Chapter 4

Case Study #2: Drinking Water

4.1. Drinking Water in the Delaware Estuary Watershed

The Delaware River, its bay, and 216 tributaries provide a source of drinking water for over 17 million people, or over 5 percent of the United States population. Approximately 88 percent of drinking water taken from the Delaware River watershed is from surface water and approximately 12 percent is from groundwater. The City of Philadelphia's drinking water supply, servicing over 1.4 million people, comes exclusively from surface water sources. In addition to the Estuary's population, much of New York City also gets its drinking water from reservoirs in the upper Delaware Basin. Approximately 736 million gallons of water per day are exported for populations in New York City and northeastern New Jersey.

Drinking water providers in the Basin encounter numerous challenges to the quality and availability of their supply. Drinking water suppliers must share the resources of the Basin with other large water users such as power generation and industry which make up approximately 95% of total water use in the tidal Delaware Basin. Suppliers depend on sound, science-based decision-making by state and federal regulators to ensure appropriate and equitable flow allocation. Water quality stresses from wastewater and industrial discharges, stormwater and agriculture runoff, discharges from abandoned mines, and other influences all pose serious threats to the ability of water providers to consistently deliver safe drinking water. Anticipated population growth in the region is likely to increase demand for drinking water and exacerbate water quality problems by increasing burdens on wastewater infrastructure and potentially eliminating forests critical to water supply protection.

Potential effects of climate change on the Delaware Basin include warmer air and water temperatures, increased frequency and intensity of severe precipitation, and reduced snowpack. Such altered conditions in the Basin may aggravate existing water quality and quantity problems and potentially create new stresses for water supplies. For example, increases in precipitation in the region could lead to increased runoff, increased streamflow, higher groundwater levels, increased flooding and changes to watershed vegetation and forest cover in the Delaware Basin. These conditions could damage drinking water treatment plants and infrastructure, inundate treatment plants and pump stations and further degrade water quality. Increased temperatures alone from climate change could increase potable water demand from drinking water supply systems.

4.1.1. Drinking Water Case Study

The purpose of the CRE Drinking Water Supply Case Study is to consolidate and evaluate information about climate change, potential effects on conditions in the Delaware Basin, and the impacts of these potential effects on drinking water supply. The focus of this effort is primarily on surface water supplies in the Lower Basin and Philadelphia's water supply in particular. Specific goals of the case study are as follows: (1) develop an inventory of potential conditions in the Basin which could be altered due to effects of climate change and catalog the possible impact of these changing conditions on drinking water surface supplies; (2) evaluate results from Goal 1 to identify potential planning priorities; (3) identify opportunities for drinking water providers, with support from other stakeholders, to increase their overall adaptive capacity in the face of current challenges and future uncertainty; and, (4) identify priority research needs.

The potential breadth of impacts to drinking water from climate change, combined with current threats to water quality and availability, necessitate strong leadership from water providers and state, local and federal government. The future of our drinking water supplies also depends on the education, cooperation and commitment of Basin communities. The information in this report provides these groups with a preliminary road map to help navigate the substantial uncertainty associated with future change.

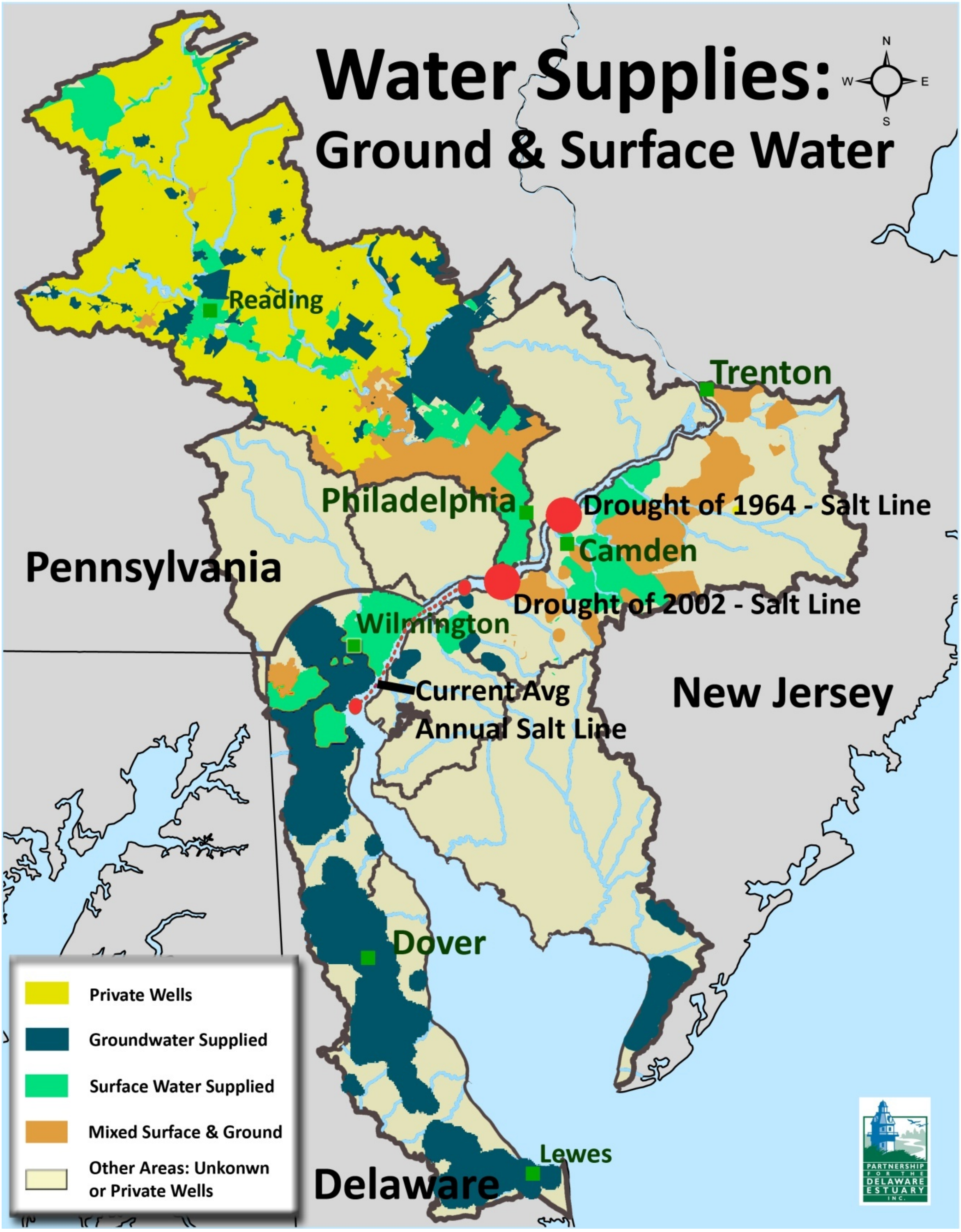

Figure 4.1. The map above shows the service areas of community water supply systems in the estuary. The major cities in the northern parts of the estuary get much of their water from surface water or a mix of surface and ground water. Parts of the Schuylkill River watershed and most of southern Delaware rely exclusively on ground water. The location of the salt line is important to drinking water suppliers in the Upper Estuary. Sea level rise and storm surges can push the salt line further up the Delaware Bay, leading to potentially high chloride and sodium concentrations at the drinking water intakes for Philadelphia and Camden.

Feature Box: Salinity and the Philadelphia Baxter Intake

The Baxter water intake facility provides drinking water to nearly 1 million people, including 60% of the population of Philadelphia and 155,000 Bucks County residents. Baxter is located in the tidally-influenced fresh waters of the Delaware River. It receives freshwater flow from the upstream non-tidal Delaware River, which pushes salt levels down below Baxter. At the same time, tidal waters from the Delaware Bay push salt levels up river towards Baxter. When flow in the Delaware River decreases during drought, the tidal waters push salt further northward towards Philadelphia. Releases from existing reservoirs upstream of Philadelphia are needed to provide enough water during droughts to keep salt at acceptable levels. Since the Baxter plant is a conventional treatment facility, it is not capable of removing salt from the source water. Levels of 250 mg/L chloride or greater at Baxter may require Philadelphia Water Dept. (PWD) to stop withdrawing water from the Delaware River at this site. Any salt present in the source water passes through the plant and distribution system to customers, which may pose unacceptable health risks for sensitive dialysis patients and those on sodium restricted diets. To remove salt at Baxter would require a costly desalination facility. Otherwise, recent analysis by PWD demonstrates that flow targets at Trenton, as defined by the Delaware River Basin Commission Water Code, must be kept at least at current levels to protect the Philadelphia water supply under present day climate conditions.

4.2. Drinking Water – Approach to Assessing Vulnerability and Adaptation Options

The vulnerability of drinking water supply to climate change and potential adaptation options were assessed by a Drinking Water Workgroup comprised of regional scientists and managers from both public and private sectors. For the purposes of this project, the Drinking Water Work Group operated as a subgroup under the Climate Adaptation Work Group. Tasks completed by the workgroup include:

- Created an inventory of available literature on drinking water issues related to climate change (Appendix J);
- Prepared a review document based on the literature inventory (Appendix I);

- Identified the main physical and chemical environmental factors that are likely to change with changing climate and also affect drinking water supply systems (Section 4.3.);
- Identified the specific impacts, or vulnerabilities, of changing environmental factors on drinking water supply systems (Section 4.3);
- Prepared a survey to rank the relative level of concern for how projected changes in physical factors might impact drinking water supply systems served by surface water (Section 4.4);
- Used the survey format to poll experts (Section 4.5);
- Identified priority adaptation options that might be used to lower the vulnerability of drinking water supplies to climate change (Section 4.6.);
- Identified research needs to improve estimates of changing physical conditions and impacts of those changing conditions on drinking water supplies (Section 4.7) and,
- Prepared final recommendations (Section 4.8).

4.3. Drinking Water Vulnerabilities

Using the results of a literature search (Appendix I) and input from regional drinking water experts, the Drinking Water Case Study workgroup developed an inventory of potential conditions in the Basin which could be altered due to effects of climate change and catalogued the possible impact of these changing conditions on drinking water surface supplies. Table 4.1 below includes the results of the inventory. Possible impacts on the water supply, referred to as vulnerabilities, appear across the top of the table. Conditions in the Basin due to climate change which could lead to those impacts, referred to as drivers, appear along the left side of the table. An "X" indicates where a physical driver may impact the corresponding vulnerability. For example, the physical driver of increased river discharge and stream flow may impact supply in 3 ways: 1) cause damage to infrastructure, 2) influence reservoir levels, and 3) facilitate degradation of source water quality.

Table 4.1. Drinking Water Supply Vulnerabilities plotted against the physical drivers which might cause those vulnerabilities. An "X" indicates a possible driver/vulnerability relationship.

Supply Vulnerabilities→

Physical Drivers ↓	Degraded Source Water Quality	Upstream Movement of Salt	Salt Intrusion in Aquifers & FW Habitats	Inundation of Treatment Plants & Pump Stations	Damage to Infrastructure	Power Outages & Customer Supply issues	Impacts to Reservoir Levels	Decreased Supply Availability	Increased Spills and Accidents
sea level rise	**X**	**X**	**X**	**X**	**X**				**X**
storm surge	**X**		**X**	**X**	**X**	**X**	**X**		**X**
extreme flooding	**X**			**X**	**X**	**X**	**X**		
flooding	**X**			**X**	**X**	**X**	**X**		
decreased river discharge & stream flow	**X**	**X**					**X**	**X**	
changes in watershed veg. & forest cover	**X**				**X**				
increased runoff	**X**				**X**		**X**		
disruptions to aquatic ecosystems	**X**	**X**	**X**						
decreased groundwater levels	**X**	**X**					**X**	**X**	
increased freq. of short-term drought	**X**		**X**				**X**	**X**	
increased # and intensity of wild fires	**X**				**X**	**X**			
increased river discharge and stream flow	**X**				**X**		**X**		
increased groundwater levels	**X**				**X**		**X**		
lightning and electrical disturbances						**X**			**X**

Water supply vulnerabilities are defined as follows:

Degraded Source Water Quality

Refers to changes in water quality which could lead to interference with drinking water treatment effectiveness and/or increases in parameters that can pass through conventional treatment and potentially cause illness among some customers.

Upstream Movement of Salt Line

Refers to the possible upstream migration of the 250 mg/L chloride isochlor in the Basin. Upstream salt line movement is an indicator of increased salinity for surface water supplies in the Basin. Salinity is not removed during conventional drinking water treatment and may include constituents problematic to certain customers.

Salt Intrusion in Aquifers and Freshwater Habitats
Refers to possible increases in salinity of groundwater and freshwater which may feed Basin surface waters. Salinity is not removed during conventional drinking water treatment and may include constituents problematic to certain customers.

Inundation of Treatment Plants & Pumping Stations
Refers to flooding of pumps, monitoring equipment and other structures crucial to collecting surface water from the Basin and/or treating raw water.

Damage to Infrastructure
Refers to the destruction of pumps, monitoring equipment, and other structures crucial to collecting surface water from the Basin and/or treating raw water.

Power Outages and Customer Supply Issues
Refers to possible interruptions to the ability of water providers to supply drinking water consistently for reasons not otherwise captured.

Impacts to Reservoir Levels
Refers to changes in expected reservoir levels which dictate how much water is available for various uses including drinking water in the Basin.

Decreased Supply Availability
Refers to possible decreases in flows needed to serve drinking water supplies, possibly leading to difficulties for water suppliers in meeting peak demand (i.e., demand during summer months).

Increased Spills and Accidents
Refers to the possible increased frequency of upstream spills, fires and accidents which could lead to toxic contamination of downstream water supplies.

4.4 Drinking Water - Survey Methods

Once the inventory of drivers and vulnerabilities was completed, the workgroup developed a survey to capture regional drinking water expert opinions on the potential impact of the physical drivers on the vulnerabilities. The survey was also designed to capture respondents' opinions about the science available to determine potential impacts. For each physical driver/vulnerability combination identified as having a relationship in table 4.1, survey respondents were asked to provide two rankings on a scale of 1 (lowest) to 5 (highest). The first ranking, referred to as the impact ranking, reflects the respondent's opinion of the physical driver's potential ability to impact the vulnerability. The second ranking, referred to as the confidence ranking, reflects the confidence of the respondent in the information available to determine potential impact levels. It is important to note that the rankings are based on the opinion and knowledge base of the respondents and not an extensive analysis of available research. Surveys were distributed to all 6 members of the Drinking Water Workgroup via e-mail and 4 responses were received. [1] Survey results were collected and compiled by the Drinking Water Workgroup lead and CRE coordinator.

4.5 Drinking Water - Survey Results

Table 4.2 represents the compilation of survey results for each supply vulnerability. Impact rankings from the returned surveys were averaged to produce a total impact score for each driver/vulnerability combination. Similarly, confidence rankings were averaged to produce a total confidence score for each driver/vulnerability combination. For each driver/vulnerability combination, the impact and confidence scores were multiplied to produce a combined score.

A grading system of Highest, High, Med-High, Med-Low, and Low was assigned according to the distribution of combined scores.

Impact, Confidence, and Combined scores are shown only for the first vulnerability for demonstration purposes. All other vulnerability/driver combinations are shown alongside just their final rankings.

The final rankings help identify the drivers of greatest importance, which are highlighted dark red and orange. Higher scores reflect drivers with potentially significant impact where information is more readily available and accurate. This provides some guidance as to where to focus planning efforts with respect to drinking water supply and climate change vulnerabilities.

The survey results are best interpreted as a ranking of the drivers which are of most concern to each vulnerability. The survey does not attempt to rank the vulnerabilities relative to each other, but it does show the driver/vulnerability areas for which suppliers should start to plan. For example, the vulnerability 'Degraded Water Quality' is most at risk from sea level rise, increased runoff, and changes in watershed vegetation and forest cover. 'Power Outages and Customer Supply Issues' is most at risk from extreme flooding and storm surge. Relative to each other, degraded water quality may have more impact to water suppliers than power outages depending on the extent and timing of the vulnerability.

According to the survey results, sea level rise will be a great concern to water quality for source and finished water. Treatment plants and pumping stations will have to plan for disruption from flooding, sea level rise and storm surges. Likewise, damage to supply infrastructure is most likely to occur because of sea level rise and flooding. Survey respondents did not think that wild fires would be much of an issue for power outages and customer supply issues.

[1] Survey respondents included representatives of the Philadelphia Water Department, Environmental Protection Agency Region III, Penn State University, and Drexel University.

Table 4.2. Results from the Drinking Water Workgroup Survey

Damage to Drinking Water Infrastructure		Impact Score	Confidence Score	Combined Score	Final Ranking
Drivers	sea level rise	2.3	5.0	11.7	High
	extreme flooding	3.0	4.0	12.0	High
	increased runoff	2.7	3.0	8.0	Med-High
	storm surge	2.7	3.5	9.3	Med-High
	flooding	2.7	3.5	9.3	Med-High
	increased river discharge and stream flow	2.5	2.3	5.8	Med-Low
	changes in watershed vegetation and forest cover	2.0	3.0	6.0	Med-Low
	increased groundwater levels	2.0	1.0	2.0	Low
	increased number and intensity of wild fires	1.3	1.0	1.3	Low

Impacts to Reservoir Levels		
	increased runoff	Med-Low
	increased frequency of short-term drought	Med-Low
	decreased river discharge and stream flow	Low
	decreased groundwater levels	Low
	increased river discharge and stream flow	Low
	increased groundwater levels	Low
	extreme flooding	Low
	storm surge	Low
	flooding	Low

Inundation of Treatment Plants & Pumping Stations		
	extreme flooding	High
	storm surge	High
	sea level rise	High
	flooding	High

Increased Spills and Accidents		
	storm surge	Med-High
	lightning and electrical disturbances	Med-Low
	sea level rise	Low

Degraded Source Water Quality		
	sea level rise	Highest
	increased runoff	High
	changes in watershed vegetation and forest cover	High
	increased river discharge and stream flow	Med-High
	decreased river discharge and stream flow	Med-High
	disruptions to aquatic ecosystems	Med-High
	disruptions to distribution systems	Med-High
	flooding	Med-High
	extreme flooding	Med-Low
	increased frequency of short-term drought	Med-Low
	storm surge	Med-Low
	increased groundwater levels	Low
	decreased groundwater levels	Low
	increased number and intensity of wild fires	Low
Upstream Movement of Salt Line		
	sea level rise	Highest
	decreased river discharge and stream flow	High
	decreased groundwater levels	Low
	disruptions to aquatic ecosystems	Low
Decreased Supply Availability		
	increased frequency of short-term drought	Med-High
	decreased river discharge and stream flow	Med-Low
	decreased groundwater levels	Med-Low
	Increases in demand	Med-Low
	increased number and intensity of wild fires	Low
	storm surge	Low
Power Outages & Customer Supply Issues		
	extreme flooding	High
	storm surge	High
	lightening and electrical disturbances	Med-High
	flooding	Med-High
	increased number and intensity of wild fires	Low
Saltwater Intrusion in Aquifers and Habitats		
	sea level rise	Highest
	storm surge	High
	increased frequency of short-term drought	Low
	disruptions to aquatic ecosystems	Low

In summary, the vulnerability/driver combinations in Table 4.3 below have scores of High or Highest in the above evaluation and provide ideal starting points for drinking water supply planning in the Lower Basin with respect to climate change. This guidance is most helpful in identifying areas suitable for further analysis to better quantify effects of physical drivers on drinking water vulnerabilities. This quantification will likely require aggregation and modeling of available information in order to refine predictions about specific outcomes for water supplies due to climate change. Specific recommendations for these analyses are explored in Section 4.7.

Table 4.3. Priority Vulnerabilities with their Physical Drivers.

Priority Drinking Water Vulnerabilities	Responsible Physical Drivers
Damage to Drinking Water Infrastructure	Flooding; sea level rise
Inundation of Treatment Plants and Pumping Facilities	Flooding; sea level rise; storm surge
Degraded Source Water Quality	Increased runoff; changes in watershed vegetation and forest cover; sea level rise
Upstream Movement of Salt Line/Salinity Intrusion in Aquifers and Habitats	Sea level rise; storm surge
Power Outages and Customer Supply Issues	Flooding; storm surge

4.6 Drinking Water - Adaptation Options

The analysis in Section 4.5 is most useful in identifying areas suitable for further study to refine estimates of the specific effects of physical drivers on drinking water vulnerabilities. These areas of recommended study are described in section 4.7. Another important aspect of climate change planning is to identify adaptations that increase the resiliency of water utilities and the Basin against the effects of climate change. As more detailed analyses become available, more specific adaptations can be identified. For the purposes of this plan, however, the workgroup identified reasonable actions that drinking water utilities and regional stakeholders can take now to help prepare for climate change while more detailed evaluations of climate change and its impacts on drinking water supplies are underway.

Adaptations identified by the workgroup are listed below in Section 4.6.1. For each vulnerability identified above, the workgroup selected one priority regional level action and one utility level action. These actions were regarded by the workgroup as the single most important steps in guarding against a particular vulnerability. Selected adaptations generally address one or more climate change vulnerabilities without requiring extensive climate change modeling. They may also minimize current threats to drinking water supplies in order to provide a “cushion” for physical changes expected as a result of climate change. Many of the selected actions improve current knowledge of conditions in the Basin in order to facilitate future projections.

In general, climate change will likely exacerbate existing threats and challenges to drinking water supplies. Therefore, the actions listed represent source water protection measures needed to address current and future challenges. The prospect of climate change only adds emphasis and urgency to development of regional support for drinking water supply protection.

4.6.1 Inventory of Adaptation Options

Degraded Source Water Quality

Regional Level Action ~ Protect Forests

Forest protection in the upper Basin is the single most important action needed to minimize degradation of drinking water supply quality. Forests assimilate nutrients, filter out waterborne sediments, hold soils in place to prevent erosion, and act like a sponge to hold rain water which is then slowly released to replenish streams and groundwater supplies. Municipal governments must develop a strategy for development to avoid clearing of forested and buffered areas. The importance of protecting forests for the preservation of drinking water supplies must be legally acknowledged on a state and federal level.

Also Addresses: Impacts to Reservoir Levels; Decreased Supply Availability

Involves: Environmental Protection Agency (EPA), Delaware River Basin Commission (DRBC), state government, municipal government

Utility Level Action ~ Improve Monitoring of Priority Parameters
Improved monitoring of parameters of concern to drinking water supplies, such as UV254, chlorides, dissolved organic carbon, total organic carbon, *Cryptosporidium*, etc., is needed. These parameters are likely to be impacted by changing conditions in the basin. Monitoring becomes even more important if water quality becomes further degraded due to the physical drivers associated with climate change. Monitoring data will be valuable in examining future changes to intake locations, sources, or alternative treatment technologies which may be necessary in the future. A comprehensive program with other utilities and monitoring entities that coordinates samplings spatially, agrees on a standard set of parameters, and includes a sampling schedule that ensures maximum utility for analysis of climate change impacts is recommended.
Also Addresses: Increased Spills and Accidents
Involves: DRBC, EPA, state government, drinking water utilities

Decreased Supply Availability/Impacts to Reservoir Levels
Regional Level Action ~ Support Green Stormwater Infrastructure
Green stormwater infrastructure solutions that emphasize infiltration can manage stormwater, improve water quality, revitalize communities, and help mitigate potential effects of climate change such as the heat island effect. If implemented on a large scale, green infrastructure can help maintain groundwater and baseflow levels in the Basin which may be critical to meet water demands especially during periods of low precipitation.
Also Addresses: Degraded Water Quality, Impacts to Reservoir Levels
Involves: EPA, DRBC, state government, municipal government

Utility Level Action ~ Evaluate Drought Readiness and Response Plans
Water utilities should evaluate drought response plans to identify vulnerabilities, fill gaps and develop needed contingency plans. Historical droughts should be evaluated to determine efficacy of usage restrictions. Utilities should examine the impact of large upstream consumptive users on their water availability. Agreements should be explored with upstream users for usage contingency plans during drought.
Also Addresses: Impacts to Reservoirs

Inundation of Treatment Plants and Pump Stations/Damage to Drinking Water Treatment Infrastructure
Regional Level Action ~ Update 100-year and 500-year Floodplain Maps
Regardless of the quality of science available to determine the impacts of climate change on physical conditions in the Basin, specific inundation risks can only be effectively evaluated with updated shoreline topographical information.

Utility Level Action ~ Evaluate Placement of New Construction and Materials Resiliency
Drinking water utilities should evaluate the placement of new construction, monitoring equipment, and other infrastructure to avoid low-lying areas or locations vulnerable to storms and other harsh weather

conditions. Ranges of potential flooding should be evaluated using the best available science. Adaptations can be refined as more information becomes available about specific impacts of sea level rise, potential increases in streamflow and other changes in the basin that pose a risk to drinking water utilities. Utilities should also evaluate and incorporate use of more resilient construction materials during day-to-day upgrades.

Increased Spills and Accidents/Power Outages and Customer Supply Issues

Regional Level Action ~ Support the Delaware Valley Regional Early Warning System

The Delaware Valley Regional Early Warning System notifies drinking water utilities in the event of accidental contamination in certain areas of the Delaware Basin. The system provides critical information to utilities so they can respond swiftly and appropriately to unexpected threats. Efforts to expand and improve this system must be supported to ensure the continued protection of drinking water supplies in the Basin.

Addresses: Increased Spills and Accidents

Involves: EPA, DRBC, state government, USCG, municipal government, Offices of Emergency Management

Utility Level Action ~ Evaluate Emergency Response Protocols

At the same time that regional emergency response protocols are being evaluated, water suppliers should conduct assessments of their individual utility emergency response protocols to identify vulnerabilities, fill gaps and develop needed contingency and customer communication plans. Revisiting emergency response plans can help protect utilities in the event of unexpected accidents or spills which may become even more prevalent with changing physical conditions in the Basin.

Addresses: Increased Spills and Accidents, Power Outages & Customer Supply Issues

Upstream Movement of Salt Line/Salinity Intrusion in Aquifers and Freshwater Habitats

Regional Level Action ~ Support Policies that Protect Drinking Water Supplies from Salinity Intrusion

Analyses by the Philadelphia Water Department demonstrate that streamflow targets at Trenton as defined by the Delaware River Basin Commission must be kept at least at current levels to protect the Philadelphia water supply under present day climate conditions. As more information about effects of climate change on physical conditions in the Basin becomes available, flow management policies in the Basin must be evaluated and modified to ensure continued protection of drinking water supplies.

Utility Level Action ~ Evaluate Customer Notification Needs and Protocols

Analyses show that sodium and chloride are steadily increasing in the main stem Delaware most likely because of increased development, road salts application, and inputs from wastewater and drinking water treatment. These parameters are not removed during conventional drinking water treatment and could pose problems for special needs customers such as dialysis patients and certain industries. Impacts of climate change on conditions in the Basin may exacerbate rising salinity. Water utilities should evaluate current salinity levels to determine if more frequent notification to special needs customers is required.

4.7. Drinking Water – Identify Priority Research Needs

As discussed above, survey results identify priorities for water suppliers, government agencies and other key decision makers with respect to climate change and drinking water supplies. This guidance is most helpful in identifying key research needs with respect to climate change. The survey allows water suppliers and regulators to identify priority science gaps among the myriad research needs and substantial uncertainty associated with future change. Focusing on these key research needs will provide more information necessary to refine planning and adaptation efforts.

Survey results point to two main categories of research needs: Physical Drivers and Impacts of Physical Drivers on Drinking Water Supplies. The first category, Physical Drivers, focuses on increasing the understanding of how global climate model results translate to changing Delaware Basin conditions such as streamflow. The second category, Impacts of Physical Drivers on Drinking Water Supplies, aims to quantify the potential impact of physical drivers on drinking water supply vulnerabilities, such as the impact of changing streamflow on salt line movement. The first category of research needs is described below in Section 4.7.1. The second category of research needs is described in Section 4.7.2.

4.7.1. Research Needs – Physical Drivers

Research needs on Physical Drivers are based on topics identified in the workgroup survey as having a high impact score and low confidence score. A low confidence score indicates that the workgroup was not assured of the availability of data on the physical drivers that impact supply. These drivers have a large potential for impact, but require more localized climate predictions to assist in identifying impacts of climate change on physical conditions in the Basin. These drivers were flagged as priorities requiring more research. Table 4.4 summarizes research priorities in this category.

Table 4.4 Recommended areas of further research on physical drivers

Drivers	Delaware Basin Specific Research
▪ Decreased/increased river discharge and streamflow ▪ Decreased/increased groundwater levels ▪ Increased runoff ▪ Increased frequency of short-term drought ▪ Disruptions to aquatic ecosystems ▪ Increases in demand	▪ Precipitation predictions (volume and intensity) and implications for priority drivers ▪ Air temperature and heat index predictions and implications for priority drivers ▪ Impacts of climate change on snowpack and implications for priority drivers ▪ Regional water demand projection ranges (seasonal and peak) based on population growth, development, temperature/heat index changes, and a potentially longer growing season

4.7.2 Research Needs – Impacts of Physical Drivers on Drinking Water Supplies

Research needs in this category focus on topics identified as having a high potential impact score and a low confidence score in the workgroup survey. A high confidence score indicates that the workgroup was certain of the availability of data on the physical drivers that impact supply. Yet available information about physical drivers requires further modeling and study in order to quantify specific effects on supply vulnerabilities. Recommendations in this category are outlined in Table 4.5.

Table 4.5. Top research needs for quantifying the impacts to water utilities from changing physical drivers

Vulnerability	Delaware Basin Specific Research
Damage to Drinking Water Infrastructure	▪ Evaluate impacts of potential flooding, sea level rise and storm surge on infrastructure vulnerability; use historical information about impacts of flooding on infrastructure as guideline ▪ Consider impact of direct temperature change on infrastructure vulnerability
Inundation of Treatment Plants and Pumping Facilities	▪ Evaluate impacts of flooding, sea level rise and storm surge on the vulnerability of drinking water infrastructure to temporary and permanent inundation using updated floodplain maps
Degraded Source Water Quality	▪ Evaluate impacts of sea level rise on parameters of concern to drinking water supplies including *Cryptosporidium*, *E.coli*, *Giardia*, turbidity and suspended sediment, alkalinity, pH, dissolved metals, buffer capacity, dissolved organic carbon, dissolved oxygen, aquatic health and biochemical oxygen demand ▪ Factor in changes in runoff, watershed vegetation and forest cover as more information about these changes becomes available ▪ Consider effects of direct temperature change on parameters of concern ▪ Examine effects of changes in watershed vegetation and forest cover and direct temperature effects on migration patterns of waterfowl and pathogen transport
Upstream Movement of Salt Line/Salinity Intrusion in Freshwater Aquifers and Habitats	▪ Model effects of sea level rise and storm surge on salinity levels at drinking water intakes ▪ Factor in changing streamflow as more information becomes available
Power Outages and Customer Supply Issues	▪ Evaluate effect of flooding and storm surge on possible increased disruptions on ability to provide service; use historical data on service interruptions as guideline

The workgroup also identified the assessment of vulnerabilities and adaptation options regarding groundwater supplies (which were not part of this effort) as a major gap in knowledge/information related to drinking water that needs to be addressed.

Feature Box: A Hypothetical Exercise for Demonstration Purposes

In the year 2000, demand for drinking water in the watershed of the Delaware Estuary was around 164 billion gallons annually. Currently, the mean cost to treat and supply is about $5/1000 gallons of water (Corrozi and Nelson, 2008), meaning that the Estuary spends around $820 million annually on drinking water supply. Over the next century, the Estuary population is anticipated to grow by 83%. This number was calculated using two different population project models called Straight and Cohort which used 2000 Census data for the counties in the Delaware Estuary. See Table 4.6 for the output of these models on population projections. Realistically, technology improvements and water saving practices would likely prevent water demand from increasing at a 1:1 ratio with population growth. But for this hypothetical exercise, let's assume that an increase in population will result in a proportionate increase in water demand.

Table 4.6. Population Predictions

Year	Estimated Population	Population Increase
2000	6,441,769	--
2050	8,902,778	38%
2100	11,793,956	83%

If we assume that water demand per person holds at 2000 Census numbers, then water demand will increase by 38% at 2050 and 83% by 2100. Population growth alone may put great strain on drinking water supplies, and climate change will only add to the problem. Salinity rise around the freshwater intakes and flooding are among the many climate change impacts that may lead to physical damage and corrosion of infrastructure. Even 1% damage to drinking water infrastructure from climate change added to a 2050 population growth of 2.5 million people (Table 4.7) could put pressure on supply systems.

As drinking water suppliers reach capacity and infrastructure is damaged from climate change, this region will have to pursue alternatives to the current supply system. In a worst-case scenario, this shortage would be filled with bottled water at a cost of just under $1 billion per day, which is probably not a realistic long-term option. Fortunately, demand for water per person can be reduced by employing conservation BMPs proposed by the California Urban Water Conservation Council (UWCC) such as low flow toilets and gray water landscaping (App. L). Using an analysis of BMP costs and savings from the UWCC, we calculated that BMPs could be employed to fill this shortage for $1.2 Billion/yr – less than the cost of filling the supply deficit with bottled water *for only 2 days*.

Based on this hypothetical exercise, the Natural Capital Team recommends that water planners should consider projections of population growth and potential risks from climate change in their long range supply plans. Better planning could help water suppliers avoid some emergency situations. In addition, water planners should consider using demand cutting alternatives to address population growth, rather than simply increasing supply with new intakes and treatment plants. Often, it is assumed that the only way to address increasing demand is to meet it with increased supply. Water planners in the Delaware Estuary should be educated about demand cutting alternatives, such as those used by the California Urban Water Conservation Council (App. L).

4.8 Drinking Water – Conclusions

The above analysis provides an inventory of the potential impacts of climate change on the Basin and the implications of those impacts on drinking water supplies, suggestions for actions that help guard against drinking water vulnerabilities, and recommendations for future study. The following key messages arise from the analysis:

- Of the drivers assessed, sea level rise, storm surge, and flooding are likely to have high impact for many of the drinking water vulnerabilities identified. Future study should focus on quantifying the effects of these drivers on risks to drinking water supplies.
- Climate change will likely exacerbate existing threats and challenges to drinking water supplies. The prospect of climate change adds emphasis to the importance of regional support for source water protection.
- Both utility level and regional level actions are critical to improving the resiliency of drinking water supplies to the effects of climate change.
- Forest protection is the single most important action in protecting regional water supplies from water quality degradation. It is also critical to guarding against potential decreases in supply availability and impacts to reservoir levels.
- Ensuring continued support and funding for tools such as the Delaware Valley Early Warning System that facilitate region-wide communication during emergency is also a critical regional adaptation to climate change.
- Evaluating placement of new construction with respect to expected sea level rise and updating drought and emergency response plans are critical adaptations at a utility level.
- Understanding the interactions of various climate change factors on flow and drinking water supply and demand is complicated, but can be improved by monitoring and methodical modeling of the various flows and factors in the watershed.