

A Survey of Sustainable Water Supplies in Virginia's Lower Peninsula *Alternatives to the King William Reservoir Project*

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Prompted by a recent federal court ruling, the U.S. Army Corps of Engineers has suspended the permit for the King William Reservoir project. The project was originally conceived as a means of meeting future drinking water demand for Virginia's Lower Peninsula. As a result of the ruling, alternatives to the reservoir are once again on the forefront of water demand discussion. The need to build the reservoir has been based on information produced by Newport News Waterworks (NNWW) and US Army Corps of Engineers (USACE). The Regional Raw Water Study Group prepared a regional supply, demand and safe yield forecast as part of its 1997 Final Environmental Impact Statement (FEIS). The FEIS projected that the region's water demand would increase from 55.21 MGD in 1990 to 67.72 MGD in 2000, 80.03 MGD in 2010, and 98.22 MGD in 2040. More recent analyses have shown that the NNWW's and USACE's regional water needs predictions were grossly overestimated, undermining the necessity for the acquisition of a large water reserve (Siegel 2003). A review of actual water sales by Newport News Waterworks between 1990 and 2007 indicate that water sales by the utility have remained generally stable, showing a slight decline over that time period (Siegel 2008; Phillips 2008). NNWW had water sales of 45.7 million gallons per day (MGD) in 1990 and had projected sales to increase to 61.2 MGD by 2010. NNWW now estimates FY 2009 sales will be 42.9 MGD (*Daily Press*, 4/10/2009).

The RRWSG Draft Environmental Impact Statement (DEIS) in 1994 analyzed 31 water supply alternatives that included groundwater desalination, river desalination, wastewater reuse for potable and non-potable water, and use restrictions. Many of these alternatives are practiced in other states, as well as around the world, and are appropriate and applicable to the Lower Peninsula to meet the realistic growth in demand. Revisiting the applicability of conservation efforts and desalination and investigating the latest technologies in these fields could satisfy the future water needs of NNWW's service area.

The following options are available to meet the future potable and nonpotable water demand of Virginia's Lower Peninsula:

- Adopt low impact development practices
- Retrofit appliances and irrigation systems
- Reclaim wastewater sourced from Hampton Roads Sanitation District
- Isolate the use of potable water to potable demands
- Update water conservation rate structures
- Improve drought management strategies
- Pursue seawater desalination
- Utilize carbon nanotube membrane technology
- Invest in renewable wind and solar energy for powering desalination
- Acquire Big Bethel Reservoir and Jones Pond from military
- Purchase surplus waters

- Increase height of some reservoirs
- Utilize higher percentage draw down relative to storage capacity of current reservoirs

Water Efficiency and Conservation Measures

Water efficiency and conservation measures, also known as demand management, utilize water for everyday needs without wasting it. Efficiency is the key component of demand management; by decreasing water waste and increasing efficiency, communities can maximize their usage of known water sources. A water conservation program is directed by quantifiable best management practices, but methods of demand management are diverse and can be applied piecemeal or holistically to best suit the specific needs of a community. Water reuse, water efficient appliances and technology, water banking, low impact development practices, and water conservation rate structures all reduce the pressures on local drinking water supply while keeping costs down and encouraging economic growth. Public understanding and participation is also a critical factor not to be overlooked in developing an effective water management plan. In the case of Virginia's Lower Peninsula, analysis, promotion, and implementation of these alternatives are the first steps toward meeting current and future drinking water demand. Newport News Waterworks, the area's principal water purveyor, currently serves about 400,000 customers in the City of Newport News, the City of Poquoson, James City County, York County, and the City of Hampton (Newport News, Virginia). As this area looks to grow its economy through new development and new industries, water efficiency and conservation can meet much of current and future demand.

Water efficiency measures adopted by the federal government including reduced flow showerheads, faucets, toilets as well as more efficient washing machines are not only being utilized in new construction but in existing buildings as properties are renovated. These efficiency measures would appear to have already had a dramatic effect on water demand within the Newport News Waterworks Service area. Between 1990 and 2007, customers served increased from about 340,000 to about 400,000 at the same time that water sales were stable and actually declined slightly from 45.7 MGD in 1990 to 43.5 MGD in 2007, as reported by the *Daily Press*, April 10, 2009.

Considering that principal uses of municipal water are residential, water conservation is heavily dependent on the support and cooperation of the public. Reductions in residential water use occur proportionately with adequate public education, outreach, and enforcement, according to a 2006 Virginia Tech Water Resource Research Center study. Incidentally, the desire for conservation is already present within half of the communities serviced by Newport News Water Works. In a survey of 379 York County, City of Williamsburg, and James City County households conducted by the William and Mary Sociology Department, over ninety percent (91.6% exactly) of respondents agreed that "residents and businesses should follow tight guidelines" pertaining to nonpotable water usage. Additionally, 89.5% agreed that "developers and homeowners should be required to do landscaping that requires little or no watering." Residents are aware of the water supply issues in the Lower Peninsula, which is half the battle. The next step is mitigating concerns through education regarding household changes that conserve water. An effective water management plan will capitalize on established organizations like the Hampton Roads Water Efficiency Team to expand public relations and media outreach programs. By providing an understanding of the issues, individuals are able to make and support water-saving choices knowing the importance of their effect for the community's future growth and wellbeing.

Appliance Retrofitting

Appliance retrofitting is the term used to describe the process of replacing toilets, faucets, washing machines and showerheads with modern, water efficient ones. Mitigation programs, which are often coupled with water banking, require developers to utilize the most water efficient appliances in the homes or buildings they are proposing to construct and/or to pay a fee towards a fund that will be used to retrofit older appliances with new technologies. Both water banking and demand mitigation programs have been successfully implemented in several cases in Massachusetts, where water saving for one town has been as much as 1.2 MGD and annual funds have exceeded \$200,000 for retrofit initiatives (Ipswich Watershed Association). The impact of retrofitting cannot be overemphasized. A study in California revealed that retrofitting a three-bedroom home with low-flow appliances (showerhead, bathroom faucet, kitchen faucet, and toilets) reduced demand for potable water by 10,500 gallons/year (Dunning 2009). Simplistically, applying the same numbers to the approximately 400,000 NNWW customers would equal a savings of 4,200,000,000 gallons per year (11.51 MGD) from similar retrofits. The King William Reservoir project was planned to provide 23.0 MGD to meet drinking water demand (Siegel 2003). However, only 19.0 MGD would specifically serve the Lower Peninsula; the other 4.0 MGD is slated for New Kent and King William Counties (US ACE 2005). Sourcing an extra 19.0 MGD per year simply by conserving water is a very real possibility for NNWW customers. The service area-wide retrofit discussed above, without augmentation from a single other conservation strategy, would provide 11.5 MGD and meet 60.5% of the projected potable water supplied to Lower Peninsula by a new reservoir. That means that the amount of water used in nearly eight months could be saved if every home in the Lower Peninsula installed cheap, efficient water-saving technologies. Reduced Newport News Waterworks water sales experienced over the past 20 years as previously noted were achieved with only limited effort by the utility to promote appliance retrofits through rebate programs and to educate the public.

Low Impact Development

Commercial, industrial, and residential development plays a key role in water conservation due to the increased demand on potable water supplies. The municipalities serviced by Newport News Waterworks will grow in time and require new development, but given that the land mass is a peninsula, there is a very limited amount of space to expand and develop. Understanding the Lower Peninsula's land constraints, low impact development alternatives such as water banking, adaptive reuse, and using ultra low flow appliances can save water in the Lower Peninsula and encourage economic growth even under limited development options. The idea of water banking is to "balance the water budget" by imposing an offset ratio on developers, whereby for every gallon of water proposed to be used, the developer must offset that gallon by a predetermined number. This ratio is often 1:2. Offsetting the losses often occurs through stormwater programs that reduce runoff and increase groundwater recharge and through appliance retrofits in older homes and buildings. Benefits of the program are keeping water local by allowing it to recharge the same watershed it came from, reducing loading of sewage drains, and growing the community in a sustainable fashion. Additionally, water banking helps to accommodate new growth by encouraging developers to save water while granting access to new customers.

The reuse of buildings also provides opportunities for large-scale retrofitting. Adaptive reuse, which is a low impact development concept, effectively slows suburban sprawl by utilizing established buildings for new purposes. Water is conserved by utilizing existing hook-ups for new customers without

contributing to the development of virgin lands and further disrupting the watershed. The Williamsburg Planning Commission, in fact, recently passed an adaptive reuse plan to permit the conversion of an empty hotel into apartments. Increased permitting of adaptive reuse facilitates opportunities for the Lower Peninsula to install retrofitted appliances to further reduce its water consumption. A combination of wide-scale retrofitting and the other water conservation strategies discussed in this paper would not only be sufficient to conserve enough potable water to meet the demands anticipated by NNWW, it would appeal to Lower Peninsula constituents as the most protective option for their economic, cultural, and environmental interests.

Reclaiming wastewater and water reuse

In addition to retrofitting appliances and developing sustainably, reclaiming wastewater for reuse is one water-saving technology that is growing in popularity and is readily available to the Lower Peninsula via the Hampton Roads Sanitation District. In terms of human use and consumption, water can be separated into two distinct categories: potable and nonpotable. Potable water is treated to levels determined safe for human consumption, but it is often used to meet other demands, such as irrigation, vehicle washing, and for heating and cooling in industrial factories. Nonpotable water is that which is treated by sewage treatment plants, such as the Hampton Roads Sanitation District, to meet regulatory standards before it is released back into the environment by way of local waterways. The advantages of reclaimed nonpotable water are two-fold: (1) Nonpotable water is a sustainable resource because toilets will continue to be flushed and sinks will always drain, leading to a wastewater treatment plant, and (2) The characteristics of reclaimed water share more similarities to groundwater and surface water than dissimilarities. In other words, the quality of reclaimed wastewater is as good as, or sometimes better than, the water we source to treat for drinking water (Water & Waste Digest 2009). By capturing, reclaiming, and reusing treated wastewater, communities can reduce their consumption of drinking water without reducing their quality of life.

In addition to residential uses for reclaimed water, industries can dramatically reduce their consumption of potable water by using reclaimed water for fire protection, as well as operating their heating and cooling systems. According to the Hampton Roads Sanitation District website, since the beginning operation of a reuse agreement with Giant Industries, Inc. in 2002, the York River Treatment Plant has put 700 million gallons of reclaimed water toward reuse, effectively decreasing demand on potable water sources by that number. Supplementally, a 2007 presentation by Harr and Gudgeon reports that HRSD is poised to provide a minimum of 150 MGD of reclaimed water and as much as 230.5MGD to interested parties. In Newport News specifically, Pier IX, owned by Kinder Morgan Bulk Terminals, applied for a groundwater withdrawal permit of 116,630 gallons per day (Virginia DEQ). The water is used to spray down coal piles awaiting export so as to mitigate air quality concerns. Through a cooperative agreement with HRSD, Pier IX would be able to replace groundwater with reclaimed water. The possibilities of conservation from other Virginia peninsula industries are still in research stages, but just 1MGD of reclaimed water offsets the drinking water needs of 7500 residences (Harr and Gudgeon 2007). Enhanced efforts by HRSD to sell reclaimed water that displaces existing potable water use results in a gallon for gallon offset in drinking water needs making that potable water available to accommodate new uses.

Meanwhile, utilities customers pay less for nonpotable water. In a 2007 survey of utilities providers nationwide, the median cost of using reclaimed water was eighty percent (80%) of the cost of potable water (HDR Engineering, Inc 2008). The cost of water reuse in the Lower Peninsula is actually

below the national average, at sixty percent (60%) of the cost of potable water (HRSD). To meet the increasing demand for water in the Lower Peninsula, NNWW must begin to think of providing water in different ways, by restricting use of potable water to potable demand and encouraging water reuse to meet nonpotable demands.

Water conservation rate structure and rebates

One of the most immediate ways to initiate water conservation and realize results is through the utilities' rate structure. NNWW implements a two-block rate structure to encourage water conservation under 6 hundred cubic feet (HCF) and a summer conservation rate surcharge to promote reduced usage during months of less rainfall and greater evaporation (Waterworks FY2010 Water Budget). A multi-tiered rate structure encourages low volume usage by applying a user discount at a certain limit as well as progressively increasing rates for excessive uses of water. These penalty rates should be high enough to discourage overuse and could be removed if a customer decreases their usage habits. These efforts are effective, but only to a certain extent. There are more facets to an effective water conservation rate structure that NNWW can incorporate to further encourage its customers to cut back on their usage. Individualized accounts, based on landscape square footage, number of residents, specific needs of individual customers (medical uses, e.g.), and daily climatic demands appropriately track water usage and signal usage changes based on customer-specific data. When bills are received, customers are aware of these changes, alerting them to excessive use or leaking appliances. In Southwest Florida, the implementation of a five-tiered rate system based on the aforementioned principles caused landscape irrigation to drop 45% in the first year. The rate structure also allowed utility rates to remain steady for five years, resulting in increased economic and water savings. A second means of regulating water usage through rates is the increase of prices per gallon. According to Halich and Stephenson's study of drought management programs in Virginia, "a modest price increase of \$3.00 per 1000 gallons would result in a 13% reduction in water-use during the fall and a 15% reduction during the summer. This magnitude of reduction was greater than that achieved with most mandatory restrictions implemented in our study" (21). An effective water management plan, then, should weigh the benefits of rate adjustments compared to mandatory restrictions. Impacts of increased rates on the economically disadvantaged can largely be avoided by maintaining a reasonable rate for minimal usage and assisting these customers with appliance retrofits. NNWW can greatly improve the efficiency of its customers' water use by revising the rate structure in such a way as to discourage overusage and to keep its customers informed of their monthly consumption.

In addition to water conservation utility rates, rebates are a simple way to incentivize water conservation for Lower Peninsula homeowners and businesses. The James City County Service Authority has initiated the area's first rebate programs, one in 2005 and one in 2008, for the benefit of local homeowners and businesses. The programs offer rebates from \$50-\$500 for the installation of rain sensors that inhibit irrigation systems, low-flow appliances like toilets, and rain cisterns for water storage and reuse. Both businesses and homeowners can receive the tax credits (Davis 2005 and Zimmerman 2008). The benefits of retrofitting appliances have been discussed above in this report; rebate programs are a simple, practical way to kick start wide-scale retrofits and appliance installations. NNWW should not ignore easy opportunities to conserve water, particularly when programs have been successfully implemented within its own service area.

Irrigation and landscaping

Irrigation is one of the greatest draws off municipal water. Grass and plants do not need potable water to survive and in fact, certain plants can survive on brackish water alone. One of the easiest ways for the Lower Peninsula to reduce its demand for potable water is tackle the problem of irrigating with drinking water by utilizing reclaimed water and implementing system retrofits. Applying these strategies at both residences and businesses such as golf courses and resorts, which are both very common in the areas serviced by NNWW, will significantly conserve drinking water by restricting its use. The best source of reclaimed water to meet demand for irrigation is the effluent from HRSD or other treatment facility. At the date of this report's release, HRSD does not have the dual infrastructure in place for irrigating residential lawns, but increased demand for reclaimed water could certainly be the catalyst for the construction of such a system. Businesses and homes with irrigation systems should also be encouraged to replace old technology with the latest wireless sensor irrigation systems. State-of-the-art irrigation systems save water by detecting soil moisture level, salinity, and temperature to determine whether water application is necessary. Installing watering systems with this technology or retrofitting old systems will result in immediate water savings and can be used for golf courses, parks, professional landscaping, and residential lawns. After installing the latest technology, the Desert Mountain Golf Club in Arizona reported saving about \$130,000 from its reduced need for municipal water, and the system developers anticipate water savings of 10% for its customers (Dorman 2008). In acknowledgement of the serious drain on water supplies caused by irrigation, the U.S. Professional Golf Association advocates the use of this technology as well as using reclaimed water and fine-tuning sprinkler heads to ensure that water is being sprayed on permeable surfaces rather than pavement. Landscaping decisions supplement meticulous watering practices; using specific grasses that are adapted to brackish water is another means of conservation-minded lawn care. Both residences and the commercial sector could employ the use of plants native to the Tidewater area that would not require as much water and could tolerate higher salinity, in addition to installing moisture-sensing irrigation systems that only water when water is needed. The use of nonpotable water for nonpotable purposes like irrigation and utilizing state-of-the-art technology would result in immediate savings of millions of gallons of public water every year.

Drought management strategies

Being proactive in anticipation of decreased seasonal precipitation is an important aspect of water management in the Lower Peninsula. The need for a sustainable water supply to meet demand is readily acknowledged by NNWW, and taking steps to conserve water during particularly dry times of the year is critical for sustaining the supply for future use. In 2002, when the Tidewater region was listed under an Extreme Drought condition by the US Drought Monitor, Newport News did not institute mandatory restrictions until Governor Warner issued a state-wide mandate. By then, soil moisture levels had reached a five-year low in the Lower Peninsula (Halich and Stephenson 2006). While other Virginia municipalities were operating on sustained voluntary restrictions, Newport News was relying on the water conserved in its reservoirs. As soon as rainfall gets below long term averages, it is simply a matter of time before reliable water flow into reservoirs begins to decrease. Water restrictions are an important means of protecting water resources during drought. Rather than reacting to drought conditions and relying on reserves, NNWW should prepare for unreliable amounts of precipitation, and thus decreased groundwater recharge, during spring and summer months by increasing the time that its water use restrictions (both voluntary and mandatory) are in place. Additionally, if rainfall patterns change as predicted with global warming and Virginia begins to experience heavy rains interspersed with drought,

then managing for drought on a regular basis will be the most effective strategy to address altered rain patterns.

Desalination

In addition to water conservation opportunities, desalination is a feasible means of meeting the Lower Peninsula's water demand. Desalination technology ranges from ancient to modern. One of the oldest technologies is thermal desalination which is a process of evaporation and distillation. Current technologies include membrane filtration, which includes reverse osmosis (RO) and electrodialysis (ED), and ion exchange. Several of these technologies are in use across the United States and in the Commonwealth. Combinations of these technologies for purposes of pre-treatment and post treatment of water in the desalination process have proven successful. The choice of technologies applied is based on the feed water salinity and total dissolved solids (TDS). There are five desalination plants already in the Tidewater Region: Lee Hall Reverse Osmosis Plant in Newport News, Electrodialysis Reversal Plant in Suffolk, Northwest Reverse Osmosis Plant in Chesapeake, Gloucester Desalination Reverse Osmosis Plant, and Five Forks Groundwater Treatment Facility in James City County.

Desalination Technologies

Thermal desalination simply separates the salts from water through a process of applied heat. Salt free steam is collected and leaves behind concentrated brine that can be used as feed water for the next stage or exited from the system. The various forms of thermal desalination have not been as popular in the United States as it is in the rest of the world due to high energy costs. It can, however, successfully be used for both brackish and saltwater desalination (Younos 2004). Recent research at New Mexico State University has created a low-cost low-energy desalination process that uses the waste heat from a refrigerator or air conditioning unit to distill saline water at relatively low temperatures (Hill 2007).

Ion exchange technologies have also been employed for a long time in other capacities, such as softening water. In desalination, water washes over resin beads and an exchange of ions takes place removing the salt ions from the brackish water. When the resin beads are saturated with ions, chemicals are needed to restore them to continue the ion exchange process. This technology has low energy requirements and operates at a lower cost but requires high chemical use and only successfully desalinates brackish water (Younos 2004).

Reverse osmosis is the most popular form of membrane filtration technology used today. It is a diffusion-controlled process that allows only molecules of a certain size to penetrate a membrane, leaving behind salts, bacteria, viruses and metals. Out of the five desalination plants in the Tidewater Region, four use reverse osmosis. Pre- treatment of feed water with other filters and chemicals is essential to successful desalination by reverse osmosis. Although a dependable removal of total dissolved solids in both brackish and saltwater, reverse osmosis produces brine that is highly concentrated and must be removed from the system (Younos 2004). Current research in membrane technology at the Lawrence Livermore National Laboratory has produced carbon nanotubes that offer faster, cheaper desalination. Their website states that the membranes contain a higher density of pores but the pores are much smaller than in traditional membranes. These more permeable nanotube membranes could reduce the energy costs of desalination by up to 75% compared to reverse osmosis (Stark 2006).

Electrodialysis is the separation of dissolved minerals in water using electrical current. Electrodialysis has a high recovery rate and can remove up to 98% of total dissolved solids. Although not as sensitive to pH and hardness levels, ED only keeps its high efficiency rate and low maintenance costs

when desalinating brackish water. Electrodialysis reversal (EDR) can reverse the electrical current to “clean” the membranes and keep them functional longer (Younos 2004). The desalination plant in Suffolk Virginia uses this membrane technology.

Combination Desalination Technologies

Success has been had in combining these various types of technologies to desalinate water from different sources. Nanofiltration, ultrafiltration and microfiltration utilize membranes with large pores and are not as capable at removing salts, but they can remove solids and work as a pre-treatment for reverse osmosis. To treat a water source with a high total organic carbon load (TOC), nanofiltration can treat up to 75% of the microfiltration filtrate to remove TOC precursors. The nanofiltration reject water and the microfiltration backwash water can be combined and sent to a facility for irrigation purposes (Stratton 2009). Thermal distillation technologies can also be used with reverse osmosis to reduce costs. Ion exchange can be used in combination with reverse osmosis processes so that water treated by ion exchange can be blended with reverse osmosis product water, increasing water production. Electrodeionization combines electrodialysis and ion exchange to produce ultra pure-water from brackish water. The City of Chesapeake is utilizing an Aquifer Storage and Recovery System (ASR). ASR stores surplus from a water treatment plant in an aquifer that can be withdrawn from in times of drought (Younos 2004).

Tidewater Region’s Desalination Plants

Groundwater withdrawal in Eastern Virginia is 127 MGD. Although producing a smaller percentage of the potable water for the Tidewater Region, desalination of brackish groundwater has been a fixture in Eastern Virginia since the Suffolk Electrodialysis Reversal Plant was built in 1990 producing 3.75 MGD. The other four plants in this region utilize reverse osmosis. The Lee Hall Plant built in 1998 in Newport News has a capacity of 5.7 MGD and supplements the total water supplies by 10% in the Newport News Waterworks Service Area. The Northwest River Water Treatment Plant was originally built in 1980 with a reverse osmosis upgrade made in 1999. It has a capacity of 10 MGD and services the City of Chesapeake (Younos 2004). The Gloucester Desalination Plant was built in 2003 and provides 2 MGD. Finally, the Five Forks Groundwater Treatment Facility in James City County was built in 2005, with a design capacity of up to 5 MGD (Water Technology).

Overcoming Desalination Issues

Although desalination of both saline surface and groundwater has been successful in the United States and elsewhere, a couple of issues arise in the production of potable water from desalination. One is the high energy consumption of the desalination process. Renewable energy sources are making a growing contribution to desalination. Options include indirect solar energy from solar panels, photovoltaics, and other technologies which are often coupled with thermal desalination. Wind energy can produce power used directly by the plant or stored on the grid. Coastal areas have the best chance of harnessing this pollution free energy. A seawater reverse osmosis desalination plant in Perth, Australia, is the largest plant in the world to be powered by renewable energy. The plant is powered by the 80 MW Emu Downs Wind Farm and has an annual running cost that puts it at less than one dollar per week per household (Water Technology). Wave energy also has a high potential for energy production for the coastal areas of Eastern Virginia. Commonplace and effective in cutting down on energy costs is the combination of power and desalination plants into one cogeneration plant. The power plant’s steam waste

is collected for use in the desalination process. Also beneficial is a collocated plant where a seawater reverse osmosis plant is located with a power plant. The desalination plant draws its feed water from the power plant's heated seawater. Also, the brine from desalination is diluted with water from the power plant before being discharged into the ocean (Younos 2004). The largest seawater desalination facility in the United States is in Tampa Bay, Florida. The reverse osmosis plant has taken advantage of collocation by diverting two of the four discharge tunnels from Tampa's Electric Big Bend Power Station to supply raw water for the desalination plant (Water Technology). Tampa Bay Water's website says it provides Tampa Bay with up to 25 MGD, which provides about 10% of Tampa's drinking water supply.

Another potential concern is the end product of desalination, concentrated brine that must be disposed of into the environment. If not sufficiently diluted, the spike in salinity can have severe consequences on nearby aquatic benthic organisms. The brine is heavier and can sink to the bottom, staying submerged. To mitigate this effect the brine should be discharged at a natural point of mixing in the water column near the plant where it can be dispersed by waves, tides, and mixing. The concentrate may also need to be treated to adjust pH and dissolved oxygen levels before being discharged. Almost half of the desalination plants in the United States dispose of brine to surface waters. All five of the desalination plants in the Tidewater Region use surface water dispersal to rivers (James, Nansemond, and Elizabeth rivers). The concentrate can also be delivered underwater by extending pipes to the ocean rather than at the coastline (Younos 2004). The seawater reverse osmosis plant in Perth, Australia, has a brine that is 7% salt, but the diffusers discharge the concentrate so that the mixed water has a salinity of less than 4% within 50 meters of the point of discharge. This greatly decreases the salinity, preventing salt shock to the surrounding waters (Water Technology).

The second most common disposal method takes the brine and delivers it to the front end of a wastewater treatment plant. If this proves to be too much influent for the wastewater treatment plant to handle, the concentrate can be piped to the end of the water treatment process which dilutes the brine before it is disposed. Other concentrate disposal options include deep well injection, land application, evaporation ponds and zero liquid discharge technologies. Deep well injection into aquifers is suitable for aquifers not used for drinking water. Land application uses spray irrigation to disperse the concentrate and can be beneficial to irrigate salt-tolerant crops and golf courses. Evaporation ponds are effective but are not as feasible if large land area is not available. Zero liquid discharge converts the liquid concentrate to a dry solid creating solid waste disposal. This method is most effective for areas where surface disposal and deep well injection are not an option (Younos 2004).

Other Source Alternatives

There are over thirty lakes and reservoirs that service Eastern Virginia. Surface water use for Eastern Virginia totals 4,692 MGD where freshwater makes up 1,298 MGD and saline makes up 3,394 MGD (Younos 2004). Although not yet formally evaluated, more sources of freshwater that do not require desalination exist to further supplement the Tidewater Region's water needs. Big Bethel, a 266-acre reservoir and treatment facility formerly used by the military at Fort Monroe is standing unused, as is Jones Pond, another former military reservoir. If the Newport News Waterworks obtained access to these reservoirs from the military, they could add over 2.0 MGD. Another 5.0 MGD increase in fresh water supplies could come from raising the level of the Chickahominy reservoir (Siegel 2008). Another 0.72 MGD could come from the Stonehouse system wells. Also, a two foot increase in the height of the Diascund and Little Creek reservoir dams would yield another 5.0 MGD. The potential to purchase the City of Richmond or City of Norfolk's surplus water could also contribute upwards of 20.0 MGD. If the

regional reservoirs were drawn down below the proposed 33% of reservoir storage capacity to 25%, there would be a contribution of another 1.55 MGD (Siegel 2003). In the early 1990s, Newport News and Hanover County discussed a possible water reuse approach that was not considered among the alternatives in the FEIS. The Hanover Totopotomoy wastewater treatment plant could be potentially upgraded to pump tertiary treated water to the Chickahominy River that Newport News could withdraw and treat further downstream at its current dam site. With these additional sources of freshwater and the prospects of desalination of surface and groundwater, the Tidewater Region's water needs are more than met without constructing another reservoir.

Conclusions

Drinking water demand in Virginia's Lower Peninsula can be met without placing the financial and environmental burden of building a new reservoir on local taxpayers. Current technologies and facilities already exist to facilitate more efficient water use in the Lower Peninsula and specifically the areas serviced by Newport News Waterworks. In the case of the Hampton Roads Sanitation District, not only do these facilities exist, the HRSD is actively promoting the possibilities of reusing water (and displacing current potable water uses) by seeking new cooperative agreements. The water sources and conservation methods identified in this report offer the means of meeting potable water demand tailor-made to the Lower Peninsula communities and their characteristics, and all of them are being used successfully across America and even globally. Through desalination options and a well-developed water management plan, the Lower Peninsula is poised to set water conservation precedents for the Commonwealth of Virginia. Moreover, the optimization of these strategies will not cause any detriment to either the quality of life enjoyed by residents serviced by Newport News Waterworks or limit economic growth due to natural resource constraints. When considering how to mitigate concerns regarding water needs in Virginia's Lower Peninsula, Newport News Waterworks and local governments would be remiss to ignore the vast water-saving opportunities available to that area.

With the federal court's recent decision finding the Corps of Engineers' consideration and evaluation of alternatives to the King William Reservoir to be deficient, a comprehensive and detailed analysis of the alternative approaches outlined in this survey, as well as possible other methods, is warranted.

Supplementary Information

Table 1. Water Conservation Strategies Implemented Across the United States, including voluntary conservation and regulatory mandates*

	Areas served by NNWW	Area Served by James City Service	Georgia	SW Florida	California
Outdoor Water Use Restrictions	* only in drought conditions	X		X	X
Education/Media Outreach		X	X	X	X
Native Landscaping		X	X	X	X
Irrigation Technologies		X	X	X	X
Retrofitting Appliances in Commercial Sector				X	X
Retrofitting Appliances in Residential Sector		X		X	X
Rainwater Collection		X	X	X	X
Permeable Surfaces		X			
Rebates		X			X
Water Reclamation and Reuse				X	X
Water Conservation Rate System	X			X	X

*Adapted from Davis 2008, Dunning 2009, Fisher and Delagah 2009, Greener Building Staff 2008, and South Florida Water Management District.

Table 2. Advantages of Water Conservation*

• Immediate results • Increased water quantity ○ Decreased diversion of freshwater from wetlands and other ecosystems. ○ Reduced use of potable water by industrial, housing, and recreational development projects that use reclaimed water. ○ Reduction in the amount of groundwater withdrawal, which impacts base flow in many rivers and streams • Easier and less expensive than developing new source of water • Less energy intensive than building new treatment facilities • Supports economic growth without developing new water sources • Reduces strain on stormwater systems by reducing runoff • Better water quality ○ Reducing runoff reduces nutrient loading to the Chesapeake Bay, its tributaries, and other water bodies. ○ Water reuse reduces the amount of wastewater effluent discharged.
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*Adapted from Haering et al 2008, South Florida Water Management District, and Harr and Gudgeon 2007

Table 3. Utilization Potential of Reclaimed Water*

Urban Reuse	Industrial Reuse
• Ornamental fountains and ponds ○ Golf courses, residences, hotels • Fire protection • Dust control on construction sites • Car washing • Window washing • Toilet flushing in public, commercial, and industrial buildings • Irrigation ○ Golf courses, agricultural land, personal property	• Cooling water • Boiler make-up water • Industrial process water • Fire protection • Irrigation of property • Dust control

* Adapted from Haering et al 2008 and Harr and Gudgeon 2007.

Sources

- Chaplin, Scott. Comments Regarding the Final Environmental Impact Statement (FEIS) for the Lower Virginia Peninsula Regional Raw Water Supply Plan 1990-2040. Report presented to US Army Corps of Engineers. 23 July 1997.
- Davis, Beth. "The James City Service Authority Initiates Rain Sensor Rebate Program." James City County Communications. 28 July 2005. <[http://www.jccgov.com/news/news_details-a.php?RECORD_KEY\(news_results\)=news_id&news_id\(news_results\)=126](http://www.jccgov.com/news/news_details-a.php?RECORD_KEY(news_results)=news_id&news_id(news_results)=126)> (accessed 21 May 2009).
- Davis, Deron. "Georgia Launches *waterSmart* Campaign." Georgia Environmental Protection Division. From American Water Works Association – Sustainable Water Resources. 2008.
- Dorman, Larry. "On Golf Courses, Sensors Help Save Water." *The New York Times*, 20 May 2009. <http://www.nytimes.com/2009/05/21/sports/golf/21watering.html?_r=1> (accessed 21 May 2009).
- Dunning, Justin. "Three Ways to Save: Case Studies from California Green Builder." Presented at PG&E 2009 Water Conservation Showcase. 24 March 2009
- Fisher, Don and Amin Delagah. "Sustainable Hot Water: Better Design, Delivery, and Use. Fisher-Nickel, Inc. PG&E Food Service Technology Center." Presented at PG&E 2009 Water Conservation Showcase. 24 March 2009.
- Haering, Kathryn C., Gregory K. Evanylo, Brian Benham, and Mike Goatley. "Water Reuse: Using Reclaimed Water for Irrigation." Virginia Cooperative Extension. Pub 452-014. 2008.
- Halich, Greg and Kurt Stephenson. "The Effectiveness of Drought Management Programs in Reducing Water-Use in Virginia." Virginia Water Resources Research Center. VWRRC Special Report SR29-2006. 2006. 21.
- HDR Engineering, Inc. Water Reuse Rates and Charges Survey Results. Prepared for American Water Works Association Water Reuse Committee. 2008.
- Hampton Roads Sanitation District. "News and Education> Water Reuse." <<http://www.hrsd.state.va.us/pdf/livenow/waterreuse.htm>> (accessed 7 May 2009).
- Hampton Roads Water Efficiency Team. <http://www.hrwet.org/> (accessed 7 May 2009).
- Harr, Karen and Rebecca Gudgeon "Industrial Water Reuse Project: Case Study." Presented at 2007 Annual Environment Virginia Symposium. <<http://www.environmentva.org/Agenda/ARCHIVE/PDF2007/KarenHarr-HamptonRoadsSanitationDistrict.pdf>> 10 April 2007.
- Hill, Karl. "Researchers develop low-cost, low-energy desalination process." NMSU News Releases. 29 May 2007. <http://www.nmsu.edu/~ucomm/Releases/2007/may/desalination_project.htm> (accessed 8 May 2009).
- U.S. Army Corps of Engineers. Final Record of Decision. 2005 1.c. and Table 1
- Ipswich Watershed Association. Water Bank/Water Demand Mitigation Program. Water Wise Communities: A Handbook for Municipal Managers in the Ipswich River Watershed. <http://www.ipswichriver.org/waterwise/tool12.htm>
- James City County website. <<http://www.bewatersmart.org/>> (accessed 4 May 2009).
- Kelly, Jennifer, Jackie Rickards and Rodrigo Salcedo. The Feasibility of Expanding Desalination in the Hampton Roads Region of Virginia. Virginia Commonwealth University. 2008.

Lawrence Livermore National Laboratory. "Nanotube membranes offer possibility of cheaper desalination" < https://publicaffairs.llnl.gov/news/news_releases/2006/NR-06-05-06.html > (accessed 8 May 2009).

Newport News, Virginia. "Waterworks." <http://www.nngov.com/waterworks> (accessed 4 May 2009).

Parsons, Dan. "Adaptive Reuse Plan Passes Williamsburg planning commission." 18 April 2009. <http://www.dailypress.com/news/local/williamsburg/dp-local_wbgplanners_0418apr18,0,4340705.story> (accessed 29 April 2009).

Phillips, Donald. An Analysis of Probable Future Water Demand on the Virginia Lower Peninsula. 3 August 2008.

Roberts, J. Timmons. "New Survey Reveals Large Majorities in James City, York and Williamsburg Fear Overdevelopment, Favor Restrictions on Growth Until Water Issues Resolved." 10-14 July 2002. <http://jtrobe.people.wm.edu/development_and_water_in_Wburg.htm> (accessed 4 May 2009).

Siegel, Michael. "A Review of the Proposed King William Reservoir's Escalating Cost, Debt, and Risk Factors, and Practicable Alternatives." 4 August 2008.

Siegel, Michael. "A Review of Water Needs and Water Supply Alternatives for the Lower Peninsula of Virginia." Testimony submitted to Virginia Marine Resources Commission. 22 April 2003.

Siegel, Michael. Michael Siegel to Allan Carroll. Memorandum. "RE: Review of VDH Comments dated July 1999 on IWR Draft Report dated May 1999." 13 August 1999.

South Florida Water Management District. Water Conservation: A Comprehensive Program for South Florida. <https://my.sfwmd.gov/portal/page?_pageid=3074,20103213&_dad=portal&_schema=PORTAL> (accessed 29 April 2009).

Stark A. M. "Nanotube membranes offer possibility of cheaper desalination" Lawrence Livermore National Laboratory Public Affairs. 18 May 2006. < https://publicaffairs.llnl.gov/news/news_releases/2006/NR-06-05-06.html > (accessed 8 May 2009).

Stratton, Richard and Joe Zoba. "A Supplemental Source for Distribution." Water and Waste Digest vol. 49, number 4. <<file:///C:/Environm-1eso18/shareddocs/ESC/Current/King%20William%20County/Sierra%20References/A-Supplemental-Source-for-Distribution-article10249.htm>> (Accessed May 11 2009).

Tampa Bay Water. Tampa Bay Water Desalination. <<http://www.tampabaywater.org/watersupply/tbdesal.aspx> > (accessed 8 May 2009).

U.S. Army Corps of Engineers. Memorandum for Record. 29 July 2005. Page 3. <<http://www.nad.usace.army.mil/kwr/decision.pdf>> (accessed 21 May 2009).

U.S. Army Corps of Engineers Norfolk District. Draft Environmental Impact Statement, Regional Raw Water Study Group, Lower Virginia Peninsula Regional Raw Water Supply Plan. 0114-951-140. February 1994.

Virginia DEQ. Archive of Public Notices. <<http://www.deq.virginia.gov/gwpermitting/pnarchive.html>> (accessed 12 May 2009).

Water & Wastes Digest. Study Finds Reclaimed Water Quality Similar to Other Water Types. 7 May 2009. <<http://www.wwdmag.com/Study-Finds-Reclaimed-Water-Quality-Similar-to-Other-Water-Types-NewsPiece18232>> (accessed 11 May 2009). <<http://www.tampabaywater.org/watersupply/tbdesal.aspx> > (accessed 8 May 2009).

- Water Technology. Five Forks Groundwater Treatment Facility, James City County, VA, USA. <<http://www.water-technology.net/projects/five-forks/>> (accessed 4 May 2009).
- Water Technology. Perth Seawater Desalination Plant, Seawater Reverse Osmosis (SWRO), Kwinana, Australia. <<http://www.water-technology.net/projects/perth/>> (accessed 4 May 2009).
- Water Technology. Tampa Bay Seawater Desalination Plant, Florida, USA. <<http://www.water-technology.net/projects/tampa/>> (accessed 8 May 2009).
- Waterworks Fiscal Year (FY) 2010 Budget. Received via email from Don Phillips to report authors. 11 May 2009.
- Younos, Tamim. The Feasibility of Using Desalination to Supplement Drinking Water Supplies in Eastern Virginia. Report of the *Virginia Water Resources Research Center* at Virginia Polytechnic Institute and State University to the Governor and the General Assembly of Virginia. June 2004.
- Zimmerman, Nicolas. "Residents paid to conserve limited water supplies." *Daily Press*, 21 August 2008. <http://www.dailypress.com/news/local/williamsburg/dp-local_jccconserve_0821aug21,0,7827888.story> (accessed 21 May 2009).