Puerto Rico Electric Power Authority
Palo Seco Steam Plant Units 1, 2, 3 & 4
Emergency Structural Steel Assessment Report

Prepared by:

ISLAND STRUCTURES ENGINEERING, PC

319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

August 25, 2017

Puerto Rico Electric Power Authority
Palo Seco Steam Plant Units 1, 2, 3 & 4
Emergency Structural Steel Assessment Report

Prepared for:

Puerto Rico Electric Power Authority

San Juan, PR 00936

Prepared by:

Island Structures Engineering, PC

319 Sunrise Highway
West Islip, NY 11795

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

INDEX

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

LEGAL NOTICE AND STATEMENT OF CONFIDENTIALITY

The information contained in this report is intended for the exclusive use of PREPA and may contain confidential or privileged information supplied by PREPA. This document was prepared by Island Structures Engineering, PC (Island) solely for the benefit of PREPA. Neither Island, PREPA nor their parent corporations or affiliates, nor any person acting on their behalf (a) makes any warranty, expressed or implied, with respect to the use of any information or methods disclosed in this document; or (b) assumes any liability with respect to the use of any information or methods disclosed in this document.

Any recipient of this document, by their acceptance or use of this document, releases Island, PREPA, their parent corporations and affiliates from any liability for direct, indirect, consequential, or special loss or damage whether arising in contract, warranty, express or implied, tort or otherwise, and irrespective of fault, negligence, and strict liability.

Report Updates

Island has no responsibility to update this report for any changes occurring subsequent to the issuance of this report.

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

I. GENERAL OVERVIEW

William Schlumpf and other staff of Island Structures Engineering, PC (Island), as a sub-consultant to Sigma Energy Solutions, previously performed a preliminary boiler building structural steel framing condition assessment at the Palo Seco Steam Plant Units 1, 2, 3 and 4 for the Puerto Rico Electric Power Authority (PREPA) in mid-September 2011. Sigma issued a Preliminary Structural Assessment report subsequent to that inspection and identified several "critical" structural conditions. Mr. Schlumpf and staff performed follow-up site visits in January, March and April 2012 for the purpose of performing a detailed structural inspection of the items identified during the first visit as "critical" and in need of immediate remediation. Mr. Schlumpf and staff subsequently performed yet more detailed inspections of the units in May and June of 2016 for the purpose of evaluating and updating serious defects in the structural framing that need to be addressed at once.

Units 1, 2, 3 and 4 are oil fired CE boilers with a capacity of approximately 75/75/200/200 MW respectively each, constructed in the late 1950's and mid-1960's. Each boiler structure is essentially unclad, structural steel, with top supported boilers, exposed to the elements. The units are located on the north side of the island of Puerto Rico, west of San Juan in the Palo Seco area.

Puerto Rico experienced a magnitude 4.8 seismic event just north of San Juan on August 25, 2017. PREPA requested that ISEPC (as a sub-consultant to GE) perform an emergency inspection of Units 1-4 at Palo Seco to assess any damages resulting from the seismic event

II. OBJECTIVES

The purpose of this emergency effort is to provide a current updated assessment of the Units with specific attention to indications of damage from the seismic event. Additionally, PREPA requested that Island opine on the viability and safety of proceeding with the remediation efforts recommended in the June 2016 evaluation. Changes in conditions since both the 2012 and 2016 inspections were of particular concern to PREPA. Only limited repairs have been undertaken since the 2012 inspection report was issued. The scope of work includes the evaluation and

recommendations for remediation of corroded or otherwise compromised structural members throughout the units that require structural repair or replacement in order to remediate significant and dangerous structural deficiencies.

This report includes the recommendations for the critical items that were identified in the June 2016 Report, subsequent to this re-inspection. This emergency inspection revealed areas of significant structural risk that require immediate remediation. This Report emphasizes six specific areas identified previously as posing such risk of imminent failure if subjected to substantially less than original design loads. They are identified herein as items IV-a through f. While these are specifically identified as "critical", this should not be construed to lessen the need for remediation of more general structural defects noted within the June 2016 Report and the associated remediation spread sheets and drawings. These other defects also have the potential for failure with consequential life safety and plant operation impacts and should also be addressed at once.

III. LIMITATIONS OF STUDY

The assessment is limited to the structural steel framing, including beams, girders, columns, bracing, connections and platform sub-framing.

This assessment does not include the stacks themselves, or any ductwork. Small bore pipe supports were not examined in any detail, however are referred to in some of the repair details, where structural remediation affects them.

IV. OBSERVATIONS

Primary structural members of each unit were inspected visually, as well as with electronic or other probing tools where warranted, at each framing level and at each vertical bracing elevation. There are numerous instances of members with either significant corrosion or perforation corrosion that will require either structural repairs or member replacement at each Unit. Members were previously assigned unique "piece marks" on the drawings, and were given detail numbers on spread sheets that relate to the detail drawings indicating the particular remediation required. The required

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

structural repairs and replacements were indicated in the spread sheets included in the June 2016 Report.

Each Unit was re-inspected on a level by level basis. Each boiler has multiple main framing levels above the ground (numbered 1 up to as high as 9), plus the main boiler hanging steel level above highest numbered level. Several levels are split, with slightly raised platform elevations at partial areas, or have partial sub-levels immediately above or below. Additionally, each main framing line of the Units was detailed on Elevation view drawings, in order to depict the vertical framing and bracing system members and columns. These were inspected again for this assessment.

Throughout this and prior reports, certain levels of corrosion are identified using specific terminology. This terminology is consistent with that used in prior reports. The following definitions provide an understanding of the general condition of structural members so identified:

Surface Corrosion - Indicates coating defects and/or exposed bare steel requiring only limited surface preparation before recoating would be effective.
Corrosion - Indicates coating failure and pitting of steel surface, with a pitted profile typically less than 1/16". Corrosion at this level does not result in a severe enough loss of material to compromise the load carrying capacity of the member.
Significant Corrosion - Indicates surface coating failure and deep pitting and/or scaling with a corroded profile depth in excess of 1/16", but not complete perforation of the member. Significant corrosion has the potential for compromising the load carrying capacity of the member, particularly if located at a stress critical location of the member.
Perforation Corrosion – Indicates a complete loss of cross section of the member to the point where a portion of the web or flange under consideration is completely gone. This level of defect clearly compromises the member, and its structural integrity and load carrying capacity cannot be relied upon.

Units 1 through 4 were specifically inspected for signs of overstress or damage resulting from the recent seismic event. Areas of particular concern included the vertical bracing systems that resist lateral loading. Such lateral loads typically are the result of wind or seismic events. Additionally, areas of interest included the steam drum hanger supports, large high-energy piping hangers, interconnecting bridges between boilers, interconnecting

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

bridges between boilers and stacks, as well as other areas that previously exhibited significant and extensive perforation corrosion. Prior inspections revealed extensive corrosion at the bottom of the vertical bracing systems at all columns in Units 3 and 4, so these were given particular attention as well.

Inspections did not reveal extensive damage from the recent seismic event on any of the units. Units 3 and 4, however, were observed to have sustained some buckling of the already weakened (due to corrosion) gusset plates between the base of the columns and the diagonal bracing (see photo 0038). This is the likely initial failure mode of these connections when subjected to compression loads in excess of their current limited capacity. No other telltale signs of significant seismic movement were observed at the steam drum and high-energy piping hangers and interconnecting bridges. It is important to note, however, that the recent magnitude 4.8 event was relatively small. For comparison, a magnitude 5.8 event, at the same location would be 10 times as severe. For reference, the Puerto Rico area experienced a magnitude 6.4 event several years ago, and several magnitude 5.4 events in 2010-11.

Six specific areas of structural defects were identified by Island during its prior inspections and were documented in its June 2016 Report. These areas pose the threat of imminent collapse or failure and pose a significant threat to both personnel and to the equipment supported thereon. In the case of items listed below as b), c), d) and e), immediate and total restriction of personnel access should be placed on these areas. In the case of the item f) (i.e. under the checkered floors at Unit 3), a restriction on loads other than from required maintenance personnel should be enforced. Item g) is a condition that warrants further investigation as noted.

During this inspection, it was observed that PREPA had begun, but not completed, installing barriers to restrict access as recommended previously. These areas have now become more critical. Other structural defects that require immediate repair are addressed in sections h and i. All areas of remediation are listed in the Spread Sheets that were included in Appendix B of the June 2016 Report. Member identification numbers used in those spread sheets are indicated on the drawings that were included as Appendix C in the same report. The spread sheets were also highlighted in different colors, as indicated on the lead sheet, to identify more easily which repairs belong in each of the noted categories. In order to make recent revisions easy to detect, changes to the spread sheets since the Interim Report was

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

issued were identified with red font (or white in the case of red highlighted areas).

a. Unit 3 & 4 Column Bases and Lateral Bracing System (Photos 0054, 0057, 0063, 0064, 0067 and 0068)
    i. Assessment: The column base connections of the lateral bracing systems for Units 3 & 4 are severely compromised. The original bracing systems were designed for loads considerably lower than current code requirements, and the degradation of these structural members further reduces the capacity of the main boiler structures to resist both wind and seismic loads. Loads in the diagonal members of the bracing system at this base level are on the order of over 220,000 # in each brace. It is estimated that the capacity of the system in the north-south direction has been compromised to the point where it only has between 15% and 25% of its originally designed strength. The east-west direction is only marginally better. Photos 0063 and 0064 depict the center column bracing on the east side of Unit 3. Photos 0067 and 0068 depict the center column bracing on the west side. Photo 0054 shows the bracing at the center column on the east side of Unit 4. As these show, the gusset plate connections from the diagonal bracing to the bottom of the column are virtually completely corroded. Photo 0057 also shows the degradation of the high strength bolts at these connections. The corner columns at each boiler are similarly corroded, providing only limited lateral stability for the unit. The severity of the current condition is such that even relatively minor storms or seismic events, considerably lower than originally designed for, could result in GROSS failure of the units. As an example, if the original Units were designed for 120 mph winds, the optimistic range of the current capacity would be for only 60 mph winds.
    ii. Remediation Details: The remediation work associated with these defects is identified in the June 2016 spread sheets with blue highlighting. The column base repairs typically consist of chopping the surrounding concrete to expose the diagonal bracing connection plates, and the replacement or repair of those plates. Also included are several member replacements and several structural repairs. Replacement steel and all remediation details should be prime-painted and finish coated as specified in Specification 09900. Replacement members and replacement connection details noted as "replacement in-kind" should be field

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

detailed for fabrication. All new bolts (typically 7/8" diameter A325N) should be used for connections. Replacement of the concrete and installation of replacement concrete piers should be done such that storm and/or operational water will no longer pool next to the steel, but rather will be conveyed by sloping concrete away from the steel. Remediation work details for the column base repairs are indicated on Detail Sheet RD-625-900-4 (Details 43 through 49) in the June 2016 Report. Due to their extreme weakened condition, it is recommended that the initial column base/bracing repairs begin with the center columns on the east and west sides of the Unit 3 boiler (i.e. columns I_3-10.44 and I_3-12.56). Only one column on each side should be worked on at a time. The center columns at Unit 4 should be simultaneously with those at Unit 3, or immediately after. **If wind loads are expected to exceed 50 mph, the work should be stabilized to the extent possible, and personnel should leave the area until such time as the winds abate.** Once at least two columns on each side of the boilers are repaired, personnel may remain in the area with winds up to 75 mph. Concrete repairs need not be completed before moving to the next set of columns.

b. Unit 1 Soot Blower Platform Framing at Elevation 82'-0" and 94'-8" (Photo DSFC-2101)
   i. Assessment: On the east side of Level 4 (soot blower elev. 82'-0" and 94'-8") sections of platform framing have corrosion so severe that the platforms are unsafe for any use (see photo DSFC-2104). **These sections of platform should be immediately cordoned off to prevent any usage, until such time as a detailed repair/replacement can be implemented. The area affected is east of column line 3 2/3. This will preclude the ability to perform periodic maintenance of the soot blowers in those areas.**
   ii. Remediation Details: The remediation work associated with these defects is identified in the spread sheets with yellow highlighting. The repairs include several member replacements and several structural repairs. Replacement steel and all remediation details should be prime-painted and finish coated as specified in Specification 09900. Replacement members and replacement connection details noted as "replacement in-kind" should be field detailed for fabrication. All new bolts (typically 7/8" diameter A325N) should be used for connections.

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

c. Unit 1 Deaerator Tank Upper Platform Framing (Photo 836 and DSFC-2101)
    i. Assessment: The structural framing supporting the upper level of the Unit 1 deaerator tank access platform has deteriorated to the point where it is in danger of collapse under normal platform loading, and perhaps under its own weight. **This area should be restricted from any personnel access until it is replaced.** The corrosion is pervasive to the point where complete replacement of the entire platform is warranted. This replacement work was previously detailed in the drawings and spread sheets developed in 2012, as well as in 2016.
    ii. Remediation Details: The remediation work associated with these defects is identified in the spread sheets with deep purple highlighting. The repairs include the complete member replacement of this platform level. Replacement steel and all remediation details should be prime-painted and finish coated as specified in Specification 09900. Replacement members and replacement connection details noted as "replacement in-kind" should be field detailed for fabrication. All new bolts (typically 7/8" diameter A325N) should be used for connections.

d. Unit 1 Level 1 Platform Framing Over Electrical Building Roof (Photo DSFC-2109)
    i. Several members supporting the Level 1 platform over the Electrical Building roof (Elevation 39'-4" south of column line E) have deteriorated to the point that they pose imminent threat of collapse under their own equipment and dead load. The southernmost W14 spandrel beam is already failing with noticeable deflection (see photo DSFC-2109). This area requires immediate member replacement and/or supplemental support. **Until such remedial work is completed, access to this platform should be prohibited. This will preclude the ability to monitor and maintain the unit-critical equipment located thereon.**
    ii. Remediation Details: The remediation work associated with these defects is identified in the spread sheets with deep orange highlighting. The repairs include several member replacements, several structural repairs, and the installation of a new member under the main spandrel beam to provide additional support to that failed member, while limiting the associated plant equipment

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

impacts. Replacement steel and all remediation details should be prime-painted and finish coated as specified in Specification 09900. Replacement members and replacement connection details noted as "replacement in-kind" should be field detailed for fabrication. All new bolts (typically 7/8" diameter A325N) should be used for connections.

e. Unit 3 & 4 Elevator Area Framing (Photos 0040, 0041, 0042 and 0043)
   i. Assessment: The area in the vicinity of the original common Unit 3 & 4 elevator shaft platform framing is extremely critical. The main platform framing girders in these areas typically have severe perforation corrosion at the penetration of the siding to the elevator shaft (see photos 0040, 0041, 0042 and 0043) where the girders and beams attach to the elevator shaft columns. At some levels this is so severe as to provide no visible means of support to these main framing members. The member in photo 0042 is already starting fail under its own weight. It also noted that many of these platform areas support soot blowers. **These areas should be immediately cordoned off to prohibit any personnel from walking on or below them, as the pose an imminent threat of collapse even under current equipment and dead weight alone. This restriction will preclude the ability to perfrom routine maintenance on the soot blower located thereon.** The situation exists at multiple levels (from level 1 through 9).
   ii. Remediation Details: The remediation work associated with these defects is identified in the spread sheets with green highlighting. The repairs include the installation of structural connection "seats" at many of the beam connections to the elevator shaft columns (See Details 41 and 42, Drawing RD-625-900-4). These "seats" can be installed without complete removal of the deteriorated structural members. Additionally, some member replacements and several structural repairs are required. The situation exists at multiple levels (from level 1 through 9), precluding the possibility of temporary posting from the level immediately above or below. As such it is recommended that level-one repairs be performed first, using manlift equipment. Subsequently, the upper levels should be temporarily shored down to this level.
   iii. Remediation details for this area were previously indicated on Drawings RE-629-366-3 through RE-629-374-3 and in details

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795

shown on Drawings RD-420-900-1 through 4. Replacement members and replacement connection details noted as "replacement in-kind" should be field detailed for fabrication. All new bolts (typically 7/8" diameter A325N) should be used for connections. Replacement steel and all remediation details should be prime-painted and finish coated as specified in Specification 09900. Additional repairs, particularly at bracing connections have also now been identified and are included in the remediation details.

f. Unit 3 & 4 Level 2 Framing Beneath Checkered Plate (Photo 809)
   i. Assessment: The framing on the south side of Units 3 & 4 at Level 2 (Elevation 60'-11") is mostly covered with checkered plate (instead of open grating). The checkered plate has allowed moisture to be retained between the plate and the top flange of these members, resulting is significant pervasive corrosion of many of the top flanges. This area will require removal of the checkered plate during remediation and re-inspection is recommended at that time to verify the condition of these top flanges. **Until such time as that is completed, it is recommended that only critical personnel loading (i.e. no equipment or tools or unnecessary transit) be permitted on these areas.**
   ii. Remediation Details: The remediation work associated with these defects is identified in the spread sheets with red highlighting. The repairs include member replacements and structural repairs. There may be additional repairs required, after a re-inspection is performed subsequent to the checkered plate removal. Replacement steel and all remediation details should be prime-painted and finish coated as specified in Specification 09900. Replacement members and replacement connection details noted as "replacement in-kind" should be field detailed for fabrication. All new bolts (typically 7/8" diameter A325N) should be used for connections. Most of the steel in this area has poor coating condition. Proper cleaning and recoating will be required for much of the area once the plate is removed.

g. Unit 3 Deaerator Platform Pipe Support Hanger Beam
   i. Assessment: It was observed during the June 2016 re-inspection that the beam running along the south side of the deaerator had significant deflection in it. This beam does not support the

ISLAND STRUCTURES ENGINEERING, PC
319 SUNRISE HIGHWAY
WEST ISLIP, NY 11795