



# Heritage Wharf & Kings Wharf: Cruise Ship Docking Facilities Improvements

Cathodic Protection Performance Specification

March 2013

Ministry of Public Works





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Ministry of Public Works

Government of Bermuda  
Ministry of Public Works  
Dept of Works & Engineering  
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Bermuda



# Issue and revision record

Revision	Date	Originator	Checker	Approver	Description	Standard
A	March 2013	R Merola	A Foster	C Atkins	1 <sup>st</sup> Issue	



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# 1 Introduction

## 1.1 Background

Mott MacDonald has been appointed by the Department of Works and Engineering of the Government of Bermuda’s Ministry of Public Works (GBMPW), to undertake consultancy services for upgrading the docking facilities for their cruise terminal at the Royal Naval Dockyard in Bermuda.

## 1.2 General

This Part of the Specification describes the cathodic protection requirements to be adopted on the project, and shall be read in conjunction with all other contract and relevant documents and standards specified.

## 1.3 Extent of the Works

The overall extent of Works is defined on the Drawings, which are listed in Table 1.1.

Table 1.1: Drawings

Title	Drawing Number
Site Plan and Drawing List	MMD-311437-C-DR-00-XX-0001
General Arrangement	MMD-311437-C-DR-00-XX-0010
Berthing Dolphin H-BD3&4 General Arrangement	MMD-311437-C-DR-00-XX-0011
Mooring Dolphin H-MD5 General Arrangement	MMD-311437-C-DR-00-XX-0012
Mooring Dolphin H-MD6 General Arrangement	MMD-311437-C-DR-00-XX-0013
Walkway H-MD6 and Walkway Support General Arrangement	MMD-311437-C-DR-00-XX-0014
Walkways Details: H-MD5, H-BD3 and H-BD4	MMD-311437-C-DR-00-XX-0015
Deck Furniture Sheet 1 of 2	MMD-311437-C-DR-00-XX-0016
Deck Furniture Sheet 2 of 2	MMD-311437-C-DR-00-XX-0017
Mooring Dolphin H-MD6 Reinforcement Details Sheet 1 of 2	MMD-311437-C-DR-00-XX-0020
Berthing Dolphins H-BD3 and H-BD4 Reinforcement Details Sheet 1 of 2	MMD-311437-C-DR-00-XX-0021
Mooring Dolphin H-MD6 Pile Plug Reinforcement Details	MMD-311437-C-DR-00-XX-0022
Berthing Dolphin Pile Plug Reinforcement Details	MMD-311437-C-DR-00-XX-0023

Title	Drawing Number
Walkway Support and Walkway Pile Plug Reinforcement	MMD-311437-C-DR-00-XX-0024
Mooring Dolphin H-MD5 Reinforcement Details	MMD-311437-C-DR-00-XX-0025
Mooring Dolphin H-MD5 Pile Plug, Reinforcement Details	MMD-311437-C-DR-00-XX-0026
Mooring Dolphin H-MD6 Reinforcement Details Sheet 2 of 2	MMD-311437-C-DR-00-XX-0027
Berthing Dolphins H-BD3 and H-BD4 Reinforcement Details Sheet 2 of 2	MMD-311437-C-DR-00-XX-0028
Mooring Dolphin H-MD5 Reinforcement Details Intermediate Pour	MMD-311437-C-DR-00-XX-0029
Berthing and Mooring Dolphins, Electrical Continuity	MMD-311437-C-DR-00-XX-0030
Mooring Dolphin H-MD6 Reinforcement Details Intermediate Pour	MMD-311437-C-DR-00-XX-0031
Berthing Dolphins H-BD3 and H-BD4 Reinforcement Details Intermediate Pour	MMD-311437-C-DR-00-XX-0032

## 2 Cathodic Protection System

### 2.1 Work, Scope and Function

A cathodic protection (CP) system shall be designed, supplied, installed, constructed, tested and commissioned by the Contractor to prevent corrosion of the following structures of Heritage Wharf at the Royal Naval Dockyard in Bermuda:

- Berthing Dolphin H-BD3;
- Berthing Dolphin H-BD4;
- Southern Mooring Dolphin H-MD5;
- Northern Mooring Dolphin H-MD6; and
- Intermediate Walkaway Support for the H-MD4 / H-MD6 walkaway.

Drawings of the structures to be protected are listed in Table 1.1.

The CP system shall be designed in accordance with the requirements set out in this Specification Document.

The CP system shall arrest all accelerated low water corrosion (ALWC) and/or microbiologically induced corrosion (MIC) from the date of commissioning and shall totally protect the steel piles from corrosion below the mid tidal zone (Mean Sea Level).

The CP system shall be a Galvanic (Sacrificial) Anode system.

The tide levels in Bermuda, according to Admiralty Chart No. 332 (Grassy Bay and Great Sound / Ireland Island), are listed in Table 2.1.

Table 2.1: Bermuda tide levels

Tide	Level mCD	Level ft CD
MHWS	+1.2	+3' 11.25" (+3.94)
MHWN	+0.9	+2' 11.4" (+2.95)
MLWN	+0.4	+1' 3.75" (+1.31)
MLWS	+0.2	+0' 7.9" (+0.66)

Source: Admiralty Chart 332

The required design waves and currents are provided in Table 2.2.

Table 2.2: Design wave and current parameters

Wave condition	Significant Wave Height ( $H_s$ ) (m)	Average Wave Period ( $T_z$ ) (seconds)	Current Velocity (knots)
Normal conditions	1.2	3.95	1
Storm conditions	3.5	9.3	1

Source: Bermuda Coastal Erosion Vulnerability Assessment, Smith Warner International, November 2004

## 2.2 Contractor's Specialist

The Contractor or his specialist Sub-Contractor employed to provide the detailed design and to install the CP System shall demonstrate competence in the design and installation of CP systems used in similar applications.

All work relating to the design, installation, testing, commissioning and operation of the CP System shall be supervised and signed off by a cathodic protection specialist employed by the Contractor or specialist Sub-Contractor certificated to Level 3 Marine Sector in accordance with BS EN 15257. Where the designer is not certified to this level, evidence shall be provided to the Employer of equivalent competence and experience.

## 2.3 Design Standards

The Contractor is required to produce a design for the CP system in accordance with the latest revision of the following standards:

Table 2.3: Design standards

BS EN 12473	General Principles of Cathodic Protection in Sea Water
BS EN 13174	Cathodic Protection for Harbour Installations
BS EN 13509	Cathodic Protection Measurement Techniques
BS EN 15257	Cathodic Protection Competence Levels and Certification of Cathodic Protection Personnel

Where there is conflict between the above Codes and Standards, the highest standard and most onerous requirement shall take precedence.

## 2.4 Pre-design Information

Prior to carrying out the detailed design for the CP system the Contractor is required to carry out a pre-design survey of the site to determine the following information required for detailed design and confirm any assumptions made in Section 2.5 of this Specification Document:

- The diameter and extent of piles exposed to seawater;
- The condition of any protective coatings to the steel piles;
- The average resistivity and temperature of the surrounding waters;
- The existence or otherwise of high seawater velocities in proximity to the structures to be protected;
- The possibility of reduced salinity due to fresh water run off in proximity to the structures to be protected;
- Any other piece of metal that could affect the CP system, and
- Any other information required to produce the final design for the CP system.

The Contractor shall submit the proposed number and distribution of test locations and full details of test procedures and evaluation methods to the Employer for approval prior to undertaking the pre-design site survey. The information from these surveys shall be included in the Contractor's design process and document submission.

## 2.5 Design Requirements and Criteria

The CP system shall be designed in accordance with the design standards outlined in Section 2.3.

The designed system shall be capable of providing adequate cathodic protection for a period of at least 50 years and shall use a galvanic anode system. The galvanic system shall not require replacement in 10 years of installation.

The system shall be designed to provide minimum in-service inspection, operation and maintenance throughout the design life.

The protection is considered to be achieved by potentials more negative than -900mV relative to the Ag/AgCl/seawater reference electrode.

The construction information available for the dolphins' steel piles is shown on the drawings listed in Table 1.1.

For the purposes of tendering the Contractor shall assume the following, to be confirmed by the Contractor on award during the pre-design site survey.

- Initial coating breakdown factor of 5% for immersed areas and 50% for buried areas, and a depletion rate of 2% per year;
- The resistivity of the seawater is assumed to be 20 ohm cm;
- There are 61 Nr piles to be protected in total with pile diameters of 0.762m and 0.914m;
- The sea bed is between 11.5m and 12.50m below LAT, and the piles extend up to a further ~30m below sea bed level, see Construction Drawings listed in Table 1.1; and
- The maintenance design current density is assumed to be 100mA/m<sup>2</sup> to sea bed level and 20mA/m<sup>2</sup> below this level.

## 2.6 Materials and Structural Form

The CP system design shall take account of the following.

- Connections to the steel piles shall be in accordance with the anode manufacturer's recommendations.
- Anodes shall be readily accessible for inspection and the pile attachment details shall be such that anodes can be easily replaced in the future without damaging the steel piles and the fixing bracket assemblies.
- Brackets for fixing anodes shall be suitably robust to satisfy the design life requirements for the CP system.
- The Contractor shall verify that the anode support brackets and anodes are of sufficient strength to withstand wave action, propeller/thruster wash and extreme weather events, including the design conditions referenced in Table 2.1 and Table 2.2.
- Anode fixings shall permit anode installation to the brackets without underwater welding (except to achieve electrical continuity) and shall readily facilitate replacement at the end of the anode design life.
- Anodes shall be attached to the piles such that they are permanently submerged.
- The system shall not interfere with any other port operation and shall not be a threat to shipping.

- Anode to bracket electrical continuity shall be achieved by tack welding.
- Anode cores and fixing brackets shall be fabricated from non-rimming, weldable, mild steel to BS EN 10025 grade S235 or S275.
- Each installed anode assembly shall be marked (indented) with a unique reference number for inspection and future reference purposes.
- Each anode casting shall be die-stamped on the top casting face with a unique furnace heat or batch number from which it has been cast.
- The fixing system for all anodes shall incorporate the absolute minimum number of bolted connections consistent with a reliable, durable and efficient fixing system.

## 2.7 Design Documents

The Contractor is required to submit an outline design with their preliminary submission showing as a minimum the number, size and type of anodes required. The outline design shall also illustrate the proposed method of attachment of the anodes to the steel piles.

Prior to the supply / installation of any equipment the Contractor shall provide a detailed design document for review and acceptance by the Employer. This document shall contain design criteria, assumptions, calculations, layout and fixing drawings. The following information shall be included as a minimum:

- The size, number and individual mass (net weight of alloy and gross weight of anode plus insert) of each anode;
- Details of the connection between the anodes and steel piles (including amount of offset) including detailed drawings of the anode fixing bracket and the structural calculations demonstrating its adequacy;
- Details for the provision of continuity bonds;
- Limits (levels) of the CP system;
- Calculated lengths, surface areas and current demand of each of the pile types in seawater and below the sea bed;
- The design sea water resistivity;

- Calculated individual anode current outputs at the Initial, Maintenance and Final Repolarisation anode dimensions; and
- The system of testing and commissioning.

The Contractor shall also submit with their detailed design document, full documentation on the anode properties and long-term performance, information shall include:

- Alloy chemical composition;
- Electrochemical properties as per manufacturer's standard properties;
- Electrochemical properties as determined by an independent test laboratory or by certified field measurements;
- Test results for potential, electrochemical capacity and passivity; and
- Detailed design drawings of the anodes including details of the anode inserts and their fixing brackets.

The Contractor shall also provide details of the anode manufacturer's BS EN ISO 9001:2008, third party Quality Management certification and DNV type approval certificates for the anode alloy material proposed and for the anode manufacturer's production facility for the approval of the Employer.

The Contractor shall allow a minimum of one week within his programme for this review.

## **2.8 Installation and Commissioning**

The Contractor shall maintain detailed records throughout the system installation, including reports of all tests performed in accordance with the approved quality plan, method statements, inspection and test procedures.

The Contractor shall submit a method statement for pre-commissioning checks and commissioning including, but not limited to, the programme and acceptance criteria. Pre-commissioning and commissioning shall be undertaken by an approved, qualified and experienced representative of the Contractor.

The Contractor shall provide a full report detailing all records of installation and commissioning.



## 2.9 Operation and Maintenance Manual

The Contractor is required to submit to the Employer an Operation and Maintenance Manual for the system installed within 28 days of the completion of the works. The Operation and Maintenance Manual shall be a complete and comprehensive reference manual with all the information necessary within one volume for the Employer to operate the system. It shall include and describe in detail with diagrams, drawings, manufacturers, data-sheets, pro-form results sheets, procedures etc. at least the following:

### (i) Operation

- A narrative description of the system, what it does, how it works and when it was installed.
- Details of the anode outputs etc.
- Monitoring – step-by-step guide on how to carry out measurements with details of equipment necessary, location and recognition of connections, how to judge significance of results obtained etc.
- System monitoring – recommended testing programme and how to complete standard pro-forma test result sheets, what records to keep.

### (ii) Maintenance

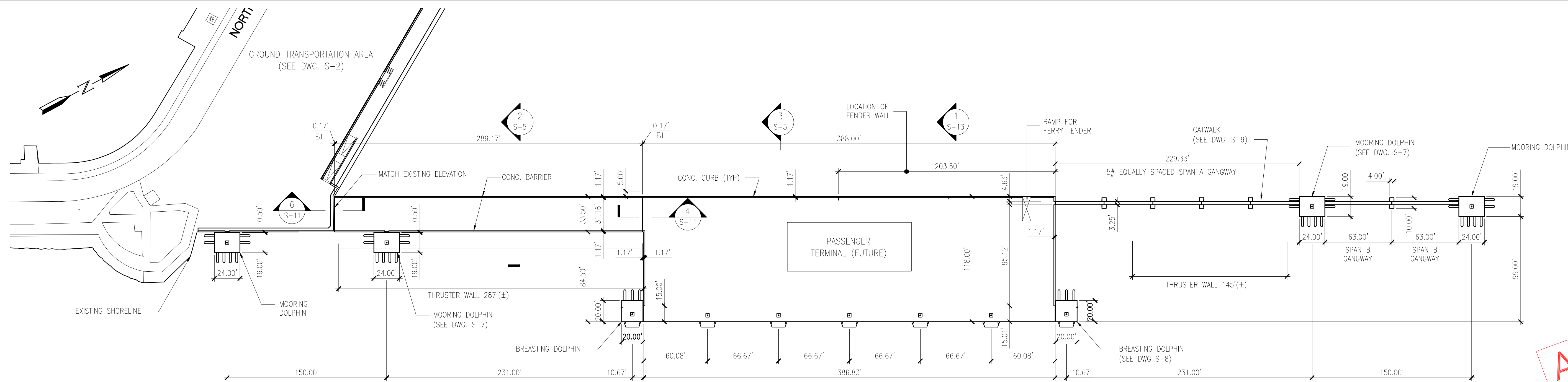
- Technical details of all equipment installed.
- Guide to routine maintenance operations including step-by-step fault finding, diagnosis, rectification guide and schematic diagrams.
- Manufacturer's details and spares stock list.
- Anode maintenance requirements, guide to localised repair and renovation procedures with details of materials and their stock lists.

## 2.10 Inspection and Monitoring

The Contractor is required to monitor the system for a period of 12 months after installation and confirm protection is being achieved. This will involve undertaking a half cell potential survey of the structure at 3, 6, 9 and 12 months after completion of the installation at each pile.

Half-cell readings will be gathered using calibrated silver / silver chloride seawater reference electrodes at 1m centres vertically down each pile from MSL level to the sea bed. The readings are to be taken within 2 hours before high tide and 2 hours after high tide.

Where protection has not been achieved within 9 months the Contractor is required to carry out, at his own time and expense, remedial measures to ensure protection is achieved at 12 months.



1 GENERAL PLAN  
S-5 SCALE: 1"=50'-0"

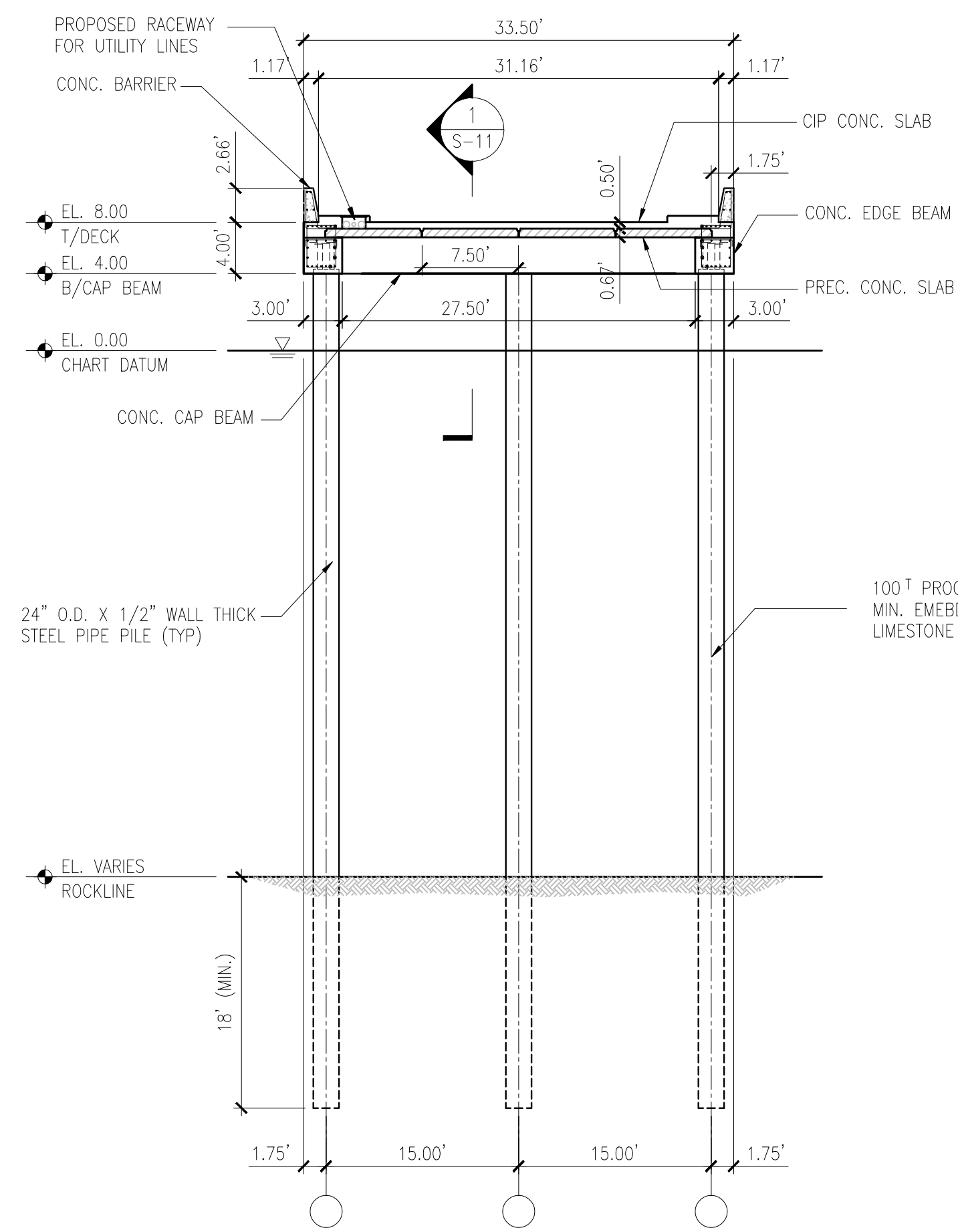
NOTE:  
1. REFER TO DWG. S-6 FOR DECK DETAILS AND PILE LAYOUT  
2. REFER TO DWG. S-2 GROUND TRANSPORTATION AREA.  
3. REFER TO DWG. S-9 FOR CATWALK DETAILS.

**AS BUILT**

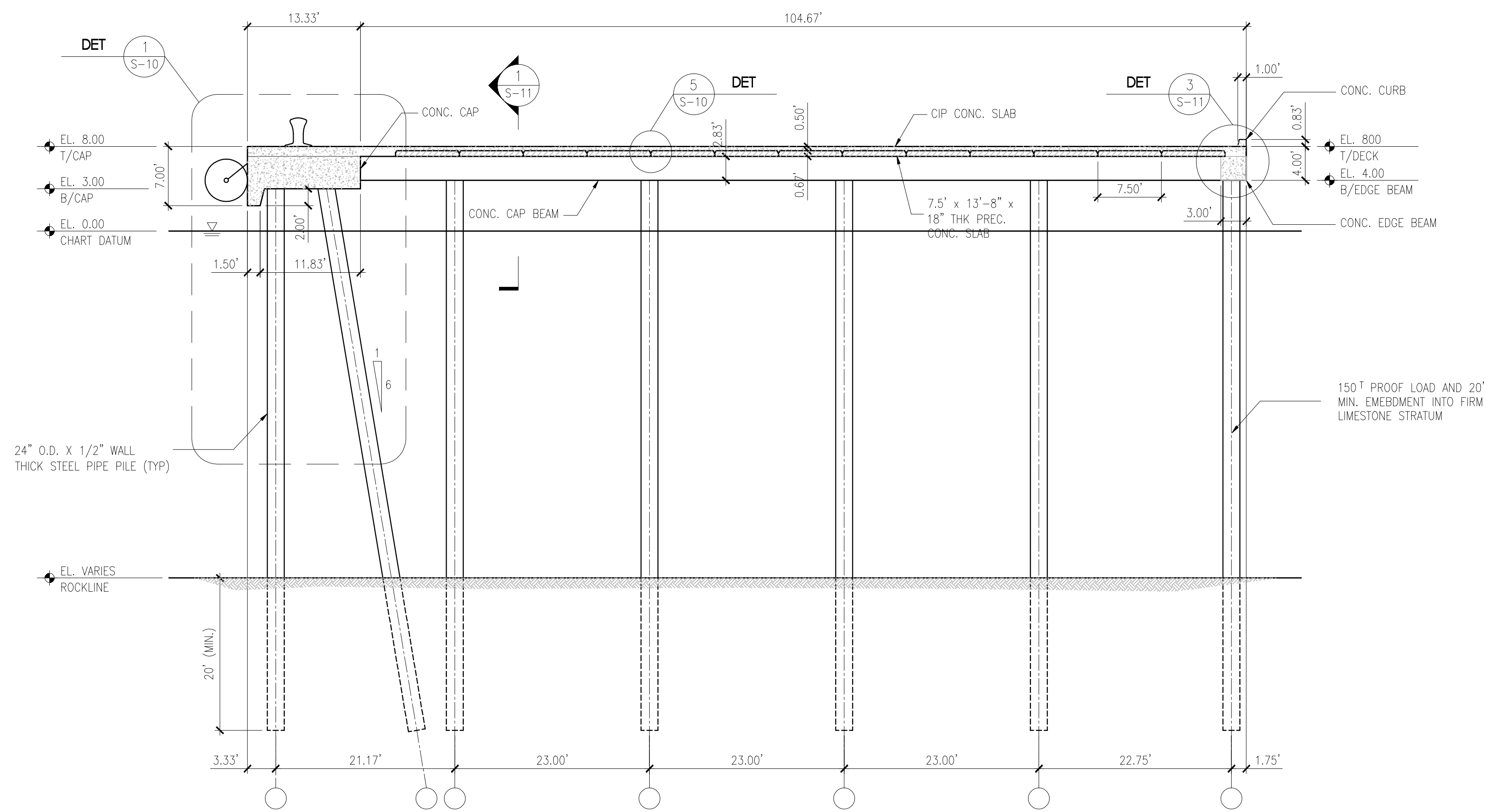
**GENERAL NOTES**  
1. REFER TO DWG. S-0 FOR GENERAL NOTES AND SPECIFICATIONS.  
2. REFER TO ARCHITECTURAL DWGS FOR DETAILS OF RAMP, GUARD RAILS, TERMINAL BUILDING, LIGHTINGS, ETC.

DATE	No.	REVISION
15.SEP.'08	-	REVISED CATWALK SUPPORT
30.NOV.'07	-	ADDED FERRY RAMP
28.AUG.'07	-	ADJUSTED ELEVATIONS
22.AUG.'07	-	ADDED SECTION/DETAIL
26.JUL.'07	-	LOCATION OF FENDER WALL
12.JUL.'07	-	REVISED NEW DOCK
20.JUN.'07	-	REVISED - NEW DOCK, GRID DIM
05.MAY.'07	-	REVISED PRECAST DETAILS
01.MAY.'07	-	ISSUED FOR BUILDING PERMIT

CONTRACTORS SHALL VERIFY ALL DIMENSIONS AND UTILITY LOCATIONS ON THE JOB SITE.



2 BRIDGE SECTION (100T PILE)  
S-5 NTS



3 PIER SECTION (150T PILE)  
S-5 NTS

designed by	DR	scale	AS SHOWN
drawn by	RP	job no.	E07017
checked by	DR	drawing no.	<b>S-5</b>
approved by	-	date	March 07

CLIENT  
**WEST END DEVELOPMENT CORPORATION**

PROJECT  
**PROPOSED ROYAL NAVAL DOCKYARD CRUISE IMPROV. DOCKYARD, BERMUDA**

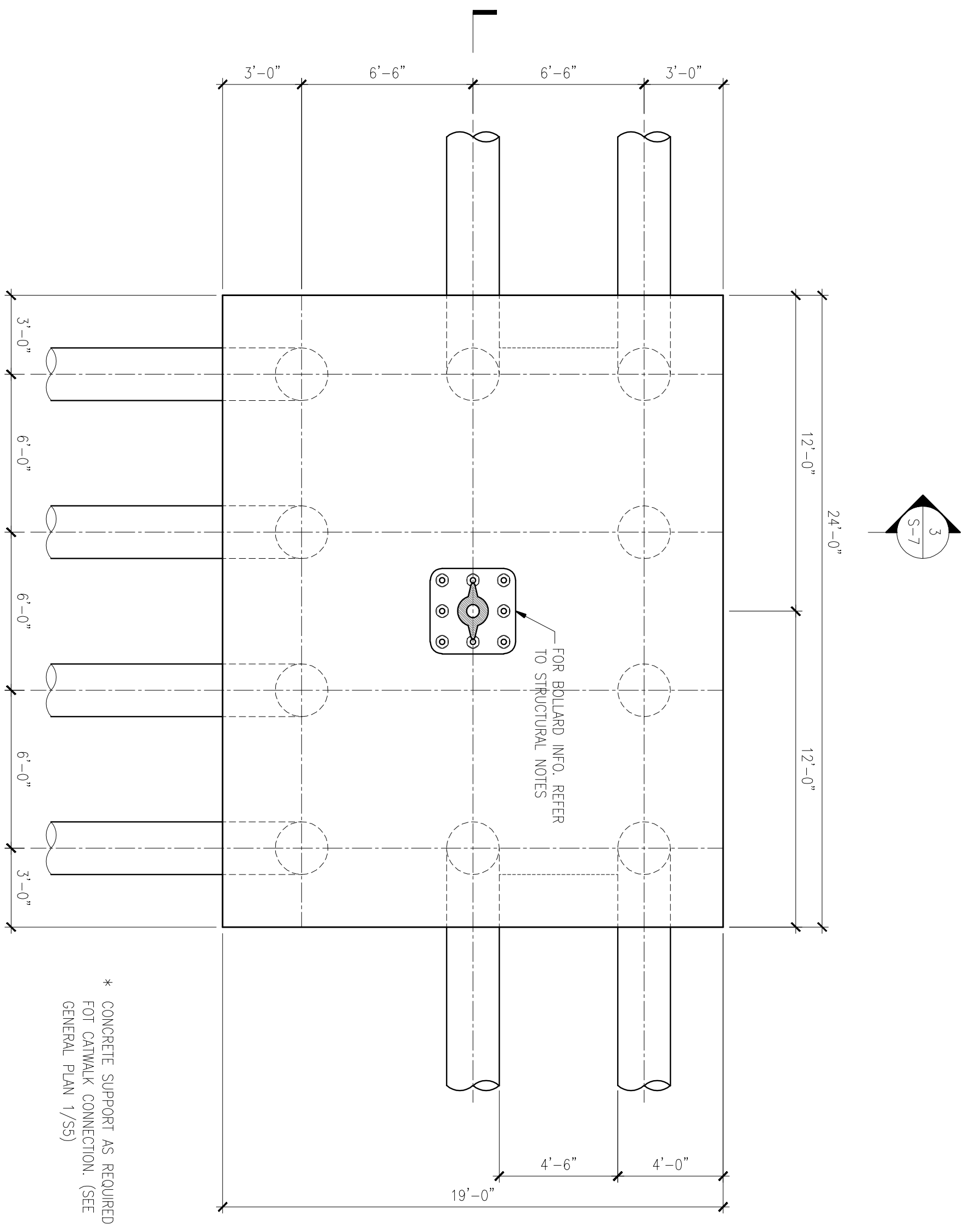
TITLE  
**PIER. GENERAL PLAN & SECTIONS**



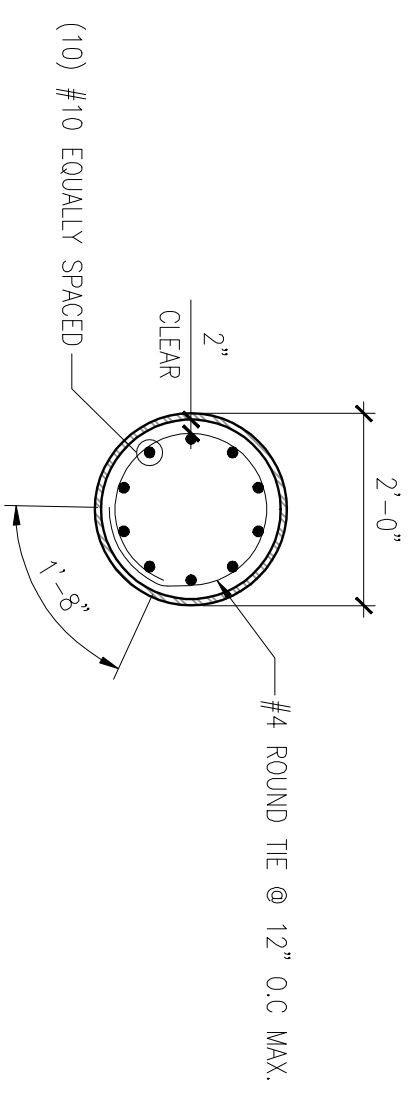
P.O. BOX HM 2574 HAMILTON HM-KX BERMUDA  
TEL. (441)-292-9192 FAX. (441)-292-9468 EMAIL. admin@entech.bm

**GENERAL NOTES**  
1. REFER TO DWG. S-0 FOR GENERAL NOTES AND SPECIFICATIONS.

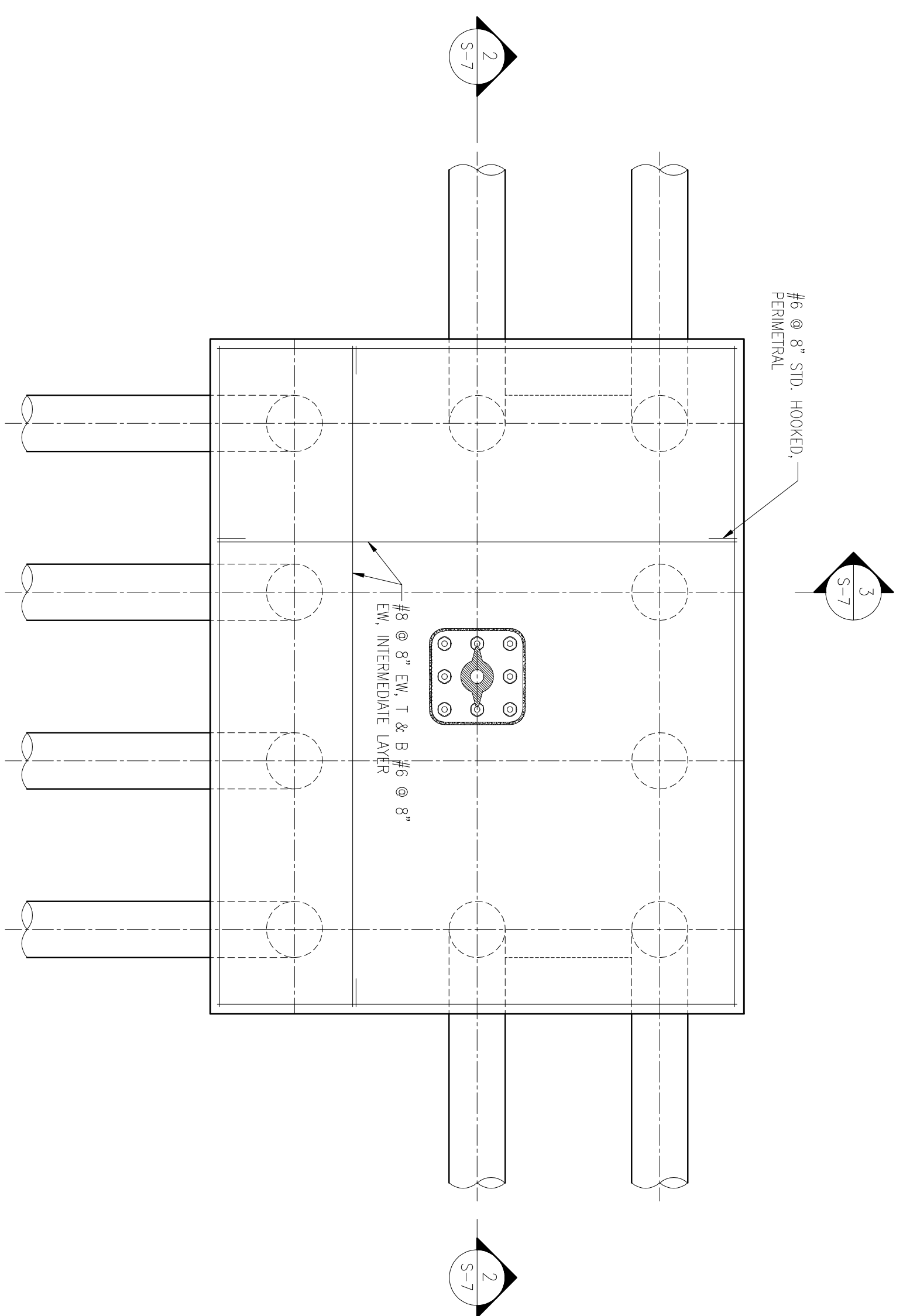
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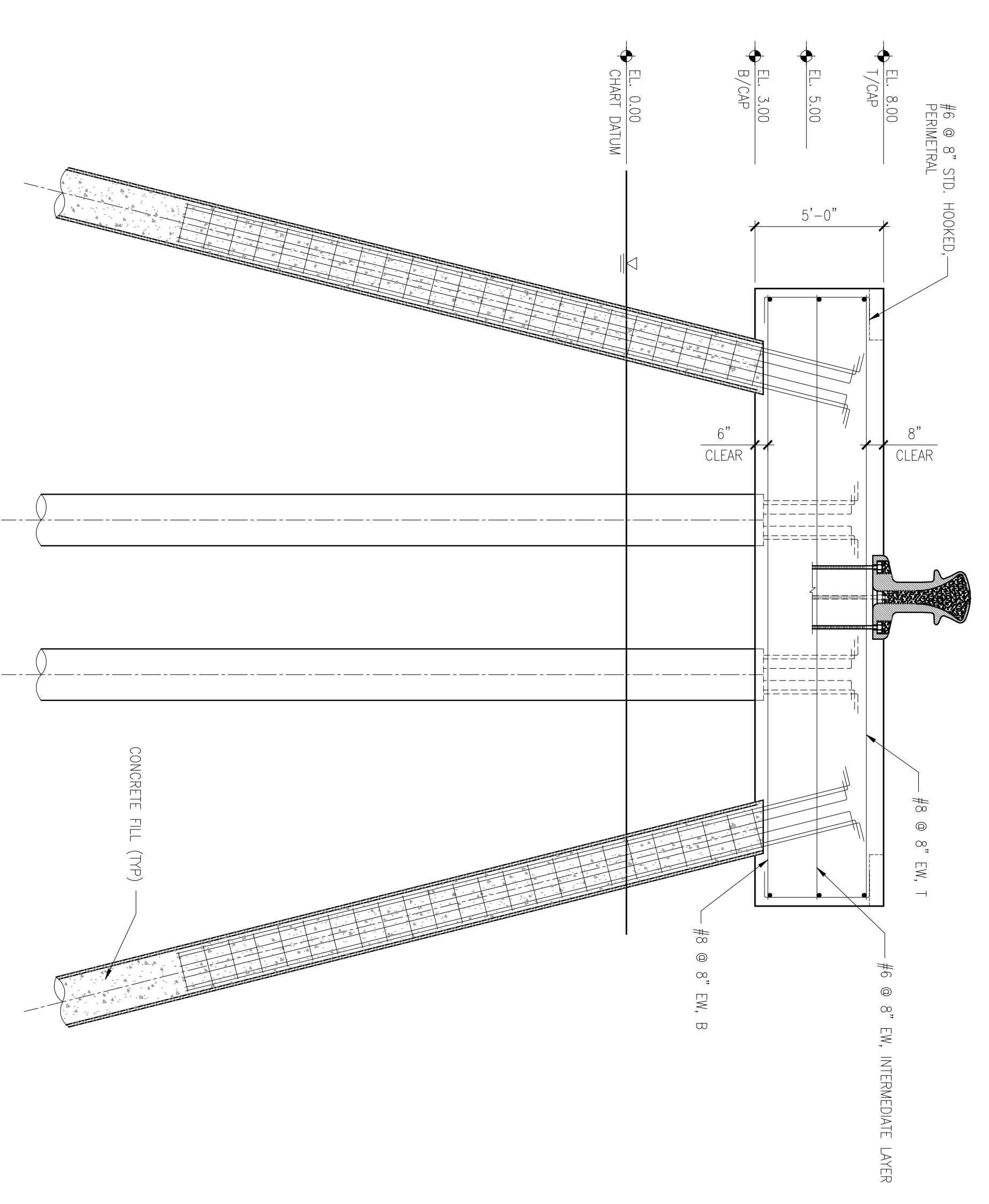
**1 PLAN VIEW**  
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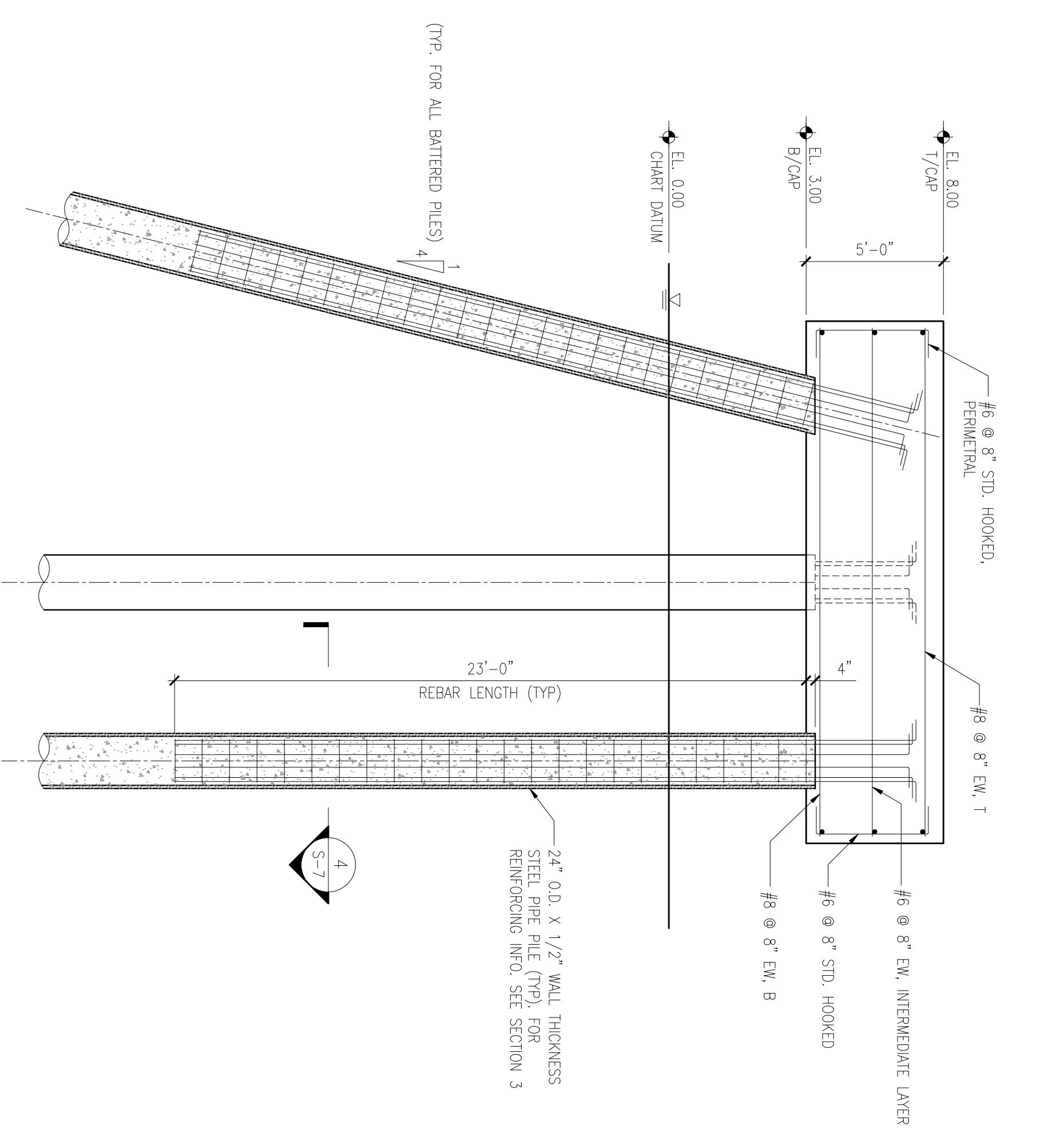
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**5 REINFORCING PLAN**  
SCALE: 1/4"=1'-0"



**2 SECTION**  
SCALE: 1/2"=1'-0"



**3 SECTION**  
SCALE: 1/2"=1'-0"

15 SEP '08	-	NEW INSTALLATION DETAILS
30 AUG '07	-	ADJUSTED ELEVATIONS
01 MAY '07	-	ISSUED FOR BUILDING PERMIT
DATE	NO.	REVISION

designed by	DR.	scale	AS SHOWN
drawn by	-	job no.	E07017
checked by	DR.	drawing no.	-
approved by	-	date	March 07

CLIENT  
**WEST END DEVELOPMENT CORPORATION**

PROJECT  
**PROPOSED ROYAL NAVAL DOCKYARD CRUISE IMPROV. DOCKYARD, BERMUDDA**

TITLE  
**MOORING DOLPHIN**

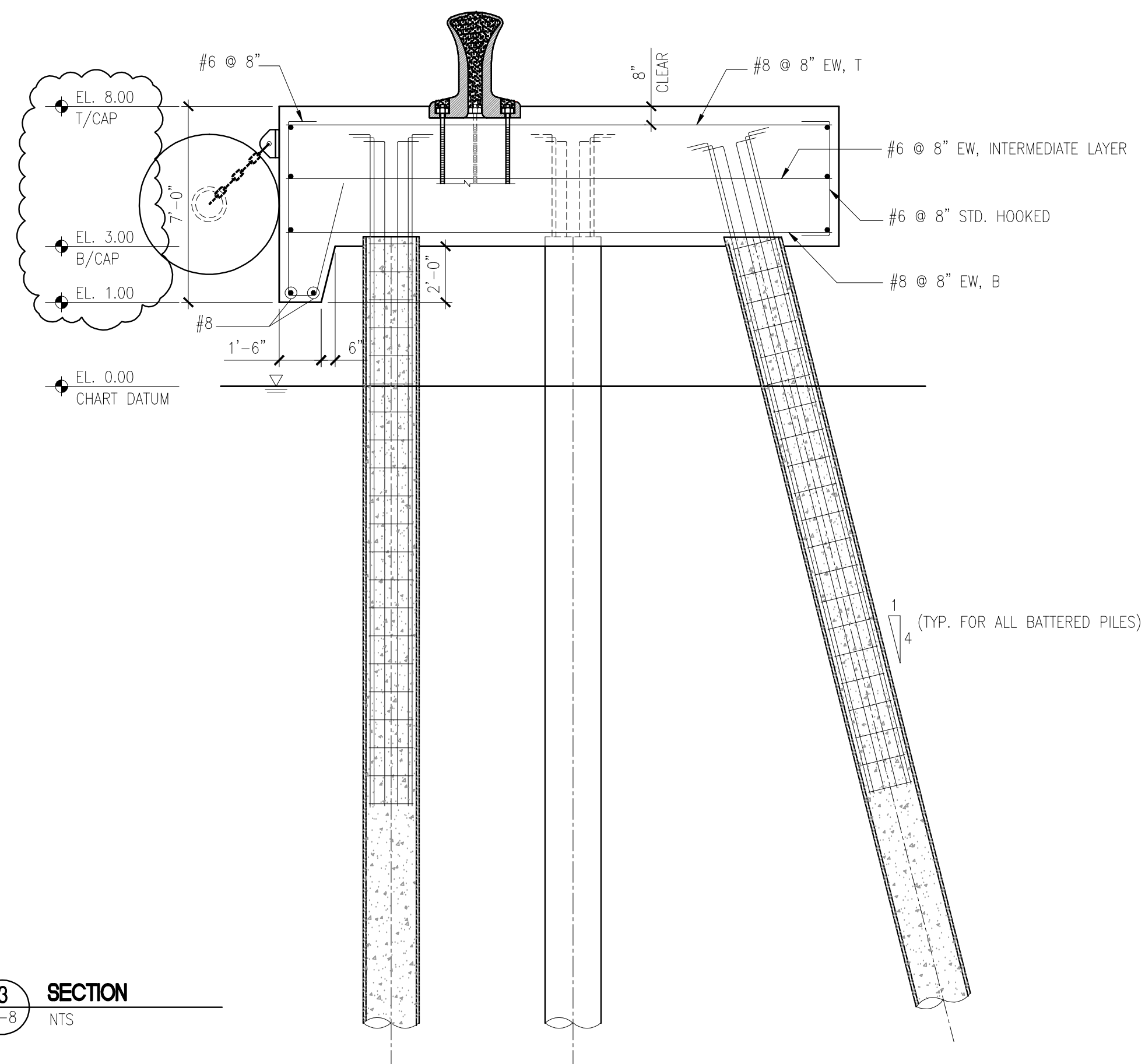
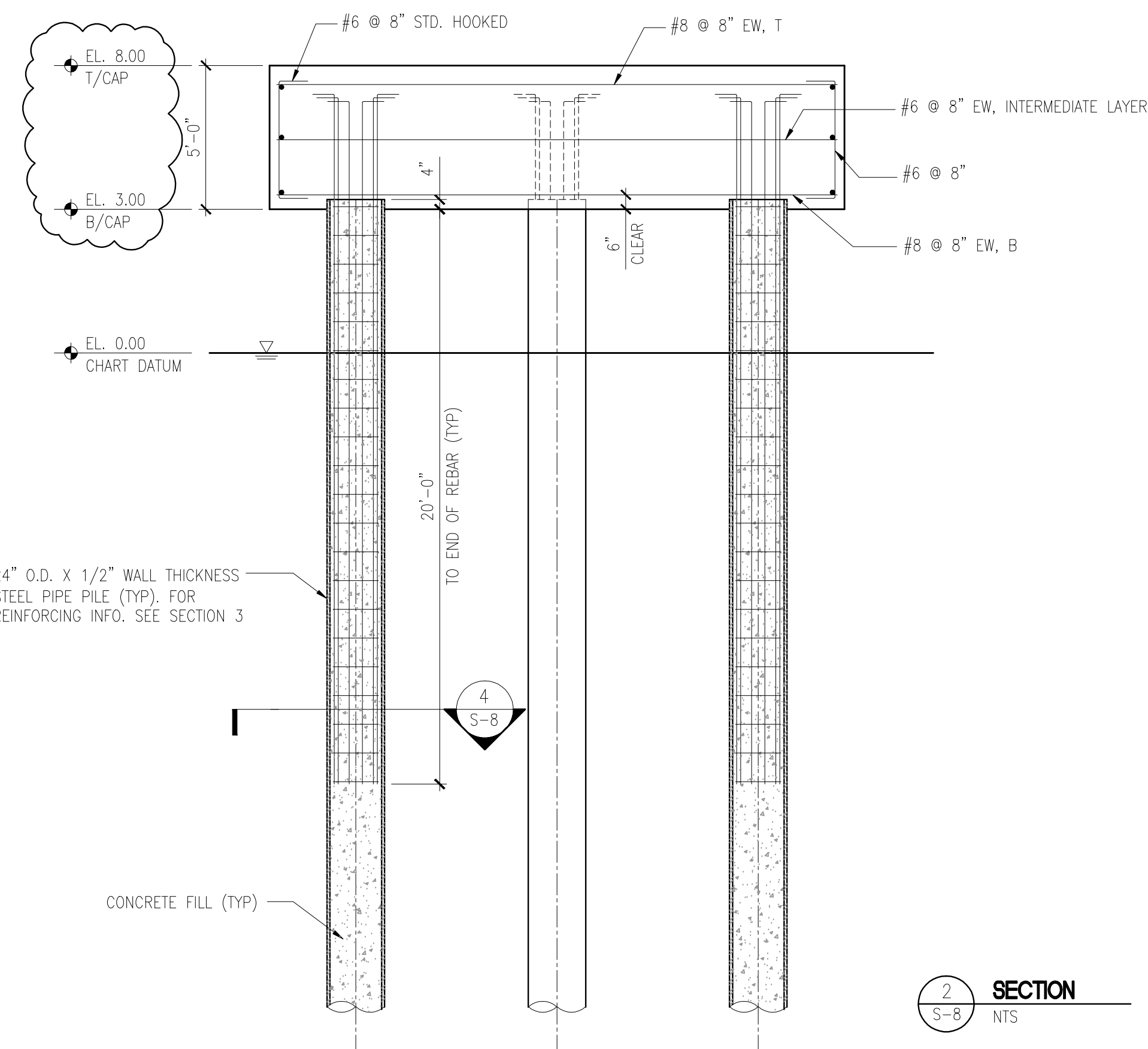
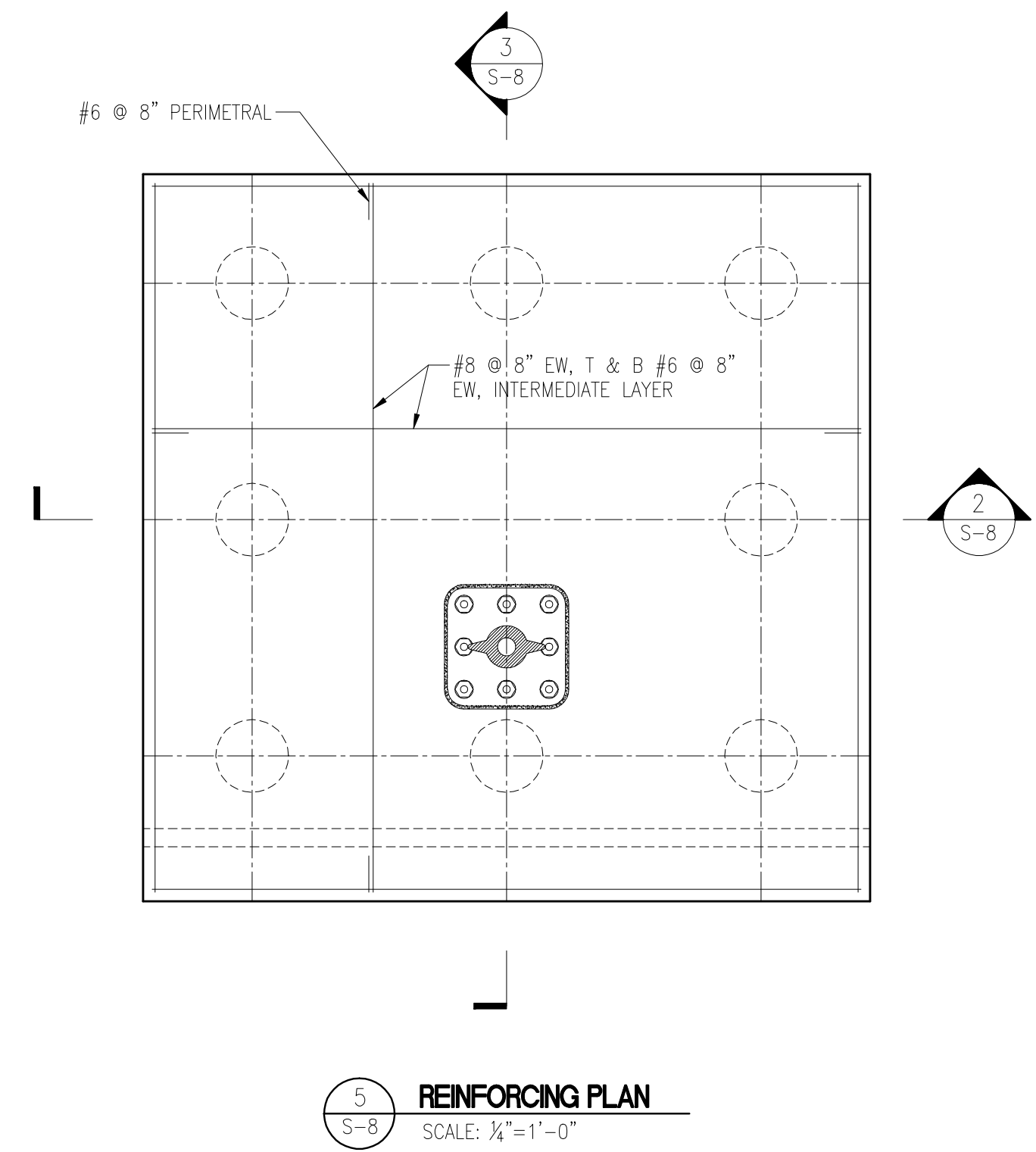
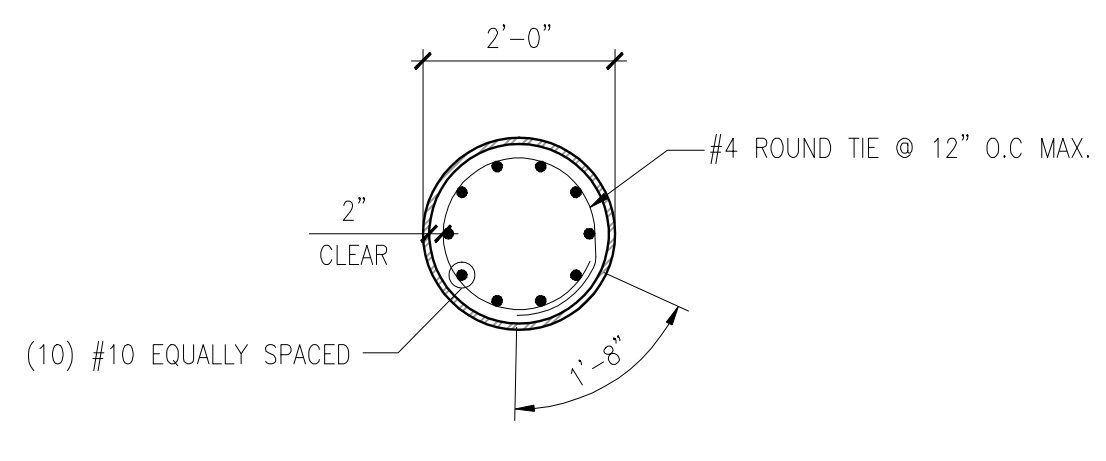
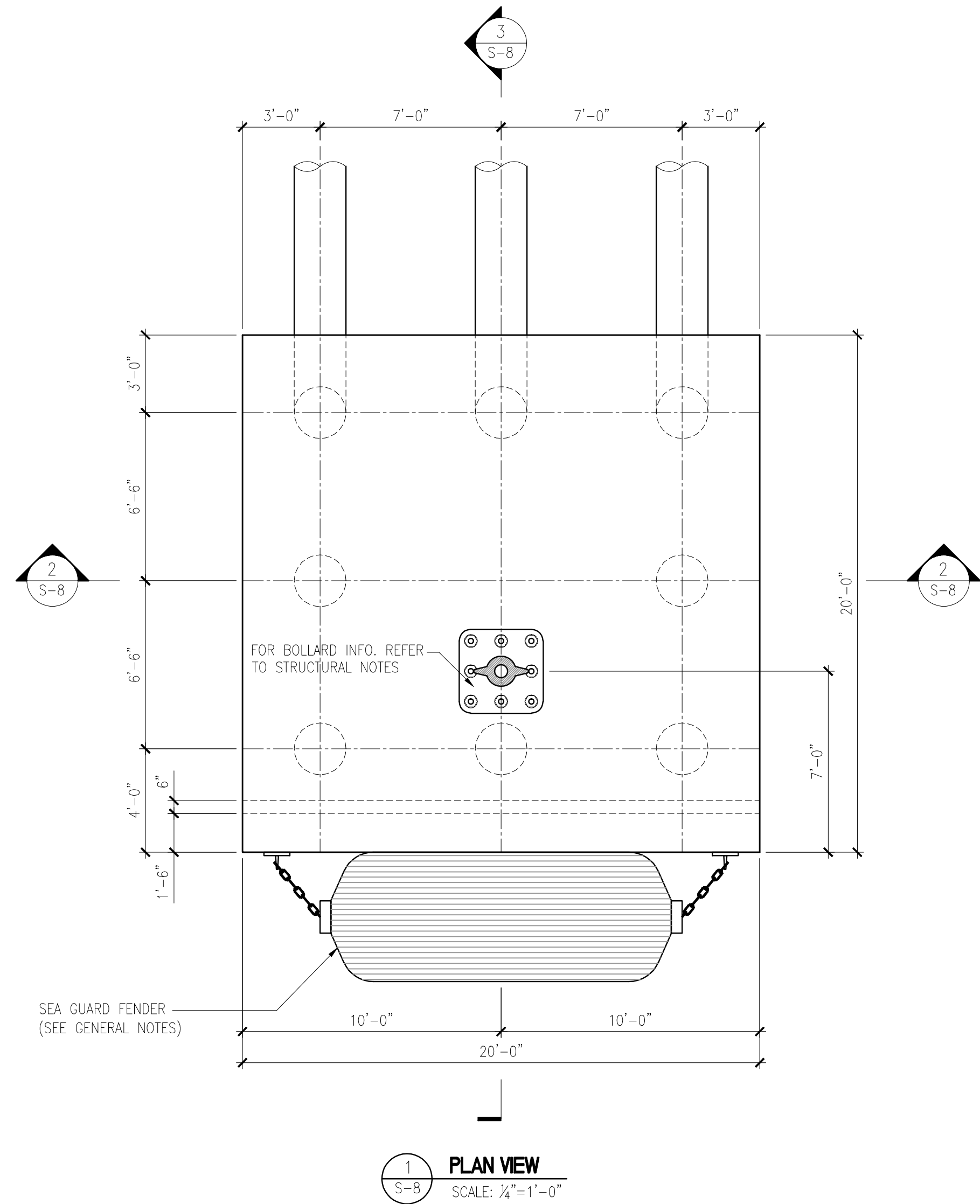
**Enitech LIMITED**  
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**GENERAL NOTES**

1. REFER TO DWG. S-0 FOR GENERAL NOTES AND SPECIFICATIONS.

**AS BUILT**



DATE	No.	REVISION
30.AUG.'07	-	ADJUSTED ELEVATIONS
01.MAY.'07	-	ISSUED FOR BUILDING PERMIT

CONTRACTORS SHALL VERIFY ALL DIMENSIONS AND UTILITY LOCATIONS ON THE JOB SITE.

designed by	DR	scale	AS SHOWN
drawn by	-	job no.	E07017
checked by	DR	drawing no.	<b>S-8</b>
approved by	-	date	March 07

CLIENT  
**WEST END DEVELOPMENT CORPORATION**

PROJECT  
**PROPOSED ROYAL NAVAL DOCKYARD CRUISE IMPROV. DOCKYARD, BERMUDA**

TITLE  
**BREASTING DOLPHIN**

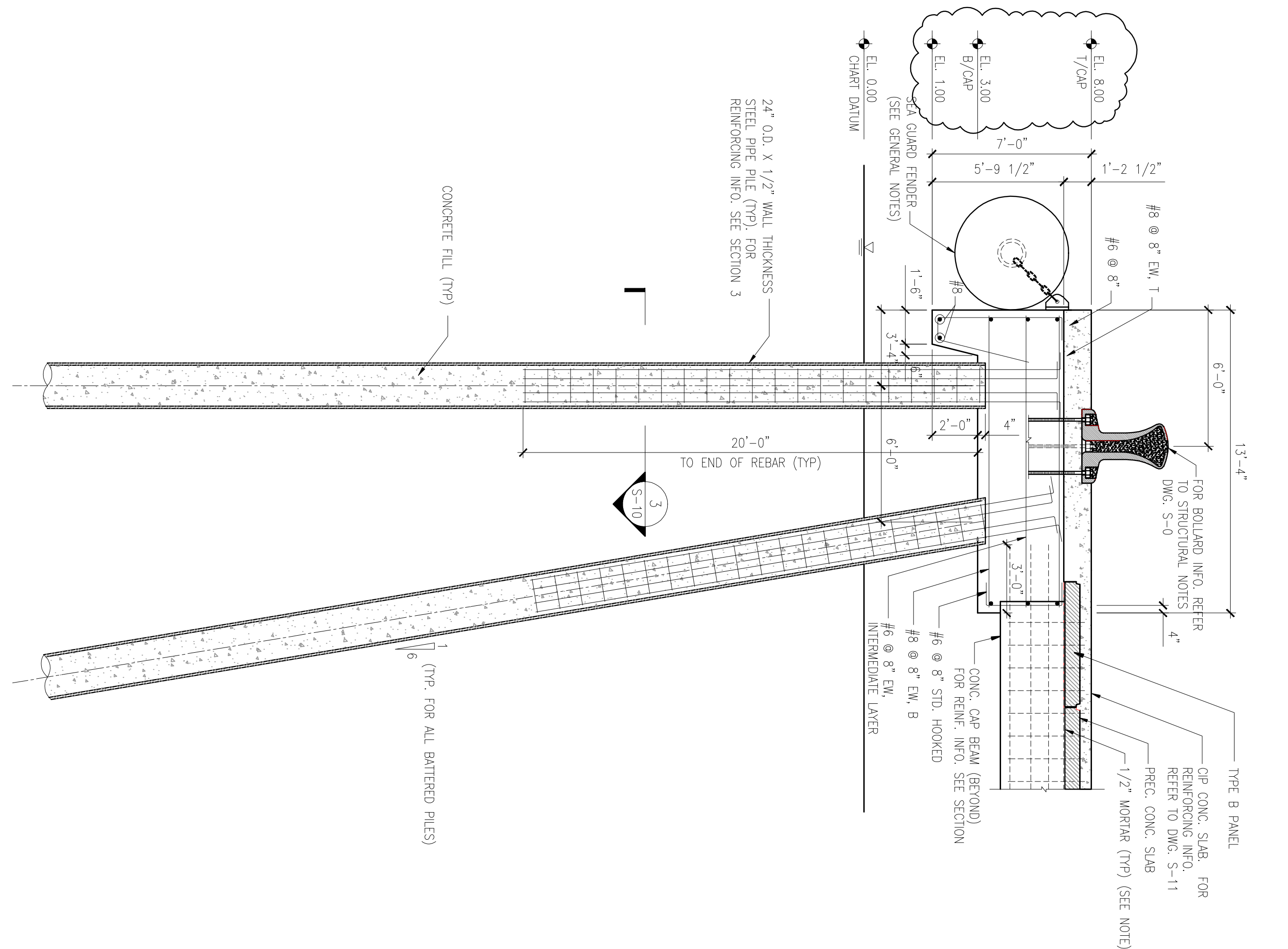


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TEL. (441)-292-9192 FAX. (441)-292-9468 EMAIL. admin@entech.bm

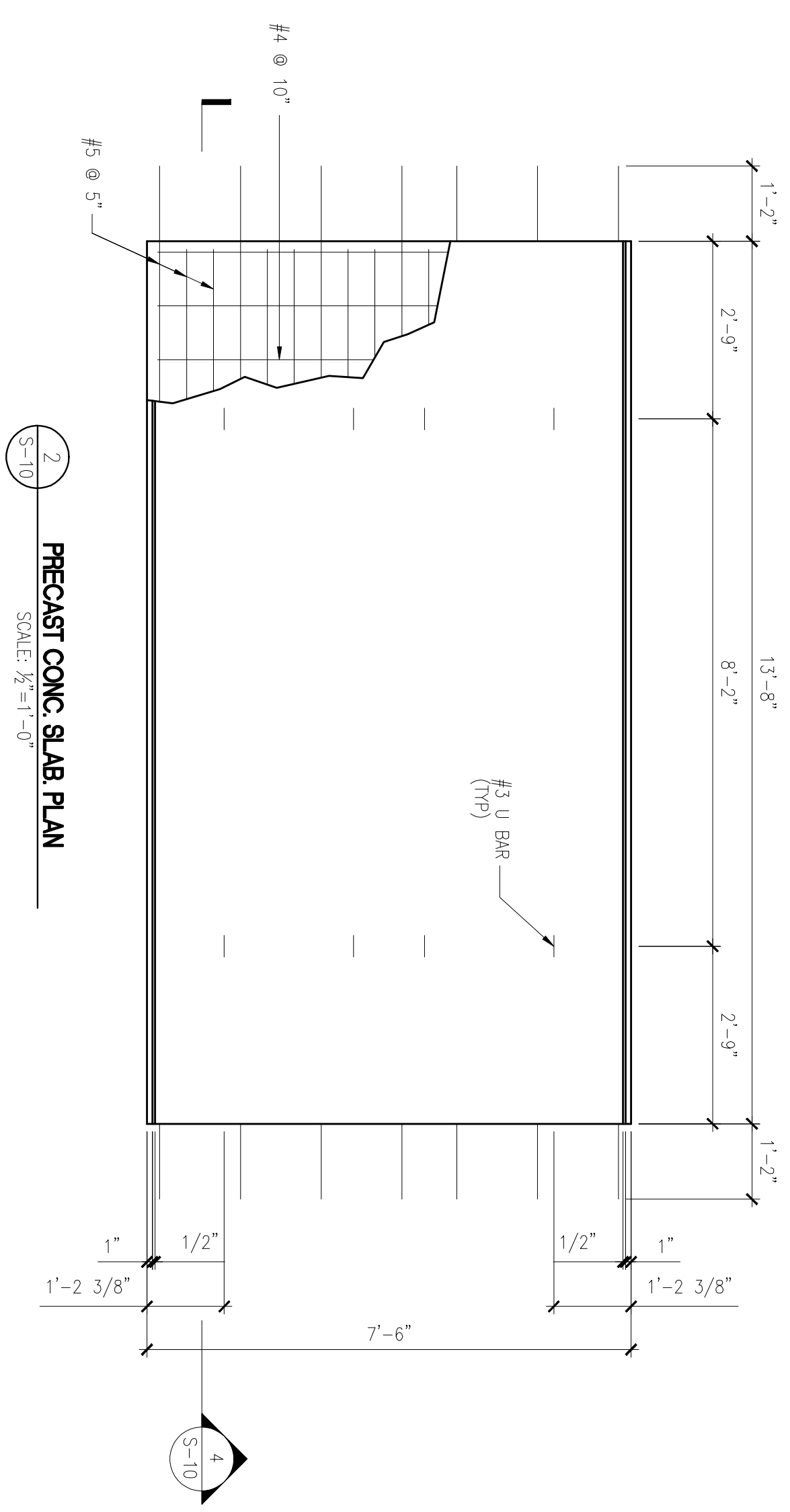


**GENERAL NOTES**  
1. REFER TO DWG. S-0 FOR GENERAL NOTES AND SPECIFICATIONS.

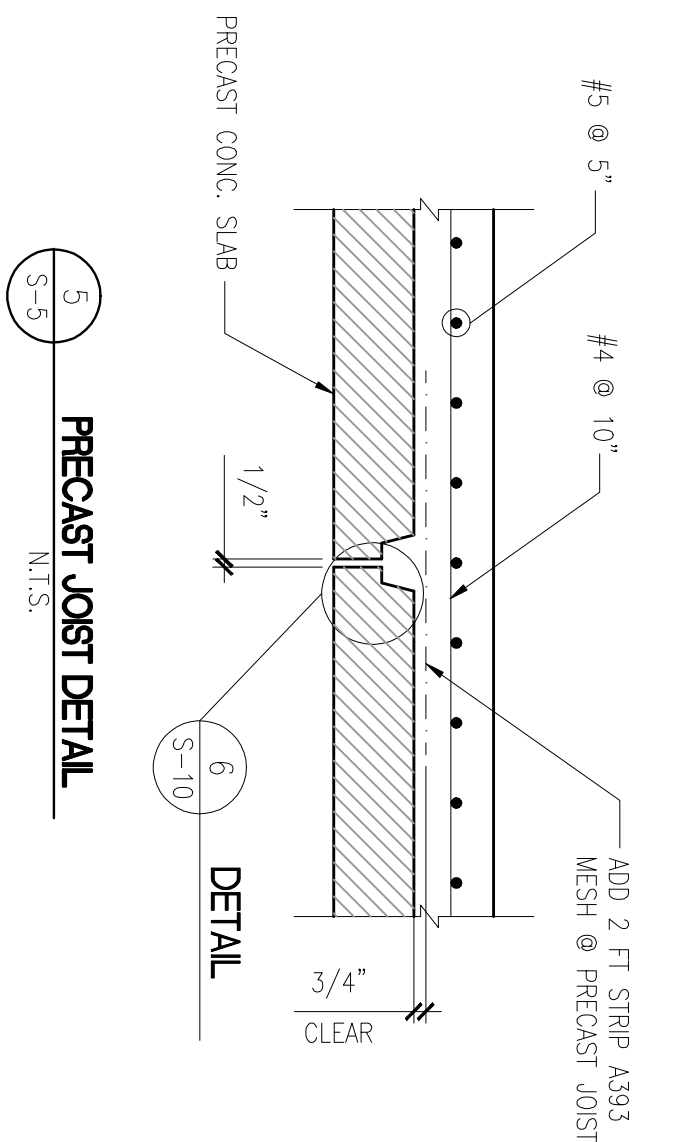
**AS BUILT**



**1 DETAIL**  
S-5  
N.T.S.

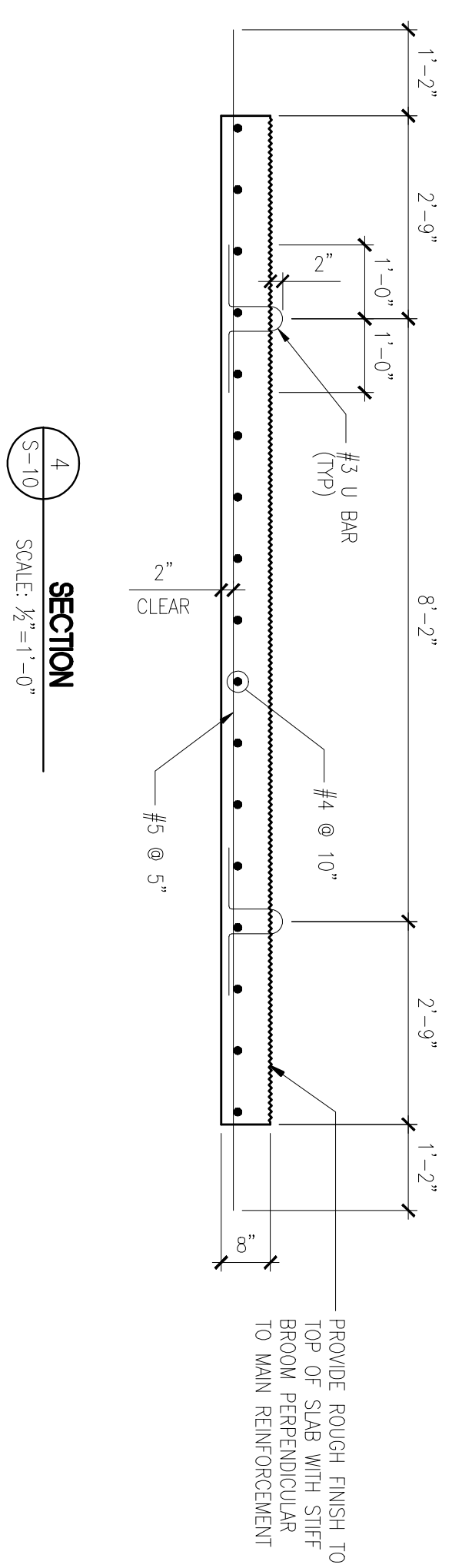


**2 PRECAST CONC. SLAB PLAN**  
S-10  
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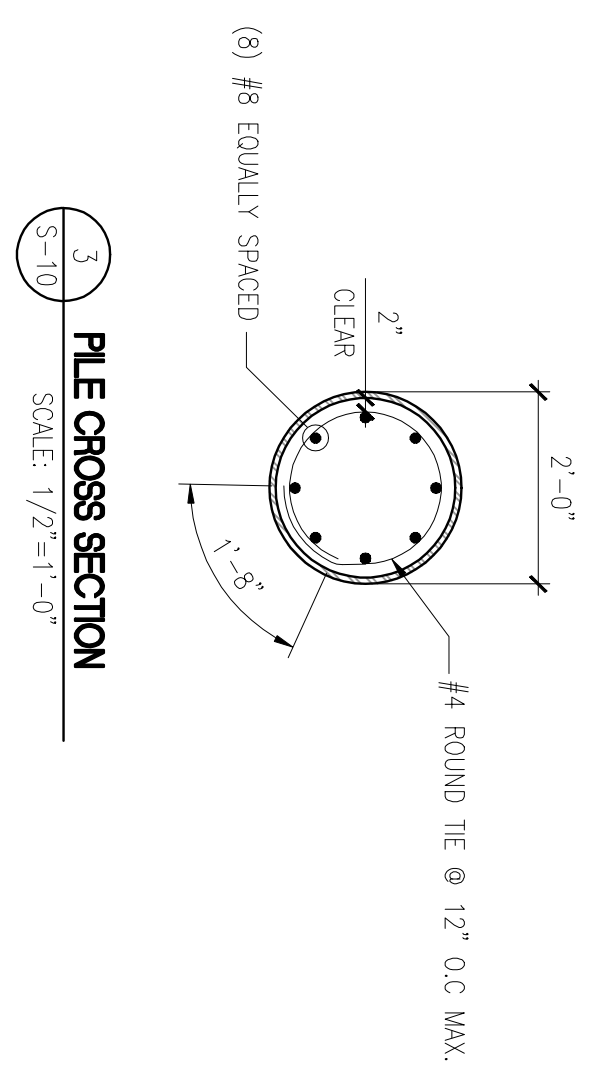


**3 PRECAST JOIST DETAIL**  
S-5  
N.T.S.

**6 DETAIL**  
S-10  
N.T.S.



**4 SECTION**  
S-10  
SCALE: 1/2"=1'-0"



**3 PILE CROSS SECTION**  
S-10  
SCALE: 1/2"=1'-0"

30.AUG.07	-	ADJUSTED ELEVATIONS
05.MAY.07	-	REVISED PRECAST DETAILS
01.MAY.07	-	ISSUED FOR BUILDING PERMIT
DATE	No.	REVISION

CONTRACTORS SHALL VERIFY ALL DIMENSIONS AND UTILITY LOCATIONS ON THE JOB SITE.

designed by	DR	scale	AS SHOWN
drawn by	-	job no.	E07017
checked by	DR	drawing no.	-
approved by	-	date	March 07

**S-10**

CLIENT  
**WEST END DEVELOPMENT CORPORATION**

PROJECT  
PROPOSED ROYAL NAVAL DOCKYARD CRUISE IMPROV. DOCKYARD, BERMUDDA

TITLE  
**PIER SECTIONS & DETAILS**

**Enitech LIMITED**  
ENGINEERING / PLANNING CONSULTANTS

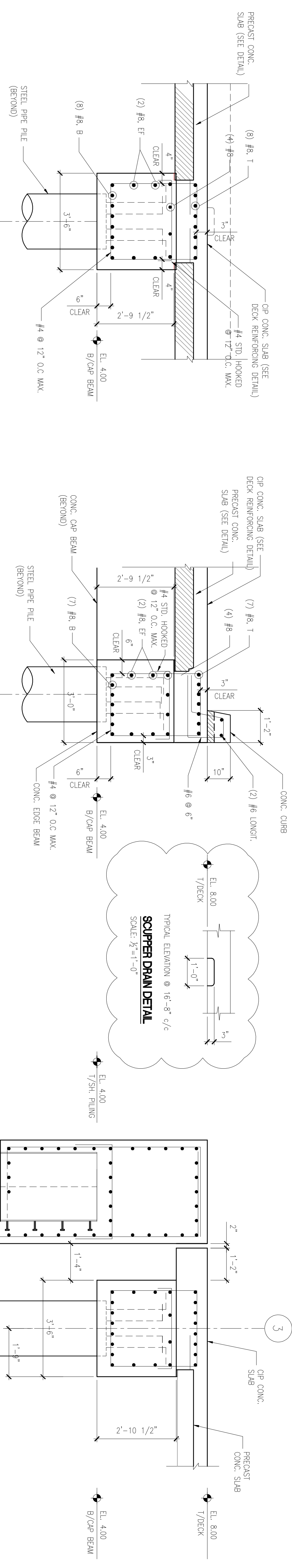
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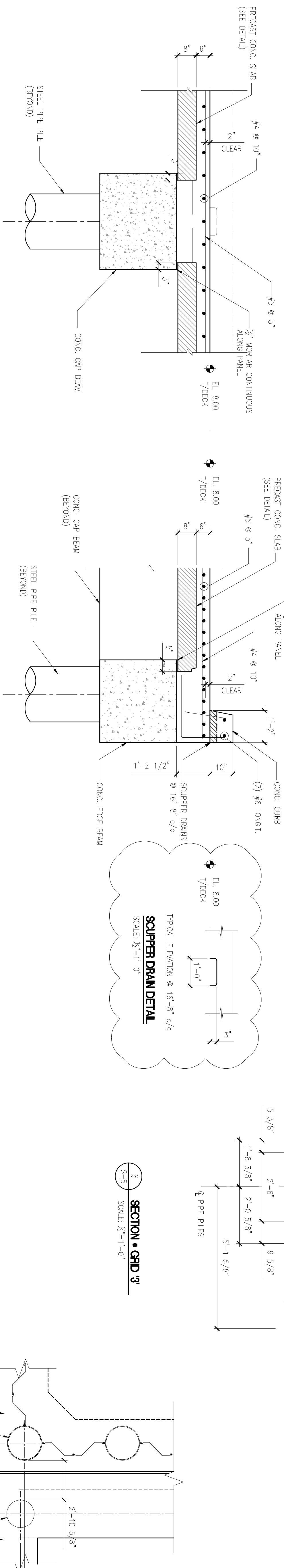
**GENERAL NOTES**  
1. REFER TO DWG. S-0 FOR GENERAL NOTES AND SPECIFICATIONS.

**AS BUILT**



1 SECTION-BEAM REINFORCING  
S-5 SCALE: 1/2"=1'-0"

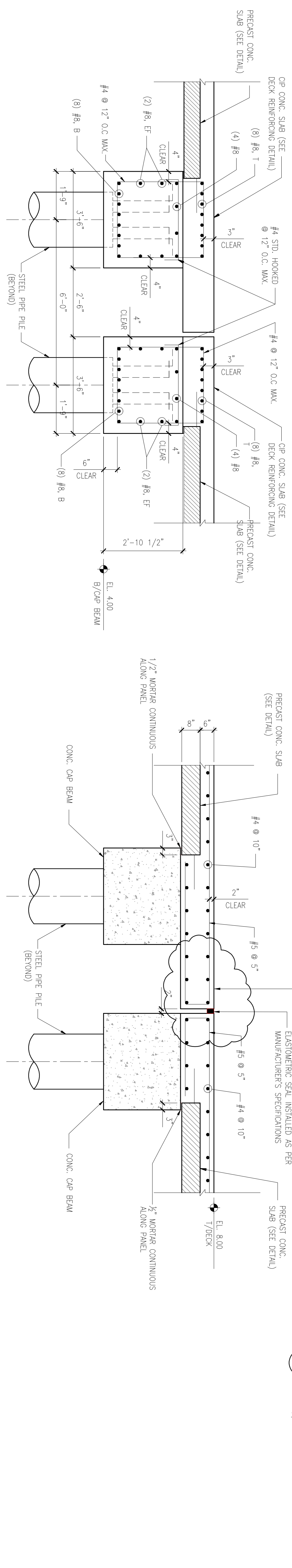
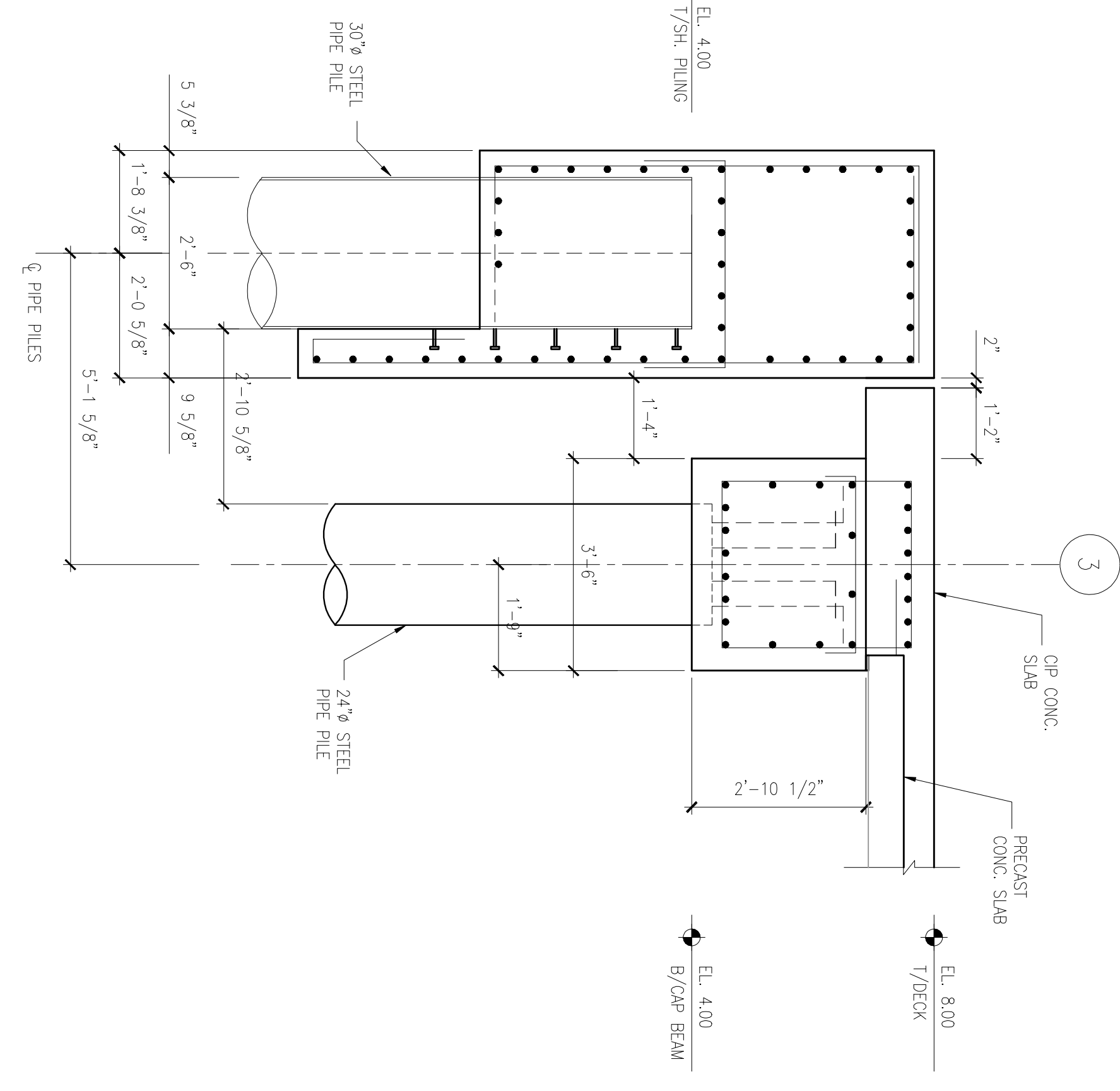
3 BEAM REINFORCING DETAIL  
S-5 SCALE: 1/2"=1'-0"



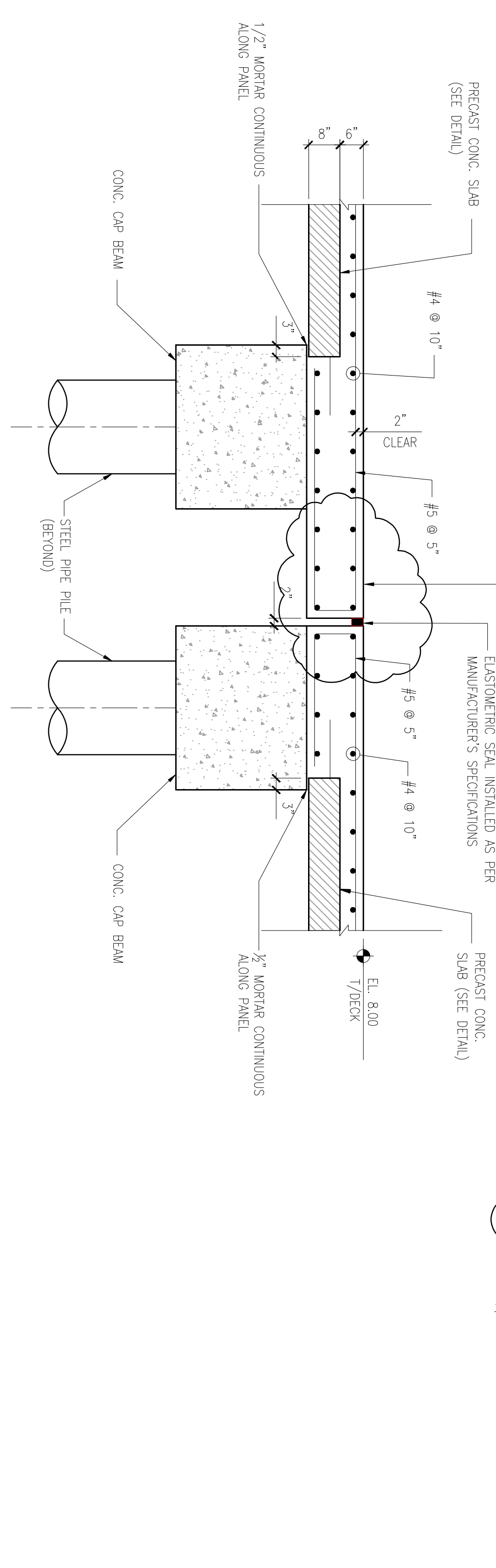
1 SECTION-DECK REINFORCING  
S-5 SCALE: 1/2"=1'-0"

3 DECK REINFORCING DETAIL  
S-5 SCALE: 1/2"=1'-0"

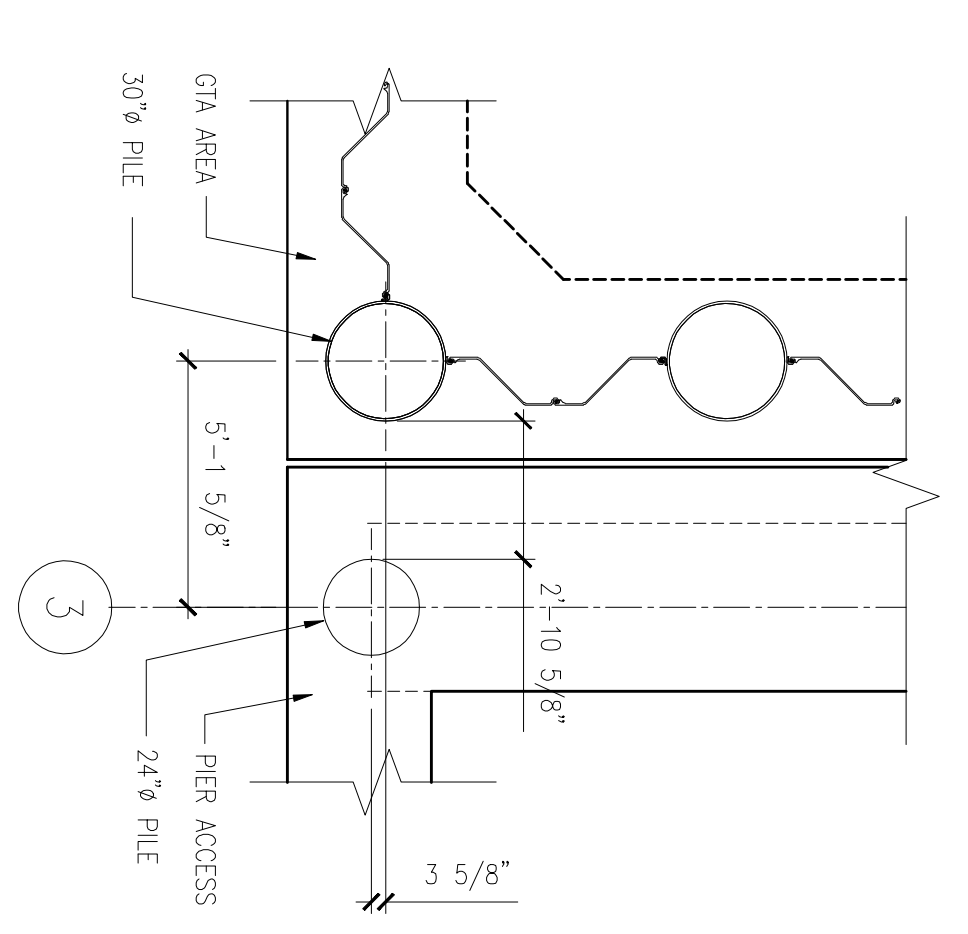
6 SECTION • GRID 3  
S-5 SCALE: 1/2"=1'-0"



4 EXPANSION JOINT SECTION BEAM REINFORCING  
S-5 SCALE: 1/2"=1'-0"



4 EXPANSION JOINT SECTION DECK REINFORCING  
S-5 SCALE: 1/2"=1'-0"



7 DETAIL • GRID 3  
S-6 SCALE: 1/4"=1'-0"

\* SLAB THICKENING MAY BE REQUIRED ON EITHER SIDE FOR FLEXIBLE FITTINGS

ELASTOMERIC SEAL INSTALLED AS PER MANUFACTURER'S SPECIFICATIONS

06.OCT.08	7	REVISED SCUPPER DRAIN CRS.
01.OCT.08	6	SCUPPER DRAIN DETAIL
04.DEC.07	-	REVISED DETAIL @ GRID 20' / 21'
30.AUG.07	-	ADJUSTED ELEVATIONS
22.AUG.07	-	SECTION & DETAIL @ GRID 3'
05.MAY.07	-	REVISED PRECAST DETAILS
01.MAY.07	-	ISSUED FOR BUILDING PERMIT
DATE	NO.	REVISION
CONTRACTORS SHALL VERIFY ALL DIMENSIONS AND UTILITY LOCATIONS ON THE JOB SITE.		
designed by	DR	scale AS SHOWN
drawn by	-	job no. E07017
checked by	DR	drawing no.
date	March 07	<b>S-11</b>

CLIENT  
**WEST END DEVELOPMENT CORPORATION**

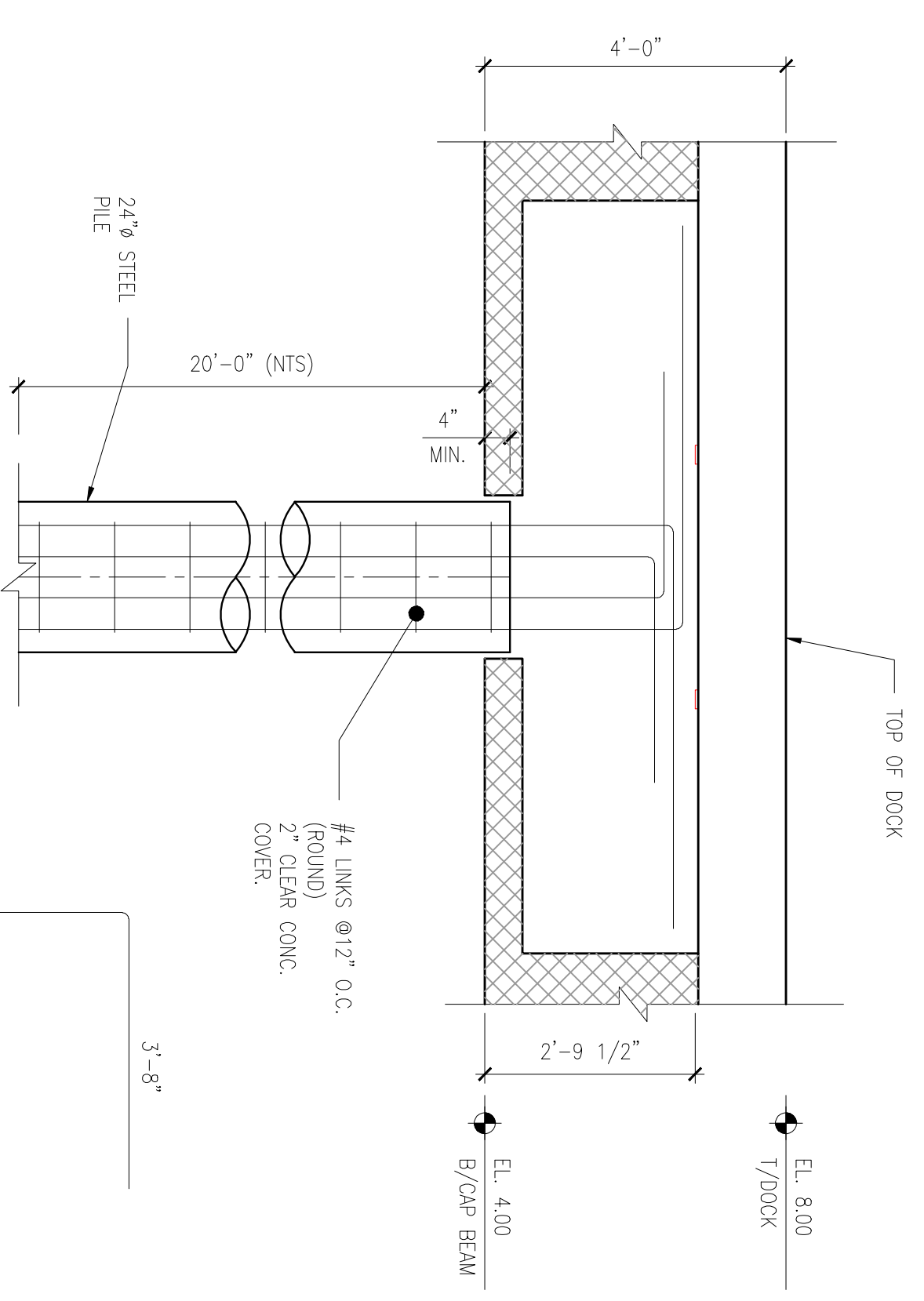
PROJECT  
**PROPOSED ROYAL NAVAL DOCKYARD CRUISE IMPROV. DOCKYARD, BERMUDA**

TITLE  
**PIER SECTIONS & DETAILS**

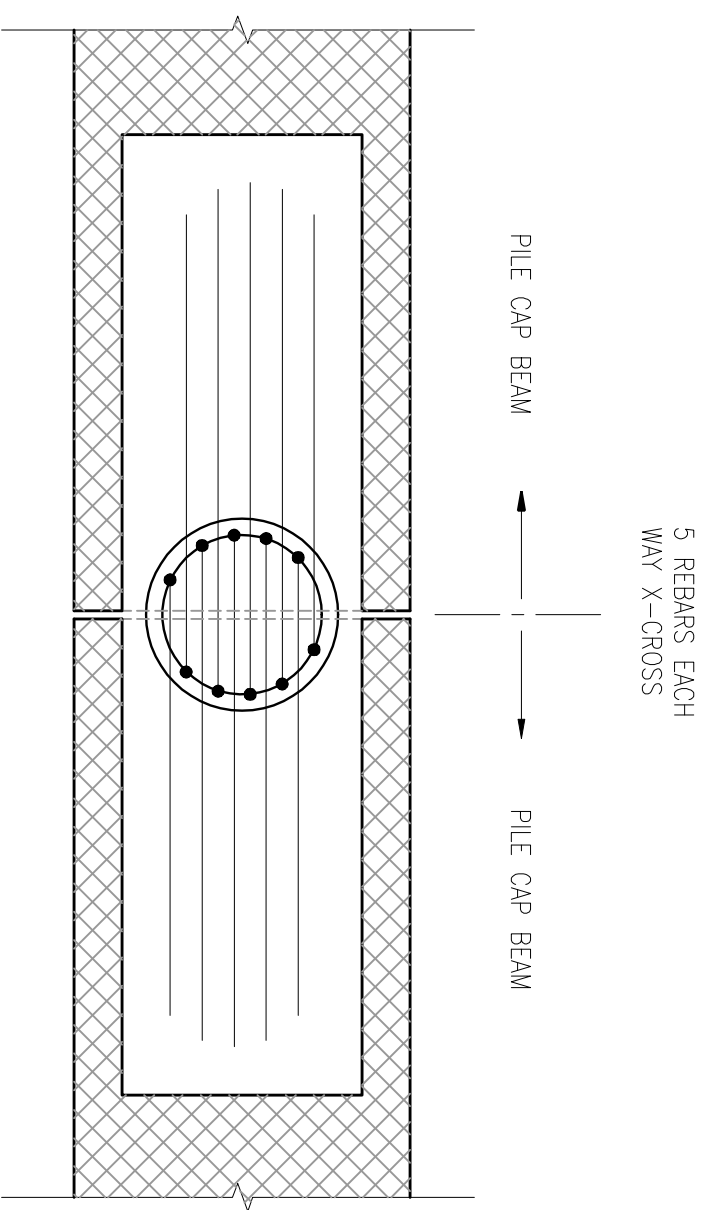
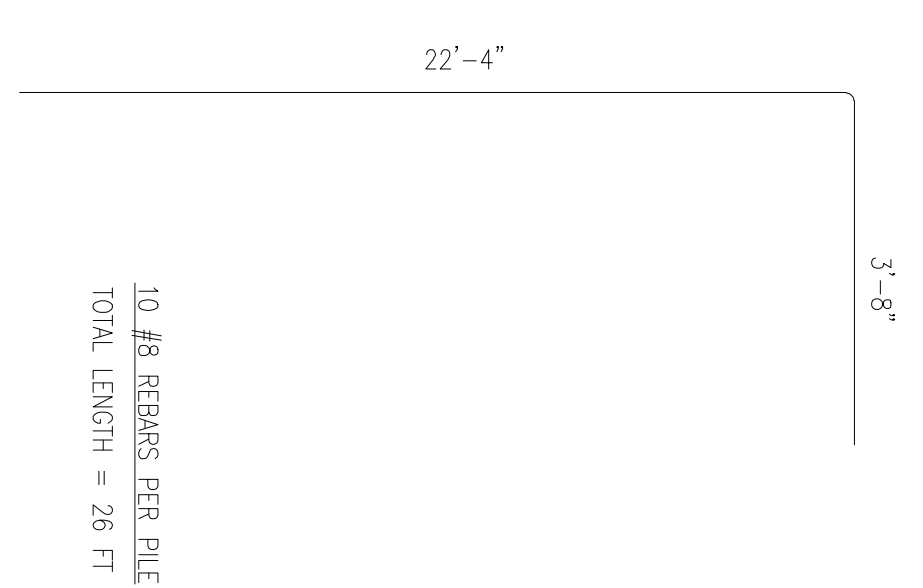


**GENERAL NOTES**  
 1. REFER TO DWG. S-0 FOR GENERAL NOTES AND SPECIFICATIONS.

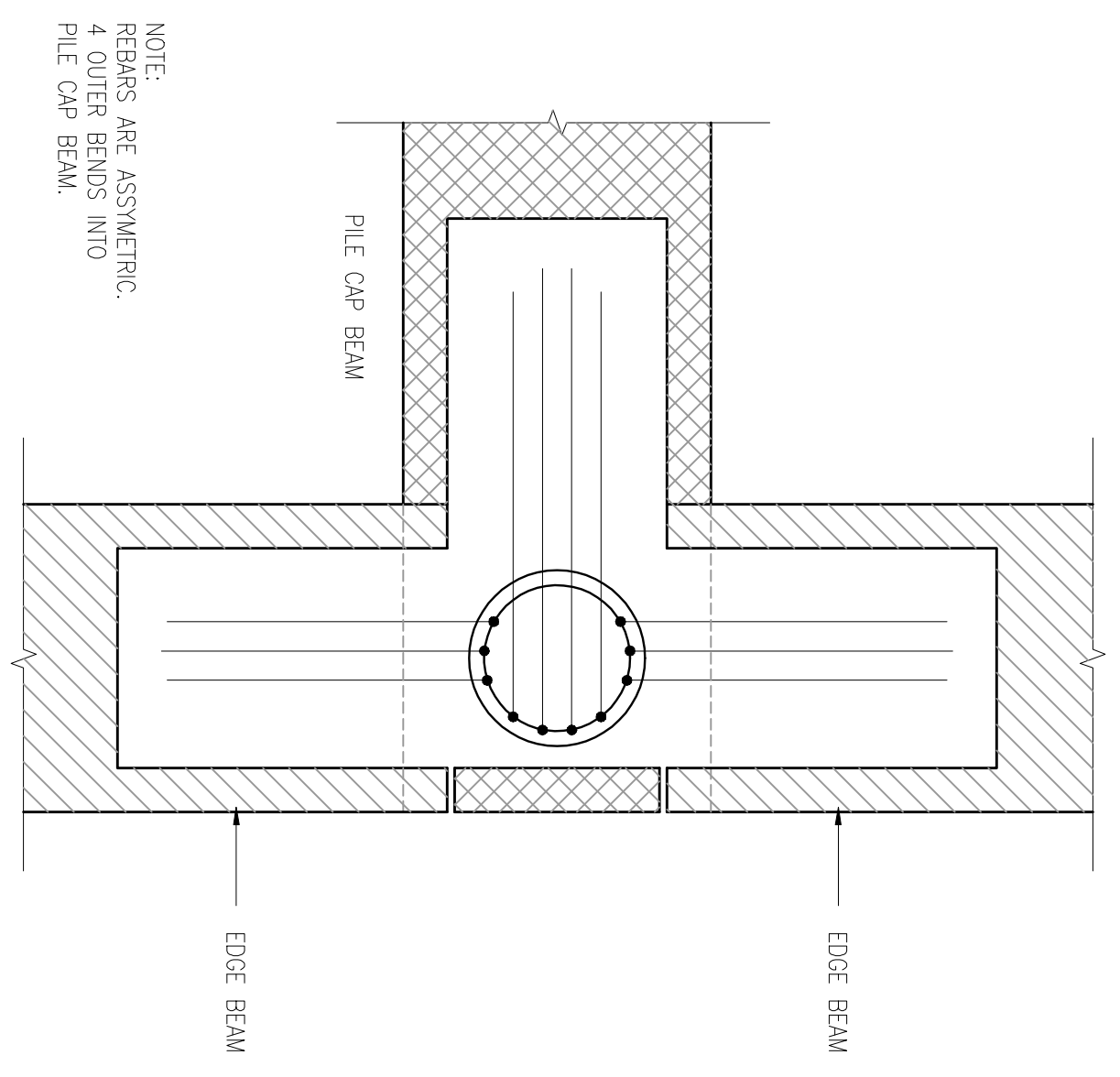
**AS BUILT**



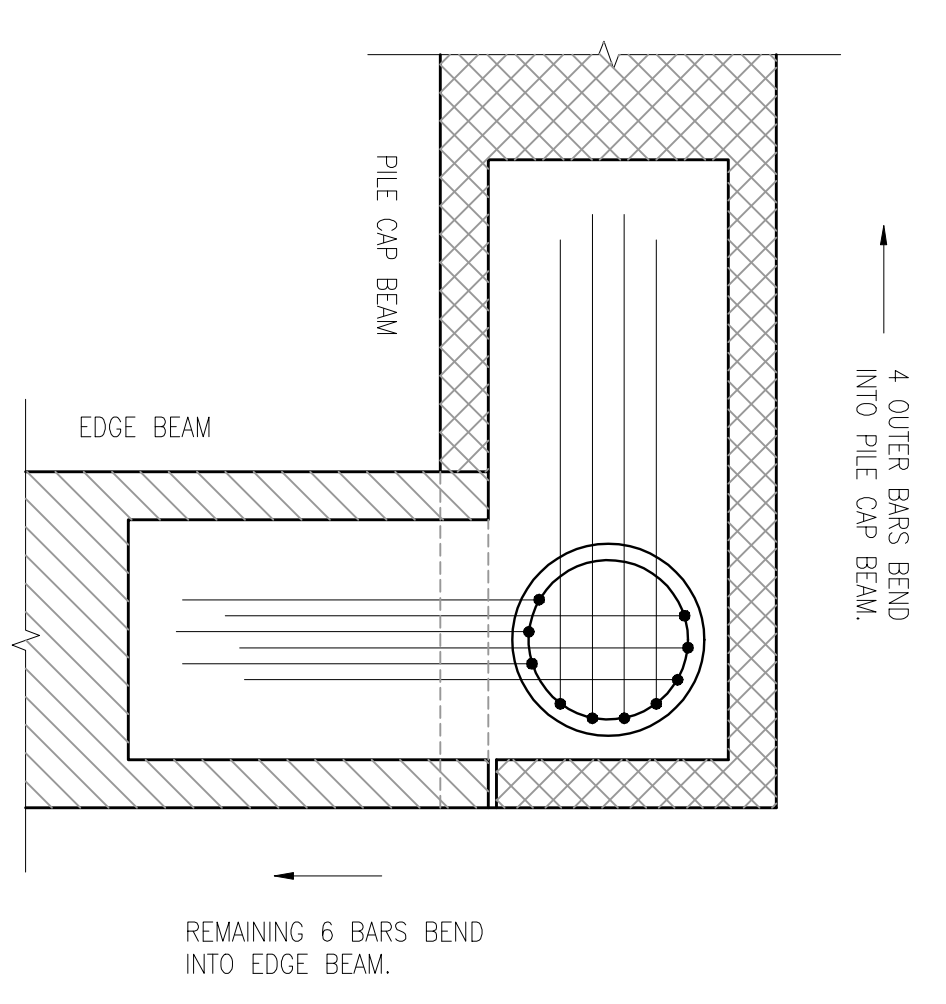
**1 DETAIL -** BRG BENDING FOR PILES UNDER MAIN CAP BEAM  
 S-16 SCALE: 1/2"=1'-0"



**TYPE A**  
 PLAN OVER PILE CAP BEAMS AT INTERNAL PILES SHOWING PILE REINFORCEMENT



**TYPE B**  
 PILE REBARS AT TEE JUNCTION



**TYPE C**  
 PILE REBARS AT CORNER

NOTE:  
 REBARS ARE ASYMMETRIC.  
 4 OUTER BENDS INTO PILE CAP BEAM.

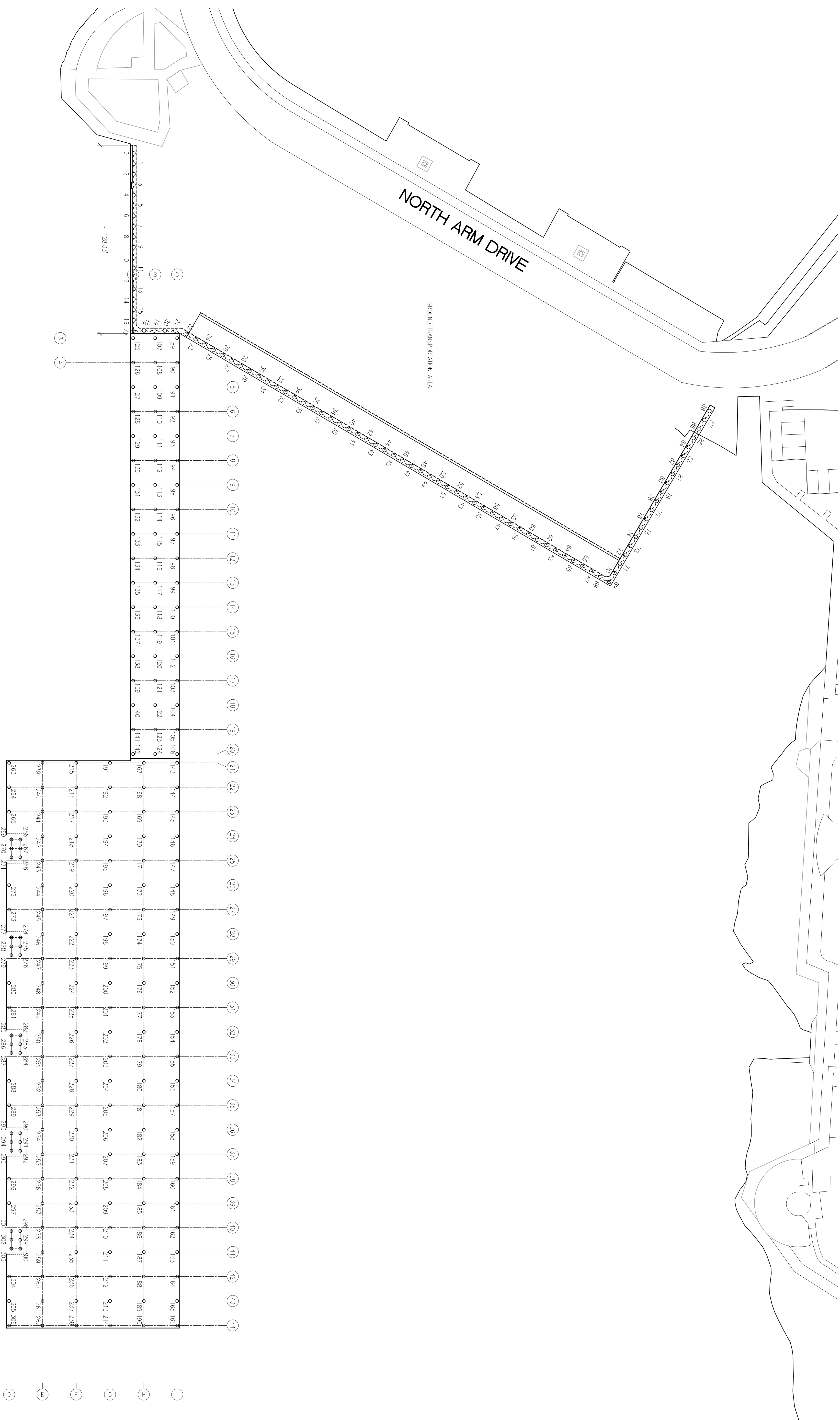
**2 PLANS OVER PILE CAP BEAMS**  
 S-16 SCALE: 1/2"=1'-0"  
 TYPE A  
 TYPE B  
 TYPE C

designed by	DR	scale	AS SHOWN
drawn by	ep	job no.	E07017
checked by	DR	drawing no.	
approved by	-		
date	JUL 07		
CLIENT	<b>S-16</b>		
PROJECT	WEST END DEVELOPMENT CORPORATION		
TITLE	SECTIONS & DETAILS		

PROPOSED ROYAL NAVAL DOCKYARD CRUISE IMPROV. DOCKYARD, BERMUDA



**GENERAL NOTES**  
 1. REFER TO DWG. S-0 FOR GENERAL NOTES AND SPECIFICATIONS.



**1** PILE NUMBER LAYOUT  
 S-22 SCALE: 3/8"=1'-0"

DATE	No.	REVISION
-	-	ISSUED FOR INFO

CONTRACTORS SHALL VERIFY ALL DIMENSIONS AND UTILITY LOCATIONS ON THE JOB SITE.

designed by	DR	scale	AS SHOWN
drawn by	RP	job no.	ED0717
checked by	JP	drawing no.	
approved by	-		
date	SEPT 07		

**CLIENT**  
 WEST END DEVELOPMENT CORPORATION

**PROJECT**  
 PROPOSED ROYAL NAVAL DOCKYARD CRUISE IMPROV. DOCKYARD, BERMUDA

**TITLE**  
 PILE NUMBER LAYOUT

**EnTech LIMITED**  
 ENGINEERING / PLANNING CONSULTANTS

P.O. BOX HM 2574 HAMILTON HM44X BERMUDA

TEL. (441) 282-9192 FAX. (441) 282-4468 EMAIL: admin@entech.com



## **Underwater Infrastructure Survey**

*Issued: 30 August 2017*

**For: Bermuda Government**  
**Attn: Mike Murphy**

### **Heritage Wharf Inspection Report**

#### **Introduction**

This inspection was conducted over multiple days from the 29<sup>th</sup> of July through the 8<sup>th</sup> of August by a three person team. Water depth under the wharf was 40 to 45 feet for the majority of the structure. Near the North Arm, depths shallowed to roughly 30 feet. 10% of the piles on the structure were given a level 2 Inspection in 3 locations; at the top, middle and bottom of the pile. As such, scuba equipment and various hand tools were used accordingly. The inspection began on northern end of the Main Wharf and progressed southward toward the North Arm. Upon completion, focus shifted to the Breasting and Mooring Dolphins, again starting on the northernmost dolphin progressing southbound. The inspection focused on the pile legs from below the pile cap down to the seabed level. Sketches of the structure and its defects were not made for this inspection. The number of piles was too great, and the defects too scattered and not distinct enough to warrant independent sketches of each pile. This report will present observations of the structure in the order it was surveyed. These observations will describe typical defects seen across the piles in general rather than focus on individual piles.

#### **Structure Description**

Heritage Wharf is a very large structure that is comprised of multiple dolphins, a Main Wharf and a Gangway connecting the wharf with the North Arm. The structure is made entirely of pile and cap construction. In total there are 331 piles; 218 on the Main Wharf and Gangway and 113 on the dolphins. The piles under the main dock were given a numbered identification system for the purpose of the inspection and this report.

#### **Summary**

The Level 1 inspection did not reveal any detrimental structural issues, overall the structure appeared to be in good condition. The underside of the concrete deck and the intersection between the pile and its cap appeared in good condition. The section of pile in the splash zone that remains above water is suffering from accelerated levels of corrosion (Fig. 1j, 1p, 1q). The protective rubber coating around the piles in most cases is compromised in this splash zone region of the piles (see Fig. 1t, 1u). Below the water's surface the piles were all in consistently fair condition. The protective coating had random small areas where it had blistered and ripped but was mostly intact and working effectively. Corrosion could be seen on these compromised areas but it was superficial at this stage. On one pile a small blister was cut away in order gain a visual comparison of the protected steel and the exposed steel. The steel behind the coating showed no signs of corrosion and still held a metallic grey colour (Fig. 2a), compared with the brown surface rust on the exposed steel (Fig. 3k, 3l). There were a number of piles that appeared to be suffering from localized ALWC, this was observed in random locations and depths. Some of these locations were probed to inspect the depth of corrosion, which varied from 1 to 3 mm at best estimate. These areas of ALWC are relatively small often less than 3 to 4 cm in diameter (Fig. 1i). At the base of the piles there was signs of scour but it was very limited and often less than 6" in depth.

Regarding the Breasting and Mooring Dolphins, there are Originals which were constructed at the same time as Heritage Wharf and four newer dolphins were constructed years later. The Original Dolphins were in more or less the same condition as the piles under the Main Wharf. The "New" dolphins were in very good condition and showed



almost no signs of corrosion at this stage (Fig. 3f, 3w). There are large anodes installed on these piles and it is evident they are working effectively by the white compound building on the anodes surface. The anodes all exhibited some level of corrosion, some were noticeably more corroded than others indicating a differential rate of electrolysis across the structure.

### Observations

Observations from the site inspection are presented below by way of a tabulated notes. Each structural items condition was rated on a scale from 1 to 4 based on the urgency of repair:

1. Serious structural issue requiring immediate attention
2. Structural issue to be dealt with as soon as possible
3. A non-urgent issue or a routine maintenance issue.
4. No visual structural defects observed, continued monitoring suggested

Schedule of Observations				
Figure	Item	Location	Observation	Rating
1d-1w	Main Wharf	Pile #1 - #134	<ul style="list-style-type: none"> <li>• Protective coating compromised in splash zone above water, very visible corrosion has set in</li> <li>• Protective coating intact on most piles</li> <li>• Localised and scattered areas where protective coating is damaged and steel is exposed</li> <li>• Localised and scattered locations of ALWC (not detrimental at this stage)</li> </ul>	3
2a-2j	Gangway	Pile #135 - #188	<ul style="list-style-type: none"> <li>• Similar condition as Main Wharf</li> <li>• Protective coating compromised in splash zone above water, very visible corrosion has set in</li> <li>• Protective coating intact on most piles</li> <li>• Localised and scattered areas where protective coating is damaged and steel is exposed</li> <li>• Localised and scattered locations of ALWC (not detrimental at this stage)</li> </ul>	3
3j-3hh	Original Mooring Dolphins	H-MD1 to H-MD4	<ul style="list-style-type: none"> <li>• Same condition as Main Wharf and Gangway, similar number and severity of defects observed</li> </ul>	3
3s & 3x	Original Breasting Dolphins	H-BD1 to H-BD2	<ul style="list-style-type: none"> <li>• Same condition as Main Wharf and Gangway, similar number and severity of defects observed</li> </ul>	3
3a-3dd	New Mooring Dolphins	H-MD5 & H-MD6	<ul style="list-style-type: none"> <li>• Very good condition overall, compared to original structure.</li> <li>• Very limited levels of corrosion observed on pile surface</li> <li>• Red surface coating on piles still in good condition</li> </ul>	3



			<ul style="list-style-type: none"><li>• Cathodic protection appears to be working effectively</li></ul>	
3t-3w	New Breasting Dolphins	H-BD3 & H-BD4	<ul style="list-style-type: none"><li>• Very good condition overall, compared to original structure.</li><li>• Very limited levels of corrosion observed on pile surface</li><li>• Red surface coating on piles still in good condition</li><li>• Cathodic protection appears to be working effectively</li></ul>	3

\*Note: This inspection is limited to visual observations only from the high watermark to the seabed level and comments cannot be made on the structures condition above or below these points.

### **Comments & Visual Representation**

Please refer to the Appendix for sketches, field notes and relevant photographs of each structural item. All items of concern can be cross-referenced with the photographs attached.

Please continue to monitor the structure and any repair works for defects or future damage (particularly after large storm events), and do not hesitate to contact us if you have any questions regarding this report or if we can provide further assistance.

Sincerely,

Keith Hodgkins, P.Eng.  
For Onsite Engineering Services Limited.





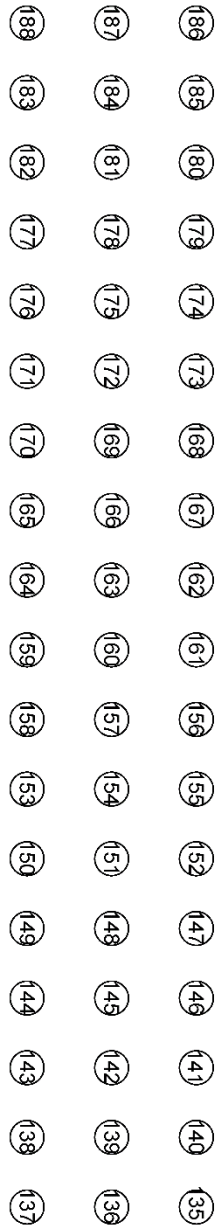


Fig. 1b - Heritage Wharf Gangway Pile Layout

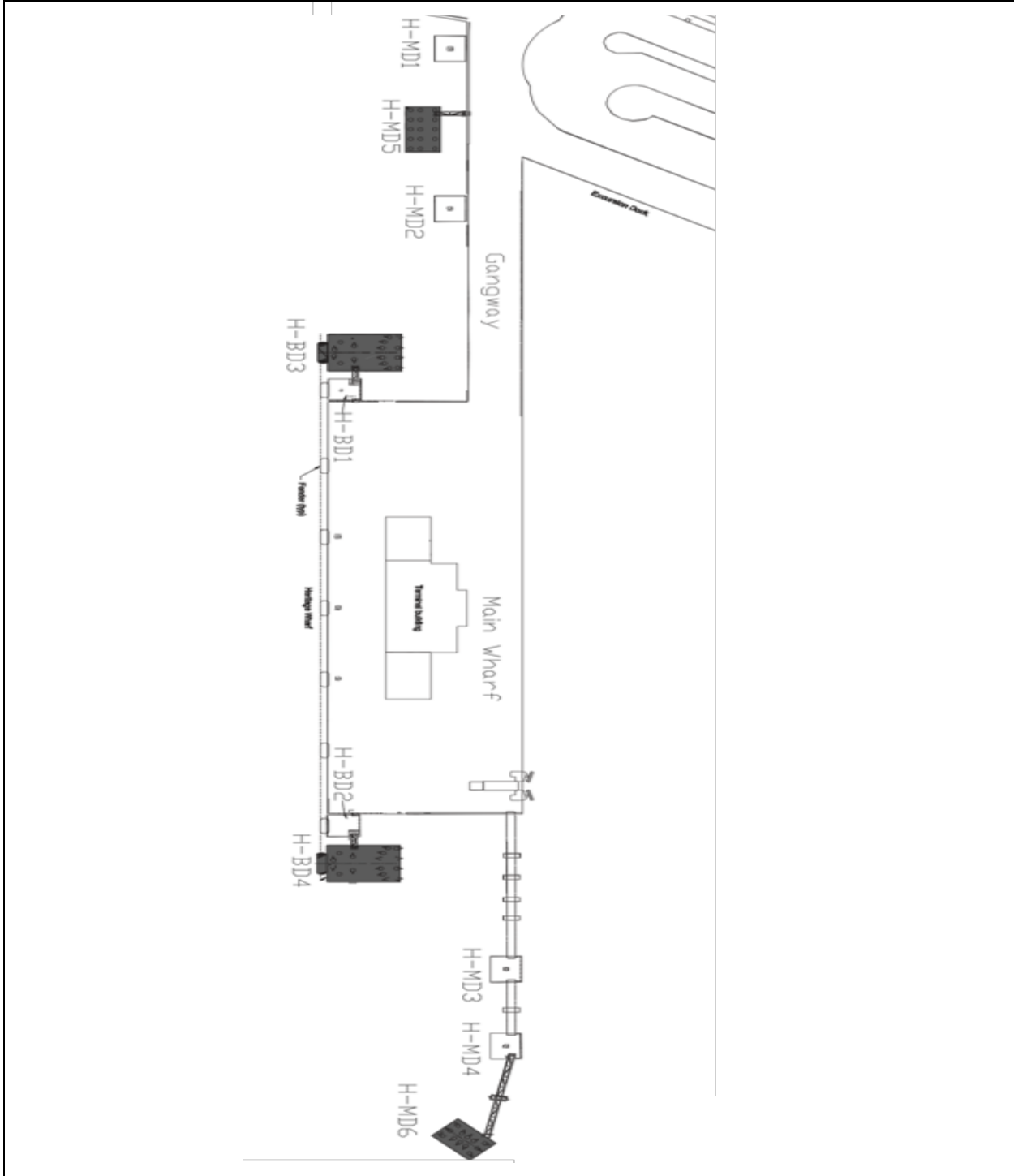


Fig. 1c - Heritage Wharf Locations of Breasting and Mooring Dolphins



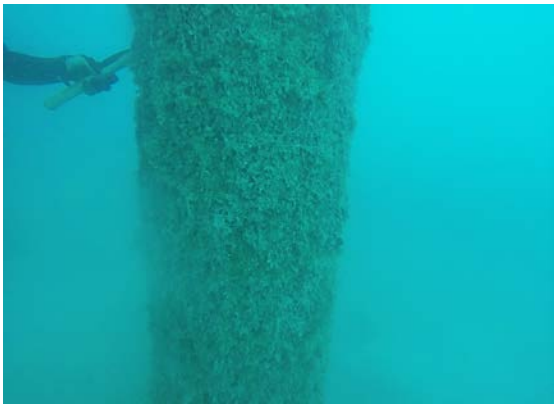


Fig. 1d - Typical marine vegetation growth on piles



Fig. 1e - 1<sup>st</sup> Level 2 inspection, Pile 1



Fig. 1f - 2<sup>nd</sup> Level 2 inspection, Pile 1



Fig. 1g - 3<sup>rd</sup> Level 2 inspection, Pile 1



Fig. 1h - ALWC near high water mark



Fig. 1i - Typical example of ALWC on pile surface



Fig. 1j – Compromised protective coating and corrosion in splash zone



Fig. 1k Cluster 1 composed of 6 piles



Fig. 1l 1<sup>st</sup> Level 2 inspection, Pile 45, protective coating intact



Fig. 1m 2<sup>nd</sup> Level 2 inspection, Pile 45, protective coating intact

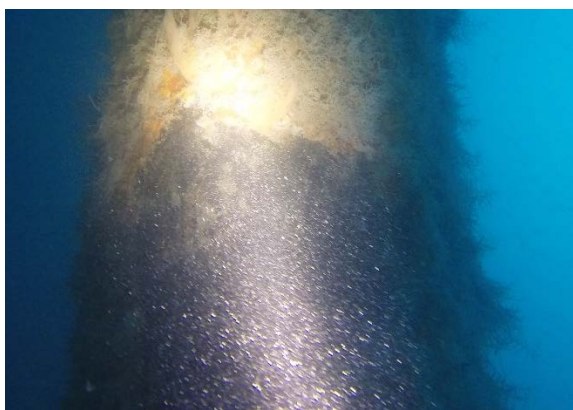


Fig. 1n 3<sup>rd</sup> Level 2 inspection, Pile 45, protective coating intact



Fig. 1o General view of three of the piles from Cluster 2





Fig. 1p Top of pile of Cluster 2



Fig. 1q Top of pile of Cluster 2



Fig. 1r – Blisters on protective coating in splash zone



Fig. 1s - Protective coating peeled away just below surface



Fig. 1t - Typical example of corrosion of exposed steel in splash zone



Fig. 1u Compromised protective coating and corrosion



Fig. 1v – Coating peeling away



Fig. 1w – Just below surface, Pile 66



Fig. 2a Protective layer peeled away to show steel underneath, Pile 158



Fig. 2b 1<sup>st</sup> Level 2 inspection, Pile 165



Fig. 2c 2<sup>nd</sup> Level 2 inspection, Pile 165



Fig. 2d 3<sup>rd</sup> Level 2 inspection, Pile 165, protective layer not present





Fig. 2e – General view of Gangway splash zone



Fig. 2f – Extreme example of corrosion in splash zone



Fig. 2g – Pile 187, connection with concrete cap



Fig. 2h - ALWC on metal sheet pile of North Arm



Fig. 2i - Level 2 inspection on sheet pile to probe ALWC depth



Fig. 2j - ALWC on metal sheet pile



Fig. 3a General view of the, H-MD6



Fig. 3b - Underside of H-MD6

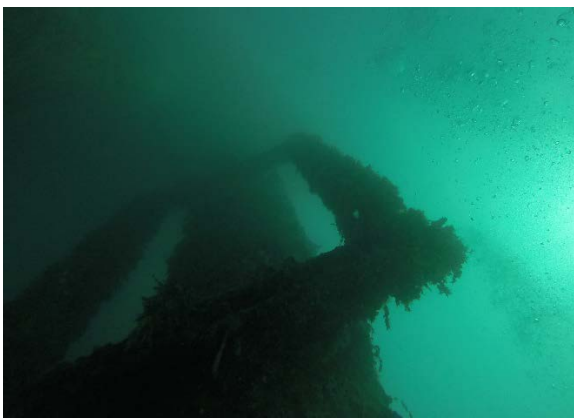


Fig. 3c - Anode on H-MD6



Fig. 3d - Level 2 inspection on anode, H-MD6



Fig. 3e - 1<sup>st</sup> Level 2 inspection, HMD6, very minor surface corrosion



Fig. 3f - 2<sup>nd</sup> Level 2 inspection, HMD6





Fig. 3g - One of the three piles on walkway dolphin



Fig. 3h - Anode on walkway dolphin



Fig. 3i - Anode of walkway dolphin, more corroded than others



Fig. 3j - Piles under H-MD4



Fig. 3k - Steel exposed under protective layer, H-MD4

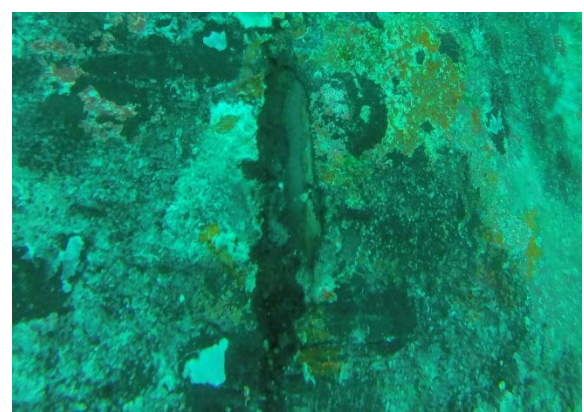


Fig. 3l - Steel exposed at base of pile under protective layer, H-MD4



Fig. 3m - ALWC on H-MD3



Fig. 3n Piles driven into sandy bottom, H-MD3



Fig. 3o General view of walkway dolphin



Fig. 3p General underwater view of original walkway dolphin piles



Fig. 3q - 1<sup>st</sup> Level 2 inspection, walkway dolphin



Fig. 3r - 2<sup>nd</sup> Level 2 inspection, walkway dolphin





Fig. 3s - Protective coating peeling away on H-BD2, minimal corrosion



Fig. 3t – Anode and Level 2 inspection on H-BD3



Fig. 3u - Level 2 inspection, H-BD3



Fig. 3v - Level 2 inspection on anode, H-BD3



Fig. 3w - 2<sup>nd</sup> Level 2 inspection, H-BD3, minimal corrosion of pile



Fig. 3x - Level 2 inspection at base, H-BD1, no protective layer present



Fig. 3y - Level 2 inspection at middle of pile, H-MD2, protective coating intact



Fig. 3z - Level 2 inspection at base, H-MD2 – surface pitting and corrosion

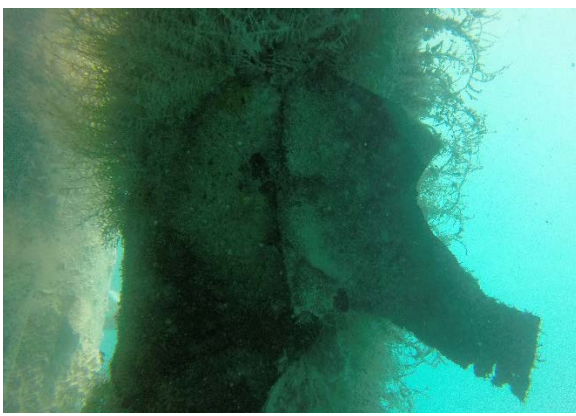


Fig. 3gg - Protective layer peeling away on H-MD2



Fig. 3hh - Band of extreme corrosion, H-MD2





Fig. 3cc - Extensive ALWC, H-MD2



Fig. 3dd - Above water view of H-MD5

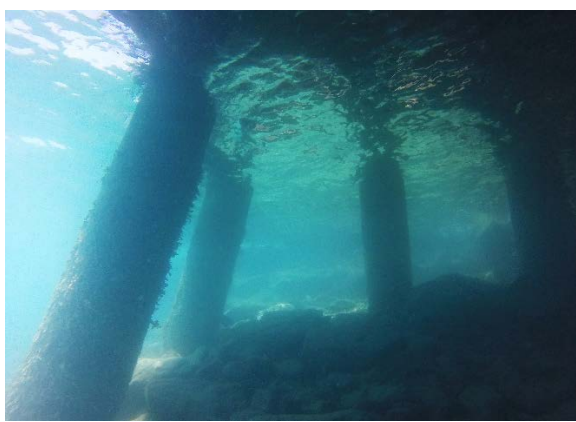


Fig. 3ee - Relatively short piles, H-MD1



Fig. 3ff - Level 2 inspection, H-MD1, protective coating still intact.



# ONSITE ENGINEERING SERVICES LIMITED

Structural, Civil, Mechanical & Electrical Engineering Services

## Underwater Infrastructure Survey

Issued: 11 September 2017

For: Bermuda Government  
Attn: Mike Murphy

### Heritage Wharf Pile Thickness Report

#### Introduction

This inspection was carried out on the 9<sup>th</sup> through the 12<sup>th</sup> of September by a three person dive team. The Thickness testing was carried out using scuba equipment, hand tools, and the Cygnus Dive Ultra Sonic Thickness Gauge. The inspection began on the northern end of the Main Wharf on Pile 1 and progressed southward. This report will present results from the thickness testing of the steel piles.

#### Summary

In total 10% (22) of the piles under the Main Wharf and Gangway were measured using the Thickness Gauge. The piles were tested in four equally spaced locations along the length of the pile. The gauge worked effectively during probing and even measured reliably through the protective coating on the pile. One of the newer "red" piles on one of the breasting dolphins was measured as a control, the original thickness of these piles was known and could be compared to the measured value. From the results a trend can be seen, the piles are corroding faster above the water surface in the splash zone compared with the submerged sections.

#### Plan View and Pile Numbering

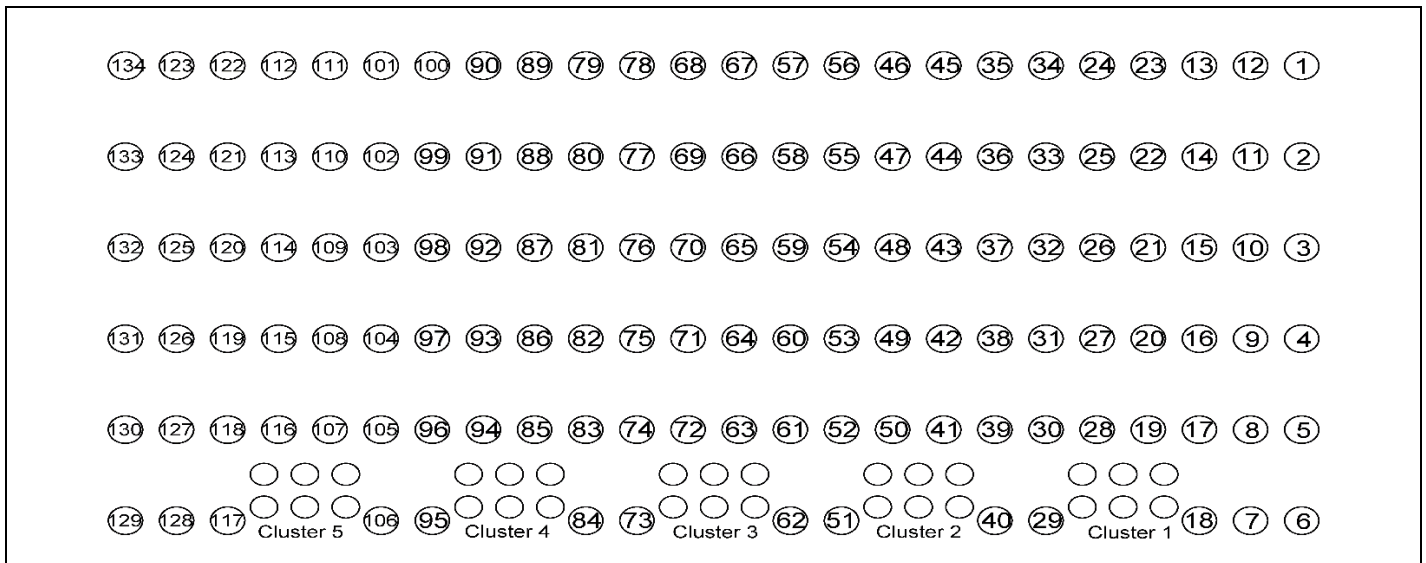


Fig. 1a – Pile Numbering Plan Under Main Wharf

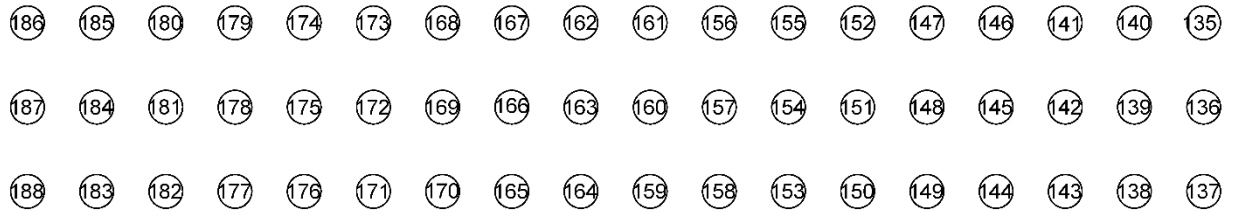


Fig. 1a – Pile Numbering Plan Under Gangway

### Results

Results collected during the testing are presented below.

Pile #	Top (mm)	Middle Upper (mm)	Middle Lower (mm)	Bottom (mm)
1	12.05	12.00	12.10	12.20
11	12.15	12.50	12.70	12.66
15	11.80	12.15	12.20	12.10
27	11.00	12.15	12.20	12.10
39	11.80	12.10	12.15	12.10
51	11.50	12.15	11.75	12.00
63	11.25	12.10	12.10	12.15
75	12.30	12.15	12.05	12.10
87	11.50	12.10	12.25	12.10
99	12.20	12.05	12.10	12.10
111	12.35	12.31	12.30	12.20
121	12.20	12.25	12.25	12.25
132	12.20	12.35	11.90	12.05
136	12.20	12.10	11.80	11.35
141	11.80	12.10	12.15	12.10
148	12.00	12.10	12.10	11.15
153	12.05	12.05	12.10	11.80
160	12.15	12.15	12.25	12.25
167	11.75	12.15	12.20	11.95
172	12.05	12.10	12.00	12.00
177	12.05	12.05	12.00	11.70
184	12.05	12.00	12.55	12.35



\*Note: This inspection is limited to observations only from the high watermark to the seabed level and comments cannot be made on the structures condition above or below these points.

**Comments & Visual Representation**

Please continue to monitor the structure and any repair works for defects or future damage (particularly after large storm events), and do not hesitate to contact us if you have any questions regarding this report or if we can provide further assistance.

Sincerely,

Keith Hodgkins, P.Eng.  
For Onsite Engineering Services Limited.