VULNERABILITY ASSESSMENT
&
LOCAL ADAPTATION PLAN:

IMPROVING RESILIENCY OF THE VILLAGE OF RHINEBECK WATER TREATMENT PLANT TO FLOODING AND SEA LEVEL RISE

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I. EXECUTIVE SUMMARY

Some components of the Village of Rhinebeck water treatment system, located near the banks of the tidal Hudson River, are currently at risk of flooding. The risk is expected to increase as sea level rises due to global increases in ocean and atmospheric temperatures.

Site surveys have been conducted to determine the existing elevations of equipment at the water treatment plant (WTP). Additionally, safe design elevations for each of four main components of the facility were established based on the design criteria issued by the 10 States Recommended Standards for Water Works, the New York State's (NYS) Uniform Code, and the guidance established by directive of the NYS Community Risk and Resilience Act (CRRA). Based on this guidance, the sea level is projected to rise as much as 9 inches by the 2020s, 27 inches by the 2050s, 54 inches by the 2080s, and 71 inches by 2100. These projections are uncertain, however, and flood risk could increase due to other factors such as increased storm intensity, more frequent storm surge, and more rapid sea level rise.

A vulnerability assessment was conducted showing that The WTP is sufficiently elevated to avoid flooding in all sea level rise (SLR) scenarios; though pending research may indicate that the plant should develop measures to protect against saltwater intrusion in the future. Similarly, the raw water intake is not vulnerable to flooding but may be vulnerable to saltwater intrusion. Adaptation options have been presented and evaluated for the low-lift pump station (LLPS), access road, and lagoon, which were found to be at risk of flooding. The recommended adaptation plan is presented in Table 1 below, including budgetary figures in present day (2017) dollars for funding.

Table 1: Recommended Local Adaptation Plan

	Now	2020s	2030s	2050s	2080s
Raw Water Intake	*No action proposed; Re-evaluate vulnerability to saltwater intrusion as data becomes available.*				
Water Treatment Plant (WTP)	*No action proposed; Re-evaluate vulnerability to saltwater intrusion as data becomes available.*				
Low Lift Pump Station (LLPS)	<u>Wet Floodproof to 13.5'</u> *$65,000*	-	-	-	<u>Increase Height</u> *$500,000, pending feasibility study*
Access Road	<u>Relocate</u> *$360,000*	-	-	-	-
Lagoon	<u>Purchase On-Site Dewatering</u> *$1,000,000*	-	-	-	-

II. INTRODUCTION

The Village of Rhinebeck is located on the northwestern side of Dutchess County and is surrounded on all sides by the Town of Rhinebeck. Though the Town of Rhinebeck population primarily relies on distributed, privately owned on-site wells for water, the Village has a municipal water system that draws water from the Hudson River and treats it at a facility located in the Town of Rhinebeck approximately 500 feet from the shores of the Hudson River. At Rhinebeck, the Hudson River is a tidal estuary and is directly affected by changes to the ocean. For example, Rhinebeck regularly observes tidal changes in water level of about 3ft. The salt front, or the extent of brackish seawater, currently extends to Newburgh Bay (about 67 miles north of the Atlantic Ocean) during regular summer conditions, or as far as Poughkeepsie (about 15 miles further north of Newburgh, and about 16 miles south of Rhinebeck) in droughts.

Over the past century, the oceans have risen approximately one foot[1]. Multiple state sponsored reports[2,3,4] have projected that sea level will continue to rise as a result of global increase in ocean temperature and melting of the polar ice caps. This is expected to increase the frequency and severity of flooding at Rhinebeck's shoreline, and may shift the typical salt front further north such that it could affect the Village's freshwater intake. The Village of Rhinebeck Water Treatment Plant (WTP) has witnessed the effects of these environmental changes firsthand. The plant experienced historic coastal storm surges during Superstorm Sandy in 2012. Floodwaters from Sandy engulfed the adjacent train tracks and made the access road to the WTP impassable by vehicle. According to the plant operators, the water level also came within a few feet of the first floor elevation of the low-lift pump station (LLPS). The operators were able to wade through the shallow water to access the LLPS and WTP, though.

The flooding from Hurricane Sandy highlighted the need for more comprehensive flood planning, as the extent of flood zones along the waterfront are projected to expand through the end of the century. The Village applied for a Hudson River Estuary Local Stewardship Grant for Local Stewardship to complete a Vulnerability Assessment / Local Adaptation Plan for the Village's water system intake, LLPS, and WTP. In April 2016, the Village was awarded a grant to complete the review contained herein. The review involved:

- identifying sea-level rise (SLR) /future flooding conditions
- obtaining specific topographic elevation data for the key water system components
- assessing the vulnerability on the water intake system and treatment plant
- preparing a design evaluation and options for adapting the system and identifying the costs and environmental impacts of the adaptation
- preparing an implementation timeline for improvements to the water system
- preparing this Vulnerability Assessment / Local Adaptation Plan

This report is intended to be used by the Village to guide capital planning decisions, and to identify resiliency projects that merit additional funding. The report is organized to include a general description of the approach used to assess vulnerability to flooding (Section III) followed by a discussion of the specific criteria used to assess vulnerability (Section IV). This is followed by a section describing the design criteria that was considered in evaluating alternative means for adapting to future flooding risk (Section V). Section VI contains the Vulnerability Assessment for each component of the water system. Possible adaptations are presented within the vulnerability assessment for each vulnerable component including budgetary figures in present day (2017) dollars for funding. Section VII discusses general protective measures and Section VIII includes a table of adaptation options and recommendations.

III. APPROACH TO FLOOD RESILIENCE

The process used to review the water treatment system follows the Flood Resilience Guide for Water and Wastewater Utilities published by the United States Environmental Protection Agency (USEPA) in 2014[5], as summarized in Figure 1.

Figure 1: Vulnerability assessment and adaptation planning process

The first step of this process is to understand the threat of flooding. Projected sea level rise (SLR) rates and future flooding conditions were used to establish vulnerability assessment criteria as presented in Section IV: Vulnerability Assessment Criteria.

Next, the vulnerability assessment criteria were applied to the major water treatment system components in Section VI: Vulnerability of the Village of Rhinebeck Water Treatment System. By comparing surveyed elevation data to projected flood conditions, the vulnerable assets and potential consequences were identified through the end of the century.

Additionally, a selection of flood resiliency adaptation methods were researched and design criteria established in Section VI: Vulnerability of the Village of Rhinebeck Water Treatment System. These methods were evaluated on a case-by-case basis for the major water treatment system components.

Finally, a plan to implement measures is presented in Section VII: Routine Protective Measures. The implementation timeline balances risks, costs, and equipment lifetimes to most efficiently improve the resiliency of the Village's water treatment system.

IV. VULNERABILITY ASSESSMENT CRITERIA

Water treatment systems are often in low-lying areas and are particularly vulnerable to flooding. Vulnerability is defined as "the propensity to be adversely affected" by flooding. Structures and equipment must be below the flood elevation, must have a pathway for water to reach the item, and must have potential to be damaged by water to be considered vulnerable. The water treatment system as a whole is considered vulnerable if vulnerable equipment would impact the ability of the system to provide adequate potable water to the Village. This report assesses vulnerable equipment that would contribute to the overall vulnerability of the water treatment system.

In order to understand the vulnerability of the Village water treatment system through the end of the century, C&A has reviewed the existing high tide elevations, existing flood elevations, and the sea level rise (SLR) projections established through the New York State (NYS) Community Risk and Resilience Act (CRRA) as described below:

A. EXISTING FLOOD ELEVATIONS

In Rhinebeck, the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) provides flood elevations of the Hudson River along the Rhinebeck shoreline[6]. These elevations are shown in Table 2. FEMA uses the North American Vertical Datum of 1988 (NAVD88) as the elevation reference. FEMA presents this data as "stillwater elevations", which by definition includes the effects of storm surge and astronomic tide, but does not include the effects of waves or tsunamis. Note that FEMA does not provide a source, date, or methodology for the development of these elevations.

Table 2: Current flood elevations as reported by FEMA

10% (10yr) ACF	2% (50yr) ACF	1% (100yr) ACF	0.2% (500yr) ACF
6.1ft	7.5ft	8.3ft	10.5ft

A 1% (100yr) Annual Chance Flood (ACF) has a 1% probability of occurring every year. Consequently, floodwaters from the Hudson River have a 1% chance of reaching 8.3ft elevation in 2017, and susceptible equipment located at 8.3ft has a 1% chance of being damaged. Over a 30 year period, the probability of experiencing a 1% (100yr) ACF compounds to 25%. A 2% (50yr) ACF is more likely to occur each year, while a 0.2% (500yr) ACF is less likely to occur. FEMA has designated the 1% (100yr) ACF as the base flood elevation (BFE) for floodplain management and flood insurance purposes.

B. EXISTING INUNDATION ELEVATION

For the purposes of this report, inundation is defined as flooding caused by daily fluctuations in astronomical tide. The mean higher high water (MHHW) elevation represents the average height of the astronomical high tide; there are two high tides every day and the MHHW is the higher of the two. Compared to the flood elevations discussed above, this elevation has a 100% chance of being flooded every year, and a 50% chance of being flooded every day. The current MHHW is 3.0ft along the shoreline of the Hudson River, as reported for the City of Kingston with respect to NAVD88[7],[8].

C. PROJECTED RATE OF SEA LEVEL RISE (SLR)

The projections established by the NYS CRRA of 2014 were used to define a rate of SLR through the end of the century. In February 2017, the final version of Title 6 of the New York Codes, Rules and Regulations (NYCRR) Part 490 was released to establish SLR projections that would serve as the basis for NYS adaptation decisions[9]. Projections are reported with respect to the 2000-2004 average sea levels. Those projections applicable to the Village of Rhinebeck are as follows:

Table 3: NYS Sea Level Rise (SLR) Projections for the Mid-Hudson Region

Time Interval	*Low Projection*	*Low-Medium Projection*	*Medium Projection*	*High-Medium Projection*	**High Projection**
2020s	*1 inch*	*3 inches*	*5 inches*	*7 inches*	**9 inches**
2050s	*5 inches*	*9 inches*	*14 inches*	*19 inches*	**27 inches**
2080s	*10 inches*	*14 inches*	*25 inches*	*36 inches*	**54 inches**
2100	*11 inches*	*18 inches*	*32 inches*	*46 inches*	**71 inches**

In conversations with the NYS Department of Environmental Conservation (DEC), the high projections are currently considered the most relevant projections, though the latest research suggests that SLR may be higher. Additionally, these projections do not address increased storm intensity; today's 1% (100yr) ACF is expected to occur more frequently in the future. The latest research projects that annual precipitation in region 5 will increase by 2-7% by the 2020s, 4-12% by the 2050s, 5-15% by the 2080s, and 5-21% by 2100[10]. The effects of increased precipitation on flood elevations is considered outside the scope of this report.

D. SUMMARY OF VULNERABILITY ASSESSMENT CRITERIA

The increasing elevations of flooding and inundation through the end of the century have been calculated in Table 4, below, by adding SLR high projections to the existing flood and inundation elevations:

Table 4: Summary of Vulnerability Assessment Elevations (in feet)

Event	2017	2020s	2050s	2080s	2100
Flood (1%, 100YR ACF)	8.3	9.1	10.6	12.8	14.2
Inundation (MHHW)	3.0	3.8	5.3	7.5	8.9

The exact rate of SLR is unknown, though. The NYSDEC has indicated that the high projections may even be an underestimation, and the projected flood elevations do not consider the effects of increased storm intensity. Further, the potential for brackish water to intrude further up the Hudson has not yet been studied in detail. As time progresses, new data will be available to more accurately predict the extent of SLR and increased storm intensity. The possibility of water reaching these elevations and then impacting water system components was assessed under both inundation and 1% (100yr) ACF conditions.

V. ADAPTATION DESIGN CONSIDERATIONS

In order to improve the resiliency of the water treatment system, the Village can adapt to future flood conditions. Adaptation options include projects such as floodproofing structures, elevating equipment, relocating facilities, and more. The following codes, standards, and guidelines are applicable to the design and permitting of water system components:

- The New York State (NYS) Uniform Fire Prevention and Building Code
- The Draft New York State Flood Risk Management Guidance for the Implementation of the Community Risk and Resiliency Act (CRRA Guidance)
- The 10 States Recommended Standards for Water Works (10 States)

Design criteria covers items such as:

- the amount of freeboard to provide, or "the factor of safety expressed in feet above the design flood level"
- the suitability of protective measures depending on occupancy of the space and/or criticality of the equipment
- the acceptable materials, means, and methods to implement protective measures

A. REQUIREMENTS OF THE 2016 NYS UNIFORM FIRE PREVENTION AND BUILDING CODE

NYS regulates the construction of commercial structures in areas subject to flooding through the NYS Uniform Code. In NYS, the Uniform Code requires a freeboard of 2ft above the base flood elevation (BFE), or the 1% (100yr) annual chance flood (ACF). Freeboard can be established by elevating a structure, dry floodproofing, or wet flood proofing. The Uniform Code references American Society of Civil Engineers (ASCE) 24, "Flood Resistant Design and Construction", which establishes more detailed requirements for the means and methods to design foundations and wet or dry floodproof structures. The Uniform Code does not address the potential for the BFE to increase in height due to sea level rise (SLR), though it is the best resource to obtain detailed information on how to construct and/or modify structures to withstand a flood up to a specific design elevation.

B. NYS FLOOD RISK MANAGEMENT GUIDANCE FOR IMPLEMENTAITON OF THE CRRA

As required by the NYS Community Risk and Resilience Act (CRRA), the NYS Department of Environmental Conservation (DEC) is developing a flood risk guidance document that addresses water treatment facilities. Though it is not yet released for public comment, a draft version of the "New York State Flood Risk Management Guidance for Implementation of the CRRA" (CRRA Guidance) is being prepared to be released for public comment in the near future. Preliminary conversations with the NYSDEC suggest that the document will recommend the following:

- Non critical water supply equipment should be elevated to the current 1% (100yr) ACF plus two feet of freeboard, which is consistent with the 2016 NYS Uniform Fire Prevention and Building Code.
- Critical water supply equipment in tidal areas should be elevated to either the current 0.2% (500yr) ACF or the current 1% (100yr) ACF plus 3' of freeboard plus the high SLR projection associated with the lifetime of the equipment.

A requirement of the CRRA is that any project that will be funded with state monies will be required to comply with the recommendations of the NYS Flood Risk Management Guidance. It is assumed that the Village will require grant funding or financing to implement future adaptations, thus the guidance of the NYS Flood Risk Management weighed heavily on the consideration of possible adaptations.

C. 10 STATES RECOMMENDED STANDARDS FOR WATER WORKS

C&A also compared component elevation and inundation information to the design requirements of 10 States Recommended Standards for Water Works (10 States)[11], the design guide for water works systems referenced by NYS regulations, which states the following:

> *"Other than surface water intakes, all water supply facilities and water treatment plant access roads shall be protected to at least the 1% (100yr) ACF elevation or maximum flood of record, as required by the reviewing authority. A freeboard factor may also be required by the reviewing authority."*

VI. VULNERABILITY OF THE VILLAGE OF RHINEBECK WATER TREATMENT SYSTEM

The Hudson River serves as the source water for the Village of Rhinebeck Water System. The treatment facility was installed in 1968. As shown in the map in Figure A-1 and the schematic in Figure A-2, water is withdrawn through an intake in the River and pumped to the nearby water treatment plant (WTP) by a low-lift pump station (LLPS). From the pump station, the water goes through a filter, which is housed in the WTP. From the WTP, water is then chlorinated before being pumped to the Village's water distribution system. Backwash from the filter, also known as alum sludge, is discharged to a lagoon located between the LLPS and the WTP.

Major components of the water treatment system are listed below:

1) Hudson River raw water intake
2) Low-lift pump station (LLPS)
    - vacuum priming pumps
    - low-lift pumps
    - electrical panels, controls, and disconnects
3) Water treatment plant (WTP)
    - flow meters
    - upfloat clarifiers
    - flocculation tanks
    - settling tanks
    - filter beds
    - clear well
    - backwash pump
    - chlorine injection pump
    - distribution pumps
    - electrical panels, controls, and disconnects
    - backup generator
4) Lagoon
5) Access road

Vulnerability to flooding, consequences of flooding, service life, and possible adaptation options have been evaluated for each of the major components: the raw water intake, the LLPS, the WTP, the Lagoon, and the access road.

In order to understand the vulnerability to flooding, C&A conducted elevation analyses using publicly available topographic data[12], as well as spot elevations determined by surveys conducted on October 5 and 14, 2016. Schematic profiles were developed to show component inundation and flood risk under the high sea level rise (SLR) projections. Inundation elevations represent the mean higher high water (MHHW) mark[13] with SLR predictions added at each year. 1% (100yr) annual chance flood (ACF) elevations are composed of the same SLR predictions superimposed on current 1% (100yr) ACF elevations. These profiles are found in Figure A-3. A Flood Risk Matrix was also developed to compare WTP component elevations to various scenarios of SLR and conformance with the requirements of "10 States Recommended Standards for Water Works" (10 States) and with the "New York State Flood Risk Management Guidance for Implementation of the CRRA" (CRRA Guidance). This matrix is shown in Appendix B. Where possible, cost estimates have been provided to help evaluate the suitability of the proposed adaptation options.

A. RAW WATER INTAKE

i. Vulnerability Analysis

Flooding

The raw water intake structure is currently submerged in the Hudson River. It has not been adversely impacted by historic flood events. The raw water intake is not considered vulnerable to flooding.

Saltwater Intrusion

The raw water intake may be vulnerable to salt intrusion in the future, however. The salt front, or the extent of brackish seawater, currently extends to Newburgh Bay (about 67 miles north of the Atlantic Ocean) during regular summer conditions, or as far as Poughkeepsie (about 15 miles further north of Newburgh, and about 16 miles south of Rhinebeck) in extreme droughts. It has been reported that upstream dams have been directed to release extra freshwater to protect Poughkeepsie's freshwater intake from saltwater intrusion approximately once a decade[14],[15]. The United Stages Geological Survey (USGS) has been researching the historic shape and extent of the salt front since 1988[16], but there is little data currently available on the impacts SLR will have on the extent of saltwater intrusion, though. Further research is needed to evaluate the vulnerability of the raw water intake to salt intrusion.

ii. Consequences

Saltwater could corrode the intake and all subsequent piping components. Most importantly, salt would negatively impact the quality of treated water. Saltwater intrusion could have significant impacts to public health and safety.

iii. Service Life

The river intake and on-site raw water piping has not been replaced or upgraded since installation in 1968. The Chief Operator has indicated that dive teams regularly inspect the intake and report that it is in good condition. The underground raw water piping connecting the intake to the LLPS and LLPS to

WTP are also in good condition. He estimates a remaining lifetime of 20-30 years for this piping.

iv. Possible Adaptations

The raw water intake is not considered vulnerable to flooding, so no adaptation options have been explored.

B. WATER TREATMENT PLANT (WTP)

i. Vulnerability Analysis

Flooding

The finished grade at the WTP is significantly higher than flood elevation levels. At about 20ft, the facility is not considered susceptible to flooding by 2100. Additionally, no part of the WTP is expected to be inundated by any of the flood elevations used in this study. The facility's backup generator is also located in a storage shed next to the WTP, which is not at risk of flooding.

Saltwater Intrusion

The WTP may be vulnerable to salt intrusion in the future, however. The salt front, or the extent of brackish seawater, currently extends to Newburgh Bay (about 67 miles north of the Atlantic Ocean) during regular summer conditions, or as far as Poughkeepsie (about 15 miles further north of Newburgh, and about 16 miles south of Rhinebeck) in extreme droughts. It has been reported that upstream dams have been directed to release extra freshwater to protect Poughkeepsie's freshwater intake from saltwater intrusion approximately once a decade. The United Stages Geological Survey (USGS) has been researching the historic shape and extent of the salt front since 1988, but there is little data currently available on the impacts SLR will have on the extent of saltwater intrusion, though. Further research is needed to evaluate the vulnerability to salt intrusion.

ii. Consequences

Saltwater could corrode piping components containing raw water. Most importantly, the WTP is not designed to reduce water salinity to safe drinking levels. Salt would negatively impact the quality of treated water and could have significant impacts to public health and safety.

iii. Service Life

The WTP is currently in good operating condition. With continued maintenance, the service life of the plant is indefinite. The treatment processes may eventually need to be upgraded to address future pollutants, though there is no observed need for upgrades at this time.

iv. Possible Adaptations

The WTP is not considered vulnerable to flooding, so no adaptation options have been explored.

C. LOW-LIFT PUMP STATION (LLPS)

i. Vulnerability Analysis

A LLPS vulnerability schematic is provided in Figure 2, and discussion provided below.

Flooding

The LLPS is not currently vulnerable to flooding. A 1% (100yr) ACF in 2017 is expected to reach the LLPS by the 2020s, though. The building's foundation was not originally designed to resist hydrostatic and buoyancy forces during a flood, and so the structure is considered vulnerable.

By the 2020s, water has the potential to enter the basement through a bulkhead door at finished grade. The basement contains three Flygt low-lift pumps with an electrical disconnect for each. The low-lift pumps are submersible and are not considered vulnerable, though their disconnects are vulnerable to flooding. Three water level controllers, which coordinate the vacuum and low-lift pumps to prevent flooding of the vacuum pumps, are also in the basement, along with electric receptacles, lighting, a dehumidifier, and a sump pump.

Between the 2020s and the 2050s, a 1% (100yr) ACF is projected to reach the first floor of the LLPS. The first floor is where (2) 3hp vacuum pumps and the majority of the electrical equipment is located. The electrical equipment includes (1) pump control panel, (4) electrical subpanels, (1) disconnect, and (2) step down transformers. One subpanel nearly reaches the floor at about 10.8ft elevation, though, and is considered vulnerable between the 2050s and 2080s. Most electrical equipment is located at about 4ft above the first floor, or about 14ft elevation; this equipment is not considered vulnerable until between the 2080s and 2100.

The flood vulnerability of the components is summarized in Table 5.

Regular Inundation by High Tide

The LLPS is not expected to be inundated by 2100. As shown in Figure A-1, the extent of high tide is expected to come within 15ft horizontally of the LLPS foundation by 2100.

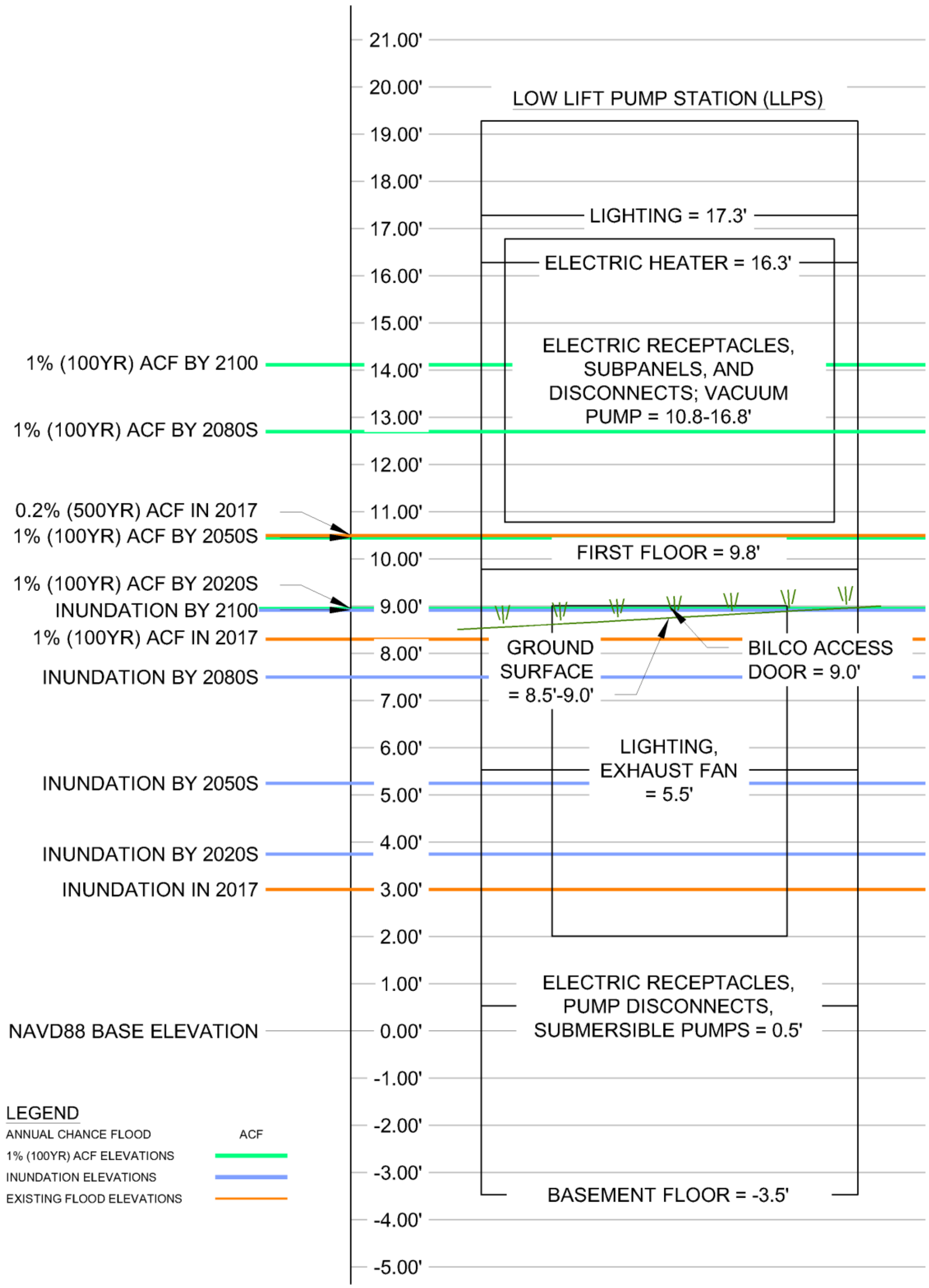

Figure 2: Low-Lift Pump Station (LLPS) Flood Vulnerability Schematic

ii. Consequences

The LLPS moves water from the intake to the WTP. The water distribution system has approximately 3 full days of storage at peak demand, which usually occurs in the summer. It is not expected that access to the LLPS would be necessary during a flood. If the LLPS were damaged for an extended period of time, though, the Village may have disruption in service or may need to pay for water to be hauled in from another location.

iii. Service Life

Most of the equipment in the LLPS was installed in 2006, including the vacuum pumps, the low-lift pumps, and approximately half of the electrical subpanels and transformers. The Chief Operator expects a remaining lifetime of approximately 15-20 years for the pumps, though with regular maintenance and motor replacement, the pumps may not outlive their usefulness by the 2100. Electrical equipment, such as subpanels and disconnects, are expected to have a remaining lifetime of up to 50 years. Electrical components are more likely to become obsolete and incompatible with new components than they are likely to fail. The equipment service life has been compared to the vulnerability timeframes and summarized in Table 5. The only equipment that is expected to be vulnerable before the end of its service life are the low-lift pump disconnects, which could fairly easily be relocated rather than replaced.

Table 5: LLPS Equipment Service Life and Vulnerability Summary

Vulnerable Component	Elevation at Which Equipment is Vulnerable to Flooding (ft)	Vulnerable Year	End of Service Life
LLPS Access	6	2017	N/A
LLP #1 Disconnect	9	2020s	2055
LLP #2 Disconnect	9	2020s	2055
LLP #3 Disconnect	9	2020s	2055
LLPS Foundation	9	2020s	N/A
Basement Lighting & Exhaust	10	2050s	2025
Vacuum Pump #1	11	2050s	2025
Vacuum Pump #2	11	2050s	2025
Pump Control Panel	11	2050s	2055
Low Lift Pump #1	14	2100	2025
Low Lift Pump #2	14	2100	2025
Low Lift Pump #3	14	2100	2025
Vac. Pump #1 Disconnect	14	2100	2055
Vac. Pump #2 Disconnect	14	2100	2055
Electrical Subpanel #1	14	2100	2055
Electrical Subpanel #2	14	2100	2055
Electrical Subpanel #3	14	2100	2055
Electrical Subpanel #4	14	2100	2055
Step Down Transformer #1	14	2100	2055
Step Down Transformer #2	14	2100	2055
Heater	16	N/A	2025
1st Floor Lighting	17	N/A	2025

iv. Possible Adaptations

Floodproof Structure

One option to improve the resiliency of the LLPS is to floodproof the structure. There are two main methods of floodproofing: wet and dry floodproofing. The primary differences between the two methods are illustrated in Figure 3.

Dry flood proofing involves sealing the building so that water may not enter. The bulkhead access door and main entrance door could be replaced with tight sealing alternatives to prevent water entering, and the walls waterproofed with a membrane or sealants. Dry floodproofing may be an acceptable short term solution to prevent infiltration up to about 3ft of standing water, as many common sealants are not rated for pressures over about 3ft of water. This method becomes exponentially less economical the higher the design flood level is above the lowest floor, though, due to the need to reinforce foundation walls to counteract hydrostatic and buoyancy forces during a flood. Detailed structural and geotechnical analysis would be required to confirm feasibility of this option. If the LLPS were dry flood proofed to 12ft, or about 3ft above finished grade, the structure would be considered resilient through the 2050s. The foundation walls would need to be able to resist hydrostatic pressures of as much as 15.5ft of water if the ground were saturated during a flood, though. The reinforcements needed to ensure structural stability may make this option cost prohibitive.

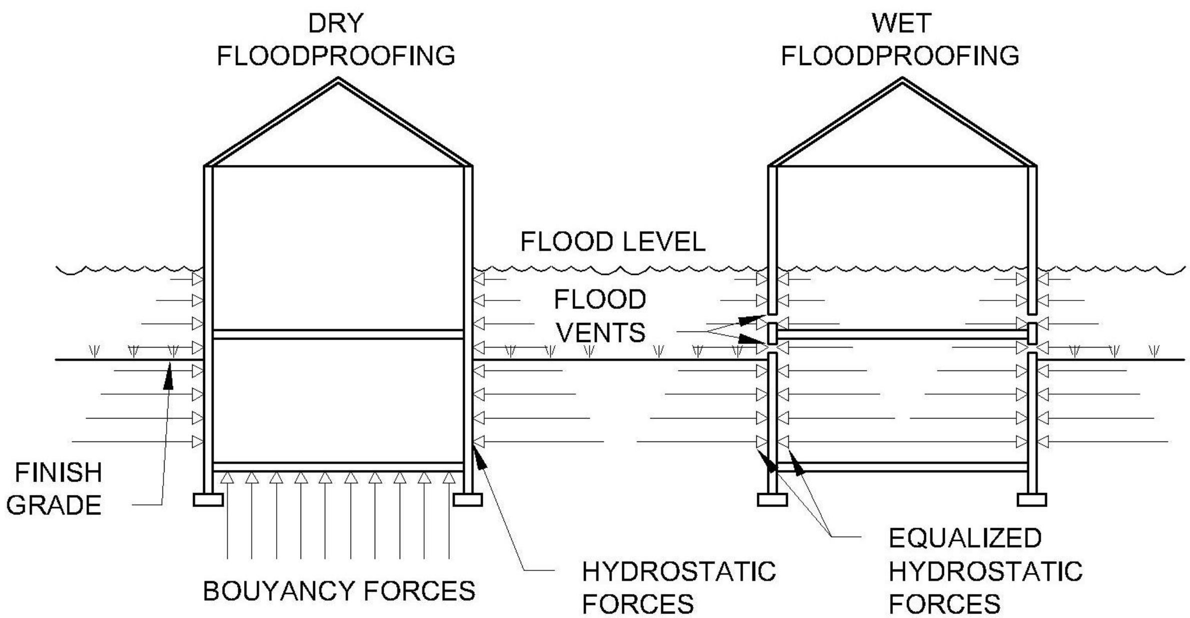

Figure 3: Dry Floodproofing vs Wet Floodproofing

A second kind of flood proofing is called “wet floodproofing”. Wet flood proofing differs from dry floodproofing in that a structure is designed to allow floodwaters into the building as shown in Figure 3. This technique is projected to be the least expensive floodproofing option. It is also considered more resilient because a wet floodproofed structure is protected regardless of flood elevation, assuming the actual flood elevation does not extend into a story that is not flood vented. There is less risk to a wet floodproofed structure than there would be with a barrier or dry floodproofing solution, which are prone to failure of predicted flood elevations are exceeded. Wet floodproofing is only appropriate in certain situations, such as unoccupied spaces used primarily for storage and in structures functionally dependent on proximity to water.

The LLPS is a good candidate for wet flood proofing as it is not normally occupied, is used primarily for storage, and is functionally dependent on close proximity to the Hudson River raw water intake. In this option, flood vents would be installed around the perimeter of the building to allow the water level to equalize on both sides of the exterior walls, eliminating the need to reinforce the foundation or walls. At least four vents would be needed to protect the LLPS: two near the top of the basement level and two at the bottom of the first floor level. If these flood vents were installed, the structure would be protected under all SLR conditions; the venting would not need to be adjusted as the flood elevation increases.

Another element to wet floodproofing is to ensure all interior finishes are water resistant, and to elevate all susceptible equipment above the predicted flood level. For example, new waterproof lighting could be installed in the basement, or portable lighting provided and stored in the first floor. The Village would also need to relocate all receptacles, exhaust fans, motors, motor starters, and disconnects above projected flood levels.

Elevating electrical equipment will involve relocating disconnects from the basement to the first floor, out of sight of the equipment they serve. Per the National Electric Code (NEC) section 430.102, the motor/motor controller disconnecting means must be located within sight of the motor/motor controller. An exception allows for disconnects to be located out of sight where such a location “introduces additional or increased hazards to persons or property” and the disconnecting means is lockable. Flood potential is a prime example of a reason to permit disconnects to be located out of view from the equipment, provided that a lockout/tagout procedure is implemented.

The CRRA Guidance recommend that critical equipment be elevated to the 1% (100yr) ACF plus 3ft of freeboard plus the high SLR projection for the lifetime of the equipment. As shown in Table 5, the low-lift and vacuum pumps all will require rebuilding or replacement during the 2020s and most electrical equipment will require replacement in the 2050s. To meet the CRRA Guidance, by the 2020s the LLPS should be wet flood proofed and electrical equipment elevated to about 13.5ft. This is the recommended design elevation to ensure resiliency through the 2050s, or the projected lifetime of most equipment. At 13.5ft, the equipment is not expected to be vulnerable until between the 2080s and 2100. There is one existing switchboard that is about 6’ tall and would not be able to be elevated any further than 13.5ft without elevating the roof of the structure or purchasing new, shorter electrical equipment. Around the 2080s, when the pumps again require rebuilding, the Village can consider other adaptation options.

The total cost for wet floodproofing the LLPS is budgeted to be $65,000 in present day (2017) dollars, which includes structural modifications as well as elevating equipment. Actual costs for relocation of electrical equipment may vary significantly, and would need to be evaluated in more detail.

Elevate Roof

By 2100, a 1% (100yr) ACF is projected to reach as high as 5ft below the ceiling of the existing structure. In this case, it may not be possible to elevate electrical equipment enough due to height restrictions of the building. Pending detailed structural evaluation, it may be possible to increase the overall height of the existing LLPS without affecting the basement or foundation. The structure is made of concrete masonry unit (CMU) block walls with a concrete slab roof. Elevating the roof of this structure would most likely require full demolition of the roof, placement of additional CMU blocks to extend the wall height, drilling reinforcement bars into the existing walls to add lateral strength to the wall structure, and installation of a new roof. All electrical equipment and the vacuum pumps could be relocated to a higher elevation, and the elevation for wet flood proofing could be increased as needed to ensure the structure is protected during a flood.

The Hudson River may extend as close as 10-15ft from the building during high tide in 2100. If the LLPS is left in its current location as described in this option, some regrading and/or shore stabilization may be required to maintain a safe distance from the shores.

The budget, in present day (2017) dollars, for increasing the overall height and elevating electrical equipment is around $500,000, but are highly dependent on a detailed structural evaluation of the building.

Relocate Structure

The LLPS could be relocated to a location on the western side of the existing lagoon. The Village already owns land adjacent to the WTP that is elevated above the projected flood hazard area of 2100. Additionally, the station could be positioned to utilize the existing underground raw water piping, so that reconfiguration of the connection at the WTP would not be required. The remaining lifetime of the existing piping has been estimated to be about 20-30 years, so waiting until at least the 2050s to relocate is expected to maximize the investment in that infrastructure if major rerouting is eventually required.

Relocation of the LLPS would involve construction of a new, similarly sized building of approximately 500sf, and relocation of existing equipment and underground piping as practical. New pumps may be required because the relocated pump station would be at a higher elevation. The amount of head required for the vacuum pumps to maintain a prime would be greater, and the amount of head required for the lift pumps to move water from the pumping station to the WTP would be lower. Finally, the existing raw water piping would need to be tapped and re-routed to pass through the new LLPS. The total budget in present day (2017) dollars for relocating the LLPS is estimated to be upwards of $1,000,000.

Barriers: Levees & Floodwalls

One method to protect the LLPS and lagoon from flooding would be to construct a barrier separating these facilities from the flooding source. A levee is typically a compacted earthen structure, whereas a floodwall is a structure built of concrete, masonry, or a combination of both. These barriers are not to be confused with in-water shore stabilization techniques like bulkheads or revetments. Rather, these barriers could be constructed on dry land to protect structures and other site features from flood events.

Barriers like floodwalls and levees may reduce the need to make modifications to the existing structures one is trying to protect, and they may be the only method to protect a site feature like the WTP lagoon. They can be quite expensive though, and the Federal Emergency Management Agency (FEMA) does not approve of barriers as an adequate way to bring a substantially damaged or substantially improved structure into compliance with local floodplain management laws[17]. This is because barriers reduce risk rather than eliminating it. Additionally, if a barrier fails, the result can be more destructive to lives and property than if the barrier had not been present. The National Insurance Flood Program (NFIP) requires that all new or substantially improved residential and commercial structures within flood hazard areas to be constructed at or above the 1% (100yr) ACF, or otherwise floodproofed to that elevation, including facilities landward of levees[18].

Finally, the land that would potentially be used to construct a levee or floodwall is owned by a railroad entity, and not the Village. Obtaining permission to construct new site features on this land may be difficult.

v. LLPS Adaptations Summary

Sometime in the next few years the Village should prepare for flooding in the 2020s. It is recommended that the LLPS be wet flood proofed in the basement and the 1st floor, assuming a design elevation of 13.5ft, or 3.7ft above the first floor. This design elevation is in line with that recommended by the CRRA Guidance and will allow the Village access to grant funding. All electrical equipment should be elevated to 13.5ft as well. This elevation provides 3ft of freeboard recommended by the CRRA Guidance through the 2050s. Once a flood damages lighting in the basement, it should be replaced with waterproof alternatives. Wet floodproofing of the LLPS is budgeted to cost approximately $65,000 in present day (2017) dollars, though reorganization of the electrical equipment will require a more detailed review.

Between the 2080s and 2100, the electrical equipment that had been elevated to 13.5ft is projected to be vulnerable again. At this point the Village can elevate the roof and electrical equipment in the LLPS at a budgeted figure of $500,000 in present day (2017) dollars. If feasible, this is expected to be the less expensive option than relocation of the LLPS because the existing pumps could be reused. Although they are expected to outlive their lifetime in the 2030s, pumps can often be rebuilt and repaired for much less than the cost of new equipment.

If detailed structural analysis indicates that modifying the existing LLPS would be structurally infeasible or economically disadvantageous, the LLPS should be relocated to a higher elevation such that the finished grade of the building is at least 17.1ft, or the 1% (100yr) ACF in 2100 plus 3ft of freeboard as recommended by the CRRA Guidance. If the site proposed just west of the WTP is used, the cost of relocation is estimated to be $900,000. It is recommended that this be done by the 2080s, or earlier if the pumps do need to be replaced in the 2030s.

Installation of levees and/or floodwalls is not recommended as a standalone solution because FEMA does not consider barriers as adequate solutions to bring buildings with substantial improvements into compliance with flood plain management laws.

Table 6: Summary of Adaptation Options for the Low-Lift Pump Station (LLPS)

	Now	2020s	2030s	2050s	2080s
LLPS	Wet Floodproof to 13.5' *$65,000*	-	-	-	Increase Height *$500,000, pending feasibility study*
LLPS	Wet Floodproof to 13.5' *$65,000*	-	-	-	Relocate *>$1,000,000*

D. ACCESS ROAD

i. Vulnerability Analysis

Flooding

The road to the LLPS, lagoon, and WTP, Slate Dock Road, has a steep driveway then hairpin turn before reaching the railway tracks. The road then parallels the tracks for about 550lft before reaching the LLPS.

The access road is within the current 1% (100yr) ACF zone and impeded access to the WTP during Hurricane Sandy. The lowest point of the access road is at the

LLPS parking lot, though nearly 190lft of the road are below the Sandy flood elevation of 9.3ft, and as much as 530lft of the road are below the 2100 projected 1% (100yr) ACF elevation of 14.1ft.

Regular Inundation by High Tide

The lowest point of the access road is expected to be regularly inundated by tides due to SLR between the 2050s and 2080s. By 2100, approximately 250lft of the road will be regularly inundated by high tide.

ii. Consequences

The WTP is not required to be operational during a flood, since the Village maintains approximately 3 days of storage even during the summer when demand is highest. However, a flooded access road makes it less safe for the WTP staff to respond to emergencies. Additionally, regular inundation of the access road by 2100 would have serious implications on the efficient operation of the WTP. Finally, the Village could incur repair costs if a flood event caused permanent damage to the access road.

iii. Service Life

With routine maintenance of the paved surface, the access road's service life is indefinite.

iv. Possible Adaptations

Relocate Access Road

To improve the accessibility of the WTP during a flood, one option would be for the Village to purchase land or an easement to construct a new access road. This option would have other benefits as well. The hairpin turn makes it difficult for large tankers to reach the facility for sludge removal from the lagoon and chemical delivery to the WTP. Finally, though the WTP is on land owned by the Village of Rhinebeck, the access road is on land currently owned by New York Central Lines, LLC, a railroad entity and a subsidiary of CSX Transportation. The Village has an easement for its access road, but construction of a dedicated access road would reduce risk of future conflict with the railroad entity, and may make it easier for the Village to maintain.

The easiest parcel to obtain may be tax lot number 520203, as shown in Figure A-5. It is a 0.4 acre vacant lot that connects Slate Dock Road to the Village's property, and has an assessment of $60,000. Lot number 527194, assessed at $47,000, is another vacant lot of 0.2 acres with the same owner and would connect the WTP directly to Rhinecliff Road. An easement directly from Rhinecliff Rd to the Village's property through parcel numbers 542217 or 557240 may also be feasible if one of the owners of the single family residences approved.

Other costs related to relocating the access road include regrading approximately 1700cy of earth and paving approximately 450lft of new road. Coordination with Central Hudson will also be required to raise the existing overhead transmission lines that follow the north side of Slate Dock Road. In total, relocation of the access road is expected to cost approximately $360,000 if completed on tax lot number 520203 to connect the WTP to Slate Dock Road.

Elevate Access Road with Fill

It is possible to elevate the access road in its current location using structural fill. The access road is currently an acceptable upland candidate for elevation with fill. The access road is not in a wetland, nor is it in a regulated “floodway”, which is “the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.” The Hudson River is defined by FEMA as a “Stillwater” area, not a riverine flooding source, and as such does not have a designated floodway. In some cases, local permits from the municipality may be required for adding fill within flood hazard areas outside of the floodway in order to ensure that the fill will not potentially cause damage to other properties. Currently, such a determination would be the decision of the Town of Rhinebeck, though the CRRA Guidelines under development may impose other restrictions on fill within floodplains in the future.

In the short term, the road could be elevated to 11ft to provide 2ft of freeboard through the 2020s as recommended by the CRRA Guidance for non-critical features, and would ensure the road is above the projected 1% (100yr) ACF through the 2050s. This would involve regrading about 2020cy and paving, which has a budgeted cost of $450,000 in present day (2017) dollars.

In order to elevate the access road in its current location to a safe 2100 elevation of 16ft, approximately 6100cy would need to be regraded and paved over about 610lft. The total budget elevating the access road to 16ft is $910,000 in present day (2017) dollars.

Feasibility of this option is expected to be low, however, because the current access road is on land that is currently owned by a railroad entity. It is unknown if the railroad entity would approve of additional fill on their land. The railroad entity may also require a retaining wall be built, which would significantly increase costs.

v. Adaptations Summary

In the long term, it is recommended that the access road be rerouted, particularly if the LLPS is also relocated. Additionally, the relocation option has other benefits such as eliminating the hairpin turn, and discontinuing use of privately owned lands. Land acquisition is key to the viability of this option.

The access road could also be elevated with fill and repaved, either in a phased approach or in one single project. This option is less attractive, though, due to the fact that it is unknown if it would be acceptable to the railroad entity.

A summary of adaptation options for the access road is provided in Table 7. Each adaptation option for the access road requires further study, as they each depend on willingness of current landowners and site specific testing and design would be required.

Table 7: Summary of Adaptation Options for the Water Treatment Plant (WTP) Access Road

	Now	2020s	2030s	2050s	2080s
Access Road	Relocate *$360,000*	-	-	-	-
Access Road	Elevate with Fill to 11' *$450,000*	-	Relocate *$360,000*	-	-
Access Road	Elevate with Fill to 16' *$910,000*	-	-	-	-
Access Road	Elevate with Fill to 11' *$450,000*	-	-	Elevate with Fill to 16' *$750,000*	-

E. LAGOON

i. Vulnerability Analysis

Flooding

The lagoon has a culvert on its west side that discharges into a tidal pond, as shown in Figure A-3. The invert elevation is approximately 7.2ft, the same as the invert elevations of the pipes that discharge sludge into the pond from the WTP. It is normally covered to prevent beavers from building in the lagoon, but is occasionally uncovered to drain the lagoon for sludge removal. The lagoon is currently vulnerable to a 1% (100yr) ACF via the culvert, though it is not currently vulnerable to overflowing and contaminating the surrounding area with alum sludge.

The berm which protects the lagoon from flooding is only about 1.6ft above the 1% (100yr) ACF. Between the 2020s and 2050s, the lagoon will be vulnerable to flooding by overtopping of the berm.

Regular Inundation by High Tide

The lagoon culvert is expected to be regularly inundated by the 2080s. High tide is not expected to overtop the existing berm, though maintenance of the berm may be necessary to protect against erosion as sea level rises.

ii. Consequences

There are few consequences if the lagoon is temporarily flooded via the culvert that connects it to the neighboring tidal pond. The WTP is permitted to discharge water from the lagoon via State Pollutant Discharge Elimination System (SPDES) permit number NY0035688.

If the berm were significantly disturbed by overtopping with turbulent storm waters or permanently damaging the berm, however, there is risk of violating the SPDES permit discharge parameters by contaminating the surrounding environment with alum sludge. The sludge consists primarily of sand, silt, and organics. Discharge of sand and silt can cause sediment issues in waterways. Discharge of organics with high biochemical/chemical oxygen demand (BOD/COD) content can have adverse effects on aquatic life by creating oxygen deficient environments. Finally, the alum sludge is considered a solid waste in NYS due to the addition of chemical additives in the water treatment process. The lagoon serves as a temporary storage location, and the sludge should be dredged and properly disposed of at a landfill or approved beneficial use in order to comply with environmental regulations.

iii. Service Life

The Village's WTP lagoon has not been dredged for many years, and currently requires removal of approximately 1,800cy of wet sludge. The volume is estimated based on an assumed depth of 3ft over 0.91 acres; the percent solids of the existing sludge is unknown. A recent solicitation for bids to complete this process over a period of three years has returned estimates in the range of $888,000-$1,122,000. With regular maintenance, however, the service life of the lagoon is indefinite.

iv. Possible Adaptations

Discontinue Use of the Lagoon

The lagoon is intended to temporarily store and dewater alum sludge, a waste product of the WTP. There are other mechanical methods of sludge dewatering, however. A press could be permanently installed to dewater the sludge. The dewatered sludge could then be hauled to a nearby landfill or other disposal facility.

To accomplish this adaptation option, a press would need to be purchased. According to the WTP operator, the plant accumulates approximately 21,840cf of wet sludge per year in the settling tanks, and a little bit more from the clarifiers, flocculation tanks, and filter backwash. Assuming approximately 23,000cf of 2-4% solids wet sludge per year, approximately 685 wet tons of sludge are generated each year. One local landfill in Colonie indicated that a minimum of 20% solids is required for disposal at their waste disposal facility, which would mean the Village would produce approximately 20 dry tons per year. A 300 dry lb/hr screw press could dewater this sludge over approximately 133 hours per year, or 11 hours per month. A press of this size is budgeted to cost approximately $300,000 in present day (2017) dollars.

In addition to purchasing a press, there are other costs that would need to be budgeted in order to support the new process. An addition would need to be added to the existing WTP, as shown in Figures A-4 and A-5. Additionally, process equipment within the WTP would need to be reconfigured to be able to move sludge from holding tanks to the filter press instead of draining into the lagoon as currently designed. The Village would also need to reconfigure the existing yard piping in order to discharge effluent liquids from the dewatering process, and also reconfigure the lagoon to prevent accumulated sludge from contaminating the surrounding environment. Overall, reconfiguration of the sludge management process would require further study.

Operations and maintenance (O&M) costs for dewatering sludge with a screw press are expected to be lower than existing O&M costs for maintenance of the lagoon. A simple cost analysis suggests that investment in a press could be recovered within 10-20 years. The cost recovery period would be less if grant funding were used to cover some of the capital costs.

Barriers: Levees & Floodwalls

Though barriers like levees, floodwalls, or raising the berm height could be used to protect the lagoon, they are not recommended. FEMA does not consider barriers to be suitable adaptation methods to bring existing structures into compliance with the NFIP. A failure of a barrier can be more catastrophic than if the barrier were not there.

v. Adaptations Summary

It is recommended that the use of the lagoon be discontinued. The simple payback calculations provided in this report suggest that the purchase of an on-site dewatering system, such as a screw press, could be recovered within approximately 10-20 years, or less with grand assistance. It is recommended that this option be pursued as early as the 2020s due to the highly advantageous economics of purchasing an on-site dewatering system and the increased resiliency to future flooding that it would provide.

It could be possible to protect the lagoon with barriers, either by elevating the existing berm or constructing a floodwall. This option is generally not recommended, though, due to the potential for failure from barrier protection methods.

Table 8: Summary of Adaptation Options for the Lagoon

	Now	2020s	2030s	2050s	2080s
Lagoon	Purchase On-Site Dewatering *$1,000,000*	-	-	-	-

VII. ROUTINE PROTECTIVE MEASURES

In addition to the adaptation projects proposed, the Village's existing maintenance program helps to improve resiliency at the facility. Providing a stock of spare parts on site is also advantageous so that the system is more able to return to full operation after a flood, and can be used as a temporary solution to protect equipment before adaptation projects can be implemented.

Currently, the water treatment plant (WTP) operators have established an unofficial Emergency Action Plan (EAP) which includes provisions for maintaining a supply of potable water for the Village during significant flood events. If the raw water intake or the low-lift pump station (LLPS) were compromised to the extent that potable water was not available to the Village, the operators would hire a 3rd party to truck in water and fill the storage tank at Burger Hill. No equipment at the Rhinebeck WTP has been damaged nor has access been prevented by flooding, so the EAP does not yet address those issues. The Village may wish to formalize a plan that includes consideration of future flooding and sea level rise (SLR). The plan can include a "Storm Surge Guidance" chart as exemplified in Appendix C. The chart enables an operator to rapidly identify at-risk equipment based on storm surge warnings. The charts were created by the New York City Department of Environmental Protection (NYCDEP) and were printed on placards as a quick reference to operators to prepare their plant in advance of a surge event.

Along with the chart described above, operators could also sign up for USGS water alert for Hudson River (http://water.usgs.gov/wateralert/index.html). The service sends texts when water levels exceed self-defined thresholds. The station at the City of Poughkeepsie would provide the most relevant data on Hudson River flood levels.

VIII. CONCLUSIONS & RECOMMENDED IMPLEMENTATION TIMELINE

The low-lift pump station (LLPS), the access road, and the lagoon are all currently vulnerable to flooding, and the threat will continue to increase as sea level rises. It is recommended that short term projects be implemented as soon as possible, while long term projects be incorporated into the Village's local adaptation plan.

The Village can pursue grant funding for implementation of the adaptation projects for the LLPS and lagoon under the Climate Smart Communities Grant Program. This program will fund 50% of the costs of implementation of adaptation actions. Since relocation of the access road will likely require more study to determine the preferred option, it is recommended that grant funding be pursued for adaptation in a future round.

The recommended short and long term solutions are described below. The recommended timelines are based on current assumptions of 9 inches of sea level rise (SLR) by the 2020s, 27 inches by the 2050s, 54 inches by the 2080s, and 71 inches by 2100 based on the "high" projections published by the New York State (NYS) Department of Environmental Conservation (DEC). The timeline may need to be accelerated or decelerated based on future observations of SLR. Further, Rhinebeck may need to prepare for intrusion of saltwater in the future, though data is not yet available to determine the likelihood or timeline for this to occur.

A summary of options has been presented in Table 9, below, including budgetary figures in present day (2017) dollars for funding. The recommended options have been highlighted in grey.

Table 9: Adaptation Options and Costs

	Now	2020s	2030s	2050s	2080s
LLPS	Wet Floodproof to 13.5' *$65,000*	-	-	-	Increase Height *$500,000, pending feasibility study*
LLPS	Wet Floodproof to 13.5' *$65,000*	-	-	-	Relocate *>$1,000,000*
Access Road	Relocate *$360,000*	-	-	-	-
Access Road	Elevate with Fill to 11' *$450,000*	-	Relocate *$360,000*	-	-
Access Road	Elevate with Fill to 16' *$910,000*	-	-	-	-
Access Road	Elevate with Fill to 11' *$450,000*	-	-	Elevate with Fill to 16' *$750,000*	-
Lagoon	Purchase On-Site Dewatering *$1,000,000;*	-	-	-	-

APPENDIX A DRAWINGS

APPENDIX B FLOOD RISK MATRIX

APPENDIX C SAMPLE STORM SURGE GUIDANCE CHART[19]

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