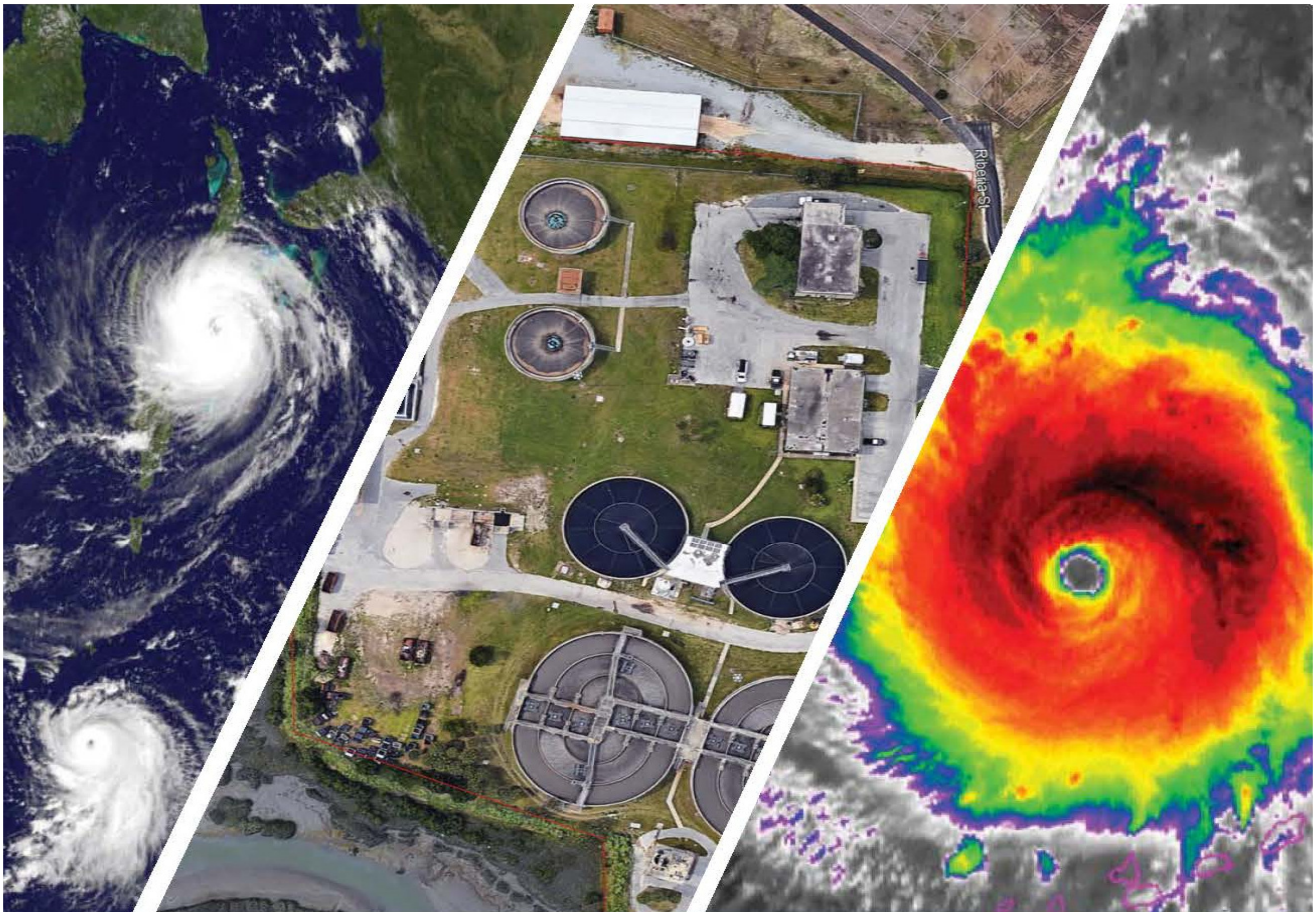

FINAL

SEPTEMBER 2018

WWTF CLIMATE RESILIENCE PLANNING ANALYSIS

ST. AUGUSTINE, FLORIDA

SUBMITTED TO:

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St. Augustine WWTF Climate Resilience Planning Analysis

1.0 Introduction

The City of St. Augustine (City) owns and operates a 4.95-million gallons per day (MGD) annual average daily flow wastewater treatment facility (WWTF) that is located on a point between the Matanzas River and San Sebastian River, see Figure 1.

The City's WWTF utilizes -a complete mix activated sludge treatment process with a headworks system consisting of mechanical bar screens and vortex grit removal, two elliptical biological treatment units (BTUs) which provide aeration, clarification, disinfection with either sodium hypochlorite or peracetic acid and post aeration. Biosolids treatment consists of aerobic digesters and belt presses (solids handling building). Four buildings onsite house the major electrical equipment for the facility: the operations building, the return active sludge (RAS) pump station, the disinfection and solids handling. The main power transformer that supplies power to the entire facility is inside of a small structure adjacent to the operations building. See Figure 2 for a site layout of the WWTF.

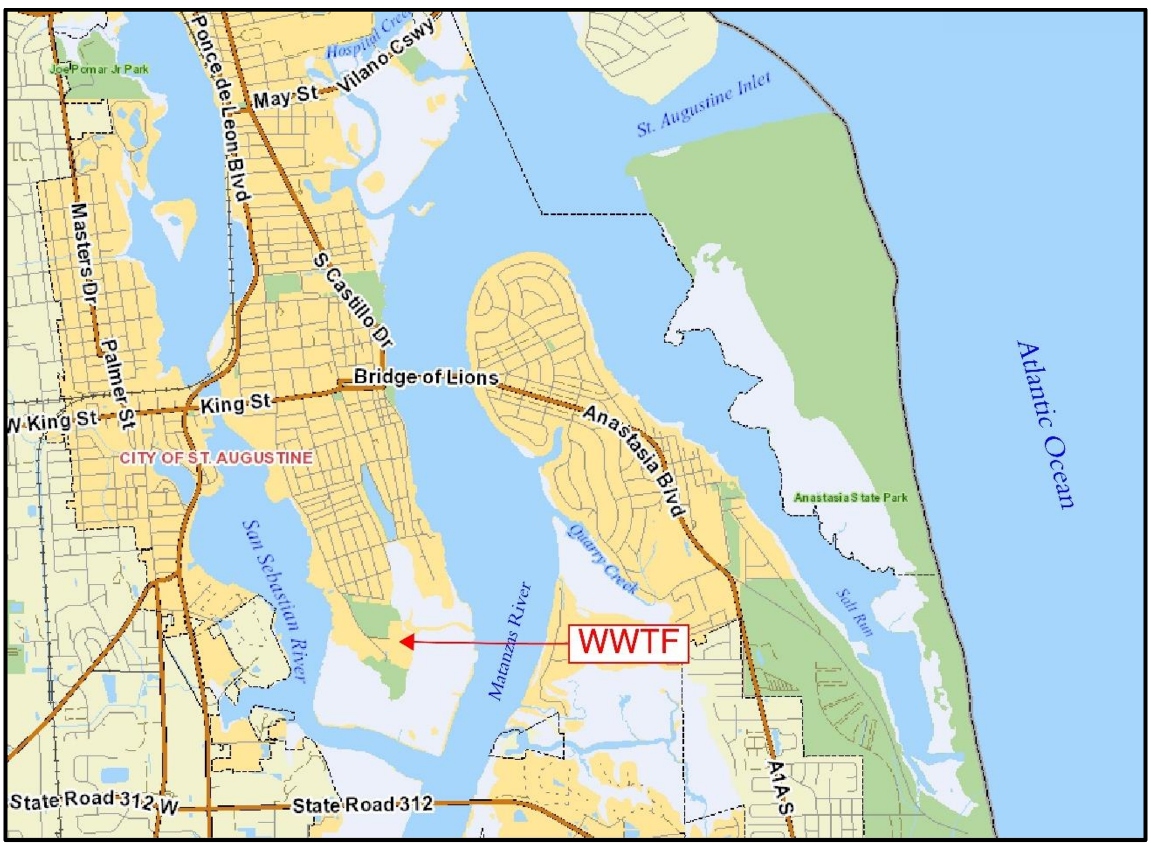

Figure 1: St. Augustine WWTF Vicinity Map

Figure 2: St. Augustine WWTF Site

The City was impacted by back to back hurricanes in October of 2016 and September of 2017 with Matthew and Irma. Both storms resulted in significant damage due to flooding. The City's Mayor, Shaver, was quoted in the September 13, 2017 edition of the New York Times, following Irma: "I've never had people ask me the questions they're asking me now: Is this the new normal? What are we going to do with the City?" Facing rising seas, and likely more frequent and more severe flooding, America's oldest City has set itself on a course to become climate resilient to meet these challenges.

A report titled, "Florida Community Resiliency Initiative Pilot Project-Adaptation Plan for St. Augustine, Florida" was completed in May 2017 for the City by Dewberry. The pilot project was a high planning level, overall assessment of the City's vulnerability to sea level rise (SLR) moving forward. The stated purpose of the pilot project was to provide St. Augustine with a law and policy framework for pursuing coastal resilience. Within section 4.3.2 of the report, the vulnerability of the City's WWTF is noted but not detailed. The WWTF's vulnerability to flooding is of great concern, flooding due to storm surge during a storm event is of even greater concern. Storm surge is mentioned as a concern but not evaluated in the pilot project. This analysis is intended to take the next step in the planning analysis already started including the projected impacts of future SLR.

The City retained McKim & Creed to assess the vulnerability of the WWTF to flooding from storm surge during storm events today and at specific years into the future factoring in projected SLR. The analysis is intended to be a high-level assessment to provide the City with "order of magnitude" capital cost estimates of the impact of potential storm surges on the WWTF. The analysis estimates the costs of potential hardening measures to prevent projected flooding damage.

The analysis included only potential damage to WWTF treatment process equipment. An analysis of the ability of structures to resist the hydrostatic pressures, hydrodynamic forces and wave action associated with storm surge or wind loads was not completed as part of this analysis. This decision was made while scoping the work to be performed in this analysis to first determine the overall vulnerability of the WWTF to storm surge, before completing a detailed evaluation and design and construction of hardening measures, if appropriate. Should the City decide hardening of the WWTF as part of an overall resilience strategy to be in its best interest, a structural analysis of components/structures deemed to be vulnerable should be included in that evaluation/design.

The analysis included hurricane storm surges associated with Category 1 through, 2, 3, 4 & 5 storm events for the region. Each event was assumed to occur at high tide or mean higher high water (MHHW). The first period evaluated was for the year 2018. Subsequent assessments were completed for the combined projected impact of sea level rise (SLR) and storm surge for the same storm events in 2030, 2050, 2070, and 2100. The guidelines used to evaluate the facility are those that are defined in EPA technical document, "Climate Resilient Water Utilities Adaptation Strategies Guide (CRWU-ASG)." As previously stated, the assessment was meant to provide information to the City to assist in making planning level decisions, on how best to make the WWTF "climate resilient". In accordance with CRWU-ASG guidelines, the high NOAA curve was used for all analyses performed. As was discussed with City staff, a reasonable, conservative approach to creating a climate resilient WWTF is to analyze, plan, and if appropriate, design and construct resilience measures at the WWTF to meet the "worst case scenario" in year 2030. During the time until 2030 it is recommended that the City compare actual SLR to projected SLR annually to account for the high degree of variability between the projected NOAA high, medium and low SLR curves.

Using this approach, the City will have the ability to assess where it is at with respect to vulnerability using EPA's Climate Resilience Evaluation and Awareness Tool (CREAT) and adjust its resilience plan for the

WWTF, as appropriate. This approach will insure that significant capital costs are not spent to "harden" the facility beyond a condition that may not be necessary. Conversely, should actual SLR outpace the projected high curve it will put the City in a position to address the issue as part of their overall regional resilience plan without spending significant monies that do not sufficiently address the issue at the WWTF independently.

2.0 Estimated Flood Water/Storm Surge Elevations at the WWTF

Storm surge elevations were calculated using the highest high tide elevations projected for 2018 by the National Oceanic and Atmospheric Administration (NOAA) for an area closest to the WWTF, Anastasia Island for this analysis. In accordance with EPA CRWU-ASG for evaluating the most critical components in a wastewater collection system, the NOAA high curve is the appropriate curve to use in projecting future events for the facility. As a result, the NOAA high curve for the region was used as the predictor of SLR for this analysis.

Table 1 summarizes projected storm surge at MHHW for the five categories of hurricanes that could strike in 2018 and consider SLR as detailed above for the four future periods evaluated at the WWTF.

Table 1: Sea Level Rise and Storm Surge Predictions for the WWTF

Year	2018	2030	2050	2070	2100
Sea Level Rise (ft)[4]	0	0.8	2.1	3.6	6.7
MHHW Tide Elevation[1] Including SLR	3.2	4.0	5.3	6.8	9.9
Category 1 Hurricane Storm Surge Elevation[1,2,3]	5	5.8	7.1	8.6	11.7
Category 2 Hurricane Storm Surge Elevation[1,2,3]	10	10.8	12.1	13.6	16.7
Category 3 Hurricane Storm Surge Elevation[1,2,3]	15	15.8	17.1	18.6	21.7
Category 4 Hurricane Storm Surge Elevation[1,2,3]	19	19.8	21.1	22.6	25.7
Category 5 Hurricane Storm Surge Elevation[1,2,3]	23	23.8	25.1	26.6	29.7

[1]Elevations in feet in reference to NAVD 88
[2]Elevations are approximate storm surge depth at high tide (MHHW).
[3]Storm Surge depths calculated by Dr. Jeffrey Matthews PhD, Director of Meteorology, Weather Underground using the National Hurricane Center's SLOSH hydraulic modeling software
[4]SLR obtained from "Adapting to Rising Tides"; April 2016; The University of Florida Resilient Communities Initiative, from projected published NOAA SLR curves.

3.0 Thresholds of Failure or Damage

Elevations of equipment essential for WWTF operation, not rated for submergence, at the WWTF were identified based on available record drawings completed by others for the City. All elevations on record drawings were converted from National Geodetic Vertical Datum of 1929 (NGVD 29) to North American Vertical Datum of 1988 (NAVD 88). Spot field elevations were recorded by a McKim & Creed survey team in May 2018 at the WWTF to assist in calibrating the conversion to NAVD 88 from the supplied record drawing elevations.

Table 2 shows elevations at which impacts, to “critical” equipment, are expected when the water level from projected storm surge meets or exceeds the elevations shown. Following the CREAT Methodology Guide 3.0, the user defines “critical assets” to include in the risk assessment. For the purpose of this analysis, critical asset is defined as a piece of equipment, system or asset in the WWTF that if destroyed, damaged or rendered inoperable would result in one or more of the following consequences: loss of revenue, partial or complete loss of an asset, impacts to source and receiving water, environmental damage and public health impacts. For this analysis, the severity of the consequences was determined by the impact to the overall WWTF operation and equipment replacement cost as designated in the last two columns.

The first column in Table 2 lists the critical system and equipment that are susceptible to water damage. The second column indicates the surge elevation that corresponds to the bottom of the equipment. Depending on the type of equipment, damage may start to occur from water at the bottom, a few inches up from the bottom or higher up from the bottom. The analysis assumes that damage starts to occur at the bottom of equipment for planning level purposes, consistency and conciseness. The third column labeled “Notes” calls out equipment that would likely be damaged at the elevation identified. The fourth column indicates whether the WWTF as a whole would be impacted by damage to the equipment listed on each line (see note 2 below the table for more information). The last column indicates the criticality of the equipment or system listed on each line to the overall operation of the WWTF. For instance, the plant pump station is the first piece of equipment to see impacts but the effects of this small lift station being offline would only impact the restrooms and drains at the WWTF draining into the lift station and not impede the WWTF from treating incoming wastewater from the City’s collection system.

The photos in Figure 3 show critical equipment susceptible to water damage in the RAS Pump Station. Electrical junction boxes, flow meters and electronic value actuators are a few examples of equipment susceptible to water damage visible in the photo. The dry pit in the RAS Pump Station is particularly at risk to flooding since it is below existing grade beneath the RAS Pump Station building. Note that the RAS Pump Station building is not floodproof. The motor control centers (MCC) shown in Figure 3 are typical for the WWTF on short concrete maintenance pads with little to no room to elevate due to ceiling heights. Figures 4 and 5 depict surge elevations overlaid on WWTF buildings for year 2018. These figures clearly illustrate the WWTF’s current vulnerability to damage due to storm surge.

Table 2: WWTF Damage Thresholds

Critical Equipment	Critical Damage Elevation[1]	Notes	WWTF Inoperable After Water Recedes[2]	Criticality[3]
Effluent Hydraulics	5.1	Plant hydraulics impacted[6]	No	Low
Plant Pump Station	6.6	Control panel submerged	No	Low
RAS/WAS Pump Station	7.6	Water entering into RAS Pump Station dry pit	Yes	High
Primary Power Transformer	8.9	Primary power transformer submerged[7]	Long-Term Yes	High
Electrical Equipment	8.9	MCCs, main switch, VFDs submerged	Yes	High
Solids Handling Equipment	9.9	Solids handling equipment submerged	Long-Term Yes	Medium
Standby Generator	10.2	Standby generator submerged	Long-Term Yes	High
Sludge Pump Station	10.8	Pumps submerged	Long-Term Yes	Low
Disinfection Basin	13.3	Tank inundated	No	Low
Reuse Pumps	13.8	Reuse pumps submerged	Long-Term Yes	Low
Secondary Clarifiers	14.8	Clarifiers inundated[8]	Yes	High
Headworks	16.1	Grit pumps submerged	Long-Term Yes	Low
Biological Treatment Units	19.9	BTUs inundated[8]	Yes	High

[1]Elevations in feet in reference to NAVD 88

[2]"Yes" means damage to equipment renders WWTF unable to maintain treatment within 12 hours. "Long-Term Yes" means damage to equipment renders WWTF unable to maintain treatment after multiple days

[3]"Low" - WWTF can treat incoming wastewater to effluent standards, "Medium" - Solids processing treatment out of operation, but WWTF can treat incoming wastewater to effluent standards, "High" - WWTF unable to treat incoming wastewater to permitted effluent limits

[4]Assumes submergence damages electrical components of treatment process equipment only

[5]Assumes submergence requires complete replacement of treatment process equipment. Costs are based on a total equipment cost replacement for the facility.

[6]Based on the hydraulic profile in the original record drawings for the WWTF by Flood Engineers the facility will not be able to send effluent to the Matanzas River at this flood elevation temporarily until the water recedes

[7]The cost of replacement for the primary power transformer typically is born by the power provider. However, a loss of primary power will have costs associated with running backup power generation

[8]Biological process may require re-seeding if tanks are inundated and washout solids inventory

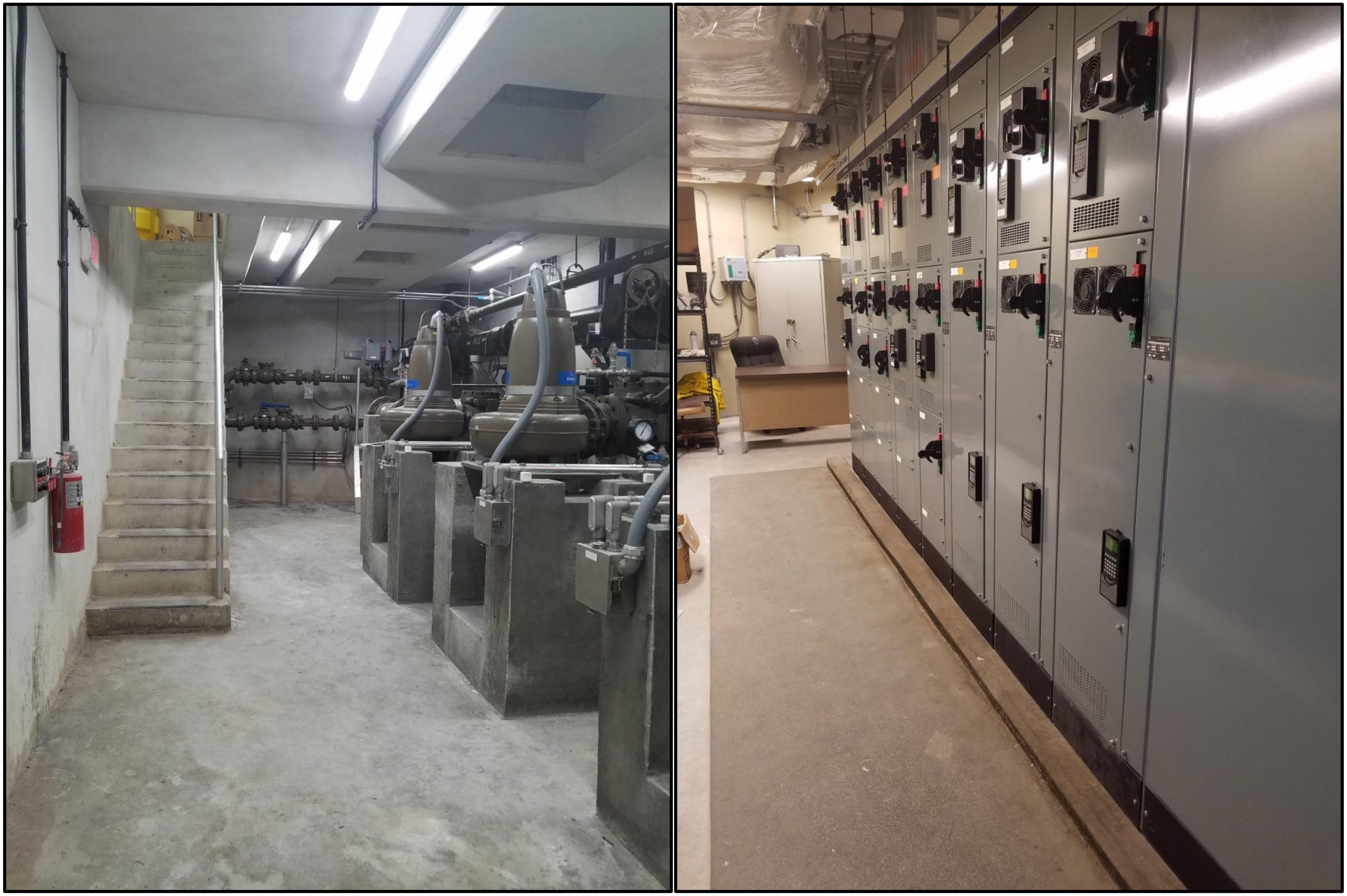

Figure 3: Photos of Existing RAS Pump Station Pump Room (left), MCCs in RAS Pump Station Main Floor (right)

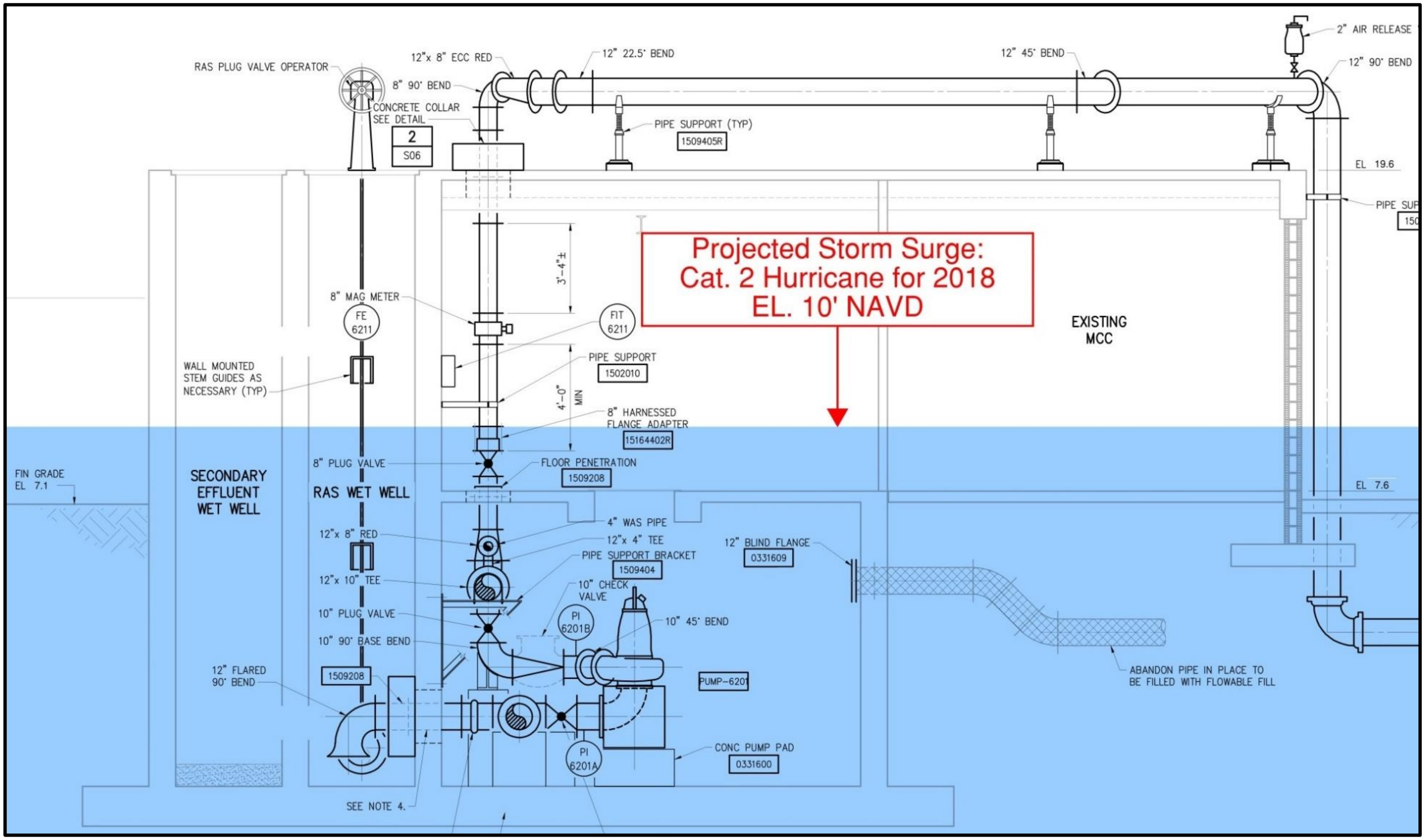

Figure 4: Depiction of Category 2 Storm Surge at the RAS Pump Station for Year 2018

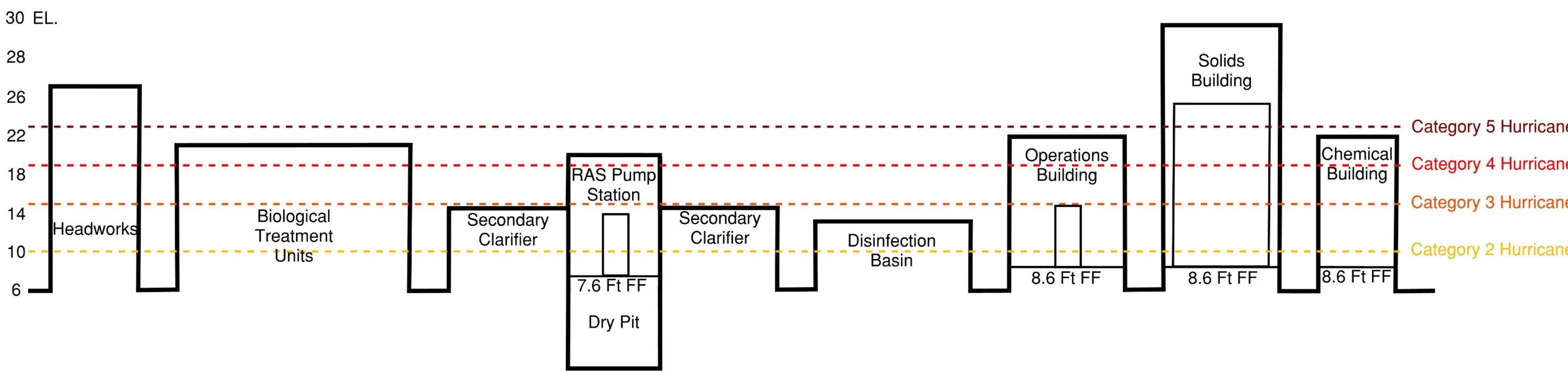

Figure 5: Depiction of Storm Surge Projections at the WWTF for Year 2018

4.0 Risk Assessment and Estimated Damage Costs

This analysis is consistent with previous reports completed for the City in that the risk of significant damage to the WWTF is high for projected hurricane storm surge now, that is 2018. The compound effects of SLR and storm surge are projected to increase the risk over time.

Damage costs were estimated at the elevations identified in Table 2 for each area of the facility. The following assumptions were made to monetize projected damage:

- In general, only electrical equipment and components would be damaged by submergence, i.e. motors, MCCs, variable frequency drives (VFD), main breakers, switch gear, local control panels, etc. These are the electrical component damage costs shown on Table 3 and Figure 6. Costs were developed based on unit costs or from recent facility improvements.
- An exception to the note above was the assumption made that wave action could damage the clarifier mechanisms and aeration systems for the BTUs at projected surge elevations above the tops of these structures, and therefore, complete equipment replacement costs are shown under the “electrical component damages” for the secondary clarifiers and BTU aeration systems.
- The complete equipment replacement costs on Table 3 and Figure 6 represent costs due to long term submergence, damage from salt water, or damage by wave action which would require complete replacement of the equipment up to the elevation indicated. The $21 million dollars for complete equipment replacement was estimated based on a percentage of the overall estimated cost to build a new WWTF. The overall estimated cost to build a new WWTF is in Section 5.5 including the cost development procedure. The total equipment replacement cost was estimated to be 35% based upon the percentage of mechanical, electrical and instrumentation & controls portion from the consultant’s past projects. Some examples of what was not included in the 35% was structures, civil site improvements, yard piping and duct banks.
- An evaluation of hydrostatic, hydrodynamic and wave action forces on existing structures was not included in this analysis. For this analysis, existing structures were assumed to remain intact from a flooding/storm surge event. Therefore, a complete loss of equipment inside buildings that were assumed to withstand submergence for a short period of time was not included in the estimated damage costs. An example is that only the electrical components of the dewatering equipment inside the solids building were included in the damage estimate. As stated in the Introduction section of this analysis, it is recommended that the City perform a structural assessment of facility structures that are deemed to be vulnerable to insure the buildings would be able to standing up to hydrostatic pressures of a given storm surge as part of a detailed climate resilience planning program for the WWTF.
- It is assumed that the City does not own the primary power transformer that supplies power to the WWTF. The direct cost for damages to the primary power transformer is therefore shown as $0 in the tables. The City would have indirect costs associated with this, such as fuel for backup power generation. Should the primary power transformer that supplies the WWTF be owned by others, it is recommended that the City approach the power supplier to discuss hardening of this component to be consistent with overall hardening measures as part of an overall resilience plan implemented at the WWTF.

Table 3: Estimated Damage Costs for Critical Water Level Elevations Identified

Critical Equipment	Critical Damage Elevation[1]	Notes	WWTF Inoperable After Water Recedes[2]	Criticality[3]	Cumulative Electrical Component Damage Costs[4]	Cumulative Complete Equipment Replacement Costs[5]
Effluent Hydraulics	5.1	Plant hydraulics impacted[6]	No	Low	$0	$0
Plant Pump Station	6.6	Control panel submerged	No	Low	$20,000	$20,000
RAS/WAS Pump Station	7.6	Water entering into RAS Pump Station dry pit	Yes	High	$620,000	$2,000,000
Primary Power Transformer	8.9	Primary power transformer submerged[7]	Long-Term Yes	High	$620,000	$3,000,000
Electrical Equipment	8.9	MCCs, main switch, VFDs submerged	Yes	High	$1,470,000	$3,000,000
Solids Handling Equipment	9.9	Solids handling equipment submerged	Long-Term Yes	Medium	$1,770,000	$5,000,000
Standby Generator	10.2	Standby generator submerged	Long-Term Yes	High	$2,520,000	$5,000,000
Sludge Pump Station	10.8	Pumps submerged	Long-Term Yes	Low	$2,540,000	$6,000,000
Disinfection Basin	13.3	Tank inundated	No	Low	$2,540,000	$10,000,000
Reuse Pumps	13.8	Reuse pumps submerged	Long-Term Yes	Low	$2,560,000	$11,000,000
Secondary Clarifiers	14.8	Clarifiers inundated[8]	Yes	High	$4,160,000	$12,000,000
Headworks	16.1	Grit pumps submerged	Long-Term Yes	Low	$4,180,000	$14,000,000
Biological Treatment Units	19.9	BTUs inundated[8]	Yes	High	$5,290,000	$21,000,000

[1]Elevations in feet in reference to NAVD 88

[2]"Yes" means damage to equipment renders WWTF unable to maintain treatment within 12 hours. "Long-Term Yes" means damage to equipment renders WWTF unable to maintain treatment after multiple days

[3]"Low" - WWTF can treat incoming wastewater to effluent standards, "Medium" - Solids processing treatment out of operation, but WWTF can treat incoming wastewater to effluent standards, "High" - WWTF unable to treat incoming wastewater to permitted effluent limits

[4]Assumes submergence damages electrical components of treatment process equipment only

[5]Assumes submergence requires complete replacement of treatment process equipment. Costs are based on a total equipment cost replacement for the facility.

[6]Based on the hydraulic profile in the original record drawings for the WWTF by Flood Engineers the facility will not be able to send effluent to the Matanzas River at this flood elevation temporarily until the water recedes

[7]The cost of replacement for the primary power transformer typically is born by the power provider. However, a loss of primary power will have costs associated with running backup power generation

[8]Biological process may require re-seeding if tanks are inundated and washout solids inventory

The following are not included in the costs shown in Table 3:

- Damage to electrical junction boxes, conduits and other minor electrical components that are below estimated flood elevations
- Repair and rehabilitation costs for the facility over the projected assessment timeline (2018 to 2100)
- Required facility improvements over the projected assessment timeline
- Recovery and cleanup costs for the site and buildings after a storm/flooding
- Reseeding biological process if required after a storm/flooding event.
- Damage costs for computers, office equipment, furniture, lab equipment, and other building furnishings
- Fuel costs while running on backup power
- Costs associated with facility downtime, i.e. bypass pumping, pumper trucks, etc.
- Structural damage to buildings
- Socio economic costs associated with an off line WWTF

Figure 6 is a visual representation of Table 3 showing electrical damage costs and equipment replacement costs compared to projected storm surge elevations for year 2030. Actual damages for a surge elevation could be between the blue and green lines. Costs not included are listed after Table 3.

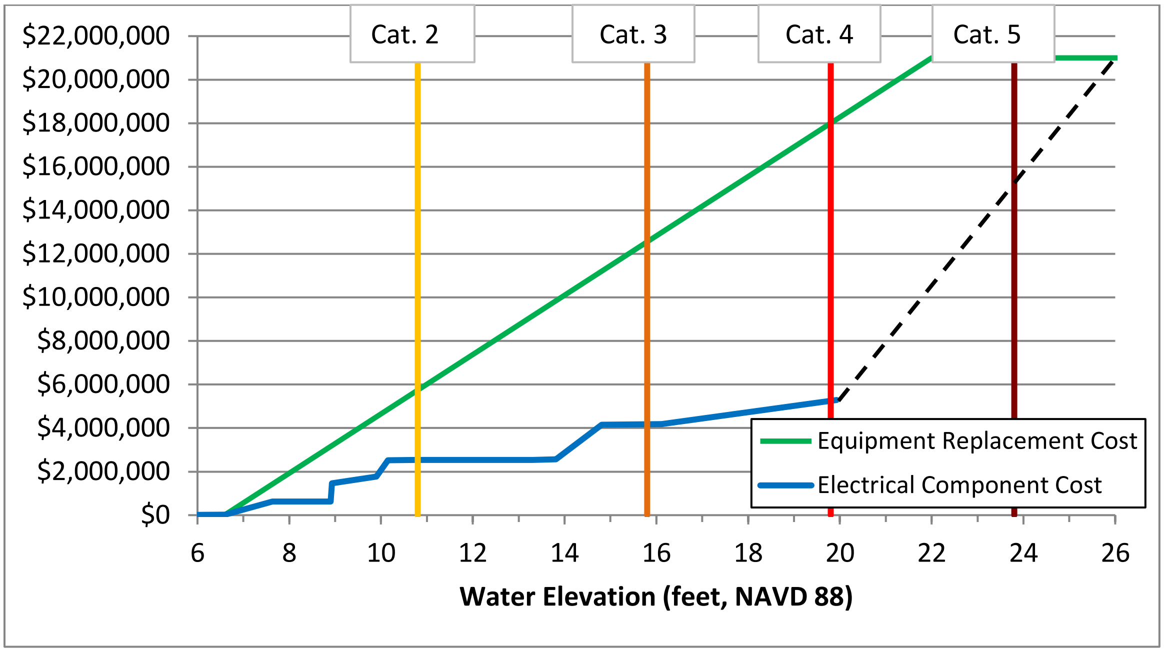

Figure 6: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2030 (2018 dollars)

5.0 Possible Adaption Alternatives

The following are possible planning level resilience and hardening alternatives for the WWTF. The estimated costs for each hardening measure are compared to the estimated damage costs with a cost benefit analysis at the flood elevation determined for each option.

5.1 Alternative 1: Do Nothing

Maintaining the status quo, that is doing nothing is a viable option to consider and is used as a baseline in planning level resilience assessments. The estimated damage costs discussed in section 4 of this analysis serve as a comparison for proposed hardening strategies. Note that the estimated damage costs do not include all possible costs associated with storm damage. Refer to section 4 for more information. A summary of estimated damage costs by category of storm surge for year 2030, for example, is shown in Table 4 based on Figure 6. Year 2030 is shown in Table 4 and the rest of the tables in Section 5 as one example of the five years considered in this analysis. Additional figures and tables for years 2018, 2050, 2070 and 2100 are included in the Appendix. The WWRF is completely inundated at an elevation of about 20 ft, which corresponds to a projected Category 5 hurricane storm surge in years 2018 and 2030.

Table 4: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2030 (2018 dollars)

Category of Hurricane	Projected Surge Elevation (feet, NAVD)	Estimated Damage Costs	
		Elec. Components	Equipment Replacement
1	5.8	$0	$0
2	10.8	$2,500,000	$6,000,000
3	15.8	$4,200,000	$13,000,000
4	19.8	$4,200,000	$18,000,000
5	23.8	$5,300,000	$21,000,000

5.2 Alternative 2: Harden Existing Buildings

The finished floor elevations of the operations building, solids handling building, disinfection building, and RAS pump station building range from elevation 7.6 feet to 8.6 feet NAVD 88. Electrical equipment inside these buildings would be the first critical equipment at the facility to be damaged by flooding. The RAS pump station has a dry pit below the ground level and would experience the first impacts from flooding as shown in Figures 3, 4, and 5 in Section 2. MCCs and other large electrical cabinets (VFDs, main switchboard, automatic transfer switches) are mounted on concrete maintenance pads that are approximately 4 to 6 inches above the finished floor elevation of each building, as shown in Figure 3. The operations building also contains the facility's standby power generator, control room, lab, offices, furnishing and other equipment at risk from water damage. Raising electrical equipment in the existing buildings is not feasible due to the height of the top of the equipment relative to the existing ceiling heights.

There are a variety of ways to flood-proof an existing building. However, dry floodproofing is not permitted in coastal A flood zones, where the facility resides, according to 'FEMA P-936 Floodproofing Non-Residential Buildings' and 'ASCE 24 Flood Resistant Design and Construction', both of which are incorporated into building codes. A viable option for the WWTF could be to erect semi-permanent mobile flood barriers around each building prior to a storm strike. Figure 7 shows an example of mobile flood barriers. Permanent anchors are installed in a solid base, and the barriers are erected prior to a storm. Setup time is estimated to be about 100 square feet per person per hour +/- 50% based on information provided by one vendor.

Figure 7: Examples of a Mobile Flood Wall Installation

The proposed location of the mobile flood barriers would completely encircle the operations building, solids building and the disinfection building. Barriers on each side of the RAS pump station building are also proposed. The proposed locations of these flood barriers are shown on Figure 8. In areas where grass, asphalt or concrete is not adequate for mounting the barriers, reinforced concrete slabs would be required along the length of the barriers for proper mounting. For cost estimation, the concrete slabs required were assumed to be 12-inches thick and 6-feet wide.

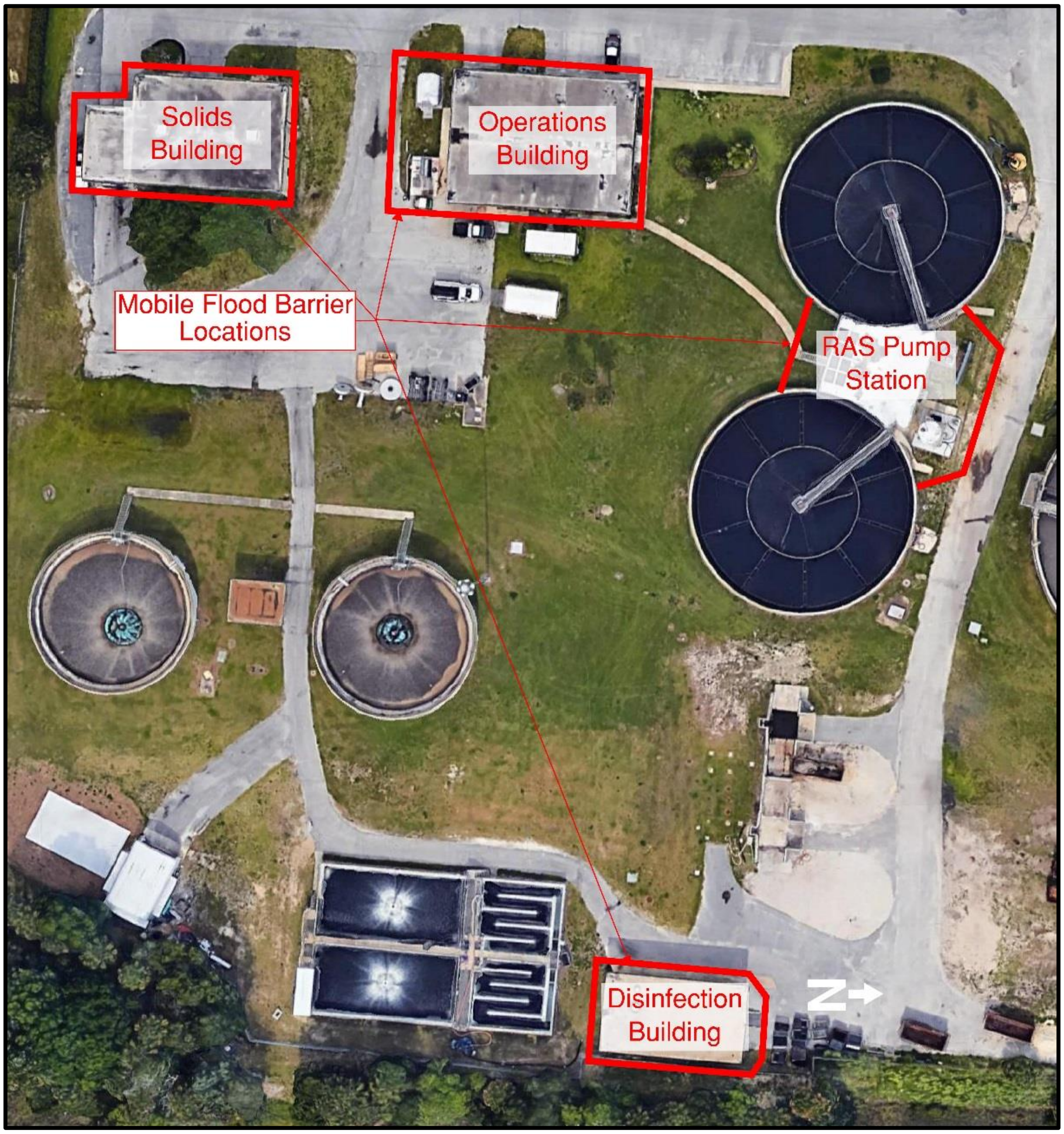

Figure 8: Proposed Mobile Flood Barrier Locations

The target top elevations for the mobile flood barriers were 14.0-feet NAVD and 20.0-feet NAVD 88. 14.0-feet would protect the facility from category 2 storm surge from 2018 through year 2070. Existing grade around the existing buildings is about elevation 9 NAVD 88 based on record drawings except the east side of RAS pump station which is about elevation 8. It is assumed that grade or a small wall would be built up to elevation 9 where needed for the cost estimation of the flood walls. The mobile flood walls should be installed per the manufacturer's recommendations. These should be incorporated in the design if selected. All of the major equipment would be protected up to this elevation except for the plant lift station. The plant lift station is not considered critical to the operation of the overall WWTF as discussed in Section 3.0, stocking spare parts onsite for the plant lift station or a portable pump station are viable solutions to bringing the WWTF back on line should the plant lift station be disabled. The setup time is estimated to be about 60 labor hours or 12 hours for a crew of five based on the assumed setup time previously mentioned.

Mobile flood barriers designed to protect to elevation 20.0-feet would protect the facility for an estimated category 4 storm surge in year 2018 and category 3 storm surge for years 2030 to 2070. The setup time is anticipated to be about 130 labor hours or 26 hours for a crew of five based on the assumed setup time previous mentioned. At elevation 13.8 the reuse pumps and other electrical appurtenances on top of the disinfection basin would be subject to water damage. Replacement costs due to damages to the reuse pump motors are estimated to be $20,000 (2018 dollars) as shown in Table 3. Stocking spare parts for the reuse pump station onsite is a viable solution.

The tops of the biological treatment units are at about the same elevation, 19.9-feet. This is the highest level of protection recommended for the mobile flood barriers. Protecting for a higher elevation would require barriers around all the structures, and a perimeter wall around the entire WWTF site would be more cost effective. Estimated costs for the two mobile barrier options are shown in Table 5. The 5-feet high option corresponds to a Category 2 hurricane protection for year 2030 with an estimated damage cost of $2.6 million to $10 million. The 11-feet high option corresponds to a Category 3 hurricane protection for year 2030. The estimated preventable damage cost is $4.2 million for this option, which is lower than the estimated damage cost of $5.3 million to $21 million. The height of the mobile flood barriers was estimated for cost estimation purposes based the average existing grade shown on record drawings.

Table 5: Mobile Flood Barriers Preliminary Cost Estimate for Year 2030 (2018 dollars)

Top Elevation (feet NAVD)	Average Height of Barrier (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2030)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
14.0	5.0	**$ 2,100,000**	2	$2,600,000 - $10,000,000	4.8
20.0	11.0	**$ 4,200,000**	4	$5,300,000 - $21,000,000	5.0

[1]Benefit/cost ratio is based on complete equipment replacement costs

[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies aroung the existing buildings and an average elevation of 9 NAVD 88 was chosen for this analysis.

5.3 Alternative 3: Construct an Elevated Building for Electrical Equipment

An alternative to protect critical electrical equipment, such as, MCCs, VFDs, main switchboard, standby generator, etc., is to construct an elevated building. The building would be elevated so that the finished floor elevation in the building is above the projected storm surge elevation for the target storm and year. The existing equipment would be relocated or replaced into the new building. Below the building could be additional parking or storage. The estimated cost to construct a 5,000 square feet (SF) elevated building supported on pile foundation is approximately $3.8 million. Replacement equipment for the main electrical gear described above is approximately $1.8 million. A 5,000 SF building is more than what would be needed for the electrical gear alone. It is estimated that the additional space could accommodate the facility's lab, control room, offices, and restrooms in the current operations building. The costs for these items are included in the $5.6 million estimate. The RAS pump station would still require protection for this alternative. The 11-foot high mobile flood barriers on either side of the pump station are recommended for this alternative and are estimated to cost approximately $600,000. Mechanical equipment and small electrical equipment, such as motors and local control panels, would still be unprotected in the solids handing building with this alternative. The 11-high mobile flood barrier around the solids handling building is estimated to cost approximately $900,000. The total estimated cost for this alternative is $7.1 million. This is less than the worst case estimated damages for the level of protection estimated to be $21 million with a benefit/cost ratio of approximately 3.0. Figure 9 shows a possible location for the new elevated building and mobile flood barrier locations.

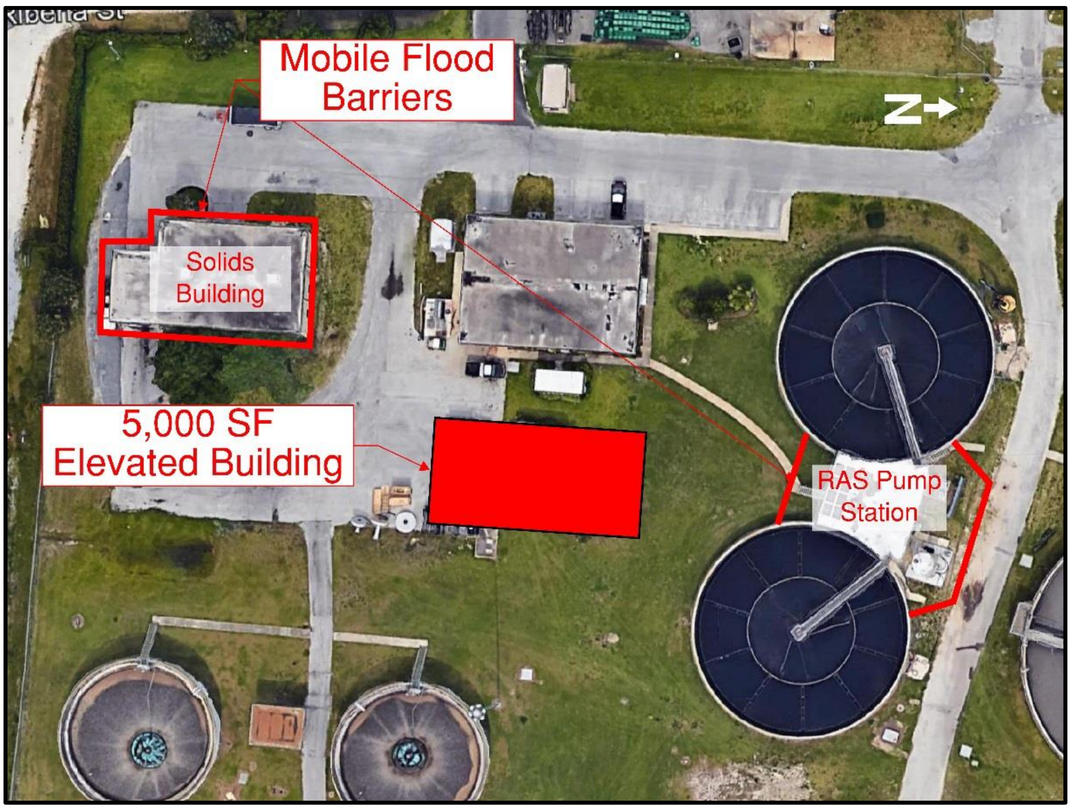

Figure 9: Possible Location and Footprint for an Elevated Building to Relocate Electrical Equipment

5.4 Alternative 4: Perimeter Flood Wall and Pump Station

Another alternative to harden the entire facility is to construct a permanent flood wall around the perimeter of the site. This would include access gates and a storm water pump station for the WWTF site. The type of flood wall is limited on the east and north side of the property due to the proximity to the water.

The perimeter flood wall alternative would require a storm water pump station for rain that falls within the wall and potential leakage through the walls. Site grading and drainage improvements to route all surface runoff to the pump station would also be recommended. A possible location for the pump station is in the northeast corner of the site near a storm water pond and the Matanzas River.

Options for a flood wall could include earthen berm, concrete or brick wall, sheet pile wall, or a combination of a shorter permanent wall with a mobile flood barrier installation on top. Earthen berms were ruled out due to the lack of available space around the perimeter of the site compared to the footprint required. A 15-foot high earthen berm would require 100 to 150-feet width at the base. In order from least expensive to most expensive, the following options were considered for this alternative: sheet piles, concrete wall, combination concrete wall and mobile flood barriers. Table 6 shows estimated costs for these options, and Figure 10 shows potential locations. The height of the flood walls were estimated for cost estimation purposes based the average existing grade shown around the site perimeter on record drawings. More top elevations were chosen for this alternative since it would be a complete WWRF protection system. Other alternatives only protect certain structures within the WWRF with top elevations based on existing structures in the site.

Table 6: Perimeter Wall and Pump Station Estimated Costs at Multiple Heights for Year 2030 (2018 dollars)

Type of Wall	Top Elevation (feet NAVD)	Average Height of Wall (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2030)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
Concrete	12	5	**$ 3,300,000**	2	$2,600,000 - $7,000,000	2.1
	18	11	**$ 6,000,000**	3	$4,200,000 - $16,000,000	2.7
	20	13	**$ 7,000,000**	4	$5,300,000 - $21,000,000	3.0
Sheet Pile	18	11	**$ 3,700,000**	3	$4,200,000 - $16,000,000	4.3
	20	13	**$ 4,200,000**	4	$5,300,000 - $21,000,000	5.0
	22	15	**$ 4,600,000**	4	$5,300,000 - $21,000,000	4.6
	25	18	**$ 5,300,000**	5	$5,300,000 - $21,000,000	4.0
Combo Conc. & Mobile	18	11 (5' conc.)	**$ 7,700,000**	3	$4,200,000 - $16,000,000	2.1
	20	12 (7' conc.)	**$ 8,700,000**	4	$5,300,000 - $21,000,000	2.4
	22	15 (9' conc.)	**$ 9,600,000**	4	$5,300,000 - $21,000,000	2.2

[1]Benefit/cost ratio is based on complete equipment replacement costs

[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies along the permiter of the site and an average elevation of 7 NAVD 88 was chosen for this analysis.

Figure 10: Perimeter Flood Wall and Pump Station

5.5 Alternative 5: Relocate the WWTF

The estimated cost to build a new 5 MGD biological nutrient removal facility (BNR) to replace in-kind the existing WWTF is $45 million in 2018 dollars. For this alternative a lift station designed to withstand storm surge would be required at the existing WWTF site to pump to the new WWTF. A new forcemain would also need to be constructed to the new facility from the old facility. The estimated cost for the new lift station and forcemain is $18 million for a total of $63 million to relocate the facility in 2018 dollars.

Note that the following costs were not included in the estimated cost:

- Land
- Easements
- Demolition and/or restoration of existing WWTF site
- Legal

Estimated costs were developed with the following methodology and assumptions:

- New treatment facility cost was estimated based on construction costs for other BNR facilities in Florida built in the last 20 years. Other BNR facility costs were compiled from EPA data, Water Environment Federation data and past projects. Costs were adjusted to 2018 dollars based on the Engineering News Record Construction Cost Indices. Other BNR facility costs (in 2018 dollars) were plotted based on rated capacity and cost to develop a curve. The cost for 5 MGD was estimated from the cost curve.

- Pump station and forcemain costs were estimated based on past project experience and unit prices.

6.0 Recommendation

Protecting the WWTF from storm surge needs to be a high priority for the City due to the immediate risks which render the WWTF vulnerable. The estimated cost for a perimeter wall is under 10 million dollars, less expensive than relocating the WWTF. This measure renders the highest benefit/cost ratio of the measures considered and could protect the WWTF with a perimeter wall if hit by a “worst case” category 5 storm surge out to year 2030. This cost comparison between relocating the facility and building a perimeter wall does not consider the land value of the existing WWTF site, socioeconomic factors and future wastewater treatment regulatory changes. For instance, facilities in Florida have been ordered to eliminate or greatly reduce the use of ocean outfalls for effluent disposal.

It is recommended that this assessment be used as part of the guidance in the City’s overall road to resilience for the WWTF. It is further recommended that the City use this information as part of a comprehensive EPA CREAT analysis, leading to a plan and implementation of hardening measures to the WWTF. Based on this planning level assessment, a preliminary engineering report to investigate the design of a perimeter wall with a pumping station to harden the facility would be a reasonable, high benefit to cost measure, as the first step in the WWTF’s overall road to resilience.

Because of the variability of projected sea level rise for coastal Florida, it is recommended that actual SLR be compared to projected SLR on an annual basis, out to 2030. The actual rate of SLR could vary significantly from that which is projected moving forward due to a various factors. Adjustments to planned improvements to the WWTF can be considered if the actual rate of increase varies significantly from that which was assessed based on current available projections and the City’s plan to insure a resilient WWTF adjusted as applicable.

APPENDIX

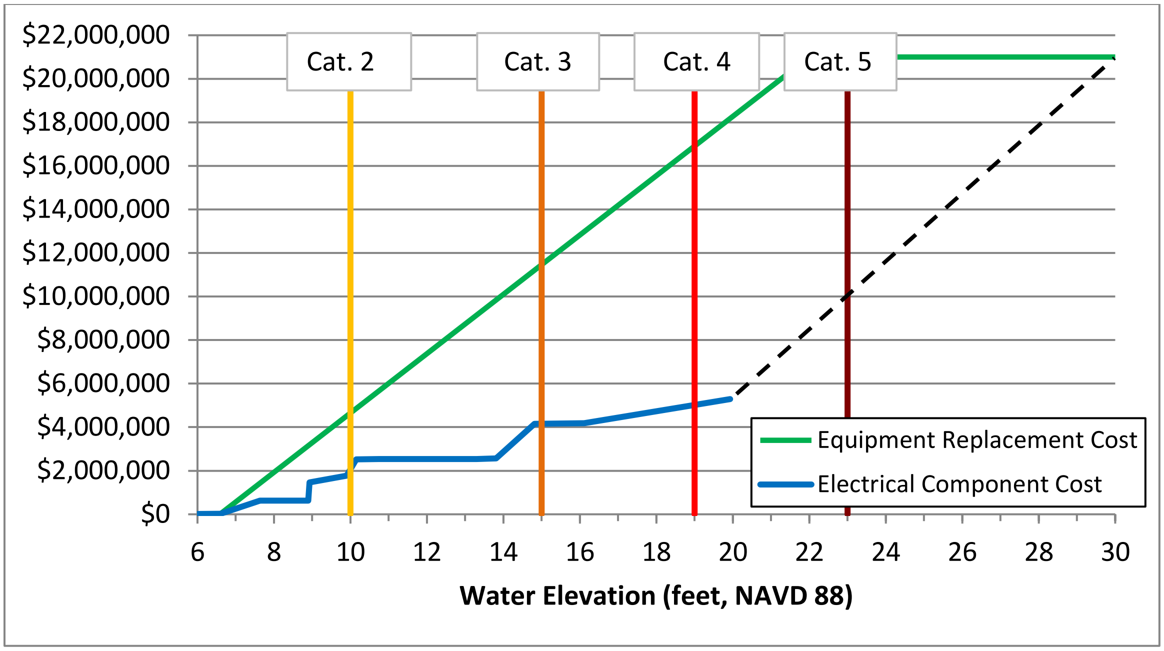

Figure 11: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2018 (2018 dollars)

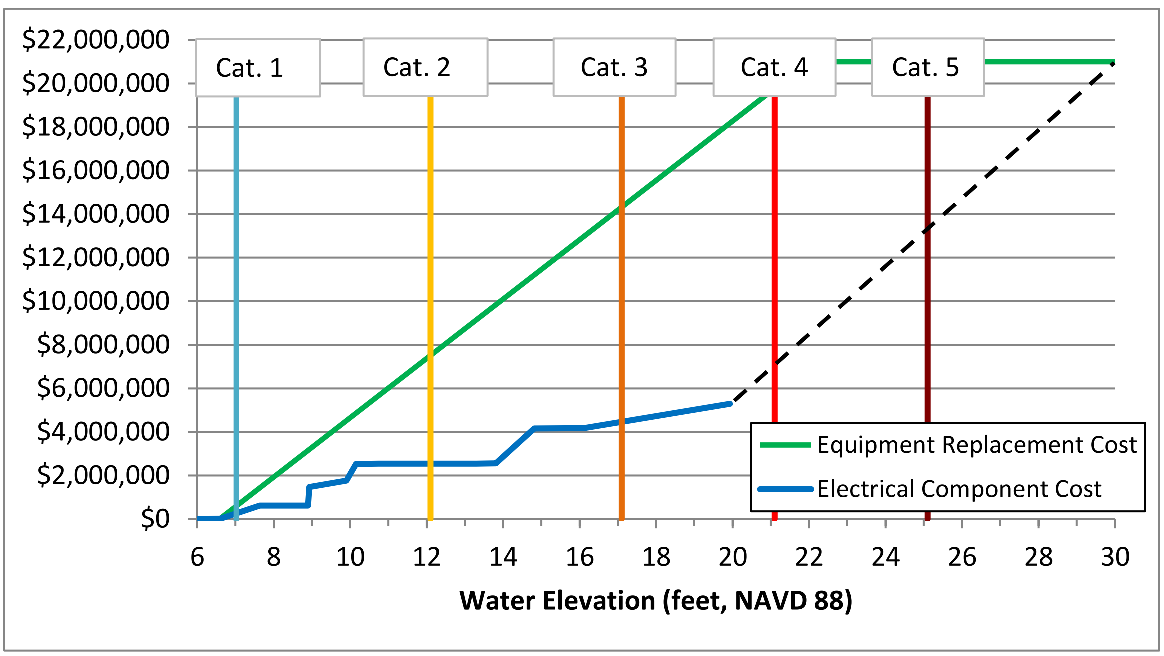

Figure 12: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2050 (2018 dollars)

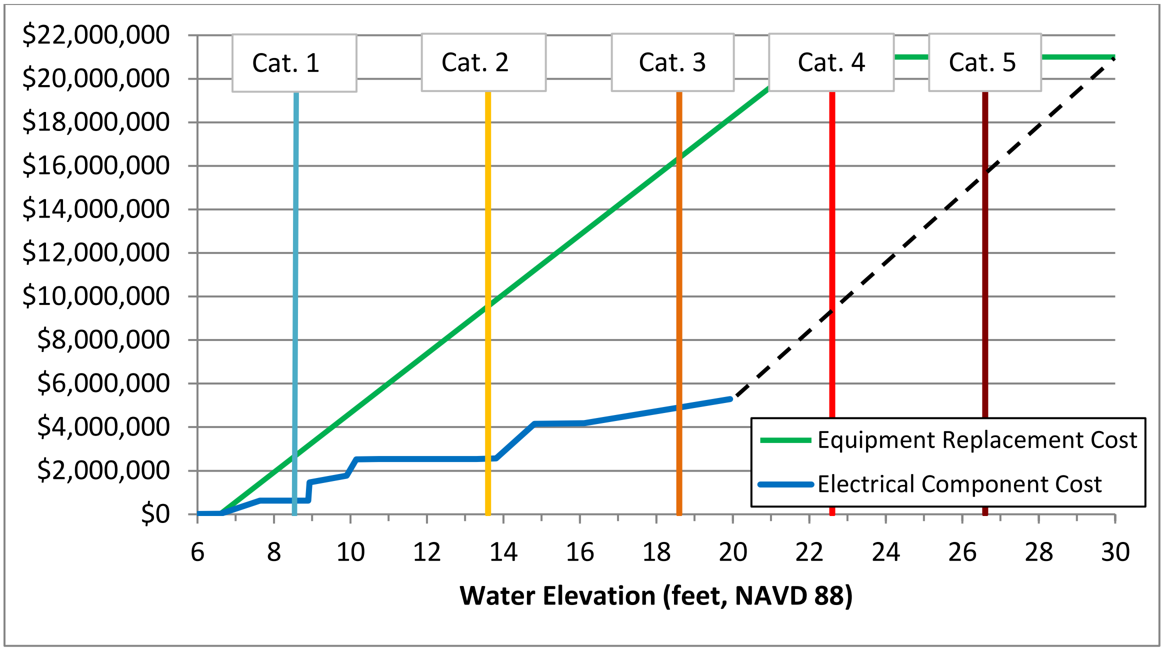

Figure 13: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2070 (2018 dollars)

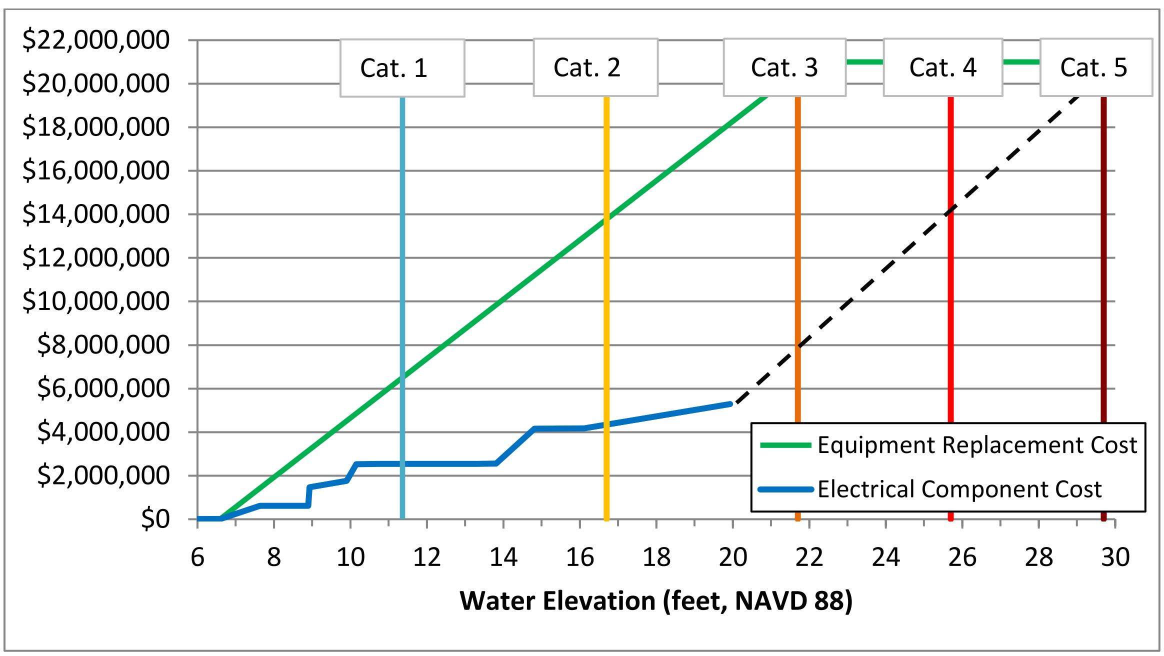

Figure 14: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2100 (2018 dollars)

Table 7: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2018 (2018 dollars)

Category of Hurricane	Projected Surge Elevation (feet, NAVD)	Estimated Damage Costs	
		Elec. Components	Equipment Replacement
1	5.0	$0	$0
2	10.0	$1,770,000	$5,000,000
3	15.0	$4,160,000	$11,000,000
4	19.0	$4,180,000	$17,000,000
5	23.0	$5,290,000	$21,000,000

Table 8: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2050 (2018 dollars)

Category of Hurricane	Projected Surge Elevation (feet, NAVD)	Estimated Damage Costs	
		Elec. Components	Equipment Replacement
1	7.1	$20,000	$0
2	12.1	$2,540,000	$8,000,000
3	17.1	$4,180,000	$14,000,000
4	21.1	$5,290,000	$20,000,000
5	25.1	$5,290,000	$21,000,000

Table 9: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2070 (2018 dollars)

Category of Hurricane	Projected Surge Elevation (feet, NAVD)	Estimated Damage Costs	
		Elec. Components	Equipment Replacement
1	8.6	$620,000	$0
2	13.6	$2,540,000	$10,000,000
3	18.6	$4,180,000	$16,000,000
4	22.6	$5,290,000	$21,000,000
5	26.6	$5,290,000	$21,000,000

Table 10: WWTF Estimated Damage Costs vs. Storm Surge Elevation for Year 2100 (2018 dollars)

Category of Hurricane	Projected Surge Elevation (feet, NAVD)	Estimated Damage Costs	
		Elec. Components	Equipment Replacement
1	11.7	$2,540,000	$0
2	16.7	$4,180,000	$14,000,000
3	21.7	$5,290,000	$21,000,000
4	25.7	$5,290,000	$21,000,000
5	29.7	$5,290,000	$21,000,000

Table 11: Mobile Flood Barriers Preliminary Cost Estimate for Year 2018 (2018 dollars)

Top Elevation (feet NAVD)	Average Height of Barrier (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2018)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
14.0	5.0	**$ 2,100,000**	2	$2,600,000 - $10,000,000	4.8
20.0	11.0	**$ 4,200,000**	4	$5,300,000 - $21,000,000	5.0

[1]Benefit/cost ratio is based on complete equipment replacement costs
[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies aroung the existing buildings and an average elevation of 9 NAVD 88 was chosen for this analysis.

Table 12: Mobile Flood Barriers Preliminary Cost Estimate for Year 2050 (2018 dollars)

Top Elevation (feet NAVD)	Average Height of Barrier (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2050)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
14.0	5.0	**$ 2,100,000**	2	$2,600,000 - $10,000,000	4.8
20.0	11.0	**$ 4,200,000**	3	$5,300,000 - $21,000,000	5.0

[1]Benefit/cost ratio is based on complete equipment replacement costs
[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies aroung the existing buildings and an average elevation of 9 NAVD 88 was chosen for this analysis.

Table 13: Mobile Flood Barriers Preliminary Cost Estimate for Year 2070 (2018 dollars)

Top Elevation (feet NAVD)	Average Height of Barrier (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2070)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
14.0	5.0	**$ 2,100,000**	1	$2,600,000 - $10,000,000	4.8
20.0	11.0	**$ 4,200,000**	3	$5,300,000 - $21,000,000	5.0

[1]Benefit/cost ratio is based on complete equipment replacement costs
[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies aroung the existing buildings and an average elevation of 9 NAVD 88 was chosen for this analysis.

Table 14: Mobile Flood Barriers Preliminary Cost Estimate for Year 2100 (2018 dollars)

Top Elevation (feet NAVD)	Average Height of Barrier (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2100)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
14.0	5.0	**$ 2,100,000**	1	$2,600,000 - $10,000,000	4.8
20.0	11.0	**$ 4,200,000**	2	$5,300,000 - $21,000,000	5.0

[1]Benefit/cost ratio is based on complete equipment replacement costs

[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies aroung the existing buildings and an average elevation of 9 NAVD 88 was chosen for this analysis.

Table 15: Perimeter Wall and Pump Station Estimated Costs at Multiple Heights for Year 2018 (2018 dollars)

Type of Wall	Top Elevation (feet NAVD)	Average Height of Wall (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2018)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
Concrete	12	5	**$ 3,300,000**	2	$2,600,000 - $7,000,000	2.1
	18	11	**$ 6,000,000**	3	$4,200,000 - $16,000,000	2.7
	20	13	**$ 7,000,000**	4	$5,300,000 - $21,000,000	3.0
Sheet Pile	18	11	**$ 3,700,000**	3	$4,200,000 - $16,000,000	4.3
	20	13	**$ 4,200,000**	4	$5,300,000 - $21,000,000	5.0
	22	15	**$ 4,600,000**	4	$5,300,000 - $21,000,000	4.6
	25	18	**$ 5,300,000**	5	$5,300,000 - $21,000,000	4.0
Combo Conc. & Mobile	18	11 (5' conc.)	**$ 7,700,000**	3	$4,200,000 - $16,000,000	2.1
	20	12 (7' conc.)	**$ 8,700,000**	4	$5,300,000 - $21,000,000	2.4
	22	15 (9' conc.)	**$ 9,600,000**	4	$5,300,000 - $21,000,000	2.2

[1]Benefit/cost ratio is based on complete equipment replacement costs

[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies along the permiter of the site and an average elevation of 7 NAVD 88 was chosen for this analysis.

Table 16: Perimeter Wall and Pump Station Estimated Costs at Multiple Heights for Year 2050 (2018 dollars)

Type of Wall	Top Elevation (feet NAVD)	Average Height of Wall (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2050)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
Concrete	12	5	**$ 3,300,000**	1	$2,600,000 - $7,000,000	2.1
	18	11	**$ 6,000,000**	3	$4,200,000 - $16,000,000	2.7
	20	13	**$ 7,000,000**	3	$5,300,000 - $21,000,000	3.0
Sheet Pile	18	11	**$ 3,700,000**	3	$4,200,000 - $16,000,000	4.3
	20	13	**$ 4,200,000**	3	$5,300,000 - $21,000,000	5.0
	22	15	**$ 4,600,000**	4	$5,300,000 - $21,000,000	4.6
	25	18	**$ 5,300,000**	4	$5,300,000 - $21,000,000	4.0
Combo Conc. & Mobile	18	11 (5' conc.)	**$ 7,700,000**	3	$4,200,000 - $16,000,000	2.1
	20	12 (7' conc.)	**$ 8,700,000**	3	$5,300,000 - $21,000,000	2.4
	22	15 (9' conc.)	**$ 9,600,000**	4	$5,300,000 - $21,000,000	2.2

[1]Benefit/cost ratio is based on complete equipment replacement costs

[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies along the permiter of the site and an average elevation of 7 NAVD 88 was chosen for this analysis.

Table 17: Perimeter Wall and Pump Station Estimated Costs at Multiple Heights for Year 2070 (2018 dollars)

Type of Wall	Top Elevation (feet NAVD)	Average Height of Wall (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2070)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
Concrete	12	5	**$ 3,300,000**	1	$2,600,000 - $7,000,000	2.1
	18	11	**$ 6,000,000**	2	$4,200,000 - $16,000,000	2.7
	20	13	**$ 7,000,000**	3	$5,300,000 - $21,000,000	3.0
Sheet Pile	18	11	**$ 3,700,000**	2	$4,200,000 - $16,000,000	4.3
	20	13	**$ 4,200,000**	3	$5,300,000 - $21,000,000	5.0
	22	15	**$ 4,600,000**	3	$5,300,000 - $21,000,000	4.6
	25	18	**$ 5,300,000**	4	$5,300,000 - $21,000,000	4.0
Combo Conc. & Mobile	18	11 (5' conc.)	**$ 7,700,000**	2	$4,200,000 - $16,000,000	2.1
	20	12 (7' conc.)	**$ 8,700,000**	3	$5,300,000 - $21,000,000	2.4
	22	15 (9' conc.)	**$ 9,600,000**	3	$5,300,000 - $21,000,000	2.2

[1]Benefit/cost ratio is based on complete equipment replacement costs

[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies along the permiter of the site and an average elevation of 7 NAVD 88 was chosen for this analysis.

Table 18: Perimeter Wall and Pump Station Estimated Costs at Multiple Heights for Year 2100 (2018 dollars)

Type of Wall	Top Elevation (feet NAVD)	Average Height of Wall (feet)[2]	Protection Cost	Category of Hurricane Protection Level (2100)	Preventable Damage Cost Range	Benefit/Cost Ratio[1]
Concrete	12	5	**$ 3,300,000**	1	$2,600,000 - $7,000,000	2.1
	18	11	**$ 6,000,000**	2	$4,200,000 - $16,000,000	2.7
	20	13	**$ 7,000,000**	2	$5,300,000 - $21,000,000	3.0
Sheet Pile	18	11	**$ 3,700,000**	2	$4,200,000 - $16,000,000	4.3
	20	13	**$ 4,200,000**	2	$5,300,000 - $21,000,000	5.0
	22	15	**$ 4,600,000**	3	$5,300,000 - $21,000,000	4.6
	25	18	**$ 5,300,000**	3	$5,300,000 - $21,000,000	4.0
Combo Conc. & Mobile	18	11 (5' conc.)	**$ 7,700,000**	2	$4,200,000 - $16,000,000	2.1
	20	12 (7' conc.)	**$ 8,700,000**	2	$5,300,000 - $21,000,000	2.4
	22	15 (9' conc.)	**$ 9,600,000**	3	$5,300,000 - $21,000,000	2.2

[1]Benefit/cost ratio is based on complete equipment replacement costs

[2]The average height of walls was estimated for cost estiamtion puprosed based on the existing grade shown on record drawings. The existing grade varies along the permiter of the site and an average elevation of 7 NAVD 88 was chosen for this analysis.