RESIDUALS HANDLING FACILITY, WARDS ISLAND WASTEWATER TREATMENT PLANT, MANHATTAN, NY

CHAPTER 1:
CITYWIDE FRAMEWORK

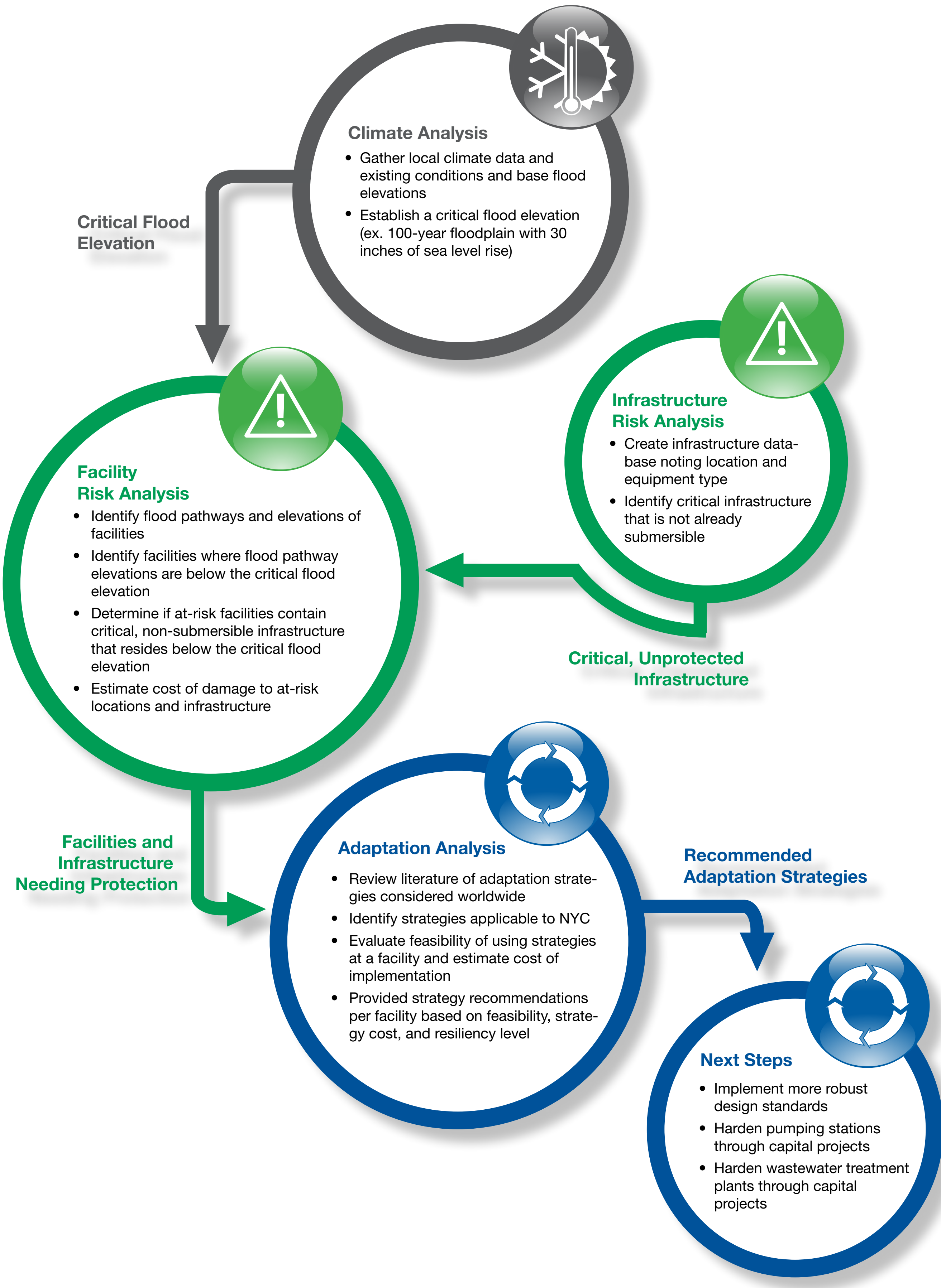
Citywide Framework

The Climate Risk Assessment and Adaptation Study was developed as a planning level framework to assess the flood risk posed to wastewater infrastructure and to provide adaptation recommendations based on site feasibility and cost-benefit evaluation. This approach evaluates the cost of adaptation strategies against the value of risk avoided after strategy implementation.

The study yielded insight into the risk of DEP's wastewater infrastructure to flood damage, documented lessons learned from Hurricane Sandy, and provides a valuable framework that may be used as a prototype to protect a wide range of vital city infrastructure in New York and around the world.

The Citywide Resiliency Framework is summarized as a flowchart in Figure 1, and comprises three main analyses: 1) Climate Analysis, 2) Risk Analysis, and 3) Adaptation Analysis. These analyses build upon each other and are described in further detail in subsequent sections.

Figure 1: Climate Risk Assessment and Adaptation Framework



Climate Analysis

While climate science cannot predict when a storm surge will occur, current climate studies project that future storm surge events are likely to be exacerbated by sea level rise. The climate analysis in this study established the future storm surge conditions for which DEP should plan and prepare.

The March 2013 FEMA 100-year advisory base flood elevation (ABFE) plus an additional 30 inches for sea level rise was selected as the "critical flood elevation" against which DEP infrastructure would be assessed. This flood elevation was obtained for each wastewater facility location from online FEMA ABFE maps which provide flood levels accounting for specific local conditions, such as topography.

The 2013 ABFE maps were developed by FEMA to guide rebuilding efforts after Hurricane Sandy and were the most current flood elevations available at the time of the analysis. The ABFEs were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. The critical flood elevations in the updated maps are in most cases very similar to the ABFE maps, and are more conservative than the PWM elevations, and therefore more protective. Using the updated maps would not significantly affect the results of this analysis.

The additional 30 inches added to the ABFEs approximates future sea level rise in the 2050s, as projected by the New York City Panel on Climate Change. As shown in Table 1, 30 inches represents a high estimate of sea level rise[2]. The year 2050 was chosen to evaluate future conditions in the study in order to be consistent with DEP capital planning programs. Using a higher estimate for the analysis provides for more conservative design standards that will better protect wastewater infrastructure from future storm surge conditions.

Table 1: NPCC 2013 Climate Projections

Chronic Hazards	Baseline (1971-2000)	2020s		2050s	
		Middle Range (25th - 75th percentile)	High End (90th percentile)	Middle Range (25th - 75th percentile)	High End (90th percentile)
Average Temperature	54 ºF	+2.0 to 2.8 ºF	+3.2 ºF	+4.1 to 5.7 ºF	6.6 ºF
Precipitation	50.1 in.	+1 to 8%	+10%	+4 to 11%	+13
Sea Level Rise[1]	0	+4 to 8 in.	+11 in.	+11 to 24 in.	+31 in.

Source: NPCC; for more details, see *Climate Risk Information 2013.*

[1]Baseline period for sea level rise projections is 2000-2004.

[2]The New York City Panel on Climate Change issued its final report in 2013, with slight changes to the high end estimate for sea level rise. The change of 1 inch to the projections would not alter the recommendations of this study.

Risk Analysis

The Risk Analysis sought to determine which facilities and infrastructure would be at risk from the critical flood elevation (100-year ABFE plus 30 inches of sea level rise), and how much damage DEP could expect to incur.

A detailed analysis of potential flood-related risks at each facility was conducted by walking through the facilities, documenting flood pathways for different buildings and plant areas, and interviewing operational staff to determine which infrastructure had been frequently subject to flooding during the facilities' active history. Of particular value was evaluating what flooded during Hurricane Sandy, which helped paint a picture of how floodwater moves throughout the facilities and the operational challenges that flooding creates. The most common flood pathways identified on site included doorways, outfall pipes, bulkheads, windows, vents, conduits, and tunnel systems. The site visit was accompanied by an analysis of facility blueprints to determine the height of a surge that would inundate the various flood pathways identified once a threshold elevation was overtopped (the sill of a door for example, or, in the case of pumping stations, the ground elevation). If the threshold elevation fell below the critical flood elevation, the location was determined to be at risk of flood damage.

An extensive assessment was performed on critical infrastructure within at-risk locations to determine the value of damage DEP could expect to incur in a large surge event. Pumps, motors, electrical equipment and controls, and other equipment necessary to meet basic (primary) treatment levels were of particular interest due to the receiving waterbody impacts.

DEP has an infrastructure database that catalogs the thousands of pieces of wastewater equipment at each treatment plant and pumping station. This database was reviewed and supplemented with information from inspections and drawing review pertaining to location, equipment resiliency, and equipment elevation with respect to the critical flood elevation. Replacement and repair costs were also developed for at-risk infrastructure. Total damage cost estimates for each plant location and pumping station considered the cost of replacement for infrastructure, and the cost to clean up the site and provide temporary power and pumping services, if necessary.

ASSESSING WASTEWATER INFRASTRUCTURE USING TRIPLE BOTTOM LINE ANALYSIS

Flood damage not only comes in the form of needing to replace equipment and clean a site, but also includes damages from extended loss of service. New York City's pumping stations convey millions of gallons of sewage from homes, businesses, hospitals, and other important buildings to treatment facilities, ensuring sewage does not back up into basements, which could pose a health risk. Similarly, wastewater treatment plants provide an invaluable service by treating sewage to protect water quality in New York's waterways. Without the treatment plants running, sewage would degrade the environment and contaminate beaches.

Thus, flood damage not only presents an economic burden, but also has significant social and environmental costs. Considered together, all three of these costs provide a more holistic assessment of damage from flood surge and can guide adaptation decision-making more appropriately for a service-driven agency such as DEP. Because it considers financial, social, and environmental consequences, this relatively new method of assessment is called Triple Bottom Line Analysis.

Quantifying the value of social and environmental damages is much more challenging than developing the cost estimates for replacing damaged equipment. For example, how does one determine the cost of damage to water ecosystems from sewage, the loss of wildlife and plant matter, and the loss of recreational uses of these ecosystems? How can we quantify the cost of health impairments in New Yorkers exposed to sewage: the medication, the sick leave from work, and the stress that results?

Answering these questions with monetary value is complex. As such, during the Risk Analysis, the environmental and social costs of flood damage at each wastewater facility were analyzed from a qualitative perspective using various metrics. DEP anticipates using these metrics within the broader set of criteria to inform implementation schedules and prioritization of capital upgrades for wastewater infrastructure.

More specifically, since water quality in New York City's waterways is highly important to the environment and public health, during the study DEP looked at each wastewater treatment plant and determined what level of impact it might have on nearby bathing beaches. Those treatment plants that can heavily affect bathing beaches were deemed higher priority for adaptation measures.

Pumping stations were prioritized based on operational, environmental, social, and financial metrics. These metrics included historical flooding frequency, proximity to beaches and sensitive waterbodies, tributary area population, facility size, number of critical facilities (hospitals, schools, etc.) potentially affected by failure of the wastewater infrastructure, and whether the facility is scheduled for improvements in DEP's 10-year capital plan.

Adaptation Analysis

For the Adaptation Analysis, a number of adaptation strategies were selected through a broad literature review of strategies in use or being considered in municipalities around the world to harden infrastructure. The strategies that were determined to be most applicable to New York City wastewater facilities included sealing a building with watertight windows and doors, elevating equipment, making pumps submersible, encasing electrical equipment in watertight casings, constructing a static barrier across doors and other access ways, temporary sandbagging, and providing backup power generation to pumping stations where feasible (wastewater treatment plants are already equipped with backup power). The purpose of these strategies is to prevent damage during a flood event and to minimize the recovery time needed to reestablish normal operations. It was assumed that any strategy would need to be operated and maintained for 50 years.

Each strategy has advantages and disadvantages associated with cost, logistics of implementation, effectiveness, and failure potential. The failure potential is the probability that the strategy will fail during a flood event, as estimated from manufacturer details, site observations, and engineering judgment. The resiliency level and failure potential are directly related — the higher the resiliency level, the better the strategy for protecting infrastructure during a flood event and the lower the failure potential. Table 2 summarizes the resiliency level, failure potential, and explanation of the residual risk for the adaptation strategies considered in this study.

The failure potential was a key quantitative metric used to select a recommended strategy for each at-risk plant location and pumping station. The strategy recommendations were also based on feasibility, the importance of the infrastructure in a location, and a cost-risk analysis. Feasibility was established during the site visits, when it was easy to see whether certain strategies could be implemented given site specific configurations and conditions.

For locations containing important infrastructure needed for the plant to meet basic (primary) treatment requirements, the feasible strategy with the lowest failure potential was recommended. As a result, flood-proofing and elevating equipment were often recommended for these locations. For instances where all critical infrastructure could not be elevated or flood-proofed due to site or infrastructure constraints, a second strategy was recommended to block flood pathways into the at-risk location. As a result, in many cases the cost of protecting these primary locations was high since multiple strategies were recommended to increase redundancy; however, since the infrastructure being protected serves such a pivotal role in protecting the environment and public health, the non-monetary benefits (social and environmental) outweigh the monetary costs.

Strategy selection for locations which contained pumps, motors, and electrical equipment that are not essential to meeting basic permit requirements were required to be cost-effective. Strategy selection for these locations was therefore based on feasibility and return on investment. To determine

Table 2: Adaptation Strategies

Strategy	Resiliency Level	Failure Potential	Explanation of Residual Risk
No Action	Level 0	100%	No protection
BUILDING LEVEL STRATEGIES			
Emergency Response (Sandbagging)	Level 1, 2	11% - 25%	Human element, may overtop
Seal Building or Control Room	Level 3	6% - 10%	May leak in from conduits; difficult to detect all leaks
Construct Barrier	Level 4	1% - 5%	Alternative flood pathways other than over the wall
ASSET LEVEL STRATEGIES			
Floodproof Equipment	Level 4	1% - 5%	May exceed rated pressure
Elevate Equipment	Level 5	< 1%	If elevated above critical flood height, only risk from larger storms and greater climate change
Provide Temporary Power Generation for Pumping Station	NA	NA	This measure does not protect the Pumping Station, but helps it to regain service following a surge

which strategy was most cost-effective, the cost of implementing and maintaining any strategy was compared to the anticipated benefit of implementing that strategy in terms of the resulting damage that would be avoided. The anticipated value of damage avoided accounts for the resiliency level of the strategy and includes the value of at-risk infrastructure in the location as estimated in the Risk Analysis. Future storms and surges are associated with a probability of occurrence based on historical storms and the likelihood that any storm will occur during any given year. Naturally, the bigger the surge, the less likely it is to occur in any given year; thus, the 100-year flood has a 1 percent chance of occurring in any given year and a 2-year flood event has a 50 percent chance of occurring in any given year.

The anticipated value of damage avoided also depends on the elevation of the location and how frequently surges are likely to reach that elevation. Certain low-lying locations are more likely to be frequently flooded over 50 years, so anticipated damage may be multiple times the value of at-risk infrastructure (as it may need to be replaced several times). Likewise implementing an adaptation strategy at these locations can protect the equipment through multiple floods, so the anticipated damage avoided may be very high over 50 years. Given that the benefits are higher than the cost of implementation, the strategy would be recommended due to its good return on investment.

In contrast, locations at high elevations may only be affected by very large storms such as the 100-year flood, which tend to occur infrequently. If strategies are implemented at these locations, they may protect against a surge that may or may not occur in the next 50 years. Therefore, the expected risk avoided at such locations will be much lower. If the risk avoided is lower than the cost to implement the strategy, the adaptation measure will not have a good expected return on investment, and would not be recommended.

An understanding of expected damage avoided provides insight into why some locations do not warrant protection at this time. These locations were often at higher elevations that would not be flooded frequently, and often contained fewer pieces of equipment, that were typically not critical to meeting primary treatment requirements. Therefore, the cost to protect a building by sealing doors or constructing a barrier could not be justified economically for these locations.

Programmatic Solutions

To ensure continued progress towards more resilient wastewater infrastructure, and to ensure that the resiliency concepts developed during this study are translated into feasible projects to harden facilities, DEP has established a number of programmatic steps which will be executed in the next few years.

- Maintain a portfolio of “shovel ready” projects that can be further developed when funding opportunities arise or when potentially at-risk assets are due for maintenance or replacement;
- Incorporate climate change and extreme weather considerations in risk assessment exercises designed to allocate funding and prioritize capital projects;
- Revise engineering design standards to accommodate anticipated increases in sea level and storm intensity;
- Include critical flood elevations in asset management databases; place storm surge guidance in visible locations within the wastewater treatment plants; and refine emergency response plans to improve disaster preparedness and recovery based on risk assessment and feedback from operating staff.

With the proper institutional mechanisms in place, DEP will be at the forefront of climate-resilient infrastructure planning, and will be able to make informed decisions about wastewater infrastructure upgrades and emergency response.