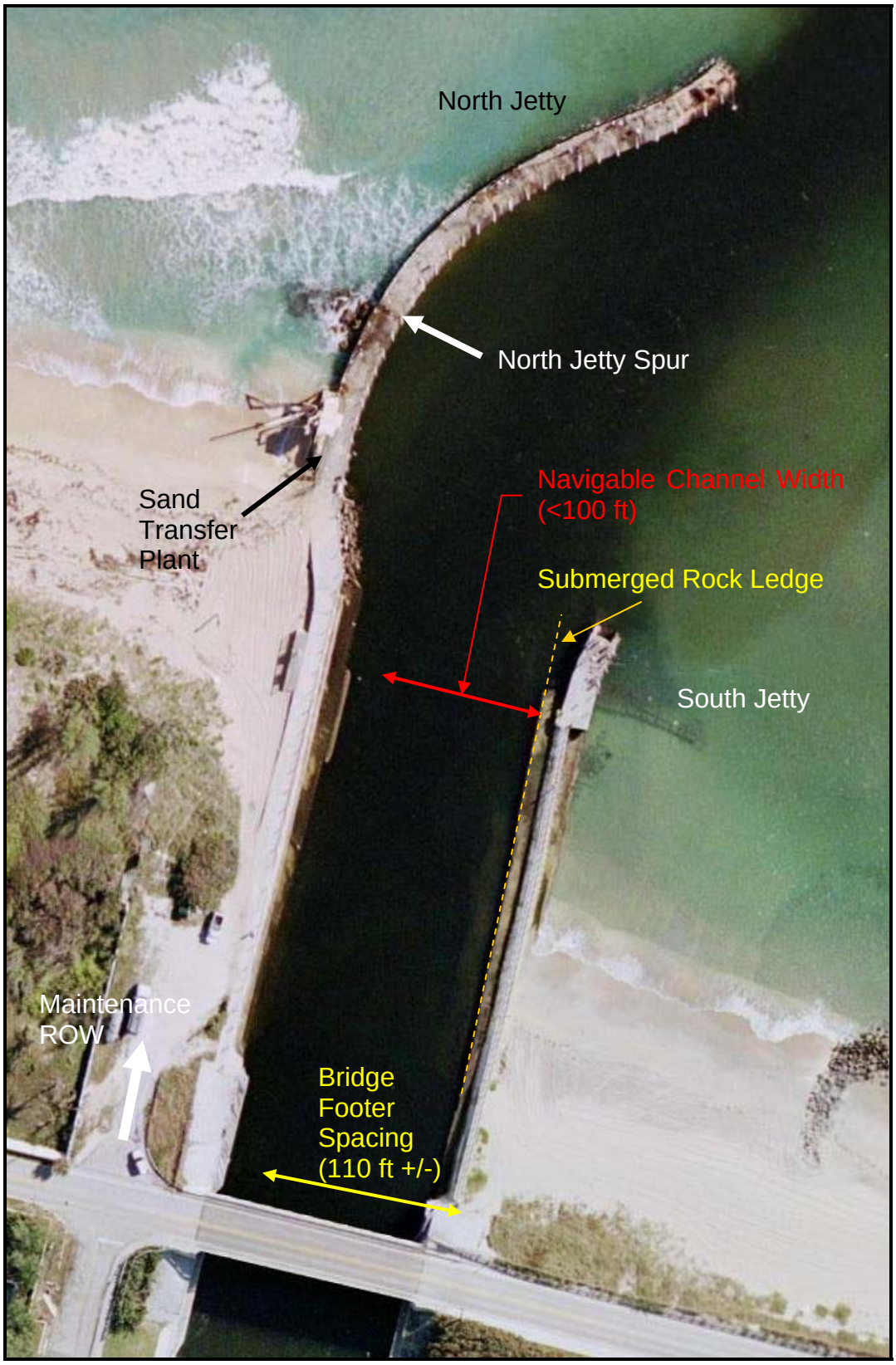

Figure 2 - Inlet Mouth

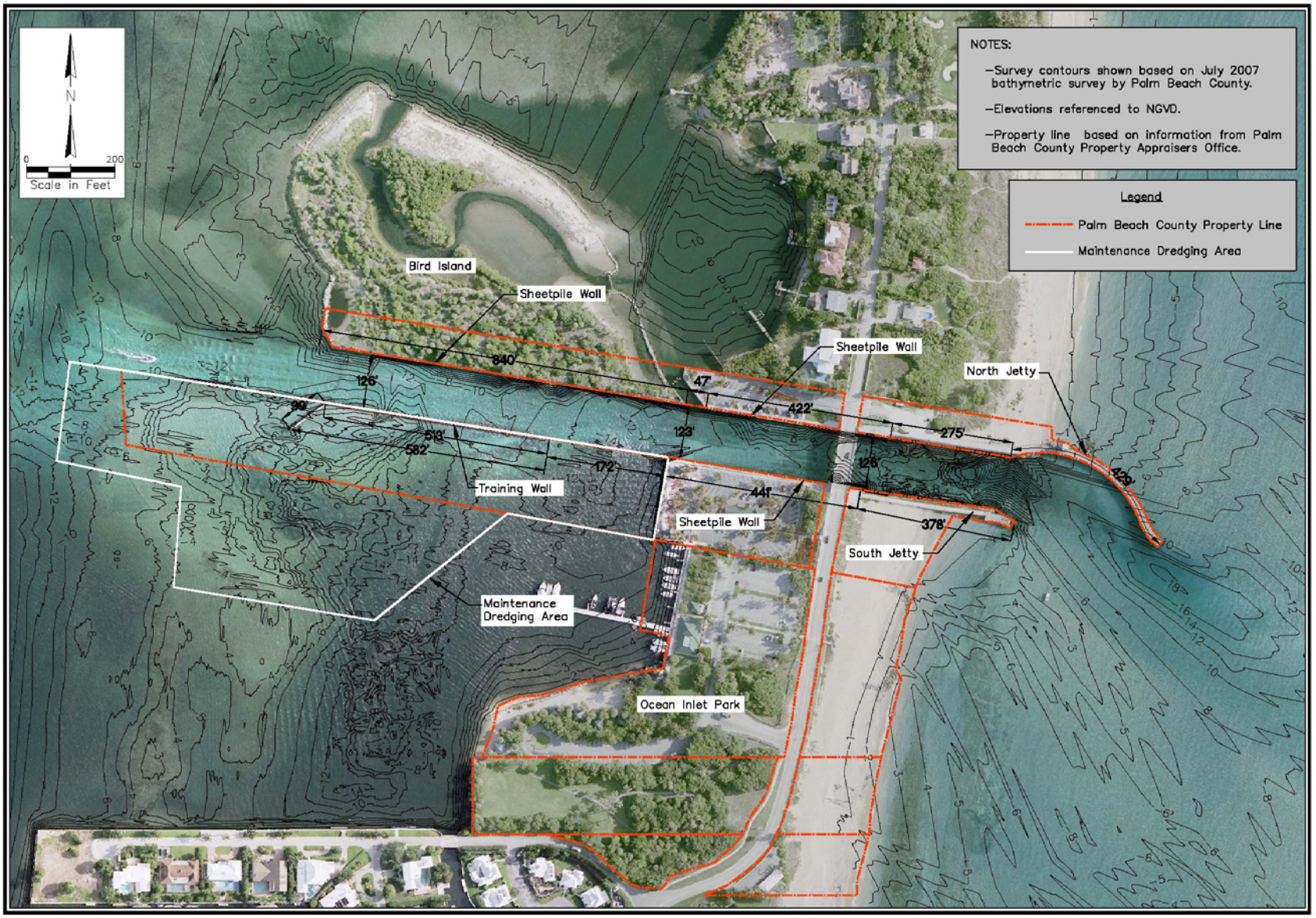

Figure 3 – South Lake Worth Inlet

The State Road A1A bridge is a single-span steel beam structure. It connects the Towns of Manalapan and Ocean Ridge and serves as an emergency evacuation route. The lowest structural member restricts clearance beneath the bridge to approximately 18 feet above the mean water line. This limits the maximum vessel size that can pass through the inlet.

Key Environmental and Safety Issues

Coastal lagoons and estuaries are highly productive ecosystems that provide habitat for a diverse array of plant and animal life. The Lake Worth Lagoon (LWL), extending 21 miles along the eastern portion of Palm Beach County, is recognized as one of Florida's important estuaries. During the past 100 years, human activities have profoundly affected the LWL. The LWL has been transformed from a relatively natural freshwater lake to an estuarine lagoon that has been heavily impacted by the urban, commercial, and industrial development that now encircles it. The LWL has over 70 linear miles of shoreline and in an assessment conducted in the late 1980's, Palm Beach County reported that over 65% of the natural shoreline vegetation had been replaced by seawalls, bulkheads, and/or shoreline armoring.

Ecological surveys in the LWL have documented a great diversity of marine life. Over 250 species of fish are known to occur in the Lagoon and in the vicinity of its inlets. Thirteen plant species and 27 animal species designated as endangered, threatened, rare, or species of special concern are either known to occur or are likely to occur in the LWL. Field surveys have documented the presence of five species of seagrass, including the threatened Johnson's seagrass (*Halophila johnsonii*), various species of macroalgae, oyster habitat, corals, and sponges.

As they support a greater diversity and number of floral and faunal species, consideration must be given to impacts on resources that may already be stressed or are currently clear of the inlet's current sphere of influence. Specifically, the plume of brackish water exiting the inlet during the ebb tidal flow extends offshore, spreading lagoon waters over nearshore bottoms. Changes to the exchange of waters and associated offshore impacts will have to be considered against potential improvements to lagoon water quality. It is beyond the scope of this work to quantitatively assess this potential - hence discussion in later sections will remain qualitative in nature.

There are multiple issues related to navigation and boating safety. Weather and boater inexperience are two critical elements contributing to boating incidents. Improved boater education and ready awareness of weather conditions are two ways to combat these elements.

South Lake Worth Inlet currently suffers from a variety of natural forces and man-made obstacles (tidal current velocities, wind and wave heights,

channel dimensions, ebb shoal formation, restricted line of sight) that make navigation potentially hazardous, even during relatively mild weather conditions.

Secondary Issues Related to Inlet Management

Natural and man-made inlets are barriers to sediment transport and have been the source of significant controversy and engineering management studies. The South Lake Worth inlet has been studied over the years resulting in multiple inlet and sand management programs. The most important aspects of those studies (Sediment Transport and Beach Management, Maintenance Dredging, Inlet Closures and Water-Based Businesses, Public Access, Boating Industry and Economics, Storm Surge and Flooding, Bridge Clearance and Maintenance and Emergency Evacuation) have all been considered with respect to this study.

Inlet Hydrodynamics and Lake Worth Lagoon Flushing

The Environmental Fluid Dynamics Code (EFDC) model was used to evaluate inlet hydrodynamics and estuary circulation. EFDC is a general purpose modeling package for simulating three-dimensional flow, transport and biogeochemical process in surface water systems including: rivers, lakes, estuaries, reservoirs, wetlands and near shore to shelf scale coastal regions.

For this study a total of five alternatives or scenarios reflecting various levels of inlet modification were modeled. Table 1 briefly describes each of the modeled alternatives. It should be noted that only those alternatives that would result in a change to the hydraulics of the inlet were examined. Other alternatives, such as shifting the jetties, would not substantially change the potential rate of water exchange through the inlet (the primary factor affecting the exchange is the inlet cross-section between the vertical bulkheads in the inlet's throat).

Table 1 - Simulated Alternatives

Alternative	Description
1	Existing configuration with channel excavation to -15 ft NGVD
2	Existing configuration with channel excavation to -20 ft NGVD.
3	150-ft wide channel (add 50' to existing) with bottom @ -20 ft NGVD
4	300-ft wide channel (adds 200' to existing) with bottom @ -10 ft NGVD.
5	300-ft wide channel (adds 200' to existing) with bottom @ -20 ft NGVD.

"Operational" Wave Modeling

For this wave study, the Bouss-2D wave model was selected, a local-scale wave model based on the Boussinesq equations for wave propagation. The Bouss-2D model is capable of modeling wave refraction, shoaling, diffraction, reflection and breaking, as well as incorporating wave-current interaction and non-linear waves. Given the scale, geometry and the magnitude of the tidal flows at South Lake Worth Inlet, the Bouss-2D model is the most appropriate wave model for this study.

Several alternative inlet configurations were evaluated by the numerical models in order to determine the combination of widening and deepening of the inlet needed to adequately reduce current magnitudes. Table 2 presents the alternative inlet widths and depths.

Table 2 – Description of Alternatives

Alternative	Description
1	Existing configuration with channel excavation to -15 ft NGVD
2	Existing configuration with channel excavation to -20 ft NGVD.
3	150-ft wide channel (add 50' to existing) with bottom @ -20 ft NGVD
4	300-ft wide channel (adds 200' to existing) with bottom @ -10 ft NGVD.
5	300-ft wide channel (adds 200' to existing) with bottom @ -20 ft NGVD.
6	Dredging of Ebb Shoal to -8 ft. NGVD

CONCLUSIONS

As a whole, the results of the study indicated that structural improvements could be implemented that would improve both the water quality of the lagoon and the safety/navigability of this inlet. Increases in the channel width and depth produced the greatest benefits. This study further suggests that there would be significant economic benefits to these alternatives.

Major structural alternatives, however, represent major capital projects and other significant hurdles. The major issues identified within this study include the following:

Environmental Impacts: Improvement to the lagoon water quality may result in a net environmental deficit associated with increases in nutrient loads to nearshore reefs. The net environmental benefit of improving a degraded waterbody (lagoon) over impacting a fairly untouched resource (offshore reef) is not fully understood at this time and therefore is a concern.

Coastal Impact: Channel improvements would result in increased potential for sand storage by the ebb shoal ranging on the order of several million cubic yards of sand. There is a potential for a major impoundment of sand within the shoal system could result in significant downdrift impacts. The existing federal project and sand bypassing regime is likely insufficient to make up this loss to the downdrift coastal system.

Bridge Issues: With the exception of the deepening only scenarios, all structural modifications requiring a widening of the inlet will require a new bridge. Given that FDOT currently has no plans for replacing the existing S.R. A1A bridge, this is a lengthy and costly undertaking to be added.

Loss of Park Property and Public Access: The property surrounding the inlet is owned and operated by Palm Beach County and represents a significant local (public) resource. The loss of property for any inlet expansion would come at a cost to valuable real estate and public access.

Costs: Overall costs associated with significant alterations to the inlet are high and there currently are limited funding sources available.

Collectively these issues represent a significant impediment to the approval and implementation of any major inlet modification.

Based on the ranking method adopted for this study, maintaining the status quo ranks high but does not achieve any of the desired improvements. Based solely on achieving improvements to lagoon water quality and navigation safety, the widening and deepening alternatives would rank highest. However, the associated direct impacts to hardbottom and seagrass (including protected johnson species), as well as potential indirect impacts to downdrift beaches and to nearshore reefs linked to increases in discharge of nutrients and other pollutants from the lagoon, are a cause for concern at this point in time.

Regarding safety and navigability, there are a number of implementable options. South jetty relocation is conceptually viable, though the high cost may not justify the limited benefit. Ebb shoal dredging is also viable but requires a funding and maintenance commitment by several parties, most notably Palm Beach County. The results of the ebb shoal dredging are also short-term and would require an ongoing commitment – the cost of which is not insignificant.

If cost and time were unrestricted, then a combination of deepening the existing channel (Alternative 1 or 2), the 50-foot southerly shift in the south jetty, and limited excavation of the ebb shoal would provide a solution with improvements to lagoon flushing and navigation safety. The level of change in lagoon flushing would be marginal and the increase in discharge outside the inlet and onto nearshore reefs would need to be investigated further. The cost benefit of the shift in the south jetty would also need to be better defined as

investigations did not indicate this area to be the source of biggest concern for navigation. Regardless, the existing width of the channel is too narrow for safe two-way traffic and would benefit from a 50-ft minimal expansion.

Non-structural options are viable, easy to implement and include the following recommendations:

Improvements to lighting, especially on the outer ends of both jetties, as well as the western ends of the training wall and Bird Island wall.

An adverse warning system consisting of clear signage and flashing (yellow) lights to warn boaters of “adverse boating conditions” that is tied to local weather and marine forecasts.

Increased boater education, specifically at the City-owned boat ramp immediately west of the inlet, providing pamphlets or flyers on boating safety along with explanations of how to assess sea conditions before going out on the water and how to avoid problems navigating inlets may result in fewer inlet-related incidents.

With the exception of the non-structural options, feasible inlet modifications would require a substantial investment in effort and resources and would impact a broad range of stakeholders. This study provides an assessment of the range of feasible alternatives and may be used as a basis for future decisions made regarding the inlet.

REFERENCES

ASCE Manuals and Reports on Engineering Practice No. 50. *Planning and Design Guidelines for Small Craft Harbors*. 1994.

American Sportfishing Association. Data & Statistics. Internet Source (www.asafishing.org/asa/statistics.htm).

University of Florida. *Hydraulic Study for South Lake Worth Inlet*. Coastal Engineering Laboratory. College of Engineering. April 1964.

Coastal Everglades Restoration Plan. Draft Lake Worth Lagoon Conceptual Ecological Model. Appendix A. January, 2004.

Coastal Planning & Engineering, South Lake Worth Inlet Engineering Alternatives Analysis. July 1998.

Coastal Planning & Engineering, *South Lake Worth Inlet Management Program.* September 1998.

Coastal Planning & Engineering, South Lake Worth Inlet Management Program Update. January 2004.

Florida Fish & Wildlife Conservation Commission. Boating Incident Reports (2005 – 2006)

Florida Inland Navigation District. Update of the Economic Analysis of the District's Waterways in Palm Beach County, December 2006.

Marine Industries Association of Palm Beach County. *Economic Impact of The Marine Industry in Palm Beach County*. Internet Source (www.marinepbc.org/pages/impact.htm).

Olsen Associates. South Lake Worth Inlet Sand Management Plan. Technical Report. December 31, 1990.

Palm Beach County Department of Environmental Resource Management, Seagrass Monitoring in Lake Worth Lagoon. Final Cumulative Report for 2000 – 2004. March 2005.

Palm Beach County Department of Environmental Resource Management. *Cumulative Report of Seagrass Monitoring Conducted During 2001, 2002 & 2003..* October 31, 2003.

Palm Beach County Department of Environmental Resource Management. *Understanding the Lake Worth Lagoon*. Pamphlet.

Palm Beach County Department of Environmental Resource Management. *Lake Worth Lagoon Monitoring Project. Final Report.* Revised November 2003.

Palm Beach County Department of Environmental Resource Management. *Lake Worth Lagoon Management Plan Revision.* May 2007.

Palm Beach County Department of Environmental Resource Management. *Palm Beach County Manatee Protection Plan.* July 2007.

Palm Beach County Department of Environmental Resource Management. *History of Palm Beach County Inlets.* Web Document. http://www.co.palm-beach.fl.us/erm/enhancement/Images/PDF_Documents/history_inlets.pdf

Recreational Boating and Fishing Foundation. Understanding the Relationship Between Recreational Boating and Fishing Participation: A National Survey. Quick Facts. Internet Source (www.rbff.org).

Sun-Sentinel. *Danger on Our Waters.* Article, May 2, 2007. Writer: Leon Fooksman.

USACE, EM 1110-2-1615. Hydraulic Design of Small Boat Harbors. 1984.
USACE, EM 1110-2-1100. *Hydrodynamics of Small Inlets*. 2006.
Villanueva, M. *Palm Beach County Boat Study*, University of Miami, Boating Research Center. 1994.

Personal Communications:

D/S Tom McElroy, Palm Beach County Sheriff's Marine Enforcement Unit officer, October 2, 2007. (Telephone)
D/S Travis Keene (#6343), Palm Beach County Sheriff's Marine Enforcement Unit officer, October 2, 2007. (In person)
Palm Beach County Lifeguard (Ocean Inlet Park), October 2, 2007. (In person)
Captain Phil Wotton, Palm Beach County Ocean Rescue South District, October 24, 2007 (Telephone and e-mail)
Don May, Chief of Ocean Rescue, Palm Beach County, October 17, 2007. (Telephone)
Mr. Sandy Daniel, FDOT Contractor, October 8, 2007. (Telephone)
Florida Fish & Wildlife Conservation Commission, Mollyann Williams, October 9, 2007. (Telephone)
Captain Amy Tolderlund, Vice President Marine Industries Association Palm Beach County, October 23, 2007. (In person)