Engineering Evaluation of Concrete Degradation
and Steel Sheet Pile Wing Wall Thickness
C-54 Canal Water Control Structure S-157
SJRWMD, Brevard County, Florida

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Materials Consultants

May 28, 2013
File No. 13-60-6303

St. Johns River Water Management District
P.O. Box 1429
Palatka, Florida 32178

Attention: Mr. Wayne Dempsey, P.E.

Subject: Engineering Evaluation of Concrete Degradation and
Steel Sheet Pile Wing Wall Thickness
C-54 Water Control Structure S-157
SJRWMD, Brevard County, Florida

Dear Mr. Dempsey:

As authorized by you, Ardaman & Associates, Inc. has completed an engineering evaluation of the subject control structure with respect to concrete degradation and the steel sheet pile wing walls. The purposes of our evaluation were to observe and evaluate the concrete degradation, determine the thickness of the existing steel sheet pile wing walls and provide our opinion as to the types and causes of degradation and to provide recommendations for remediation. This report documents our findings and presents our engineering recommendations.

SITE LOCATION AND DESCRIPTION

The subject control structure is located within the C-54 Canal near its east end in Brevard County, Florida. The GPS coordinates obtained from Google Earth, indicate that the longitude and latitude of the structure are N27.830562°, W-80.539679°, respectively.

We understand that the existing structure was constructed in 1966, and the concrete main structure and the steel sheet pile have not been modified except for periodic painting of the steel sheet pile wing walls.

Based on review of "As Built" record drawings, the triple gate hydraulic control structure is 82 feet in width. The concrete gate monolith is 76 feet in length having an upstream top of crest weir elevation of +7.5 feet dropping abruptly over an approximate horizontal distance of 23.5 feet to the downstream top of slab elevation of -11.0 feet. The structure is constructed entirely of reinforced concrete except for the metal gates and anchored steel sheet pile wing walls located at the upstream and downstream edges of the structure. According to the "As-Built" drawings, the upstream sheet pile wing walls consist of 29 sections of Type Z-27 sheet pile having a total wall length of 43.5 feet, and the downstream sheet pile wing walls consist of 28 sections of Type Z-27 sheet pile having a total length of 42 feet. Type Z-27 (now known as PZ-27) sheet pile has a nominal web and flange thickness of 0.375 inch. We note that the downstream sheet pile walls were submerged, and therefore, not observed or tested as part of this study.

SITE OBSERVATIONS

Site observations of the portion of the structure above the water level were made on March 29, 2013 by Ardaman and Associates engineer Mr. Jason Parker, P.E. At the time of our observations, the upstream and downstream water levels were approximately at +13.5 feet and -0.8 feet, respectively, based on readings made from the on-site staff gauges. Based on the water staining marks the water levels typically fluctuate a few inches on the upstream side and 12 to 18 inches on the downstream side. It is generally known that water levels during extreme hydrological events fluctuate more than typical.

For both the upstream and downstream sides of the structure, our observations indicated that the concrete appeared to be in very good condition. Pitting above and below the water surface was minimal on both the upstream and downstream side. We note that the entire surface of the concrete within the water fluctuation zone on the downstream side could not be observed due to algae and barnacle growth. No spalling, significant cracking, rust staining or other indicators of potential structural defects or corrosion were observed.

We note that some of the wall panels high above the downstream water level exhibited staining from seepage through the joints. These areas were too high to inspect from the work boats, but considering the age of the structure, the joint filler material has likely deteriorated to some degree allowing the observed seepage staining.

Relative to the steel sheet pile wing walls, the upstream walls appeared to be exhibiting greater than typical corrosion near the water line, especially the joints. The portions of the steel sheet pile walls that were below the water surface could not be observed relative to their condition. As stated previously, the downstream steel sheet piles were completely submerged.

Representative photographs of our observations are included in Appendix I.

FIELD EXPLORATION PROGRAM

The field exploration program consisted of performing a series of non-destructive and destructive testing/sampling at selected locations to evaluate the concrete on the downstream side of the structure and the steel sheet pile wing wall thickness on the upstream side only. The following describes the field exploration program in detail.

Rebound Hammer Readings

Rebound hammer testing was performed in general accordance with ASTM C 805, "Standard Test Method for Rebound Number of Hardened Concrete". A rebound hammer is a non-destructive device that consists of a plunger rod and an internal spring loaded steel hammer and a latching mechanism. When the extended plunger rod is pushed against a hard surface, the spring connecting the hammer is stretched to an internal limit and then released, causing the energy stored in the stretching spring to propel the hammer against the plunger tip. The hammer strikes the shoulder of the plunger rod and rebounds a certain distance. On the outside of the unit is a slide indicator which records the distance traveled during the rebound. This indication is known as the rebound number (R-number).

At selected locations, rebound hammer readings were obtained to assess the uniformity of the in-place concrete within and above the water fluctuation zone and to delineate regions of potentially deteriorated concrete for further testing. In general, the rebound hammer testing was performed approximately 12 inches above the water level at the time of our evaluation and a second set of readings was obtained on the concrete approximately 48 inches above the water level at the time of our evaluation. The average results of 10 readings performed at each of the ten (10) selected locations are presented on Table 1.

The approximate plan view locations where the readings were obtained are shown on Figure 1.

As shown on Table 1, the average value of the rebound number within the zone of typical water fluctuation is 3.7 and the average rebound number value above the zone of typical water fluctuation is 4.3. Though the average rebound number readings obtained above the water typical fluctuation zone is higher than the average rebound number within the typical fluctuation zone, it is our opinion that the lower rebound numbers in the zone of typical fluctuation are primarily due to the surface condition (i.e., algae and barnacles present within the zone of typical water level fluctuation). No significant areas of "softer" or "harder" concrete were distinguishable.

Concrete Coring

The field exploration program also included obtaining a series of concrete cores for evaluation. A total of ten (10) 3-inch diameter cores were obtained from selected locations. The cores were obtained from approximately 1 foot above the water level at the time of our exploration. The cores were drilled horizontally to a depth of at least 4.2 inches or until reinforcing steel was encountered in the core sample. The core samples were visually inspected and measured for length in the field and transported to our laboratory for additional testing. When reinforcing steel was encountered, observations relative to the condition of the reinforcing steel were made within the core hole. Upon completion of the coring program, all core holes were patched with high strength, rapid setting concrete patch.

A summary of the concrete core data including their length and general observations is presented as Table 2. Photographs of the core samples are included as Appendix II. The approximate core locations are schematically illustrated on a site plan shown on Figure 1. These locations were determined by estimating distances from existing site features and should be considered accurate only to the degree implied by the method of measurement used.'

We note that it was not possible to test the concrete weir due to water flowing on the weir faces.

Ultrasonic Thickness Readings

Non-destructive ultrasonic thickness readings were performed at selected locations along the upstream steel sheet pile wing walls. The downstream steel sheet pile wing walls were below the water level at the time our field program was conducted and were not evaluated. At each upstream wing wall, six (6) evenly spaced locations were tested and readings were obtained across the sheet pile section. The readings were obtained approximately 1 foot above the water level at the time of the readings. The thickness readings were obtained utilizing a Krautkramer DMS Ultrasonic Thickness Gauge. A summary of the readings for each wall is included as Table 3.

In general, the thickness readings for all walls exceeded the as-built sectional thickness of 0.375 inch. We note that readings may have been influenced by the corrosion.

Water Sampling

A sample of the creek water was obtained on March 29, 2013 downstream of the weir within the stilling basin and near the north wall. This sample was transported to our laboratory for analysis relative to corrosive properties (i.e.; pH, conductivity, chlorides and sulfates).

LABORATORY PROGRAM

Visual Evaluation of Concrete Core Samples

Selected core samples were chosen for examination to assess the depth of the erosion and examine for evidence of corrosion of embedded reinforcing steel. The selected core samples were saw-cut longitudinally and polished for examination.

In general, evidence of erosion (pitting) was not present or measurable. This was consistent with our visual observations. Within the cores we observed no evidence of rust bleeding (as would be expected from corroding reinforcing steel) or leaching of paste due to acid attack. These results also are consistent with our field observations.

Representative photographs depicting the polished core samples are included in Appendix III. We note that the photographs are oriented such that the exterior of the concrete in the structures is at the top of the photographs.

Chemical Evaluation of Concrete Core Samples

Selected core samples were also tested for carbonation and pH to assess the potential for corrosion. The pH of new concrete is typically within the range of 12 to 13 mostly due to calcium hydroxide, which is a normally occurring by-product of cement hydration. As a concrete surface reacts with carbon dioxide in air or water, the pH of the surface gradually is reduced to about 7 to 8 through a process called carbonation. Gradually the process penetrates deeper into the concrete. Once the internal pH drops below 10, the reinforcing steel passivation is disolved promoting corrosion.

To verify the pH, thin cross sections were cut horizontaly from the core samples. The thin sections were crushed into a powder and mixed with distilled water and tested with a pH meter.

The affected depth of carbonation from the surface can be readily shown by the use of phenolphthalein indicator solution. The phenolphthalein indicator solution is applied to the fresh cut surface of the concrete core. If the indicator solution turns purple, the pH is above 10.

The results of the indicator solution and pH testing are included as Table 4. In general, the results indicate that carbonation is negligible and that the pH of the concrete cores remain high and consistent with depth. These characteristics indicate that concrete within the areas explored has not undergone significant chemical attack.

Representative photographs depicting the carbonation testing using the phenolphthalein are included in Appendix III.

Concrete Compressive Strength Testing

The core samples were trimmed and capped in accordance with ASTM C-42 for compressive strength testing. The results of the compressive strength testing are presented in the following table:

Location	Original Length (in)	Trimmed and Capped Length (in)	Compressive Strength (psi)
Core 2	4.4	4.3	6,530
Core 4	4.3	4.1	5,520
Core 7	4.6	4.3	5,170
Core 9	4.5	4.3	5,640

The results indicate that the minimum and maximum compressive strength range from 5,170 to 6,530 psi respectively. The average and median compressive strength is 5,715 and 5,580 psi, respectively.

Chemical Analyses of Water

A water sample collected from the downstream stilling basin was tested for its corrosion properties. Properties tested included pH, resistivity, chloride and sulfate content. The properties and their classification according to the FDOT Structures Design Manual are presented below.

Tested Property				Environmental Classification	
Chloride (ppm)	pH	Resistivity (ohm-cm)	Sulfate (ppm)	Steel	Concrete
4,000	7.8	115	320	Extremely Aggressive	Extremely Aggressive

The environmental classification criteria is based on Table 1.3.2-1 for Substructure Environmental Classification from the Florida Department of Transportation Structural Design Manual dated January, 2012. It is noted that the Florida Department of Transportation Substructures Environmental Classification system includes three categories (i.e.; slightly aggressive, moderately aggressive and extremely aggressive). Therefore, the water test results fall into the most aggressive category. This is likely due to the salt/brackish water as evidenced by the high chloride and low resistivity readings.

CONCLUSIONS AND RECOMMENDATIONS

Based on our visual observations and the results of our field exploration and laboratory testing programs, it is our opinion that the overall structural integrity of the concrete structure is in "good" general condition and has not been significantly compromised due to erosion or corrosion. Considering the age of the structure and the extremely aggressive environmental conditions we can assume that the resistance to degregation is due to high quality concrete. It is our opinion that the concrete should continue to perform for many years before remediation is needed.

We note that while evaluation of the wall joint material was beyond our scope of work, we did observe seepage staining at some joint locations and degraded joint filler material. The provided "As built" plans referred to the "preformed joint material." Ardaman is not aware of the purpose of the joint filter and/or its importance. If deemed prudent by others, the joint filler should be replaced.

The upstream steel sheet pile wing walls are in a somewhat degraded condition considering the observed corrosion at or near the water line. Remediation of the walls is recommended. The downstream sheet pile walls could not be evaluated because they were submerged.

We recommend that the corrosion be pressure washed, ground and/or sand blasted to remove the corrosion and then repaint/coat the prepared surface as needed. Depending on the severity of the corrosion that will only be evident after the corrosion is removed, joint reinforcement (i.e. welded metal plating) may be required.

CLOSURE

The analyses and recommendations submitted herein are based on our observations and on the data obtained from our field and laboratory programs. This report does not reflect any variations which may occur adjacent to or between the test locations.

This report has been prepared for the exclusive use of St. Johns River Water Management District in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made.

We are pleased to be of assistance to you on this phase of the project. When we may be of further service to you or should you have any questions, please contact us.

Very truly yours,
ARDAMAN & ASSOCIATES, INC.
Certificate of Authorization No. 5950

JASON MICHAEL PARKER LICENSE No. 65928 STATE OF FLORIDA PROFESSIONAL ENGINEER

5/30/13

Jason M. Parker, P.E.
Senior Project Engineer
Florida License No. 65928

Charles H. Cunningham, P.E.
Orlando Branch Manager
Florida License No. 38189

JMP/CHC/ksb/nfm
13-60-6303 Engineering Evaluation of SJRWMD Structure S-157(2013 Geo)

TABLE 1
Summary of Rebound Hammer Data
C-54 Canal Water Control Structure S-157
SJRWMD, Brevard County, Florida

R-Number Location	Description	Average R-Number	
		Within Zone of Typical Water Fluctiation	Above Zone of Typical Water Fluctuation
R1	Downstream - South Wall, East Wing Wall	4.3	4.6
R2	Downstream - South Wall, Mid Panel	3.8	4.1
R3	Downstream - South Bay, South Wall	3.4	4.3
R4	Downstream - South Bay, North Wall Panel	3.8	4.4
R5	Downstream - Middle Bay, South Wall	3.9	4.2
R6	Downstream - Middle Bay, North Wall	3.7	4.2
R7	Downstream - North Bay, South Wall	3.7	4.1
R8	Downstream - North Bay, North Wall	3.5	4.4
R9	Downstream - North Wall, Mid Panel	3.6	4.2
R10	Downstream - North Wall, East Wing Wall	3.7	4.8
	Average	3.7	4.3

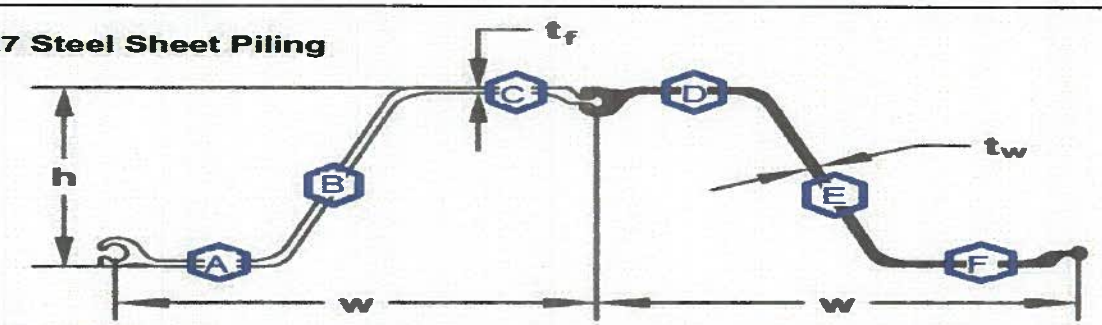
TABLE 2
Summary of Concrete Coring
C-54 Canal Water Control Structure S-157
SJRWMD, Brevard County, Florida

Location	Core Designation	Length (in)	Rebar Encountered	General Condition/Observations
Downstream - South Wall, East Wing Wall	C-1	4.3	N	
Downstream - South Wall, Mid Panel	C-2	4.3	N	
Downstream - South Bay, South Wall Panel	C-3	3.1	Y	Rebar in good condition. No corrosion observed.
Downstream - South Bay, North Wall Panel	C-4	4.2	N	
Downstream - Middle Bay, South Wall	C-5	3.2	Y	Rebar in good condition. No corrosion observed.
Downstream - Middle Bay, North Wall	C-6	2.8	Y	Rebar in good condition. No corrosion observed.
Downstream - North Bay, South Wall	C-7	4.7	N	
Downstream - North Bay, North Wall	C-8	5.0	N	
Downstream - North Wall, Mid Panel	C-9	4.8	N	
Downstream - North Wall, East Wing Wall	C-10	5.3	N	

TABLE 3
Ultrasonic Thickness Readings
Steel Sheet Pile Wing Walls
C-54 Canal Water Control Structure S-157
SJRWMD, Brevard County, Florida

Reading Designation	Wing Wall Average Thickness Reading (inches)											
	Location on South Wall (Upstream)						Location on North Wall (Upstream)					
	1	2	3	4	5	6	1	2	3	4	5	6
A	0.415	0.393	0.401	0.393	0.431	0.429	0.415	0.411	0.413	0.414	0.400	0.417
B	0.398	0.393	0.390	0.420	0.403	0.399	0.413	0.418	0.400	0.393	0.428	0.407
C	0.427	0.400	0.404	0.408	0.407	0.398	0.419	0.469	0.442	0.406	0.412	0.407
D	0.408	0.401	0.399	0.411	0.411	0.408	0.413	0.449	0.428	0.408	0.415	0.410
E	0.399	0.395	0.402	0.405	0.409	0.400	0.409	0.438	0.418	0.411	0.410	0.408
F	0.411	0.396	0.400	0.401	0.403	0.399	0.402	0.424	0.415	0.400	0.412	0.410
Maximum Value	0.427	0.400	0.404	0.420	0.431	0.429	0.419	0.469	0.442	0.414	0.428	0.417
Minimum Value	0.398	0.393	0.390	0.393	0.403	0.398	0.413	0.411	0.400	0.393	0.400	0.407
Average Value	0.413	0.395	0.398	0.407	0.414	0.409	0.416	0.433	0.418	0.404	0.413	0.410
Median Value	0.415	0.393	0.401	0.408	0.407	0.399	0.415	0.418	0.413	0.406	0.412	0.407

PZ-27 Steel Sheet Piling



ASTM A572 Grade 50

Section	Width w in (mm)	Height h in (mm)	Thickness tw in (mm)	Cross Sectional Area in²/ft (cm²/m)	Weight: Pile lb/ft (kg/m)	Weight: Wall lb/ft² (kg/m²)	Section Modulus in³/ft (cm³/m)	Moment of Inertia in⁴/ft (cm⁴/m)	Coating Area Both Sides ft²/ft (m²/m)	Coating Area ft²/ft² (m²/m²)
PZ-27	18.00 457	12.00 305	0.375 9.53	11.91 252.10	40.50 60.30	27.00 131.82	30.20 1620	184.20 25200	4.48 1.37	1.49 1.49

Approximate Reading Designation Location

TABLE 4
Summary of Concrete pH Results
C-54 Canal Water Control Structure S-157
SJRWMD, Brevard County, Florida

Project Name: Structure S-157

File Number: 13-60-6303

Client Name: St. John River Water Management District

Lab No. 6603

Date Recieved: 4/12/2013

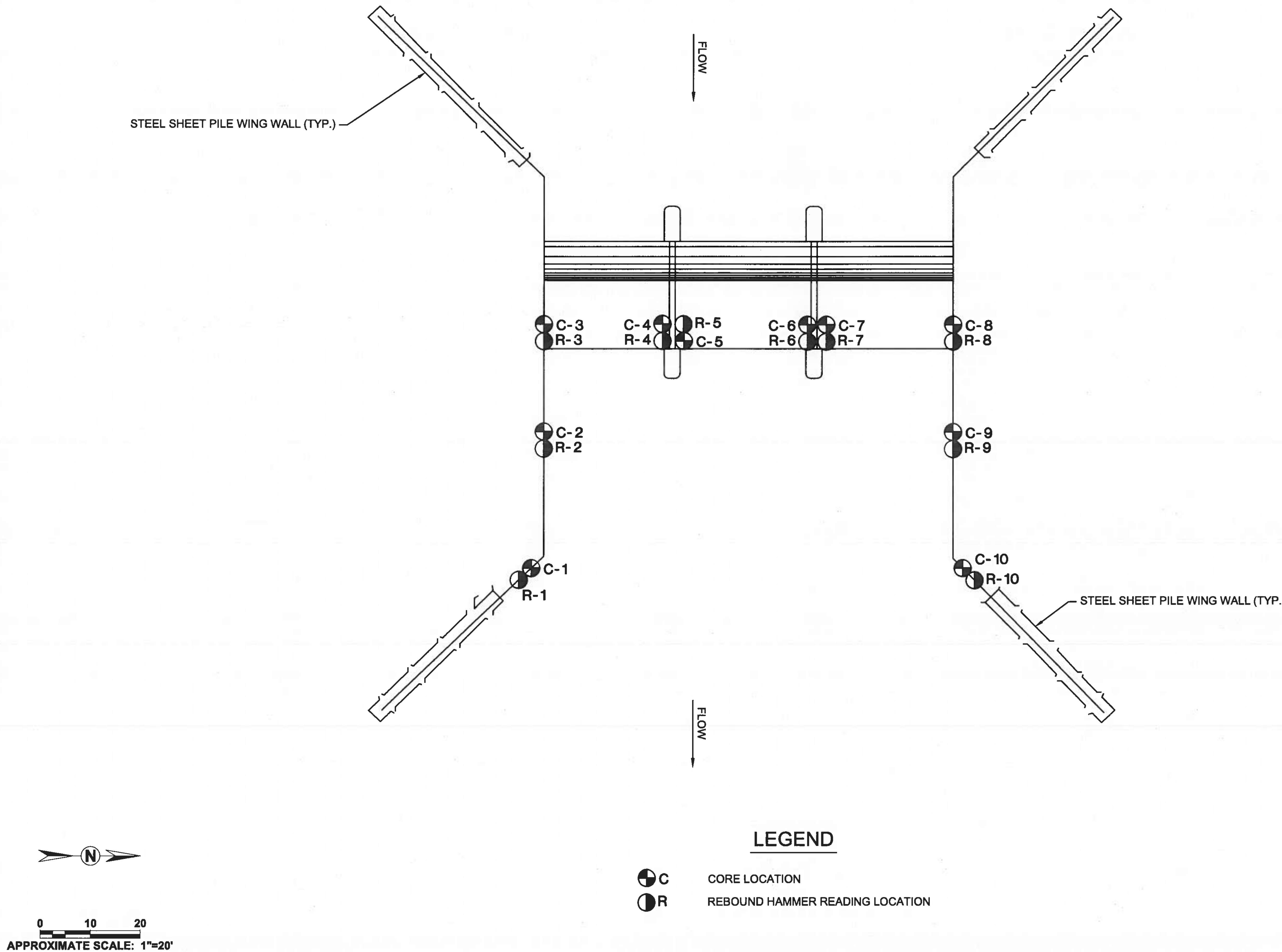
Sampled By: Orlando

Date Tested: 5/16/2013

Tested By: LW

CONCRETE pH DETERMINATION (ASTM C-1218)

Core Sections	Pan ID	Jar. No.	Wt of Concrete (g)	pH	Core Sections	Pan ID	Jar. No.	Wt of Concrete (g)	pH	Core Sections	Pan ID	Jar. No.	Wt of Concrete (g)	pH
C-1 (1)	C	36	20	12.16										
C-1 (2)	AC	1	20	12.28										
C-3 (1)	CC	2	20	12.24										
C-3 (2)	AN	15	20	12.23										
C-5 (1)	FC	7	20	12.08										
C-5 (2)	CJ	27	20	12.27										
C-6 (1)	FA	49	20	12.06										
C-6 (2)	FB	62	20	12.01										
C-8 (1)	FD	37	20	12.17										
C-8 (2)	B7	124	20	12.29										
C-10 (1)	GH	80	20	12.05										
C-10 (2)	N	56	20	12.21										



LEGEND

C	CORE LOCATION
R	REBOUND HAMMER READING LOCATION

CORE LOCATION PLAN

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

ENGINEERING EVALUATION OF SJRWMD STRUCTURE S-157 C-54 CANAL BREVARD COUNTY, FLORIDA

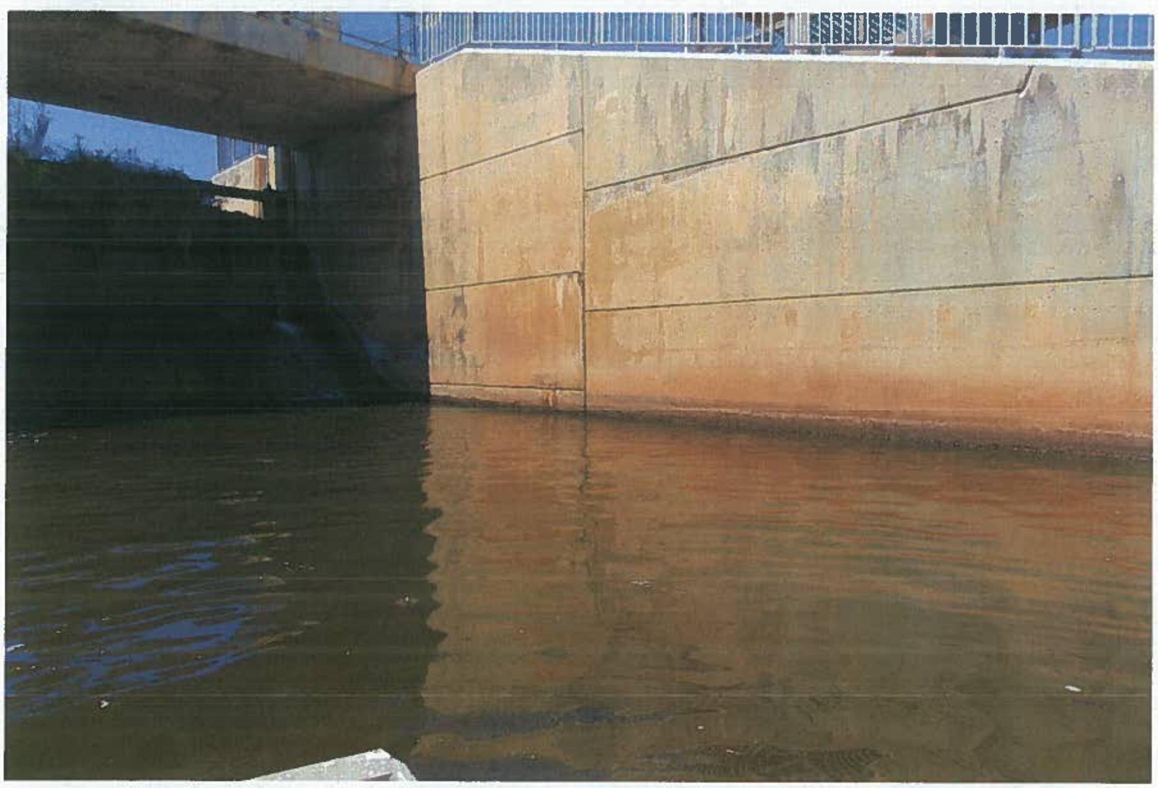
DRAWN BY: CD	CHECKED BY:	DATE: 05/23/13
FILE NO. 13-6303	APPROVED BY:	FIGURE: 1

APPENDIX I

Photographs of Site Observations

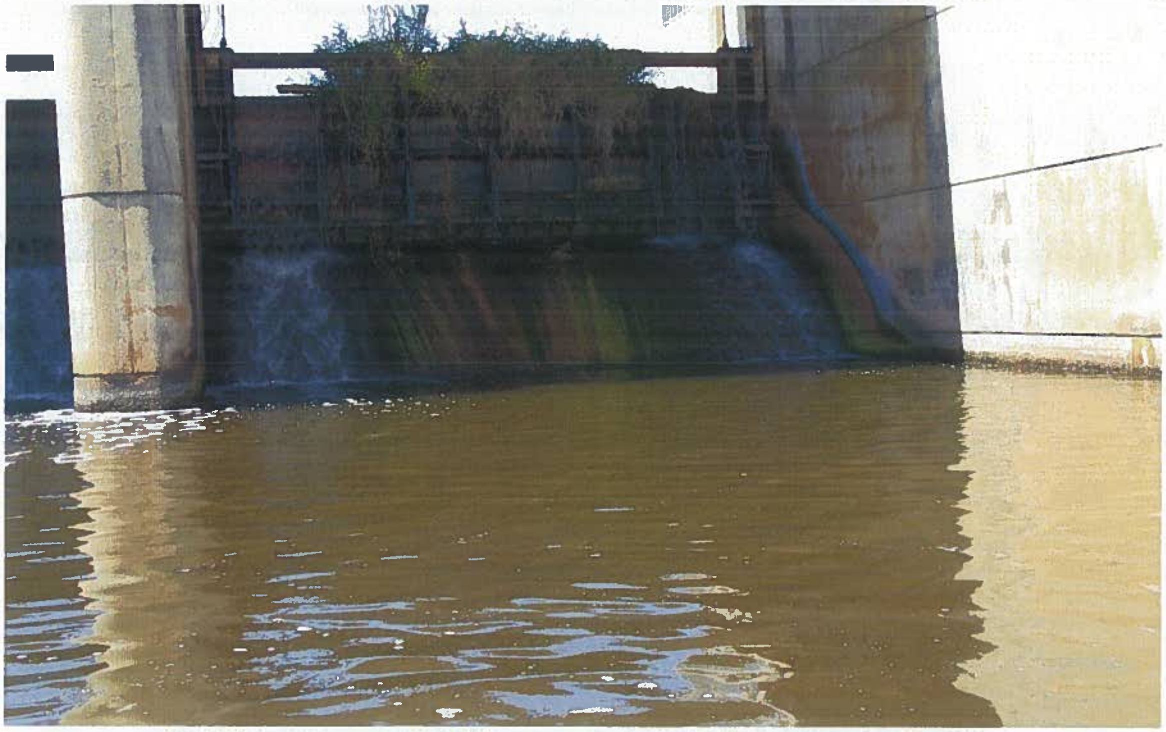
APPENDIX I
Canal C-54
Water Control Structure S-157
SJRWMD, Brevard County

Downstream - North Mid-Panel and Wing Wall.



Downstream - North Bay Wall and Mid-Panel Wall.

APPENDIX I
Canal C-54
Water Control Structure S-157
SJRWMD, Brevard County



Downstream - North Bay Weir.

Downstream - North Bay, South Interior Wall.

APPENDIX I
Canal C-54
Water Control Structure S-157
SJRWMD, Brevard County

Downstream - South Bay - North Interior Wall and Mid-Bay North Interior Wall.

Downstream - Mid Bay Weir and North Interior Wall.

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Canal C-54
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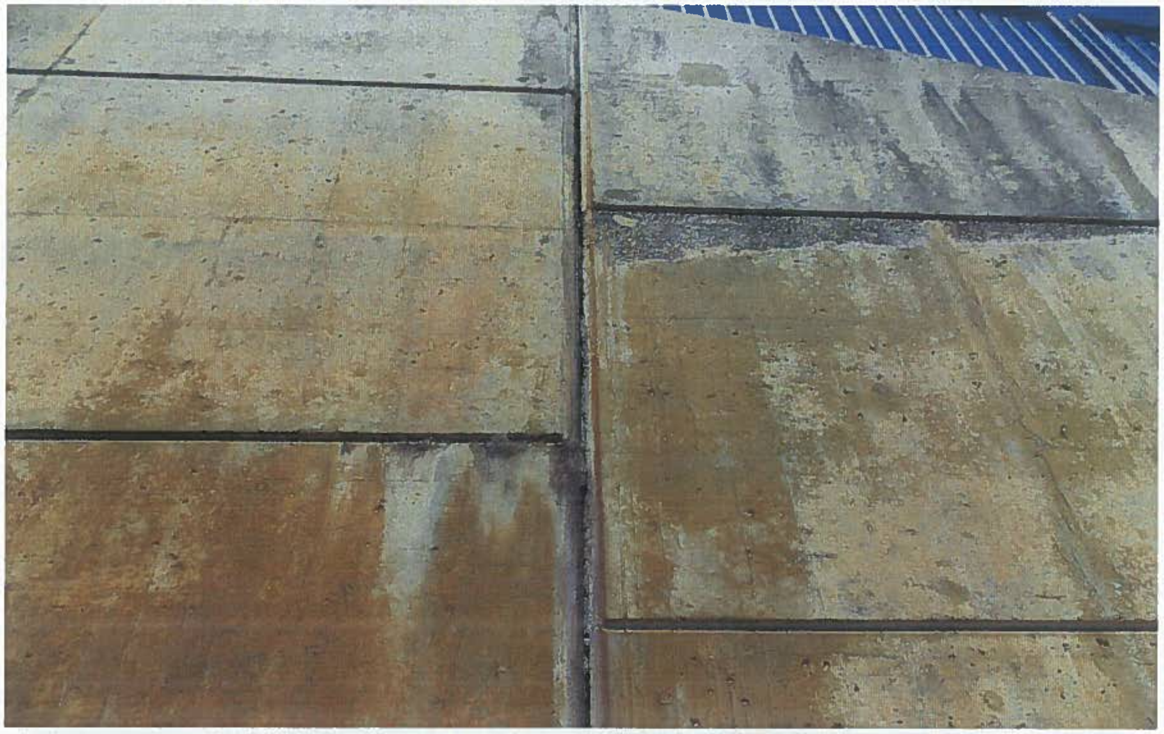
SJRWMD, Brevard County

Downstream - North Mid-Panel Wall.

Downstream - North Mid-Panel Wall. Note Joint Filler Deterioration.

APPENDIX I
Canal C-54
Water Control Structure S-157
SJRWMD, Brevard County



Downstream - South Mid-Panel Wall. Note Seepage Staining and Joint Deterioration.

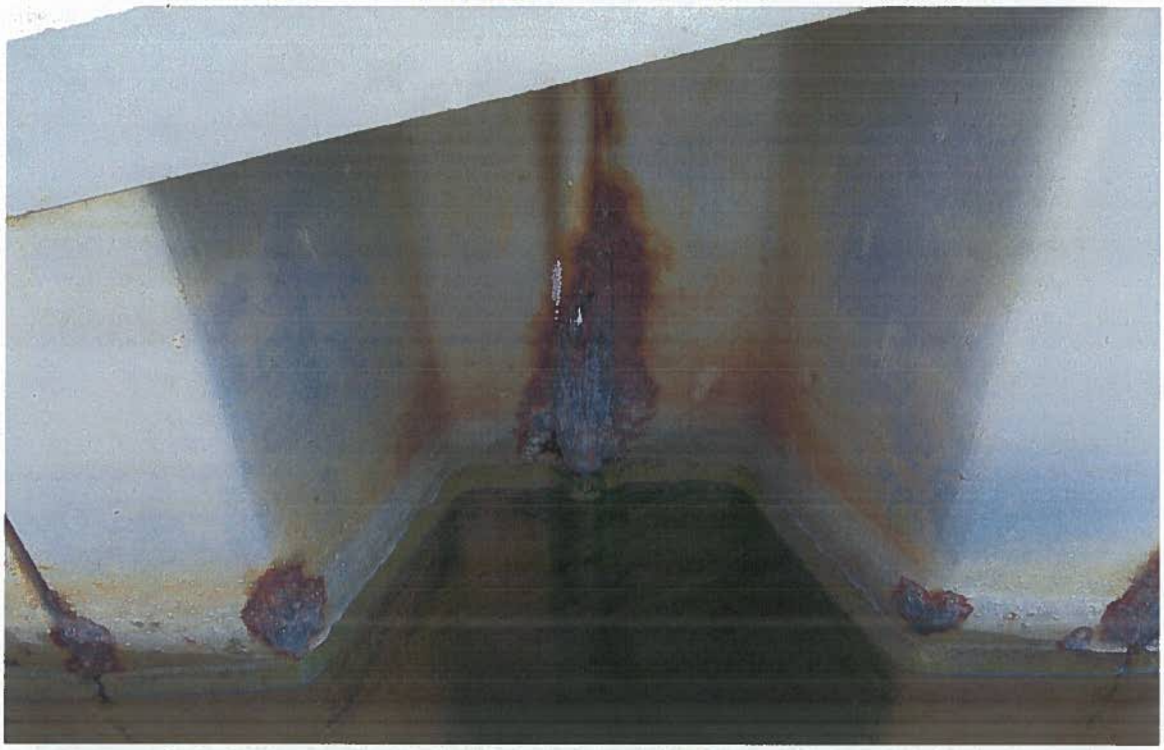
Upstream - North Steel Sheet Pile Wing Wall.

APPENDIX I

Canal C-54

Water Control Structure S-157

SJRWMD, Brevard County



Upstream - North Steel Sheet Pile Wall. Note Joint Corrosion.

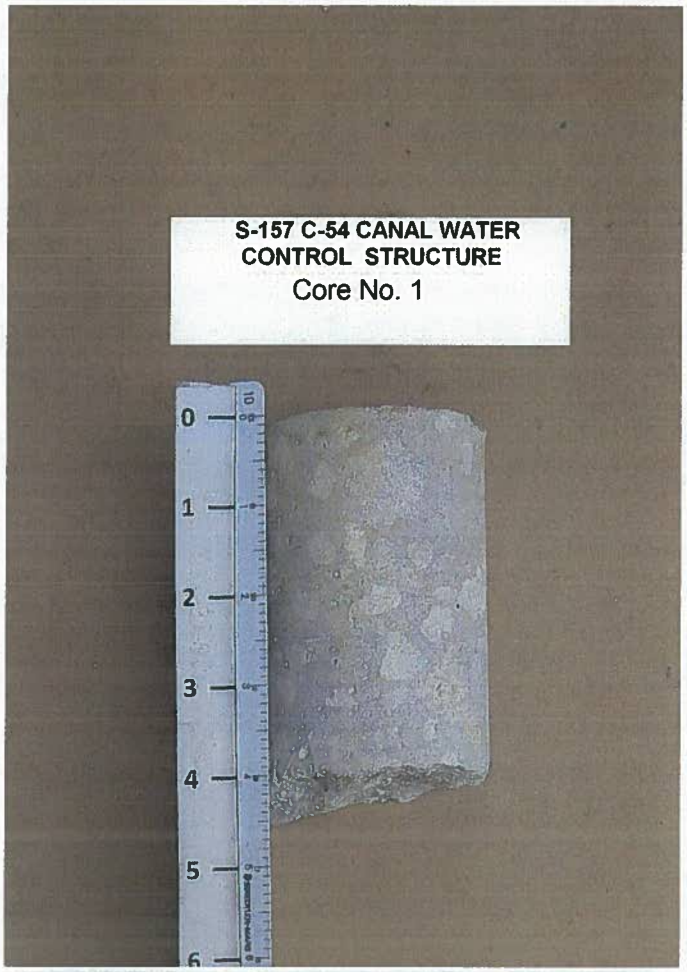
Upstream - South Steel Sheet Pile Wing Wall.

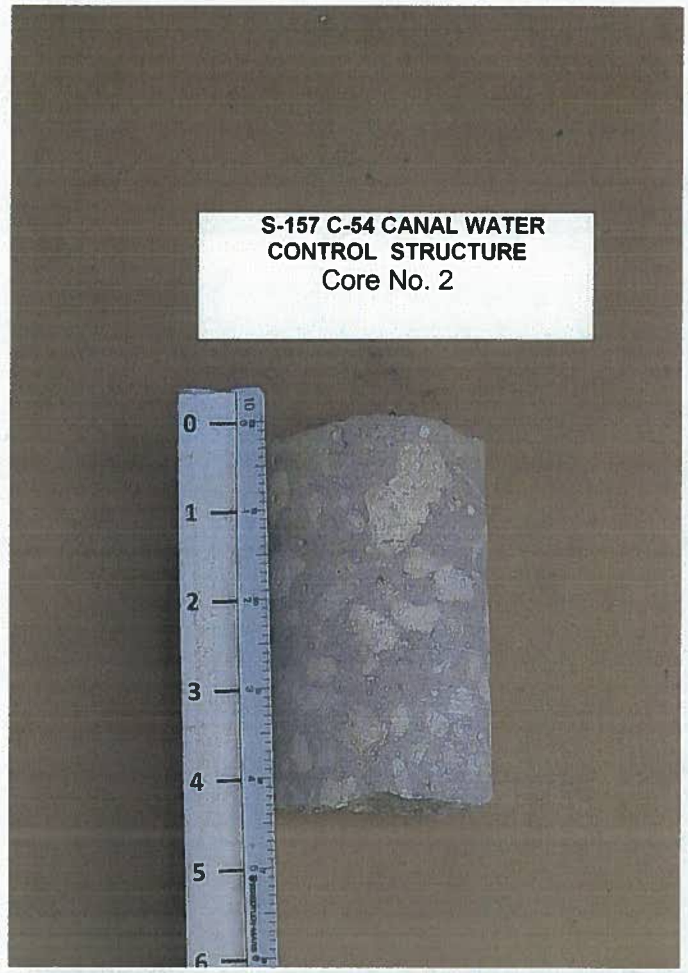
APPENDIX I
Canal C-54
Water Control Structure S-157
SJRWMD, Brevard County

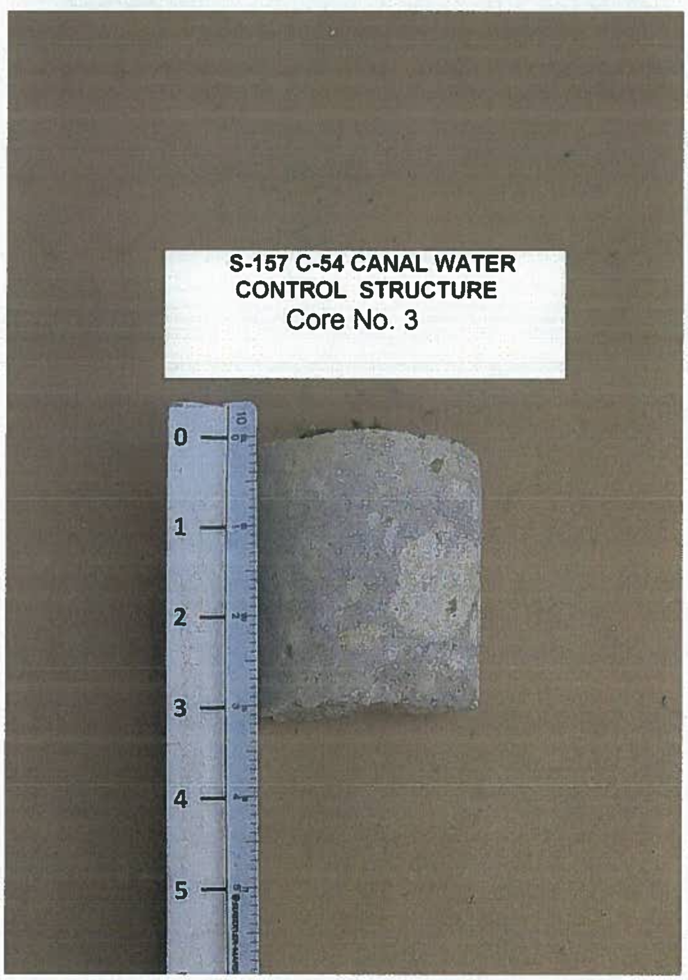
Upstream - South Wing Wall.

APPENDIX II

Laboratory Core Photographs

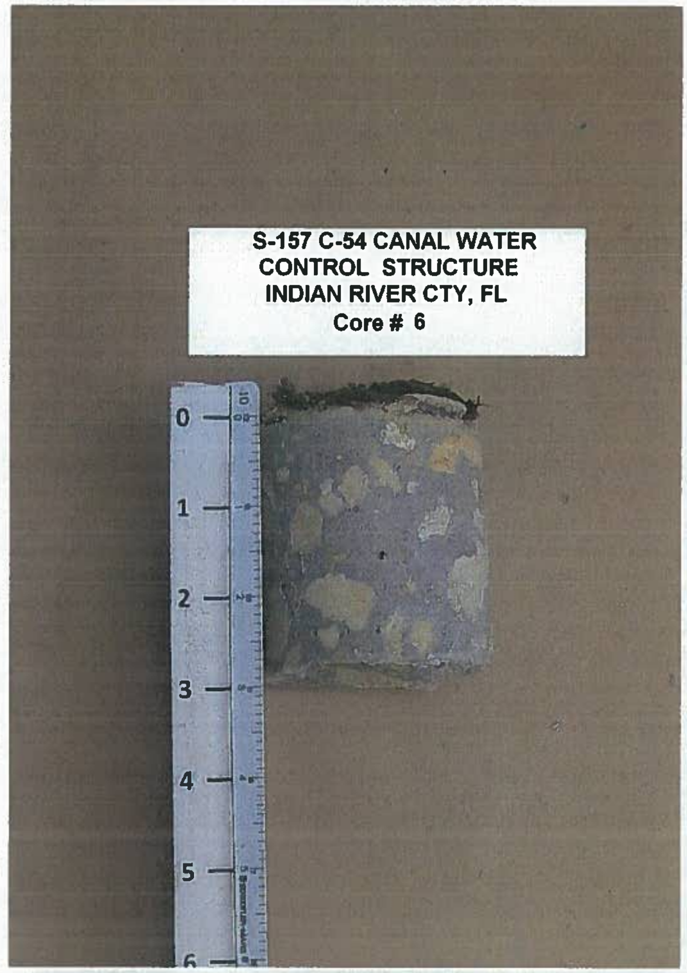

S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 1

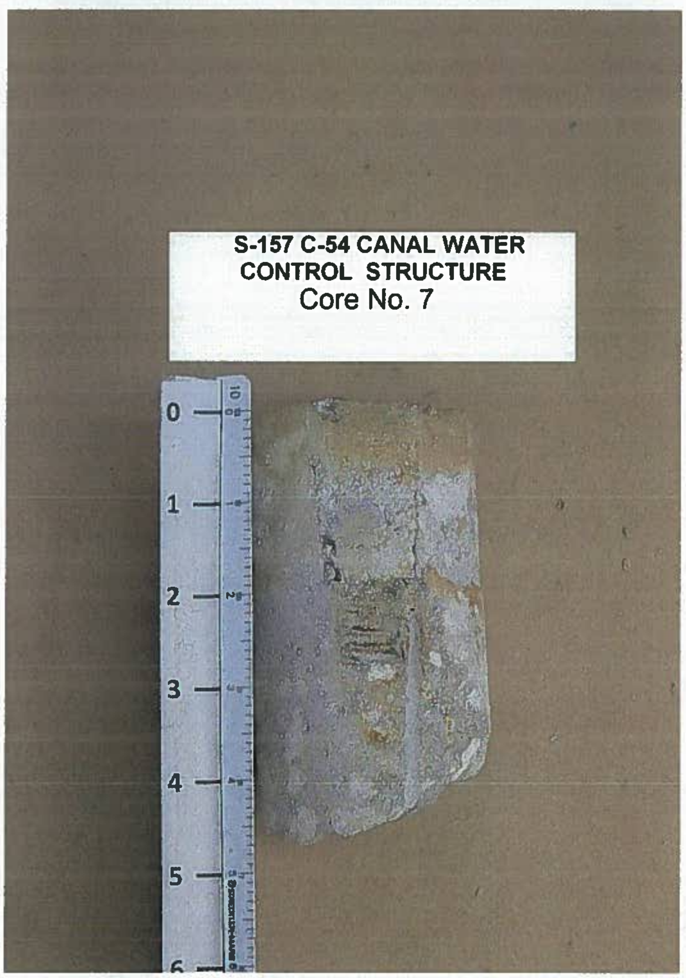

S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 2


S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 3


S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 4


S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 6
0
1
2
3
4
5


S-157 C-54 CANAL WATER
CONTROL STRUCTURE
INDIAN RIVER CTY, FL
Core # 6
0
1
2
3
4
5


S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 7
0
1
2
3
4
5


S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 8
0
1
2
3
4
5


S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 9
0
1
2
3
4
5
6


S-157 C-54 CANAL WATER
CONTROL STRUCTURE
Core No. 10
0
1
2
3
4
5
6

APPENDIX III

Petrographic and Carbonation Examination Photographs

APPENDIX III
Canal C-54
Water Control Structure S-157
Patrographic and Carbonation Examination

Core 1

Core 3

Core 6

Core 8

Core 10