Abstract- A senior capstone team at the US Coast Guard Academy has been tasked with evaluating the storm water system at Coast Guard Base Alameda and making repair and replacement recommendations for the existing storm water system. The stormwater system design on Coast Guard Base Alameda was implemented in the 1930’s. Based on the age of the system and the prolonged rain season since the 1930s, the current system is in need of major renovations. Flooding after moderate rain events at Base Alameda has resulted in loss of parking and limited accessibility to various parts of the base; hindering the Coast Guard’s ability to effectively conduct the mission. Coast Guard Base Alameda has provided a budget of $400,000 for upgrading the existing storm water system. The $400,000 budget was suggested by Base Alameda, however, the capstone team is looking at possible design solutions beyond the budget constraints to give the base more options for redesigning the system. The team focus is on the areas most affecting mission success and subject to the most severe flooding.

I. BACKGROUND

Coast Guard Base Alameda is a man-made island developed in 1913 as the result of a dredging project that extended the Oakland Estuary to San Leandro Bay in California. The current stormwater system on Coast Guard Base Alameda was originally designed and established in the 1930’s. Currently, Base Alameda experiences significant flooding after even minimal precipitation. After conducting a site visit of Base Alameda and evaluation of a condition report, the main areas of concern were identified as Bear Road, Campbell Boulevard, Spencer Road, and the parking in between the Galley and the Clinic. The main areas of concern were chosen because they experience the most severe flooding which eliminates many parking spaces during rain events and decreases mission readiness. The preliminary budget allocated for mitigation is $400,000, however, the stakeholders have asked for optional design solutions that may exceed this amount. A system analysis conducted by Tetra-Tech in 2015 revealed issues with the current storm water system such as root intrusion, deteriorated pipes, and improper invert elevations. This information coupled with a site visit by the capstone team and use of the Environmental Protection Agency’s (EPA) Storm Water Management Model (SWMM); the team was able to recommend upgrades to the stormwater system that would effectively handle stormwater using current climate change predictions.

II. OBJECTIVES

The following list outlines the project objectives:
1. Analyze the existing stormwater system on Base Alameda.
2. Recommend upgrades to the current storm water system while prioritizing the areas that most impact the base missions.
3. Develop a sound plan for maintenance of the stormwater system.

The following describes specific project tasks:
1. Analyze Tetra-Tech Assessment report
2. Create a SWMM Model of the system
3. Create and input storms into SWMM (Storm Water Management Model)
4. Research climate inflation factors
5. Create a GIS Model
6. Simulate the current situation
7. Propose solutions
8. Provide a cost estimation
9. Establish a maintenance schedule

III. SITE DESCRIPTION

The capstone team visited Coast Guard Base Alameda from November 12th to November 15th, 2017. The purpose of the site visit was to interview the stakeholders, gather information about the site, document the affected areas, and develop a project scope. During the tour of the island, the following observations were documented that were generally consistent with the Tetra-Tech findings:

1. One of the outfalls along Spencer Road is underwater when a moderate rain event coincides with high tide. Thus, during any rain event at high tide, the precipitation would not be able to drain off of the island.
2. There was significant accumulation of debris in many of the catch basins and pipes.
3. A significant portion of the pipe material throughout the system appeared to be deteriorated.
4. Root intrusion was evident in several areas of asphalt concrete surrounding the stormwater system and in the stormwater pipes.

The photos, included as Figures 1 and 2, were taken on November 16th, 2017, after an average rain storm and illustrate the severe flooding in the parking lot between the Galley and the Clinic. The parking lot between the clinic and the galley is highlighted in Figure 3.

Figure 1: Flooded catch basin between the Galley and the Clinic

Figure 2: Flooded parking lot outside of the Galley

Figure 3. Parking Lot between the Galley and Parking Lot

A major constraint of Base Alameda is the size and allocation of assets. The Base is fairly small and parking space is significantly limited. Any major construction project, such as replacing...
stormwater pipes, would have a significant impact on the personnel working on Base because the already limited parking spaces would be further decreased and main roads may have to be closed for extended periods of time. These negative effects will greatly impact mission readiness.

IV. METHODS

A. SWMM Modeling

The Environmental Protection Agency created a Storm Water Management Model (SWMM) to assess and simulate the effects of rain events on stormwater management. The Tetra-Tech report values were inputs used in the SWMM model. The Tetra-Tech report failed to include several values for invert elevations and depths; therefore assumptions were made to best represent the system in the model. Assumptions included invert elevations for pipes and catch basins, slope of the terrain, and the amount of impervious terrain in a subcatchment. The SWMM model was able to pinpoint where there would be flooding and values needed to be changed in order to accommodate water flow. In order to best represent broken pipes they were deleted from the model. When the critical areas were identified, solutions were input into SWMM, which verified that the proposed solutions were viable. The only shortcoming of the SWMM software is it cannot accurately predict if there will be standing water because the program assumes that all water that falls onto the terrain will drain into the system.

B. Storm Modeling

Possible solutions to the flooding includes inflations based on climate change combined with the information with the current climate researched by the National Oceanic and Atmospheric Association. The decision was made based on the most time and cost efficient way to implement a design that will eliminate mission disruptions. SWMM allows the user to input different rain events into the model to show how the system would react with different amounts of rain. Based on pictures provided by the base from November 16th, 2017, rain data was collected from NOAA where hourly rainfall measurements were taken over a 24 hour period. The actual data was plugged into SWMM to simulate the storm from that day. SWMM was able to analyze the current stormwater system’s ability to effectively drain the stormwater. Other storms that were simulated included an actual storm from February 20th, 2017, and a 5-year, 10-year, 25-year, 50-year, and 100-year storm based on NOAA’s precipitation frequency estimates and the Rainfall Frequency Atlas [3]. The storm on November 20th, 2017, was the last major storm that Alameda had and it was more significant than the storm on November 16th. The other storms were based on a duration of 24-hours. The total amount of rain was divided into inches per hour to find a common amount to increase the rainfall throughout the day by. The storms that were analyzed followed a parabolic hydrograph by generating greater rainfall in the middle of the day and lower rainfall accumulations at the beginning and end of the day.

Each storm was created based on projected climate change values. For example one adopted assumption is for every one degree of temperature rise, there will be approximately a two percent increase in the volume of precipitation [1].

C. GIS Modeling

The Geographic Information System (GIS) modeling program, ArcMap, was used to analyze rain water flow direction and flow accumulation. GIS integrates information using spatial location data and other informational maps. For the purpose of mapping Base Alameda, digital elevation maps (DEM’s) were downloaded from the internet and input into ArcMap as an overlay or “raster chart”. The following image (Figure 4) shows the flow directions of water on Base Alameda using a variety of different colors.
The different colors illustrated in Figure 4 each represent a different direction. Figure 5 is the key to reading the flow direction map. For example, the green shading on Coast Guard Island signifies a flow direction in the Southeast direction. In general, the GIS flow direction output shows that stormwater should be theoretically running off the island.

The flow accumulation tool is meant to map where water would accumulate due to the slopes and elevations on the island. Unfortunately the data pulled from the internet was not a high enough resolution to provide an accurate analysis of where water would pool and accumulate. The flow accumulation tool would ideally reflect the pooling that Base Alameda actually experiences.

V. Preliminary Design Alternatives

A. Replacing Broken Pipes

The system of pipes in the flooding parking lot showed signs of advanced deterioration and root intrusion. However, when the values of the pipes were entered into the SWMM model the results showed if the pipes were not broken the system would be functioning. Since the model showed that the current values of the system should be providing proper drainage for a 100 year storm, it was assumed that the reason the area was flooding was because of the pipes’ structural damage. In theory if pipes that were labeled as broken or misaligned were then replaced with PVC pipes in one of the solution in order to test if PVC pipes would affect drainage. No other properties of the pipes were changed except the material. The SWMM model proved successful during a 100 year storm if the current pipes were replaced with PVC pipes and no other specifications were changed.

B. Additional Catch Basins

Additional catch basins were added to relieve standing water on Campbell Boulevard, Bear Road, and Spencer Road. The spacing or lack of catch basins were glaringly apparent during the site visit and during rain events. The SWMM model does not show standing water so the catch basins were placed where standing water was reported to fall by the stakeholders on Base Alameda. The increased amount of catch basins did not adversely affect the flow in the pipes.

C. Porous Concrete

The specifications for porous concrete were taken from the California Department of Transportation website. Specifically, the Pervious Pavement Design Guide, Project Planning Design
Guide (PPDG), and Highway Design Manual were referenced for design. One of the proposed solutions for Spencer Road was replacing the conventional stormwater system and the asphalt concrete with porous pavement. Porous Pavement is a low impact development (LID) and best management practice (BMP). Porous Pavement allows stormwater to filter through the pavement by removing the fines from the mixture. The design consists of a permeable surface layer with a rock reservoir underneath to collect, filter, and distribute stormwater. An impermeable geotextile is often used to line the bottom of the reservoir when it is undesirable. An under drainage system is usually included in the reservoir layer when the sub-grade soil does not have a high infiltration rate [4]. The California Department of Transportation recommends there be a 10 foot space between the bottom of the reservoir layer and the ground table, therefore a water table analysis must be conducted before further exploring porous concrete. For special considerations, the California Stormwater Management Office should also be contacted. The design includes a porous layer followed by a reservoir layer filled with Class AB rocks [4]. An under drainage system at the bottom of the reservoir layer will funnel storm water to a infiltration trench downgrade. The infiltration trench will funnel storm water to the existing stormwater system. Specific dimensions and drawings are still in progress.

D. Swale on Campbell Boulevard

Another proposed solution is replacing the medians on Campbell Boulevard with swales in order to promote proper drainage. Swales are vegetated channels that receive directed flow and convey stormwater. Based on a utilities map provided by Base Alameda, there is a telephone line and a gas line running underneath the middle of Campbell Boulevard, which does raise major concern with replacing the medians with swales. Base Alameda was uncertain of the depths of these lines, therefore the depth of these lines must be determined before swales are further considered. Campbell Blvd. has approximately a 10% slope from the middle of the road, where the median is, to the sides of the road. Water currently drains to the sides of the road where there is a lack of catch basins especially on the southern side. By creating a swale in the center of the road, it will allow for water to drain into a grassy area instead of pooling on the road. Since the road has a large slope already, the road will have to be repaved, flattened and partially sloped inward for the swale to work properly. The PPDG provides requirements and design factors that are based on maximizing the use of vegetation and ability to divert runoff into specific areas. The requirements include: having a minimum vegetative cover of 70% to allow for treatment, confirmation that the proposed location is one where flow velocities will not cause scour, and satisfying more specific design criteria [3]. The design criteria under the Water Quality Flow (WQF) state that swales must have a hydraulic residence time of 5 minutes or more, maximum velocity of 1 ft/s, and maximum depth of flow of 0.5 ft. The slope of the areas around the swale must be in the direction of flow at a minimum of 0.25% and a maximum of 6%. The preferred slope is 1% to 2%. For the swale itself, a minimum width at the invert of the trapezoid is 2 feet and the maximum is 10 feet with a side slope ratio of 4:1 or flatter is required [3]. Based on the requirements above, the swales proposed will be trapezoidal channels split into three sections in place of the current medians. The swales will have a depth of 2 feet with an invert width of 2 feet at the bottom of the swale. The side slope of the swale will be 3:1.

CONCLUSION

The preliminary designs will all be evaluated against each other in a decision matrix. The considered factors will be cost, construction time, effect on mission readiness, environmental stewardship, design life, and maintenance. Recommendations will then be given to Base
Alameda based on the results of the decision matrix.

REFERENCES


