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# Langley Research Center Utility Risk from Future Climate Change

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## Abstract

The successful operation of NASA Langley Research Center (LaRC) depends on services provided by several public utility companies. These include Newport News Waterworks, Dominion Virginia Power, Virginia Natural Gas and Hampton Roads Sanitation District. LaRC's plan to respond to future climate change should take into account how these companies plan to avoid interruption of services while minimizing cost to the customers. This report summarizes our findings from publicly available documents on how each company plans to respond. This will form the basis for future planning for the Center. Our preliminary findings show that flooding and severe storms could interrupt service from the Waterworks and Sanitation District but the potential is low due to plans in place to address climate change on their system. Virginia Natural Gas supplies energy to produce steam but most current steam comes from the Hampton trash burning plant, thus interruption risk is low. Dominion Virginia Power does not address climate change impacts on their system in their public reports. The potential interruption risk is considered to be medium. The Hampton Roads Sanitation District is projecting a major upgrade of their system to mitigate clean water inflow and infiltration. This will reduce infiltration and avoid overloading the pump stations and treatment plants.

## I. Introduction

Climate change posts great risks to the infrastructure at NASA Langley Research Center (LaRC) and its operations. The center is located on the Back Bay a tributary of the Chesapeake Bay near Hampton, Virginia. The property consists of office space for 3400 employees (mostly during normal office hours), with special IT infrastructure, laboratories, and wind tunnel facilities that need to be maintained 24/7. Currently, the tenants are housed in 275 buildings spread over an 810 acre campus. The Center ViTAL plan [1] will reduce the building footprints and enable more energy efficient operations for the office complexes. However, operations to support the IT infrastructure and wind tunnels require high electric power usage for cooling and electric motor power respectively and thus drive up power demand.

The operation of NASA Langley Research Center (LaRC) depends on services provided by several public utility companies. The Center must take into account how our utility partners plan to mitigate the effect of climate change. The lack of planning will lead to interruption of service, while the cost for mitigation will likely be passed to the customers resulting in higher costs. Future climate change could interfere with one or more of the vital utilities serving the Center as shown in Figure 1 below. Being only 2-3 m above sea-level, the dominant climate change threat is sea-level rise coupled with storm surge from tropical storms and hurricanes. The Center was closed during Hurricanes Isabel and Irene. Stronger hurricanes are anticipated with future climate change.

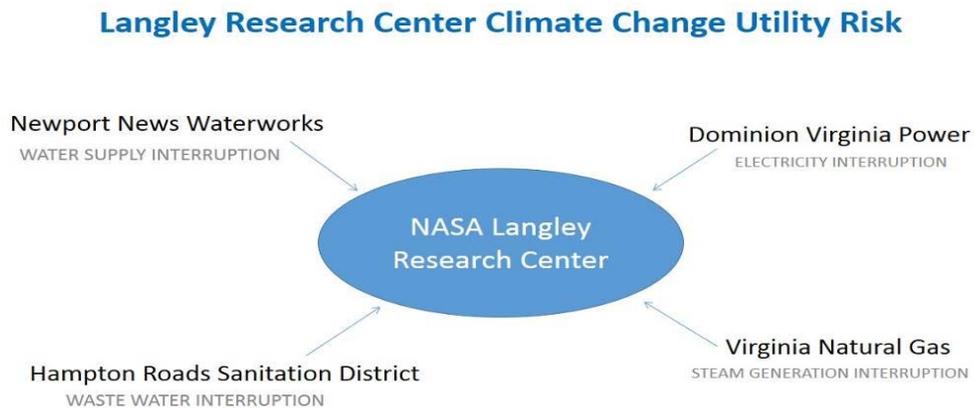


Fig 1. Utilities serving NASA Langley and their climate change potential risk.

The trends for usage at Langley are shown in Figure 2 for fiscal years 2009-2013. Here electric usage is given in million Watt-hours, natural gas in thousand cu-ft., water in Mega-gal, and sewage in Mega-gal. There was a factor of two decrease in natural gas use between 2010 and 2013 (see section IIc for the explanation). The other usages were relatively stable in the same time period. The corresponding cost of this usage is shown in Figure 3, where cost is given in million \$. Here the cost of electricity dominates all other utility cost by roughly a factor of 10. The combined cost of all the listed utilities was \$10.9 million in FY2013.

Section II in this report characterizes future climate change risks associated with the major utilities; namely, services provided by Newport News Waterworks, Dominion Virginia Power, Virginia Natural Gas and the Hampton Roads Sanitation District. In each case, we discuss Langley's future requirement relative to the suppliers' capacity. In addition information on climate change impacts for the utilities was

gathered using publically available sources and in some cases telephone conversations with knowledgeable utilities and NASA Langley Center Operations Directorate personal. While the risk of loss of service from any of these utilities varies considerably, any loss of service longer than a few days would shut down center operations, with the most abrupt termination associated with loss in electric power.

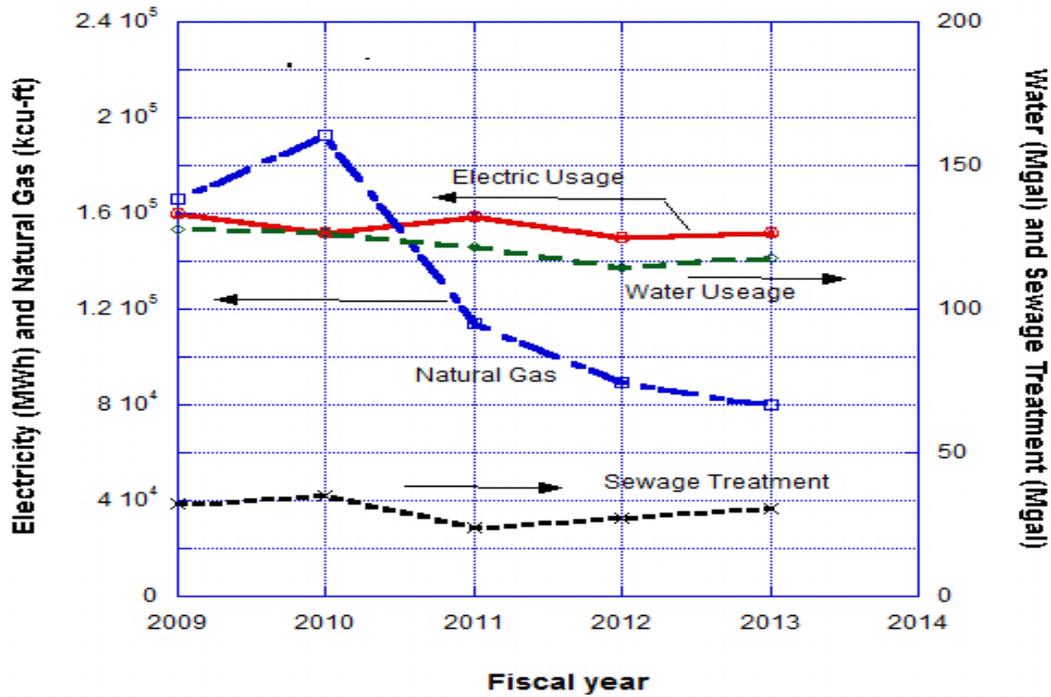


Fig. 2 Electricity, water, natural gas and sewage treatment Langley usage vs fiscal year.

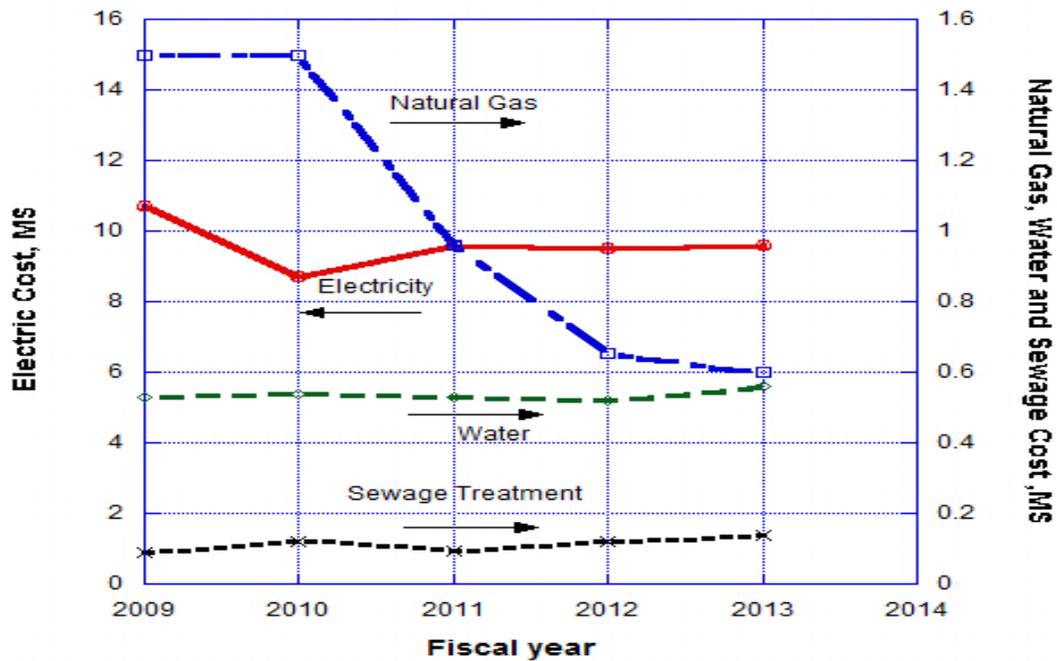


Fig. 3. Electricity, water, natural gas and sewage treatment Langley cost vs fiscal year.

## II. Findings for the various utilities

### A. Newport News Waterworks

#### (i) Langley's requirement relative to the utility's capacity

Water is supplied by the Newport News Waterworks (Waterworks), a municipally owned system, which provided approximately 35 million gallons of water per day in 2013 and served drinking water to more than 415,000 people. Its customers include eight Federal installations- including NASA Langley [2]. For comparison, LaRC consumed ~115 Mega-Gal of water in 2013.

Figure 4 shows the service area for the Waterworks and the associated water reservoirs that are in a coastal plain with average elevation < 10 meters. In recent years there has been a decrease in water demand and the Waterworks predicts the demand will further decrease by about 4% per year for the foreseeable future. This has raised the issue of maintaining financial sustainability, has resulted in water charge increases, and evoked a move to incrementally change water fees from volumetric to fixed charges. Even with these constraints the Waterworks has committed to a six year Capital Improvement Program (FY 2011-2016) at a cost of \$65.8 million. Some of this program will address climate change risk.

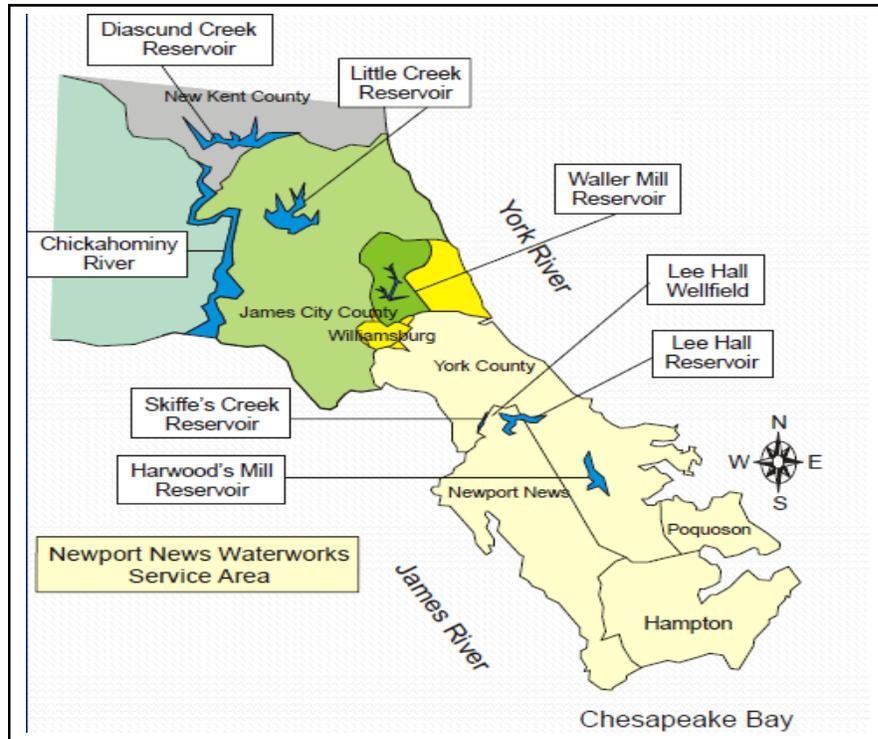


Fig. 4 The area served by Newport News Waterworks and associated water reservoirs.

***(ii) Mitigation plan by the utility company***

The Waterworks Report to the Community document [2] contains a section entitled, “Adapting to a Changing World, Climate Change Preparedness”, which discusses the specific impacts climate change will have on Waterworks operations in the future. Waterworks stresses the importance of preparing today for the potential impacts of climate change. It is noteworthy that they have used Langley climate research to plan for future risk. The following is an excerpt from the Waterworks Report to the Community:

“In addition to the Hampton Roads Planning District Commission, the NASA Langley Research Center (NASA LARC) in Hampton has been an excellent source of climate change research. In conjunction with the Goddard Institute for Space Studies (GISS), NASA LARC used 16 global climate models with multiple emission scenarios to estimate future climate conditions in Hampton Roads. The NASA-GISS studies generally confirm work published by the US Environmental Protection Agency (EPA) and others that predict changes for the Mid-Atlantic region during the coming century, including:

- 1 to 5 degrees of warming,
- Longer periods of seasonal high temperatures,
- Increases in average annual precipitation, and
- Up to 50 inches of sea-level rise, and an increase in threshold level climate events (flood and drought).

Waterworks’ staff have used these specific regional predictions to examine potential impacts to the water resources, finished water quality, and delivery reliability of our system.”

It is encouraging to see this level of concern for the impacts of climate change, which will minimize these impacts as a result. Several impacts have been identified. The Waterworks public water-supply intake is located upstream of Walkers Dam, a tidal-barrier dam on the Chickahominy River estuary. The quantity and quality of water available for withdrawal from this location are dependent on climate variability, which can cause changes in river flow and salinity levels. About 30 to 70 percent of the region's drinking-water supply originates from the lake at Walkers Dam. A consequence of reduced freshwater flows during droughts is increased salinity levels in the estuary. Historical water-quality data confirm that when freshwater flow is diminished in the James and Chickahominy Rivers, saline water moves upstream to Walkers Dam. Therefore, any increase in the occurrence or duration of salinity at the location of the intake could affect the safety of the water system. A U.S. Geological Survey study [3] that modeled the salinity impact of sea level rise on the reservoir found that, due to sea-level rise, brackish water could reach Walker's Dam at much higher frequency than historically observed. To mitigate this, the Waterworks is considering raising the water height in Chickahominy Lake when brackish water is present downstream.

Other climate change impacts include shifts in precipitation patterns with more frequent and intense extreme weather events. This makes it increasingly difficult to manage flood events and results in increased erosion and longer droughts impacting water availability. To mitigate this, spillways are being upgraded to pass maximum flood events and desalting plants and deep wells have been added to mitigate long droughts [1].

A valuable resource for drinking and waste water utilities is the Climate Resilience Evaluation and Awareness Tool (CREAT), developed under EPA's Climate Ready Water Utilities initiative [4]. Utility owners and operators can assess risks to utility assets and operations. Extreme weather events, sea-level rise, shifting precipitation patterns, and temperature changes will affect water quality and availability. Version 2.0 of CREAT provides access to the most current scientific understanding of climate change, including downscaled climate model projections that will increase user awareness of projected changes in climate, related impacts, and potential adaptation options. It has a flexible and customizable risk assessment framework that organizes available climate data and guides users through a process of identifying threats, vulnerable assets, and adaptation options to help reduce risk. CREAT supports utilities in considering impacts at multiple locations, assessing multiple climate scenarios, and documenting the implications of adaptation strategies on energy use. CREAT also encourages users to compare the performance of adaptation options in multiple time periods across climate scenarios.

### ***(iii) Initial Assessment***

The Waterworks has integrated climate change into their future planning based on local science data and thus should be able to mitigate and adapt to most potential climate risk. The termination of service to Langley as a result of climate change is considered to be of low risk.

## **B. Dominion Virginia Power**

### ***(i) Langley's requirement relative to the utility's capacity***

Langley in 2013 consumed 150,000 MWh of electricity at typically 20 MW daytime demand. There are two 110 kV transmission lines coming into the Langley Stratton substation being fed from the Virginia Power Peninsula substation. The two transmission lines are in parallel at the Stratton substation. There are very few diesel power generators (except for the Langley data center) on Langley; thus, if power was terminated the Center would immediately shut down. The Center has a fixed peak kW demand level of 24 MW during the first and second shifts, after which costs increase on energy consumed above the 24 MW

level. Most of the power distribution system on center is underground and thus robust against hurricane winds and trees falling into power lines. The Center power load has decreased over time. The existing grid at the Center has some head room to accommodate added demands with climate change impacts.

Dominion Virginia Power (DVP) is one of three business entities under the parent company called Dominion Resources Incorporated. DVP operates electric transmission and distribution franchises in both Virginia and North Carolina, providing electric service to 2.5 million customers including NASA Langley. The Dominion Energy entity operates in six states with large natural gas storage, transmission and distribution systems. It also has a liquefied natural gas terminal in Maryland. The Dominion Generation entity operates electric generation stations that serve its electric utility franchises, accounting for approximately 23,600 MW of electric generation capacity. DVP also recognizes the advantage of underground distribution lines and has implemented a program to increase underground distribution by another 4000 miles costing \$2 billion over the next 10 years.

*(ii) Mitigation plan by the utility company*

Dominion Virginia Power recognizes the reality of climate change and its impact on their system, but according to their documents, the company is more concerned with reducing carbon emissions to comply with the increased government regulation of greenhouse gases [5][6][7]. They emit one-third less carbon per unit of energy than the median of the nation's 100 largest power producers.

Since we did not find any information on how DVP addresses climate change adaptation for electrical utility, we turn to The American Society of Civil Engineers (ASCE) for further information. The ASCE gave the overall U.S. energy infrastructure a grade of D+ in its 2013 assessment where they stated:

“Aging equipment has resulted in an increasing number of intermittent power disruptions, as well as vulnerability to cyber-attacks. Significant power outages have risen from 76 in 2007 to 307 in 2011. Many transmission and distribution system outages have been attributed to system operations failures, although weather-related events have been the main cause of major electrical outages in the United States in the years 2007 to 2012. While 2011 had more weather-related events that disrupted power, overall there was a slightly improved performance from the previous years. Reliability issues are also emerging due to the complex process of rotating in new energy sources and “retiring” older infrastructure.” [8].

These comments suggest that the electric transmission and distribution infrastructure may experience additional stress as climate change progresses. Climate change impacts can be summarized as:

- Limited transmission and distribution capacity due to temperature
- Decreased substation efficiency due to temperature
- Decreased peak generating capacity due to temperature
- Substation flooding due to storms/sea level rise
- Increased frequency of power outage due to severe storms
- Increased summer peak electricity demand due to temperature

A summary of climate impacts on the US electric energy sector can be found in the following references [9][10][11].

In coastal Virginia higher sea levels increase the risk of flooding from storm surge associated with hurricanes and coastal storms, such as Hurricane Sandy when more than 8 million customers lost power across 21 states. The electric infrastructure along the coast including substations, transmission and distribution lines, and transformers are at greater risk of flooding from climate change. The power generation requires large amounts of water to condense steam into water in thermal generation plants. In a

warming climate the power station input water temperature may become too high and thus reduce the generation efficiency when electric demand is at its peak. Van Vliet et al. projected that for the summers of the 2040's a Virginia power station capacity would be reduced by -5 to -1 percent relative to the period 1971 to 2000 [12].

A transformer's peak load capacity depends on the ambient air temperature at the time of peak system load and the internal transformer hot spot conductor temperature, which in turn reduces the peak load capacity of the bank of transformers. Li et al. [13] report a decreased transformer capacity of ~0.7 percent per 1 degree C of increased ambient temperature. Likewise, higher ambient temperatures will impact transmission and distribution lines. The higher ambient temperatures increase the resistance of transmission lines and thus require greater generation capacity to compensate for this loss. This effect may be small compared to the effect of ambient temperature on transmission line heat transfer. A study for the California Energy Commission [14] determined that a transmission line capacity would decrease by ~7.5 percent for transmission line temperature held constant at 80 degrees C and wind speed of 2 ft/sec when the ambient temperature increased from 38 to 43 degrees C. This results in a dramatic capacity loss when air temperature increases by 5 degrees C and load demand is at its peak. Attempts would be made to reroute saturated transmission lines to reduce damage risk, but it could also result in temporary voltage reductions or rotating load drops.

To be cost efficient, the Power Company must right-size its generation capacity to make maximum use in the high demand summer months and minimize the unused capacity in the winter months. Figure 5 shows the Dominion Virginia Power monthly MW-h energy sales for years 1990 to 2013. The peak energy sales occur in July and the minimum sales occur in April. With warmer winters this minimum may shift to earlier months. Figure 6 plots the yearly maximum and minimum energy for the months of July and April from 1990 to 2013. Also the percent difference is plotted for the same period. Both curves show an increasing slope indicating the growth in demands with the growth in population. However, there is a slope difference between the maximum and minimum linear trend line and the difference also shows a positive slope with year. This is indicative of how climate change will affect power consumption as winters become more temperate and summers become hotter. Figure 7 extends the trend line out to 2100, which results in a maximum/minimum difference of 45 percent for 2100. This means that there is significant unused capacity during the winter months but very high capacity used during summer months. Thus additional generation capacity or efficiency offsets will be needed to cover the combined effects of increased air conditioning demand and decreased generation and transmission efficiency in the hottest summer months. The lack of such capacity could impact Langley's operations.

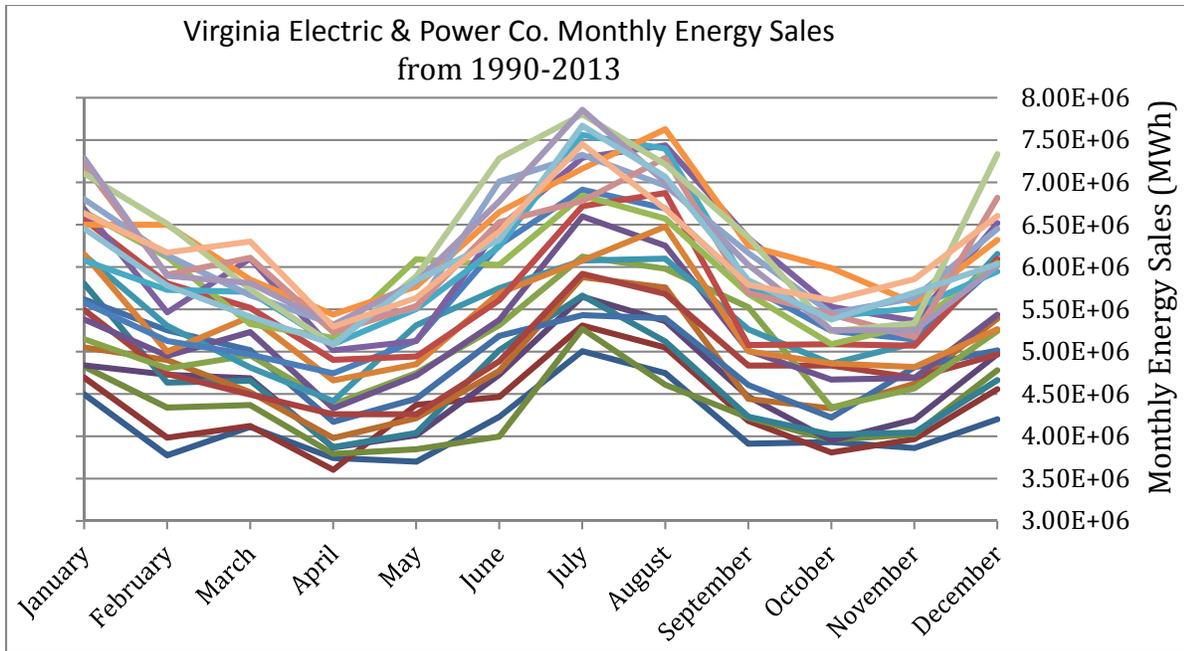


Fig. 5. Dominion Virginia Power monthly electric energy sales for years 1990 to 2013.

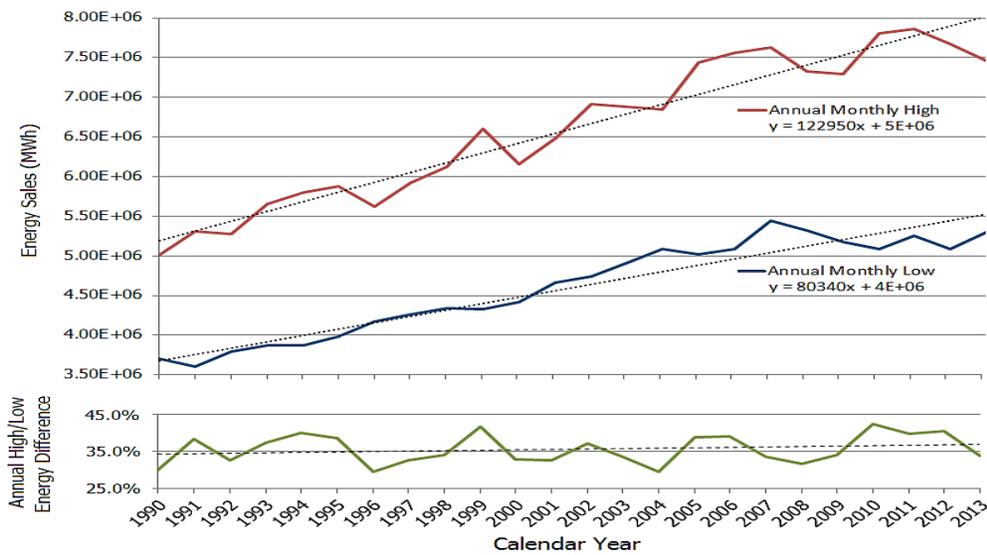


Fig. 6. Dominion Virginia Power yearly peak (July) and low (April) energy sales from 1990 to 2013. The annual high/low difference in percent for 1990 to 2013.

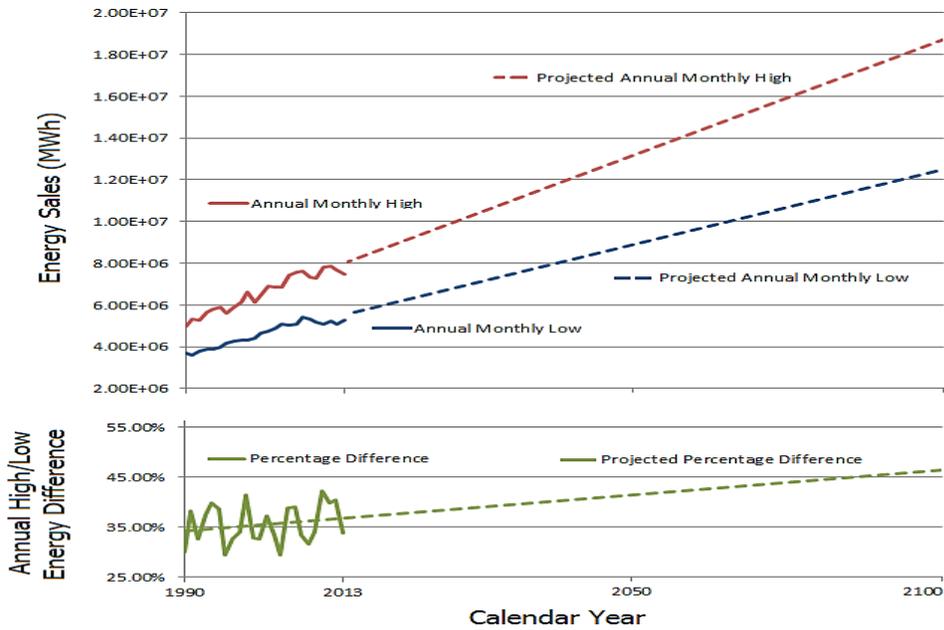


Fig. 7. Dominion Virginia Power linear electric energy trend from 2013 to 2100 and high/ low annual difference in percent. Actual energy sales from 1990 to 2013.

***(iii) Initial Assessment***

Dominion Virginia Power recognizes the potential impact of climate change but instead are focused on the regulation of carbon emissions in the future. The most dire climate impacts are regulated to emergency weather disruptions such as hurricanes, storms or other weather events. Unlike weather events, climate change will affect the electric load distribution, increasing in the summer and decreasing in the winter. The summer climate impact will act as an increased load to the system currently not accounted for. The construction of new power generation plants takes considerable time so there is the potential that toward the end of the century adequate generation may not be available in the summer months. Thus there is moderate risk that Langley could experience a power interruption during peak load summer months.

**C. Virginia Natural Gas**

***(i) Langley’s requirement relative to the utility’s capacity***

Natural gas is supplied to Langley to heat boilers, producing steam for building heating and cooling or steam ejectors for evacuating vacuum spheres to run wind tunnels. Steam can be produced by the Langley Steam Plant (by natural gas or oil backup) but typically the Hampton/Langley trash burning plant provides the majority of steam used on center. Natural gas usage has been reduced on center due to more efficient management of steam coming from the trash plant and by alleviating the requirements for the Steam Plant to be online during steam ejector use. Natural gas is piped to the Center and all lines are underground. Virginia Natural Gas maintains ownership and maintenance of the pipelines on center up to the building gas meter.

***(ii) Mitigation plan by the utility company***

Natural gas pipelines are all underground and thus climate and weather do not impact them unless there is an earthquake or digging fracture. There is an indirect climate change impact on natural gas utility. There has been a major increase in the preferential use of natural gas over coal for power production, which is now the largest user due to the incorporation of hydraulic fracturing. This technology has allowed gas to be extracted from shale gas wells, resulting in lower cost of natural gas. It is estimated that the U.S. has about 91 years of conventional and unconventional natural gas left as of 2011, if usage remains at 2011 levels [15]. Thus, this energy source is limited and as climate change increases summer heat, this energy source will be depleted even more quickly.

The production, processing, transmission and distribution of natural gas also has climate change impacts in that methane leakage can occur at any of these stages. Methane as a greenhouse gas is 102 times more potent than carbon dioxide (pound for pound) when leaked into the atmosphere and even after 100 years is 25 times (12 year lifetime) more potent than carbon dioxide.

***(iii) Initial Assessment***

Due to the limited supply (thus increasing cost) of natural gas and the harmful effect of methane release, Langley may be required to seek other more beneficial energy sources to generate steam, such as the trash plant or abandon steam use altogether. Interruption of service is considered low.

**D. Hampton Roads Sanitation District**

***(i) Langley's requirement relative to the utility's capacity***

The Hampton Roads Sanitation District (HRSD) was created in 1940, when at that time some 30 million gallons of raw sewage was dumped into the area waters. Currently the HRSD serves 17 counties and cities with 1.6 million customers, including NASA Langley. The HRSD operates 9 treatment plants (4 smaller plants in the middle Peninsula) as shown in figure 8. These plants have the capacity to treat 231 million gallons of sewage per day. Sewage from Langley is pumped to the York River plant for treatment.

The flow of sewage to the HRSD is metered at building 1223B and typically measures between 30-50,000 g/day. Langley operates under a HRSD issued wastewater treatment permit which allows up to 75,000 g/day (calendar month average) and a calendar day maximum of 106,000 gallons without a surcharge, but with heavy rains inflow and infiltration can occur which has resulted in as much as 180,000 g/day to be recorded. Raw sewage is pumped off Center to the HRSD York River Treatment Plant where it flows through a screen that removes large floating objects such as trash, sticks and rags. The wastewater then typically flows to a grit chamber and sedimentation tank which allows sand, coffee grounds, egg shells, small stones, human and animal waste solids and other small particles to settle to the bottom. Secondary treatment facilities allow microorganisms (bacteria and other organisms) to remove 80-90 percent of human, animal and plant waste. An activated sludge process speeds up the work of the microorganisms by bringing air and sludge into close contact with the wastewater in an aeration tank. Over several hours, the organic matter is broken down into harmless by-products and then flows to another sedimentation tank to settle out any excess microorganisms. Additional wastewater treatment processes are required to remove nutrient pollutants, such as the nitrogen and phosphorus. The final step of treatment is disinfection, usually with chlorine. Chlorination will kill more than 99 percent of harmful bacteria. The treated flow is then released to the York River.

*(ii) Mitigation plan by the utility company*

A report entitled, “Water/Wastewater Utilities and Extreme Climate and Weather Events: Case Studies on Community Response, Lessons Learned, Adaptation, and Planning Needs for the Future” [16] addresses the climate impacts on water and wastewater systems in the Hampton Roads region (Appendix H). The report summarizes the area water utilities and outlines major “lessons learned” for mitigating flood and other climate risks.

A major issue for the HRSD is infiltration, which is water entering the wastewater system from sources such as defective or cracked pipes, defective joints and connections, defective manhole walls, and other similar ground water leaks into the collection system pipes. Water can also enter the wastewater system from roof drains, basement drains, yard and area drains, direct connection from storm drains, flow through manhole covers, and other sources directly connecting storm water flow to the wastewater collection system. This additional water burden can overwhelm the treatment plant and potentially allow untreated water to enter local water bodies, causing health risk for humans and the environment.

NASA awarded a significant contract to correct inflow and infiltration issues at LaRC. The official Notice to Proceed with sanitary improvements was issued on July 15, 2013, and construction was completed in October 2014. The total cost of this project was \$1.5 million dollars. Numerous other sanitary sewer system repairs and upgrades were completed including cutting and capping abandoned lines, repairing and resealing the sanitary overflow tank at the pumping station, removing and replacing 2,275 linear feet of terracotta and vitrified clay lines with PVC pipe, and repairing the boiler blow down pit to keep rainwater out. Outside of the work described above that was required for compliance, NASA was able to secure an additional \$1.5 million in funding for a Phase II sanitary improvement project. This work is nearly complete, and NASA has spent \$1.25 million on improvements thus far. The following is a brief summary of completed repairs and projects:

- The remaining ninety (90) manholes on Center received new internal seals and inflow dishes.
- The main lift station (Building 1223) was hardened with an earthen berm and other high water protection measures.
- A CBM device was installed on the main sewage pump in Building 1223.
- Twelve (12) flow meters were strategically installed across the Center’s sanitary network. These flow meters are Hach/Marsh-McBirney FLO-DAR area/velocity (AV) radar flow meter sensors. These meters combine advanced digital Doppler radar velocity sensing technology with ultrasonic pulse echo depth sensing to remotely measure open channel flows.
- Twelve (12) corresponding flow meter stations were installed for permanent data logging and tracking.
- NASA is currently interfacing these flow meter stations with LaRC’s wireless network for centralized data collection.

Sea-level rise and subsidence may put the HRSD treatment plants at flood risk as most of the plants are located near bodies of water to which treated water is released. The HRSD, in cooperation with the Hampton Roads Planning District Commission, will establish flood risk for its coastal treatment plants. Also the HRSD has reached an agreement with the U.S. Environmental Protection Agency (EPA) regarding a plan to minimize sewer overflows in the region [17]. The Regional Wet Weather Management Plan, which has been underway since 2007 and will be completed in 2017, is a requirement of the EPA. The plan development is estimated to cost the region approximately \$100 million. The forthcoming infrastructure improvements as a result of the plans implementation will cost significantly more (\$2-4 billion) over the next several decades. These improvements will substantially reduce the risk of storm water infiltration and thus protect the sewage treatment capacity of HRSD into the future.

Increased average temperature due to climate change may benefit the HRSD as the waste water chemical treatment process is accelerated in warmer weather. The major climate change impacts are flooding of treatment plants and infiltration into the system from severe storms. These impacts could be short in duration if the Wet Weather Management Plan has the desired effect of substantially reducing infiltration.

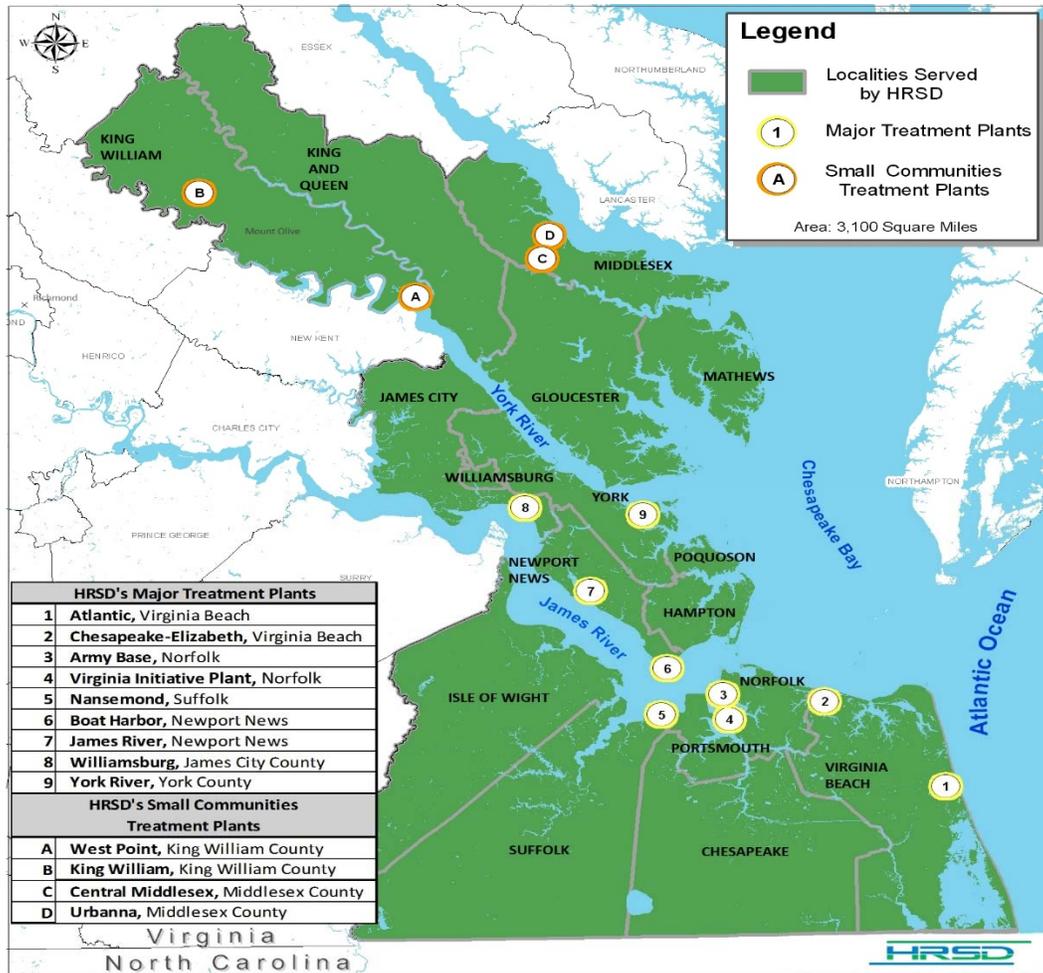


Fig. 8. The area served by the HRSD including treatment plants.

**(iii) Initial Assessment**

The Hampton Roads Sanitation District has a climate risk from severe storms causing water to infiltrate their system potentially shutting down the treatment plants. They have addressed this risk by implementing a Regional Wet Weather Management Plan. With this plan in place the risk to Langley will be low.

**III. Summary and Conclusions**

Climate change will not only affect Langley operations directly but also the utility partners that serve Langley. Future climate change impacts including sea-level rise, severe storms, more intense hurricanes,

higher summer temperatures and increased precipitation will all affect Langley utility partners very differently. Some utility disruption of service can be managed but the disruption of electric service will have the immediate impact of closing the Center. The major utilities studied here include Newport News Waterworks, Dominion Virginia Power, Virginia Natural Gas and Hampton Roads Sanitation District.

Newport News Waterworks has aggressively addressed future impacts of climate change on their system. They are raising their pump stations, raising the reservoir dam height to reduce infiltration from salt water and have used realistic estimates of future climate change as inputs to system models that will allow them to proactively adapt to future climate impacts. Because of this proactive stance, the risk to Langley from clean water disruption from climate change is low.

Dominion Virginia Power, in their public documents, have not directly addressed climate change impacts on their system. Their concern regarding climate change is the regulatory burden of adjusting to caps on carbon dioxide emissions that may be imposed by the Environmental Protection Agency and the temporary disruption of service due to severe storms. Dominion has future load projection models that estimate electric demand into the future but these projections do not include a climate impact load addition. Thus they could underestimate future electric demand. Climate change would lower thermal power plant efficiency and lower transmission line capability, resulting in increased power production to compensate for such power losses. In the peak demand summer months, rolling blackouts could be required thus potentially closing Langley Research Center. Because climate change impacts are not considered by DVP, the risk of power interruption especially in the summer months is a medium risk. This may require Langley to add independent electric generation capacity to critical research facilities in order to compensate for the potential loss of power [18].

Virginia Natural Gas supplies natural gas for steam production but is used primarily as a backup to the Hampton/Langley trash burning plant, which is used for the primary production of steam. While climate change impacts on the Virginia Natural Gas system appear to be minimal, there is however a desire to reduce Langley's carbon footprint, and finding alternatives to natural gas would lower this footprint. The climate change risk from Virginia Natural Gas is low.

Hampton Roads Sanitation District removes raw sewage from the center and is the only means of sewage treatment. While the center could still operate if this service were interrupted, extended outage would require portable devices to be installed on the Center. Long term interruption could result from large hurricanes or extended precipitation infiltrating the system thus overloading the treatment plants and pump stations. The implementation of the Regional Wet Weather Management Plan mandated by the EPA will mitigate risks to HRSD from climate change. Assuming this plan is fully implemented, the risk to the center from HRSD interruption is low.

## Acknowledgment

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<b>14. ABSTRACT</b>  Climate change will not only affect NASA Langley but also the utilities that serve Langley potentially interrupting center operations. This report studies potential climate change impacts of Newport News Waterworks, Dominion Virginia Power, Virginia Natural Gas and Hampton Roads Sanitation District. Flooding and severe storms could interrupt service from the Waterworks and Sanitation District but the potential is low due to plans in place to address climate change on their system. Virginia Natural Gas supplies energy to produce steam but most current steam comes from the Hampton trash burning plant thus interruption risk is low. Dominion Virginia Power in their public reports do not address climate change impacts on their system which could underestimate future electric loads especially during summer heat waves. Then the potential interruption risk could be medium to high. The Hampton Roads Sanitation District is projecting a major upgrade of their system to mitigate clean water infiltration. This will reduce infiltration and thus not overload the pump stations and treatment plants thus the climate change risk is low.					
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