

Coastal Hazard and Sea-level Rise Vulnerability Assessment

Chesapeake Energy Center coal ash disposal site, Chesapeake, VA

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Executive Summary

This study assesses the vulnerability of the coal ash disposal site at the Chesapeake Energy Center (CEC) in Chesapeake, Virginia, to sea-level rise and other coastal hazards. Prior to Dominion Virginia Power's (Dominion) construction of the CEC power plant in the 1950s, the natural environment at the site consisted of tidal marshes and wetlands. From the early 1950s to 1984, Dominion disposed of the coal ash generated from burning coal in unlined pits that, by 1965, extended from immediately south of the power plant to the tip of the peninsula (Figure 1, next page). Dominion estimates that these pits contain about 2.1 million tons of coal ash buried as much as six feet below mean sea level. This report finds that the buried coal ash in the unlined pits is highly vulnerable to coastal hazards, including flooding, storm surge, erosion, and sea-level rise. Further, with the changing climate in the coming decades, these hazards are only expected to worsen at the CEC site.

Overall Vulnerability

The analysis of the overall vulnerability of infrastructure consists of two components: exposure and sensitivity. Exposure is a function of location – in this case, whether the coal ash disposal site is located in an area experiencing the coastal hazard. The sensitivity component pertains to how a resource fares when exposed to a hazard.

Exposure

The exposure analysis uses mapped hazard data of four mapped exposure indicators (flooding, storm surge, erosion and sea-level rise). The exposure ranking is based on how many hazard zones the resource is situated in: low exposure (1 zone), moderate exposure (2-3 zones), and high exposure (4 zones). The buried ash in the unlined pits is exposed to each of the four coastal hazards evaluated, resulting in a high exposure ranking. Further, while the land surface on the peninsula is artificially higher than the surrounding landscape – as a result of the disposal of coal ash onsite – the lower elevations and shoreline of the peninsula are also exposed to all four hazards, thus ranking as high exposure.

Sensitivity

Because much of the roughly 2.1 million tons of coal ash is in unlined pits near or below sea level, the coal ash itself is highly sensitive (will not fare well) to the coastal hazards evaluated. In addition, flooding and storm surge can affect the groundwater system through increased connectivity between surface water and groundwater, compounding the potential impacts from these hazards. Further, over the long term, the subsurface hydrology will likely change as a result of continued sea-level rise. As more dense salt water intrudes, it will displace the (less dense) freshwater lens above. The freshwater lens on the peninsula will likely become shallower, and increasingly more coal ash near the surface will interact with groundwater. As sea level rises, the diffusion of contaminants into the groundwater system from the unlined coal ash ponds will likely increase.

Methodology

Western Carolina University's Program for the Study of Developed Shorelines initially developed the methodology used in this vulnerability assessment for the National Park Service to assess the vulnerability of park infrastructure threatened by coastal hazards and sea-level rise. To date, the methodology has been vetted and applied to infrastructure at 17 coastal national parks.

Site Background

The CEC is situated in Chesapeake, Virginia, on the banks of the Southern Branch of the Elizabeth River (SBER), Deep Creek, and adjacent to a former cooling water channel. Prior to Dominion's construction of the CEC power plant in the 1950s, the natural environment consisted of tidal marshes and wetlands, with a tidal range of approximately three feet. The plant at one time had four coal-fired power units, consuming roughly 4500 tons of coal a day. From the early 1950s to 1984, Dominion disposed of the coal ash generated from burning coal into unlined pits that, by 1965, extended from just south of the power plant to the tip of the peninsula (Figure 2, next page). Dominion estimates that these pits contain about 2.1 million tons of coal ash at varying depths. From 1984 through 2014 when Dominion stopped burning coal at the site, Dominion disposed of the coal ash in a lined ash landfill, built directly over a portion of the unlined pits (Figure 1, ash disposal mound). Bottom ash was sluiced into an unlined pond dug out of part of the original unlined pits. Dominion has estimated that these units contain roughly 1.2 million tons of coal ash.



Figure 1: Chesapeake Energy Center and surrounding area.

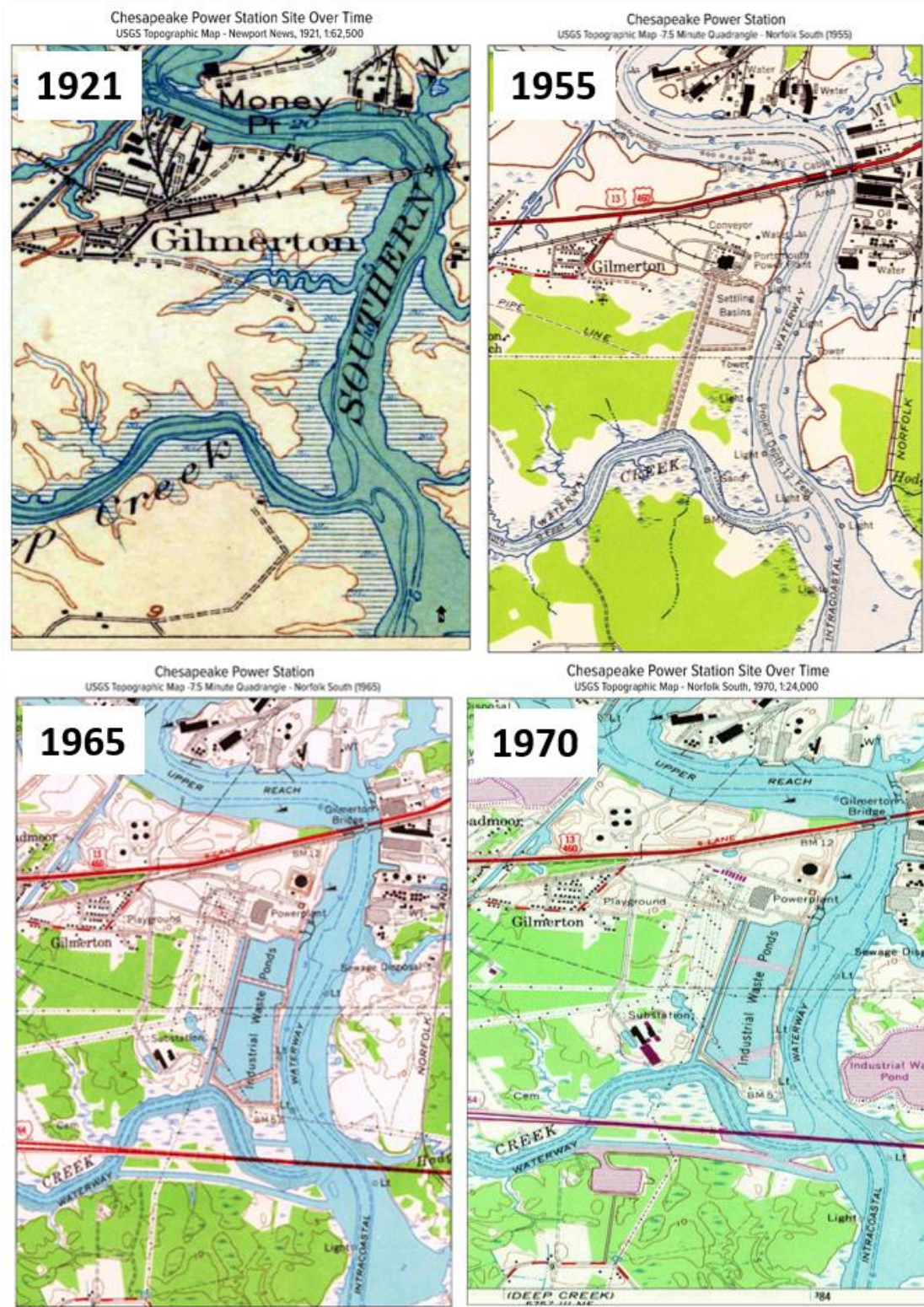


Figure 2: Topographic maps showing the evolution of the CEC site and peninsula. In 1921, the site was dominantly marsh and wetland. By 1955 settling basins were in place, now located beneath the present-day Columbia Gas site (Figure 1). By 1965, another industrial waste pond was in place, extending to the tip of the peninsula. This disposal pit is now largely covered by the ash disposal mound shown in Figure 1.



Figure 3: Elevation of the CEC and surrounding area. Data source: USGS 2013 LiDAR. The elevation of the entire peninsula is artificially higher than the surrounding wetland landscape.

Largely due to the long-term disposal of coal ash and fill onsite, the elevation of the peninsula is artificially higher than the surrounding natural landscape, which is primarily low-lying marsh (Figure 3). In fact, it is clear from historic maps (Figure 2) and LiDAR (Figure 3) that the entire peninsula consisted of low-lying marsh and wetlands, prior to the raising of the land surface through the disposal of coal ash. Today, at the northern end of the property, the land elevation is roughly nine feet or higher. The elevation of the southern peninsula is generally over 12 feet, particularly at the ash landfill mound, where the LiDAR elevation ranges from approximately 20 to 65 feet.

Defining Vulnerability

When assessing vulnerability within the built environment (buildings, structures, roads, etc.) there are two equally weighted metrics or components: exposure and sensitivity, which combine to make up the overall vulnerability (Figure 4, next page). Exposure refers to whether a resource or system is located in an area experiencing direct impacts of climate change, such as temperature and precipitation changes, or indirect impacts, such as sea-level rise. Sensitivity refers to how a resource or system fares when exposed to an impact. Therefore in order to determine overall vulnerability, separate analyses of exposure and sensitivity have been conducted.

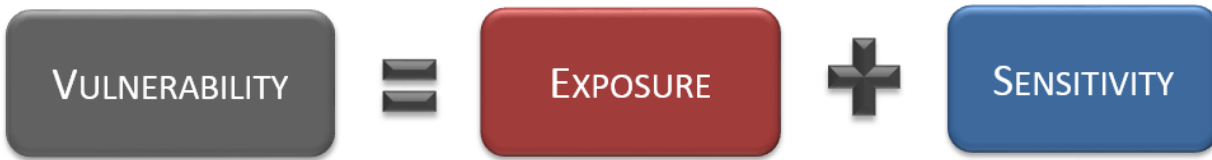


Figure 4: The metrics of vulnerability in assessing infrastructure: Exposure (a function of location), combined with sensitivity (how a system fares when exposed).

In this case, the peninsula's topography is artificially higher than the natural landscape, largely because of Dominion's long-term disposal of coal ash onsite. The buried ash in the unlined pits, however, lies at, near, and below sea level. Because much of the ash is buried in unlined pits, once a portion of it is exposed to a coastal hazard (e.g. storm surge) all of it is exposed due to the uninhibited connectivity of the subsurface hydrology. Thus, to provide a realistic assessment, the vulnerability of the buried ash to coastal hazards was evaluated as if no artificial modifications to the landscape were present.

Exposure Analysis

The exposure analysis utilizes data imported into Geographical Information Systems (GIS) format, as exposure is directly dependent on location (whether the area experiences the hazard) and mapped hazard data. The four coastal hazards evaluated at the CEC site are: 1) flood risk potential, 2) storm surge, 3) sea-level rise, and 4) coastal erosion. Each of these exposure data layers thus represents a single exposure indicator hazard zone. Exposure ranking was based on the number of exposure zones that affected the site: low exposure (1 zone), moderate exposure (2-3 zones), and high exposure (4-5 zones).

In this analysis, the unlined coal ash pits on the CEC peninsula were found to be highly exposed to all four coastal hazards (flood risk potential, storm surge, sea-level rise, and coastal erosion). It is also critical to realize that, despite the artificially elevated topography of the site, the areas on the flanks and lower elevations on the peninsula are in fact exposed to each hazard zone as well, putting buried coal ash (in places up to six feet below sea level) in direct contact with these hazards. The exposure analysis for each individual factor is explained in further detail below.

1. Flood Risk Potential

FEMA Flood Data

According to the latest FEMA flood maps of the region, the entire area surrounding the CEC site is within the AE flood zone (Figure 5, next page). The AE flood zone is the area with a 1% annual chance of flooding (referred to as the base floodplain). Properties within the AE zone are considered to have a high risk of flooding by the National Flood Insurance Program (NFIP). The peninsula itself, because of its artificially higher elevation, is elevated enough at the surface to be mostly within the X flood zone (outside the 0.2% annual chance). Properties within the X zone are typically considered to be at moderate risk of flooding by the NFIP.

However, the edges of the peninsula are in fact within the AE zone, where wave action could erode the edges of the landfill and buried ash, and flood waters could infiltrate the buried ash and interact with

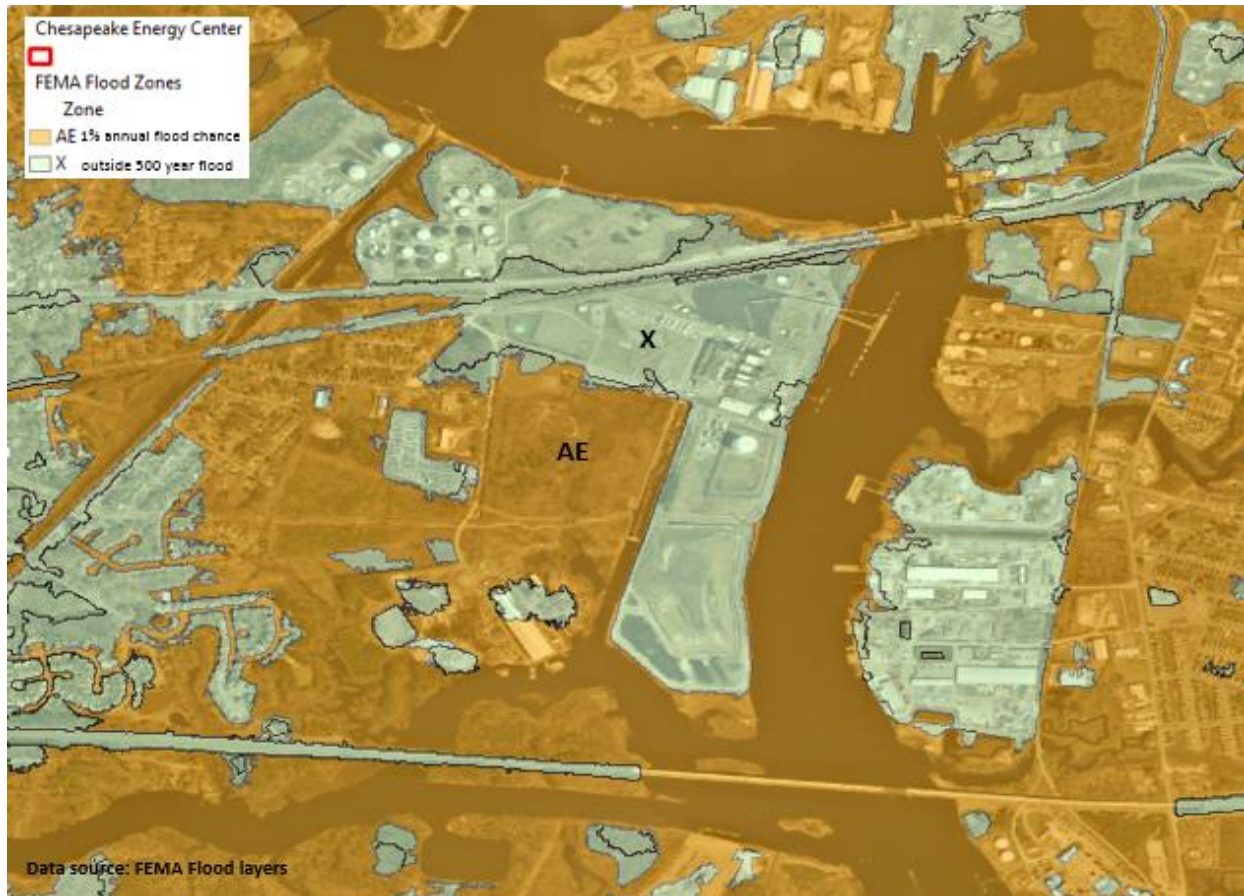


Figure 5: FEMA flood risk exposure. The perimeter of the CEC peninsula, including areas where ash is buried, is within the AE zone.

groundwater. Because the coal ash is buried in unlined pits, in some cases below sea level, the subsurface connectivity of the groundwater is uninhibited. Thus if buried ash at the edges of the peninsula is exposed to flooding (see areas mapped in the AE zone, Figure 5), the potential for water to seep into the buried ash is quite high. These factors are also considered later as part of the sensitivity analysis.

Historical flooding is another key predictor, simply because, if a site has flooded in the past, it is likely to be flooded in the future. While it is highly likely that the low-lying areas surrounding the CEC and the peninsula have been flooded in the past by storm surge and rainfall events, it was not possible to verify whether flooding has occurred on the site in the past. Therefore the flooding aspect of the exposure analysis focused solely on the FEMA maps, which are based on historical flood data.

2. Storm Surge

The CEC site and peninsula are at high exposure risk to storm surge during hurricanes. Figure 6 (next page) shows the SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model data produced by the National Oceanic and Atmospheric Administration (NOAA) for the CEC site and immediate vicinity. According to this model, a category 1 hurricane would inundate most of the area surrounding the site, including the edges of the peninsula where ash is buried (red). A category 2 surge would inundate the same areas, plus the areas to the west (orange). The surge from a category 3 or higher storm would be enough to inundate almost everything within the CEC site, except a few areas on the peninsula and the

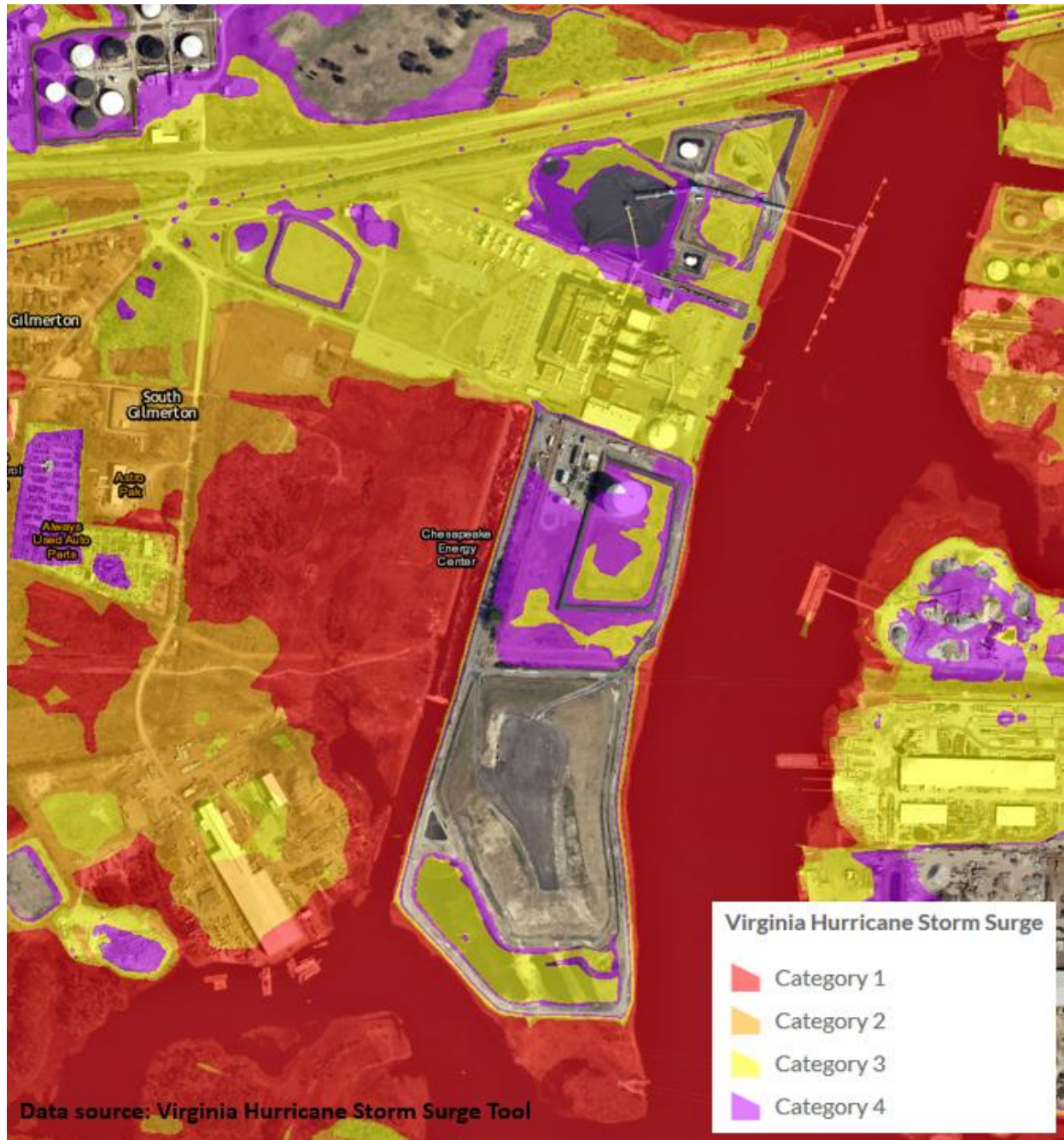


Figure 6: Hurricane storm surge exposure for the CEC site and peninsula. Most areas surrounding the site would be inundated with just a category 1 surge, and the site itself would largely be inundated by a category 3 or higher surge.

ash landfill mound itself. As with flood risk, any storm surge waters that come in contact with buried ash at the edges of the peninsula will easily infiltrate the ash buried in the unlined pits. The connectivity of the groundwater system is further considered below as part of the sensitivity analysis.

3. Sea-level rise

The tide gauge near Portsmouth (down river to the north) shows a long-term rise in sea level, currently rising at a rate of 3.76 mm/year. The rate of sea-level rise is expected to continue to accelerate, and at least 1 meter of rise is likely by the year 2100.

The series of six maps in Appendix A depict potential inundation in 1 foot increments due to sea-level rise. The site will experience increasing challenges as a result, including increased erosion and water infiltration along the edges of the peninsula where ash is buried. Because most of the areas surrounding the site are within a few feet of sea level, the CEC site will eventually become an island, after roughly 1.5 m of sea-level rise, cut off from the surrounding area. The very low elevations along the edges of the peninsula and in the surrounding land areas increase the likelihood of isolation of the site, and loss of access when inundated with floods or sea-level rise. With rising sea level, the site will become increasingly susceptible to the other three coastal hazards: flooding, storm surge, and erosion.

4. Coastal Erosion

Dominion has undertaken, and recently completed, shoreline stabilization projects on the peninsula. While such stabilization reduces sensitivity to erosion (how the system fares) it does nothing to reduce exposure to the hazard. The CEC site and peninsula are surrounded on three sides by water, and therefore the risk of coastal erosion will remain high, and increase with rising sea level. Erosion is likely to be highest along the eastern shoreline of the peninsula (west bank of the SBER, immediately north of the confluence with Deep Creek), where the tidal currents will be faster along the outside bend of the river channel. Over time and without further mitigation, coastal erosion will certainly have an increasing impact on the unlined coal ash pits increasingly exposing the ash to the environment. In addition, the steep edges of the ash landfill could experience slope instability issues (i.e., undercutting, collapse) as erosion on the coastline progresses.

Sensitivity analysis

Sensitivity refers to how a resource or system fares when exposed to a hazard. Dominion estimates that roughly 2.1 million tons of coal ash was placed in unlined pits on the peninsula, with a significant volume of ash situated below sea level. Thus, the ash will be highly sensitive (will not fare well) when exposed to coastal hazards, not only on the surface (flooding, storm surge, sea-level rise, erosion), but also when exposed to the compounding effects that those coastal hazards have on the groundwater system.

During storm surge and flood events, it is important to account for the impacts not only from inundation of the land surface, but also the increased connectivity and communication between the surface water and the groundwater system. Furthermore, over the long term, the subsurface hydrology of the site will also change with continued sea-level rise: as denser salt water intrudes, it will displace the freshwater lens laterally and upward on the peninsula. With rising sea level, the freshwater table on the peninsula will also rise, becoming shallower and exposing increasingly more coal ash near the surface to groundwater. As sea level rises, the diffusion of contaminants into the groundwater system from the unlined coal ash ponds will likely increase as well. Thus, the overall sensitivity of the buried coal ash is considered to be high.

Overall Vulnerability

In the built environment, overall vulnerability is determined by combining two equally weighted metrics or components: exposure and sensitivity. The exposure analysis of the CEC site and peninsula reveals high exposure to: 1) flood risk potential, 2) storm surge, 3) sea-level rise, and 4) coastal erosion. Sensitivity analysis of the CEC site indicates that the underlying, unlined coal ash pits are highly sensitive to these coastal hazards, especially when considering the interactions between the surface water and

groundwater systems. Based on this analysis, the coal ash pits underlying the peninsula are considered to be highly vulnerable to coastal hazards including sea-level rise.

Conclusions

To evaluate the vulnerability of the unlined coal ash pits, it is critical to consider the artificial modifications to the site topography, and the ease with which the coal ash in the unlined pits can interact with groundwater. The peninsula on which the CEC is situated has experienced dramatic modifications to its landscape since Dominion began burning coal there in the 1950s. The original landscape consisted of marsh and wetland environments, which were at or near sea level. These original wetlands were drained and subsequently filled in with the construction of two unlined coal ash disposal pits that extended to the tip of the peninsula. Over 60 years later, the ash remains buried in those unlined pits, beneath the present-day Columbia Gas property and the 65-foot high coal ash disposal mound at the southern end of the peninsula, where exchange with the natural groundwater system remains unimpeded.

Even prior to construction of the CEC site and unlined disposal pits in the 1950s, the entire peninsula would have been highly vulnerable. Today such a vulnerable site would not even be considered for industrial waste disposal. This analysis shows that the buried coal ash in unlined pits is highly vulnerable to coastal hazards and sea-level rise. With the changing climate in the coming decades, each of the hazards evaluated (flood risk, storm surge, sea-level rise, and coastal erosion) is only expected to worsen at the CEC site.

APPENDIX A:

Sea-level Rise Exposure Scenarios



Inundation due to sea-level rise in 1 foot increments (1 and 2 foot rise shown above). The current rate of sea-level rise recorded at the Portsmouth tide gauge is ~3mm/yr.



Inundation due to sea-level rise in 1 foot increments (3 and 4 foot rise shown above). The current rate of sea-level rise recorded at the Portsmouth tide gauge is ~3mm/yr.



Inundation due to sea-level rise in 1 foot increments (5 and 6 foot rise shown above). The current rate of sea-level rise recorded at the Portsmouth tide gauge is ~3mm/yr.