FEBRUARY 2022

SEVEN MILE BRIDGE 900101 REPLACEMENT REPORT

FDOT District Six Structures Maintenance Office

PREPARED BY BARBARA KING-RUSSEL, P.E.
REVIEWED BY PABLO OROZCO, P.E. & GEIDY COELLO, P.E

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SECTION 1 – INTRODUCTION

1.1 Project Location

This project involves the Seven Mile Bridge, which begins at MP 40 and ends at MP 46.6. The Seven Mile Bridge is an iconic bridge in the Florida Keys, connecting Knight's Key in the Middle Keys to Little Duck Key in the Lower Keys. At the time of its completion in 1982, it was the longest continuous concrete segmental bridge in the world and is currently one of the longest bridges in America and the longest in Florida.

This bridge represents the only route in and out of the lower keys and serves as the evacuation route during hurricane season. Each April the bridge is closed for approximately 2.5 hours on a Saturday and a "fun run," known as the Seven Mile Bridge Run, of 1,500 runners is held commemorating the Florida Keys bridge rebuilding project. The event began in 1982 to commemorate the completion of a federally funded bridge building program that replaced spans that oil tycoon Henry Flagler constructed in the early 1900s to serve as a foundation for his Overseas Railroad.

Figure 1.1 – Location Plan

1.2 Typical Section

The bridge typical section consists of two (2) 12 ft. travel lanes and 6 ft. shoulders at both sides with an overall width of 38'-6½" (Figures 1.2 and 1.3).

There are no pedestrian sidewalks or bike lanes on the existing bridge. Pedestrians and bicyclists currently use the bridge shoulders to traverse the bridge.

1.3 Clearances

The existing Seven Mile Bridge is a fixed high-level bridge. The profile grade is relatively flat for about 31,184 ft. At the high-level spans (hump), 4,683 ft. long, the profile rises with a 3% grade as it approaches the navigational span. The bridge has a vertical clearance above mean high water of approximately 18 ft. at the low-level approach spans, and a vertical clearance above mean high water of 65 ft. at the navigation channel. The horizontal clearance of the Seven Mile Bridge at the navigation channel is 90 ft. fender to fender. Unlike the other piers along the bridge, the piers adjacent to the navigation channel, behind the fenders, are supported on spread footings.

1.4 Bridge Design

The forty-year-old Seven Mile Bridge is one of the first precast concrete segmental bridge in the State of Florida. It was designed by Figg & Muller and was constructed between the late 1970's and early 1980's. The bridge structure is 35,863 feet long, composed of 38 continuous multi-span superstructure units.

The precast concrete segmental bridge was built using the span-by-span method of segment erection using an overhead gantry, with external tendons and dry joints between segments. Spans range from 81 to 142 feet long.

The bridge is supported by 265 piers, of which 236 are composed of two 3-ft. diameter columns connected by a precast strut and 29 have vertically post-tensioned box columns piers at the high-level spans. Figures 1.2 and 1.3 show the bridge typical section at low- and high-level spans, respectively. At the expansion joints, the columns have a hammerhead cap oriented longitudinally supporting two adjacent expansion joint segments. The typical pier foundation has two 42" diameter concrete drilled shafts.

The bridge also supports a 36 in. diameter water main and other utilities as outlined in Section 1.6 of this report.

1.5 Utilities

The following utilities have been identified within the bridge limits:

- Comcast Cable (Cable inside box girder)
- FDOT (Navigational Lighting)
- Florida Keys Aqueduct Authority (36" Water Main inside box girder)
- AT&T (Telephone line inside box girder)
- Florida Keys Electric Cooperative (Aerial Electrical line outside the bridge limits east of the bridge)

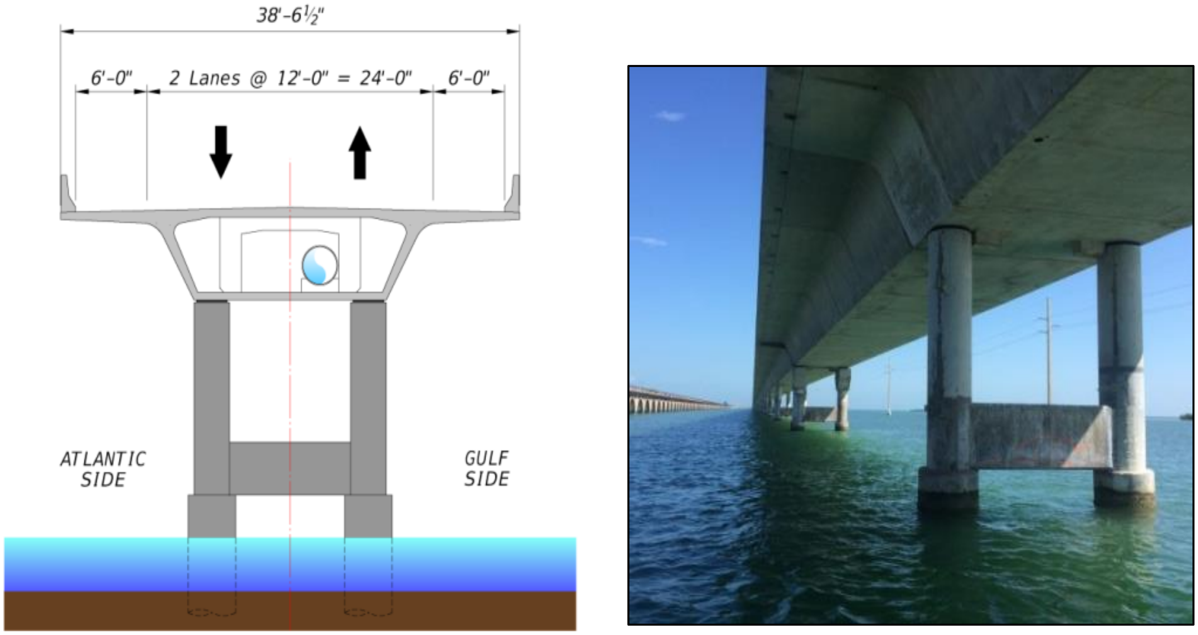

Figure 1.*2* Low-Level Spans – Typical Section

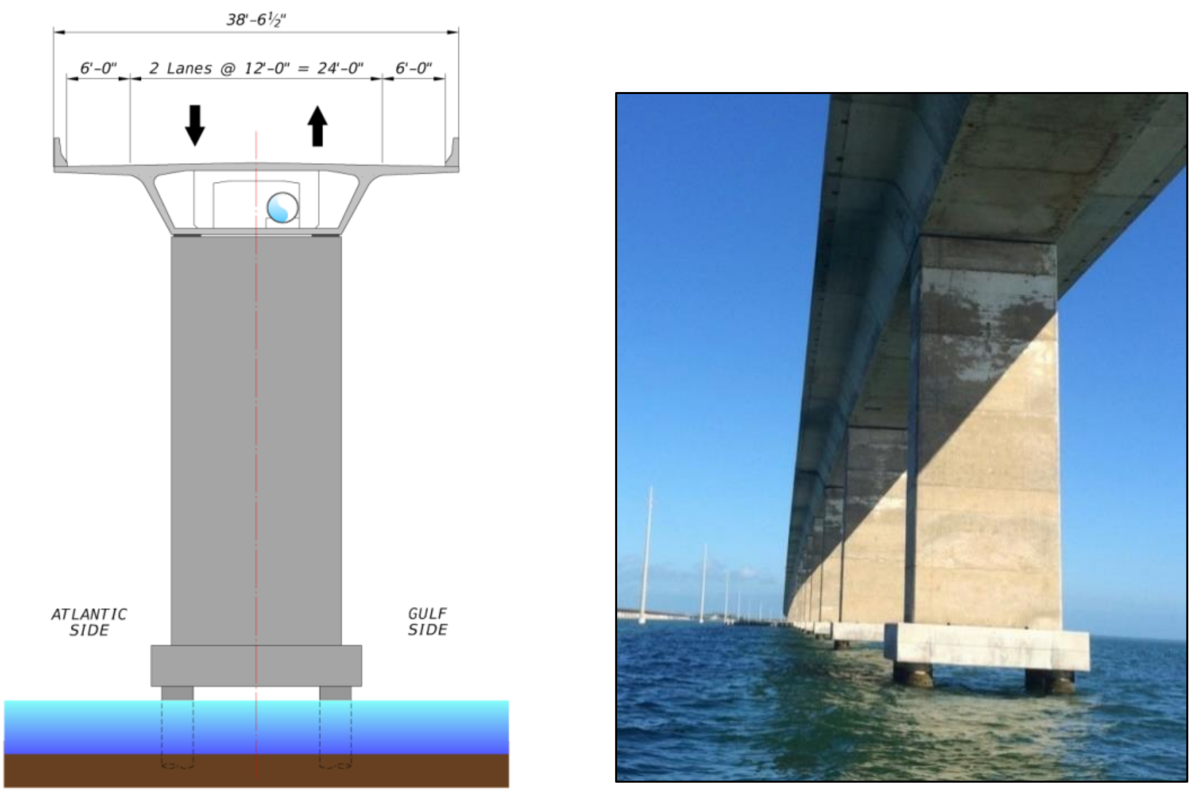

Figure 1.*3* High-Level Spans – Typical Section

SECTION 2 – BRIDGE CONDITION

2.1 National Bridge Inventory (NBI) Ratings

The NBI Ratings for the three most recent Bridge Inspection Reports, performed on 12-29-2016, 12-14-2018 and 12-18-2020 are as follow:

Date	12/29/2016	12/14/2018	12/18/2020
Deck	7 Good	7 Good	6 Satisfactory
Superstructure	6 Satisfactory	6 Satisfactory	5 Fair
Substructure	6 Satisfactory	6 Satisfactory	6 Satisfactory
Sufficiency Rating	59.1	59.1	49.1
Functionally Obsolete	No	No	No
Structurally Deficient	No	No	No

Based on Bridge Profile, Inspection, and Comprehensive Information Data Reports ranging from 2010 to 2020, the Sufficiency Rating was observed to decrease over time from 78.0 in 2010 to 49.1 in 2020. Despite the Sufficiency Rating, the bridge has never been found to be functionally obsolete nor structurally deficient.

2.2 Bridge Capacity

Per the most recent Load Rating Report, performed by Corven Engineering on April 20, 2006, this bridge has an Operating Rating Factor of 0.78, with the following Legal Truck Rating Factors:

- SU4: Rating Factor = **1.16**
- C5: Rating Factor = 1.25
- ST5: Rating Factor = 1.23

This Load Rating Report indicates that for the SU4 Truck, the bridge is only 16% above required minimum Rating Factor of 1.00. Considering the condition of the bridge, it may not be feasible to provide any additional post-tensioning to the bridge in the future if it were to become necessary to increase the capacity of the bridge superstructure. Due to the deterioration, the load carrying capacity of the bridge will need to be re-evaluated and will likely be lowered. This potential future rehabilitation is not considered in the LCCA.

2.3 Reported Deficiencies

Per the most recent Bridge Inspection Report, performed on 12-18-2020, the Condition States are as follow:

Table of Bridge Deficiencies

Elem Key	Elem. Description	Elem. Qty	CS1 (%)	CS2 (%)	CS3 (%)	CS4 (%)
15	Prestressed Concrete Girder Top Flange (sq ft)	1,384,497	76.8	0.4	22.8	0
104	Prestressed Concrete Closed Web/Box Girder (ft)	35,868	0	**27.9**	**72.1**	0
205	Reinforced Concrete Column (ea)	578	58.3	**18.9**	**22.8**	0
210	Reinforced Concrete Pier Wall (ft)	469	22.8	**52.9**	**24.3**	0
215	Reinforced Concrete Abutment (ft)	80	100	0	0	0
220	Reinforced Concrete Pile Cap/Footing (ft)	580	42.4	47.4	10.2	0
234	Reinforced Concrete Pier Cap (ft)	640	66.7	29.8	3.4	0
303	Assembly Joint with Seal (ft)	1505	92.6	0	7	0.33
310	Elastomeric Bearing (ea)	608	84.4	15.6	0	0
321	Reinforced Concrete Approach Slab (sq ft)	1544	100	0	0	0
331	Reinforced Concrete Bridge Railing (ft)	71,736	99	0.7	0.2	0
8199	External Post Tensioning Duct (ft)	215,460	93.9	6.1	0.1	0
8290	Channel (ea)	1	0	100	0	0
8298	Pile Jacket (ea)	142	100	0	0	0
8390	Fender/Dolphin System (ft)	351	100	0	0	0
8475	Wingwall/Retaining Wall (ft)	24	100	0	0	0
8563	Access Ladders & Platforms (ea)	2	0	0	0	100
8580	Navigational Light System (ea)	8	100	0	0	0

Table 2.1

2.4 Corrosive Environment

The substructure is located in an Extremely Aggressive Environment (Coastal), which presents extreme challenges in resisting corrosion, especially for a bridge of this length. Significant corrosion-related deficiencies are found in the substructure as well as in the exterior bottom face of the segmental box. According to the Corrosion Report prepared by the FDOT State Materials Office (SMO) Corrosion Research Laboratory, dated August 11, 2021, samples tested contained significantly high chloride contamination, up to 16.94 pounds of chlorides per cubic yard of concrete. The chloride content threshold is 1.2 pounds per cubic yard to initiate corrosion.

- There is widespread localized corrosion-induced deterioration at the box girders' webs and shear blocks. The deterioration takes the form of spalling which exposes reinforcement of shallow concrete cover. The chloride contents at the level of reinforcement (10.5 pounds per cubic yard at1.25" to 1.75" depth) at sound concrete locations are extremely high (several times the threshold to initiate corrosion).
- Only 1 of 27 box piers was evaluated. It showed no visible manifestations of corrosion-induced deterioration. However, the chloride content was 3.1 pounds per cubic yard, which is above the threshold. 100% of the box pier footers underwent repair and protection within the previous two to four years.

2.5 Design and Construction-Related Issues

The history of the bridge deficiencies dates back to the original construction. Besides the corrosive environment, several construction and design factors have contributed to the corrosion issues, such as:

- Insufficient concrete cover was provided, based on current standards for the Extremely Aggressive Environment the structure is in. At the time of construction, expectations may have been overestimated regarding the effectiveness of epoxy-coated rebar protection against corrosion.
- The use of epoxy-coated reinforcing in substructure and superstructure. Imperfections in the epoxy coating results in rapid corrosion when exposed to chlorides. According to the "Corrosion Evaluation of Segmental Deck Cracks in the Seven Mile Bridge" (dated June 1985), the QC of the coating operations was poor, coated steel was improperly handled and stored, and the coating could not withstand the bending process with out breaking or disbanding.
- Stresses were induced at the tops of column during construction. Uneven stresses due to pier segment misalignment created overstressing at the top of columns and random cracking that, with time, allowed the intrusion of chlorides. For the round columns, it has been recommended to reinforced them with CFRP wrapping. One expansion joint pier cap has been strengthened with external post-tensioning and it is expected for the others to need similar retrofits in the near future.
- Superstructure movements caused by high wind events necessitated bearing replacements (jacking required), as well as expansion joint replacements. Shear restrainers were also added to minimize further transverse movement of the superstructure. In addition, lateral movements caused the original concrete restrainers to impact the top of columns, initiating spalling and cracking at the tops of columns.
- The absence of transverse post-tensioning has resulted in longitudinal deck cracks. The deck has exhibited longitudinal cracking since construction was completed. This deficiency has been addressed by sealing the deck with methyl methacrylate every 10 to 20 years (most recently in 2017).

SECTION 3 – MAINTENANCE HISTORY

The state-owned bridges in the Keys have been maintained by asset maintenance contracts since 2005. However, bridge rehabilitation, including cathodic protection are managed under specific design and construction contracts.

As described below, the continuing maintenance required has been and still is significant.

3.1 Previous Rehabilitation Projects

Within the first 3 years after construction (1982 thru 1985), repairs were made related to design and construction issues discussed in Section 2.5.

According to design and construction documents dated between 1985 and 2020, several projects addressed recurring issues. The following rehabilitations performed include:

1988: The rehabilitation comprised jacking the superstructure and resetting or replacement of bearing pads at 31 piers. 7,700 LF of cracks were epoxy injected. Column spalls were repaired. Vermin guards were installed, and access hatches were replaced. Methacrylate treatment of the segmental deck was also applied. 38 Expansion joints were replaced.

1991: Lower portions of several spalled pier columns and struts were repaired, followed by the application of cathodic protection using sprayed zinc metalizing. A large amount of post-tensioning deviator block cracks was epoxy injected.

1999: Shear Restrainers (Figure 3.1) were added to address the superstructure lateral movement, as shown below. Additionally, expansion joint (finger joints) hardware was replaced and reset due to superstructure movement during hurricane winds.

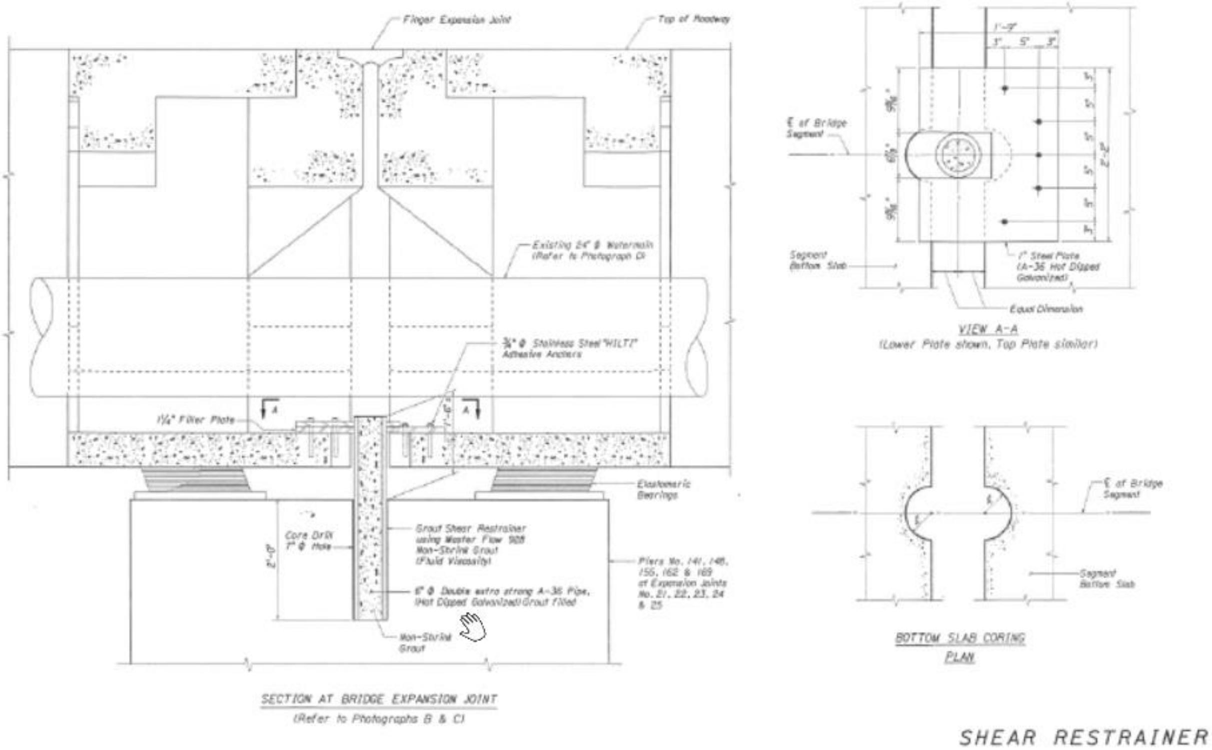
Finger Expansion Joint
Top of Roadway
Existing 24" Ø Watermain (Refer to Photograph C)
¾" Ø Stainless Steel "HILTI" Adhesive Anchors
1¼" Filler Plate
Elastomeric Bearings
Core Drill 7" Ø Hole
2'-0"
Grout Shear Restrainer using Master Flow 928 Non-Shrink Grout (Fluid Viscosity)
Piers No. 141, 148, 155, 162 & 169 at Expansion Joints No. 21, 22, 23, 24 & 25
6" Ø Double extra strong A-36 Pipe, (Hot Dipped Galvanized) Grout filled
Non-Shrink Grout
SECTION AT BRIDGE EXPANSION JOINT
(Refer to Photographs B & C)
1'-9"
3" 5" 3"
℄ of Bridge Segment
Segment Bottom Slab
1" Steel Plate (A-36 Hot Dipped Galvanized)
Equal Dimension
VIEW A-A
(Lower Plate shown, Top Plate similar)
℄ of Bridge Segment
Segment Bottom Slab
BOTTOM SLAB CORING PLAN
SHEAR RESTRAINER

Figure 3.1

2003: The rehabilitation consisted of concrete repair of the substructure in the splash zone. The restored areas of the pier footers and round columns/struts were metalized.

2009: The rehabilitation consisted of concrete restoration of diaphragms and repairing post-tensioning tendons and anchors in the superstructure. The tendon repairs involved: vibration testing; NDT inspection using endoscopes; and cleaning and re-grouting. The post-tensioning anchors repair consisted of: removal of pour-backs; visual inspection; cleaning and re-grouting; installation of PT caps; removal of caps to verify full grouting; and recapping and sealing. Tendon and anchor remediation utilized vacuum grouting.

2020: The rehabilitation included concrete repair for the superstructure and substructure. The top of the deck had Methyl Methacrylate sealant applied. The columns and struts at the low-level spans were repaired and metalizing was applied. For 17 columns on 16 piers, repairs were made utilizing an innovative Temporary Support System to jack the superstructure off the substructure. Pier 22 included the repair of the pier cap, where external post-tensioning was introduced to restore its strength. A shear restrainer was rebuilt due to a failure. This included reconstructing a section of the bottom of the segmental box bottom flange with UHPC.

3.2 Open Maintenance Issues

Periodic and costly rehabilitations will continue to be required throughout the bridge's remaining service life. These rehabilitations will need to be programmed with additional BRRP allocation from Central Office since they cannot be programmed with the District's regular allocations.

The existing level of chlorides in box girders and columns continues to increase over time. Recurring spalling occurs at the tops of columns, requiring repeated major rehabilitation projects involving jacking for bearing replacements. Piers also continue to experience corrosion-related spalls and cracks. Cathodic protection systems need to be restored every 5 to 7 years.

A horizontal misalignment of 2.5 inches has been identified at Pier 57. Several finger joints are misaligned and/or deteriorated.

Deviator blocks diaphragms have recurring cracking. Post-tensioning tendons in the superstructure require repeated monitoring and they are expected to need replacement in future rehabilitations. Post-tensioned box columns corrosion will need to be addressed.

Round columns will continue to crack and additional strengthening will be needed using CFRP wrapping.

SECTION 4 – LIFE CYCLE COST ANALYSIS

During the recent bridge rehabilitation, the need for further repairs was observed and the recent corrosion study was performed which indicated the severity of the corrosion. As a result, a Life Cycle Cost Analysis (LCCA) report, dated September 2021, was prepared. This report is provided in Appendix A.

The alternatives evaluated included Replacement and Rehabilitation. The conclusion in the LCCA is that rehabilitation has a higher life-cycle cost than replacement. Therefore, it is more economical to replace than to continue repairing the bridge.

The maintenance costs for this bridge are as indicated below.

Annual Maintenance and Inspection Costs	Cost per SF	Annual Cost
Program Oversight & Management	0.03	$41,535
Bridge Inspection (per current contract fees)		$224,530
Routine Maintenance (double the cost of a typical bridge)	0.28	$387,659
Periodic Maintenance (per AM records)		$125,000
Major Rehabilitation (per LCCA)		$11,763,940
Total Maintenance and Inspection costs per year		**$12,542,664**

Table 4.1

SECTION 5 – CONCLUSIONS AND RECOMMENDATIONS

The bridge should be replaced rather than continually repairing and rehabilitating the existing 40-year-old structure. District Six receives approximately $11 Million yearly of BRRP funding allocations for design, construction, and CEI project phases. Based on the LCCA, the Yearly Major rehabilitation cost will require that we dedicate 100% of the BRRP yearly funding allocations to perform the needed work or request this as additional BRRP allocations to perform the work. A new bridge can be designed to minimize corrosion, reducing maintenance costs. Due to the location and extremely aggressive environment, a non-segmental bridge is preferred, thus greatly reducing the yearly inspection cost. With the newer higher strength concrete, prestressed beams can span at least 30% longer than the existing segmental bridge spans, depending on means of transportation and erection.

Non-tangible improvements are not captured in the life-cycle cost analysis. Some of these intangibles, that a new bridge will provide, include:

- Full width shoulders would be provided to improve evacuation and pedestrian and bicycles accessibility during emergency events,
- Sidewalks and a Shared-Use Path would be provided to improve pedestrian and bicycle accessibility,
- The bridge carrying capacity will be improved,
- The new bridge will be designed to meet current design standards for ship impact and scour, and
- Barrier walls will meet current MASH standards.

This bridge is one of the first precast concrete segmental bridges in the State of Florida and, as such, there may be unanticipated issues arising as it ages further in its corrosive environment.

A Financial Project ID Number **448207-1-52-01** has been created in the Work Program for a recommended **Replacement Fiscal Year 2029**. Depending on funding availability, the construction phase may be delayed until Fiscal Year 2030. The following Table shows the estimated cost for each phase of this project:

Project Phase	**Cost**	**Fiscal year**
PD&E	$35,000,000	23
Design	$50,000,000	26
Construction	**$374,000,000**	**29**
CEI	$45,000,000	29
Post-Design	$5,000,000	29
Total	***$509,000,000***	

APPENDIX A (Life-Cycle Cost Analysis)