Source Water Protection Contingency Plan

City of Ripley

PWSID 3301811

Jackson County, West Virginia

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SOURCE WATER PROTECTION CONTINGENCY PLAN
FOR THE
CITY OF RIPLEY

Prepared By:

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I certify the information in this Source Water Protection Contingency Plan is complete and accurate to the best of my knowledge.

Authorizing Signatory:

____   __________________________

Carolyn Rader   Date
Mayor

____

Date of Submission

Funding By:

Office of Environmental Health Services
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EXECUTIVE SUMMARY

This Source Water Protection Contingency Plan (SWPCP) is being developed for the City of Ripley (Ripley) in accordance with Senate Bill 373. Ripley is a state regulated public utility and operates a public water system serving the City of Ripley and Evans area in Jackson County, West Virginia. The utility serves 2,146 residential customers and 321 commercial customers as reported in the 2015 PSC Annual Report. Ripley also provides water to Southern Jackson Public Service District (PSD).

Ripley's water treatment facility obtains surface water from Mill Creek for treatment. The plant has a treatment capacity of 2,300,000 gallons per day (GPD) and pumps approximately thirteen (13) hours per day producing an average of 952,000 GPD. Ripley maintains seven (7) treated water storage tanks totaling 2,002,000 gallons of treated water and does not retain any raw water storage. At this time, the water system is experiencing 21.66% unaccounted for water; however, the utility is conducting leak detection and making necessary repairs to reduce unaccounted for water. Ripley currently maintains a 500 kW stationary generator to provide power service to the raw water intake and treatment facility. The distribution system requires a portable generator to operate during power loss.

In the event Mill Creek is detrimentally affected, Ripley does not have an alternative water source to fully support the entire system. This SWPCP describes in detail the aforementioned aspects of Ripley's public water system and evaluates the technical and economic feasibility of the following four (4) alternatives to provide continued safe and reliable public water service.

Backup Intake

Ripley currently draws water from Mill Creek. Upstream of the treatment plant Mill Creek is comprised of three (3) tributaries. The Elk Fork flows into Elk Fork Lake before converging with Little Mill Creek to form Mill Creek. Further downstream Mill Creek receives discharge from the Tug Fork. A backup intake constructed upstream of the conjunction with the Tug Fork would eliminate the threat of contamination from the Tug Fork. The construction of a backup intake at an upstream location on Mill Creek was considered during feasibility analysis.

Interconnection

Ripley is interconnected with Mason County PSD via the former Evans PSD system. Evans PSD has purchased water from Mason County PSD's Letart System in the past and the interconnection is capable of fully supporting the Evans system. Ripley does not have the ability to utilize water from

Mason County PSD via the Evans system to supply the remainder of the distribution system.

Consequently, Ripley would require another interconnection to meet demands during a contamination event. The nearest viable interconnection would be Northern Jackson PSD, located approximately 450 feet north of the Ripley system along County Route 21. Northern Jackson PSD does not have a water treatment facility and is supplied by the City of Ravenswood. An interconnection with the City of Ravenswood (Ravenswood) via Northern Jackson PSD could fulfill Ripley's remaining water demand. The existing interconnection with Mason County PSD along with the construction of an interconnection with Northern Jackson PSD was evaluated in the feasibility analysis.

Treated Water Storage

Ripley currently has 2,002,000 gallons of treated water storage distributed between seven (7) storage tanks. Senate Bill 373 requires that each utility maintain at least two (2) days of system storage based on the maximum level of production experienced within the past year. The daily maximum amount of water produced by Ripley within the past year was 1,521,331 gallons, therefore 3,042,662 gallons of total water storage is required to comply with Senate Bill 373.

After re-evaluating the maximum production to address only customers dependent on Ripley's water storage, Ripley needs a minimum of approximately 229,000 gallons of additional water storage to satisfy Senate Bill 373. Additional detail of the calculation is provided in in **Appendix C**. The construction of additional treated water storage was evaluated in the feasibility analysis.

Raw Water Storage

As described above the treated water storage capacity of Ripley is 2,002,000 gallons, and after re-evaluation Ripley requires an additional 229,000 gallons of water storage to satisfy the two (2) day system storage requirement described in Senate Bill 373. The addition of raw water storage to satisfy the minimum system storage requirement was considered during feasibility analysis.

Based on the evaluation of the water system, the most feasible alternative for Ripley is the combination of existing treated water storage, the existing interconnection with Mason County PSD, and the construction of an interconnection with Northern Jackson PSD. Also, it is recommended that Ripley install an early warning monitoring system to prevent compromised surface water from contaminating the system as well as a portable generator to provide power to the distribution system during loss of power. Additional detail of the selection of this alternative is provided in **Appendix C**.

PURPOSE

The goal of the West Virginia Bureau for Public Health (WVBPH) Source Water Assessment and Protection (SWAP) program is to prevent degradation of source waters which may preclude present and future uses of drinking water supplies to provide safe water in sufficient quantity to users. The most efficient way to accomplish this goal is to encourage and oversee source water protection on a local level. Every aspect of source water protection is best addressed by engaging local stakeholders.

The intent of this document is to describe what the City of Ripley has done, is currently doing, and plans to do to protect its source of drinking water. Although this water system treats the water to meet federal and state drinking water standards, conventional treatment does not fully eradicate all potential contaminants, and treatment that goes beyond conventional methods is often very expensive. By completing this plan, Ripley acknowledges that implementing measures to prevent contamination is vital to ensuring the safety of the drinking water.

What are the benefits of preparing a Source Water Protection Plan?

- Fulfills the requirement for the public water utilities to complete or update their source water protection plan.
- Identifies and prioritizes potential threats to the source of drinking water; and establishes strategies to minimize the threats.
- Plans for emergency responses to incidents that compromise the water supply by contamination or depletion, including how the public, state, and local agencies will be informed.
- Plans for future expansion and development, including establishing secondary sources of water.
- Ensures conditions to provide the safest and highest quality drinking water to customers at the lowest possible cost.
- Provides more opportunities for funding to improve infrastructure, purchase land in the protection area, and other improvements to the intake or source water protection areas.

WV SOURCE WATER ASSESSMENT AND PROTECTION PROGRAM

Since 1974, the federal Safe Drinking Water Act (SDWA) has set minimum standards on the construction, operation, and quality of water provided by public water systems. In 1986, Congress amended the SDWA. A portion of those amendments was designed to protect the source water contribution areas around groundwater supply wells. This program eventually became known as the Wellhead Protection Program (WHPP). The purpose of the WHPP is to prevent pollution of the source water supplying the wells.

The Safe Drinking Water Act Amendments of 1996 expanded the concept of wellhead protection to include surface water sources under the umbrella term of "Source Water Protection". The amendments encourage states to establish SWAP programs to protect all public drinking water supplies. As part of this initiative, states must explain how protection areas for each public water system will be delineated, how potential contaminant sources will be inventoried, and how susceptibility ratings will be established.

In 1999, the WVBPH published the West Virginia Source Water Assessment and Protection Program, which was endorsed by the United States Environmental Protection Agency. Over the next few years, WVBPH staff completed an assessment (i.e., delineation, inventory and susceptibility analysis) for all of West Virginia's public water systems. Each public water system was sent a copy of its assessment report. Information regarding assessment reports for the City of Ripley can be found in **Table 1**.

STATE REGULATORY REQUIREMENTS

On June 6, 2014, §16.1.2 and §16.1.9a of the Code of West Virginia (1931) was reenacted and amended by adding three new sections designated §16.1.9c, §16.1.9d and §16.1.9e. The changes to the code outline specific requirements for public water utilities that draw water from a surface water source or a groundwater source influenced by surface water (GWUDI).

Under the amended and new codes, each existing public water utility using surface water or ground water influenced by surface water as a source must have completed or updated a source water protection plan by July 1, 2016, and must continue to update their plan every three years. Existing source water protection plans have been developed for many public water utilities in the past. If available, these plans were reviewed and considered in the development of this updated contingency plan. Any new water system established after July 1, 2016 must submit a source water protection plan before they begin operation. A new plan is also required when there is a significant change in the potential sources of significant contamination (PSSC) within the zone of critical concern (ZCC).

The code also requires that public water utilities include details regarding PSSCs, protection measures, system capacities, contingency plans, and communication plans. Before a plan can be approved, the local health department and public will be invited to contribute information for consideration. In some instances, public water utilities may be asked to conduct independent studies of the source water protection area and specific threats to gain additional information.

SYSTEM INFORMATION

The City of Ripley is classified as a state regulated public utility and operates a public water system serving areas of Jackson County. A public water system is defined as:

> "Any water supply or system which regularly supplies or offers to supply water for human consumption through pipes or other constructed conveyance, if serving at least an average of twenty-five individuals per day for at least sixty days per year, or which has at least fifteen service connections, and shall include:
>
> i. Any collection, treatment, storage and distribution facilities under the control of the owner or operator of the system and used primarily in connection with the system
>
> ii. Any collection or pretreatment storage facilities not under such control which are used primarily in connection with the system."

A public water utility is defined as, "any public water system which is regulated by the West Virginia Public Service Commission."

For purposes of this source water protection plan, public water systems are also referred to as public water utilities. Information on the population served by this utility is presented in **Table 1** on the following page.

Table 1 – Population Served

Administrative office location:		203 South Church Street Ripley, West Virginia 25271	
Is the system a public utility, according to the Public Service Commission rule?		Yes	
Date of Most Recent Source Water Assessment Report:		March 2003	
Date of Most Recent Source Water Protection Plan:		February 2012	
Population served directly:		**Customers** Residential 2,146 Commercial 321	**Total Customers** **2,467**
Bulk Water Purchaser Systems:	**System Name**	**PWSID Number**	**Population**
	Southern Jackson PSD	3301817	6,577
	N/A		
Total Population Served by the Utility:		11,800*	
Does the utility have multiple source water protection areas (SWPAs)?		No	
How many SWPAs does the utility have?		1	

* *Estimated based on West Virginia's 2.43 persons per household as reported by the U.S. Census Bureau*

WATER TREATMENT AND STORAGE

As required, the City of Ripley has assessed their system (e.g., treatment capacity, storage capacity, unaccounted for water, contingency plans) to evaluate their ability to provide drinking water and protect public health.

Table 2 contains information on the water treatment methods and capacity of the utility. Information about the surface water sources from which Ripley draws water can be found in **Table 3**. If the utility draws water from any groundwater sources to blend with the surface water, the information about these ground water sources can be found in **Table 4**. These tables can be found on the following pages.

Table 2 – Water Treatment Information

Water Treatment Process (List in order)	Raw Water Intake ↓ Flocculation ↓ Sedimentation ↓ Filtration ↓ Chlorination ↓ Clearwell ↓ High Service Pumps
Current Treatment Capacity (gal/day)	2,300,000
Current Average Production (gal/day)	952,358
Maximum Quantity Treated and Produced (gal/day)	1,521,331
Minimum Quantity Treated and Produced (gal/day)	563,606
Average Hours of Operation in One Day	13
Maximum Hours of Operation in One Day	22
Minimum Hours of Operation in One Day	8
Number of Storage Tanks Maintained	7
Total Gallons of Treated Water Storage (gal)	2,002,000
Total Gallons of Raw Water Storage (gal)	0

Table 3 – Surface Water Sources

Intake Name	SDWIS #	Local Name	Describe Intake	Name of Water Source	Date Constructed/ Modified	Frequency of Use (Primary/ Backup/ Emergency)	Activity Status (Active/ Inactive)
Mill Creek O'Brien Dam			30' of 12 steel conduit	Mill Creek	2008 *(M)*	Primary	Active

(C) Constructed
(M) Modified

Table 4 – Groundwater Sources

Does the utility blend with groundwater?	No

Response Networks and Communication

Statewide initiatives for emergency response, including source water related incidents, are being developed. These include the West Virginia Water/Wastewater Agency Response Network (WV WARN, see http://www.wvwarn.org/) and the Rural Water Association Emergency Response Team (see http://www.wvrwa.org/). Ripley has analyzed its ability to effectively respond to emergencies and this information is provided in **Table 5**.

Table 5 – Water Shortage Response Capability

Can the utility isolate or divert contamination from the intake or groundwater supply?	Yes
Describe the utility's capability to isolate or divert potential contaminants:	The utility can shut down the raw water intake pumps.
Can the utility switch to an alternative water source or intake that can supply full capacity at any time?	No; however the Evans system can be fully supported by the interconnection with Mason County PSD's Letart system.
Describe in detail the utility's capability to switch to an alternative source:	N/A
Can the utility close the water intake to prevent contamination from entering the water supply?	Yes
How long can the intake stay closed?	Approx. 2.1 days based on average production
Describe the process to close the intake:	Shut down raw water intake pumps and close intake valve
Describe the treated water storage capacity of the water system:	The system currently has seven (7) treated water storage tanks totaling 2,002,000 gallons. At the time of this report, Ripley was operating at 100% treated water storage capacity.
Is the utility a member of WVRWA Emergency Response Team?	Yes
Is the utility a member of WV-WARN?	No
List any other mutual aid agreements to provide or receive assistance in the event of an emergency:	None

Operation During Loss of Power

This utility analyzed and examined its ability to operate effectively during a loss of power. This involved ensuring a means to supply water through treatment, storage, and distribution without creating a public health emergency. Information regarding the utility's capacity for operation during power outages is shown in **Table 6**. The utility's standby capacity would have the capability to provide power to the system as if normal power conditions existed. The utility's emergency capacity would have the capability to provide power to only the essential equipment and treatment processes to provide water to the system. Information regarding the emergency generator capacity for each utility was calculated by the WV BPH and can be found in **Appendix D**.

Table 6 – Generator Capacity

What is the type and capacity of the generator needed to operate during a loss of power?	The treatment facility is equipped with a 500kW stationary generator and transfer switch. A 50kW, 120V, 1Ø portable generator would be required in order to operate the distribution system.	
Can the utility connect to generator at the intake/wellhead? If yes, select a scenario that best describes system.	Yes, the utility has a generator hard wired and ready to turn on.	
Can the utility connect to generator at the treatment facility? If yes, select a scenario that best describes system.	Yes, the utility has a generator hard wired and ready to turn on.	
Can the utility connect to a generator in distribution system? If yes, select a scenario that best describes system.	No, the utility does not have a generator, but is fully wired for connection.	
Does the utility have adequate fuel on hand for the generator?	Yes	
What is your on-hand fuel storage and how long will it last operating at full capacity?	**Gallons**	**Duration**
	250	~24 hours

Table 6 – Generator Capacity (Continued)

		Supplier	Contact Name	Phone Number
Provide a list of suppliers that could provide generators and fuel in the event of an emergency:	**Generator**	Cummins	Crosspoint	(304) 769-1012
	Generator			
	Fuel	RT Rogers	Roger Basler	(304) 466-1733
	Fuel			

Does the utility test the generator(s) periodically?	Yes
Does the utility routinely maintain the generator?	Yes
If no scenario describing the ability to connect to generator matches the utility's system or if utility does not have ability to connect to a generator, describe plans to respond to power outages:	

Future Water Supply Needs

When planning for potential emergencies and developing contingency plans, a utility needs to not only consider their current demands for treated water but also account for likely future needs. This could mean expanding current intake sources or developing new ones in the near future. This can be an expensive and time consuming process, and any water utility should take this into account when determining emergency preparedness. Ripley has analyzed its ability to meet future water demands at current capacity and this information is included in **Table 7** on the following page.

Table 7 – Future Water Supply Needs

Is the utility able to meet water demands with the current production capacity over the next 5 years? If so, explain how you plan to do so.	Yes, based on population trends there is no need for an increase in capacity to meet water demands. If population trends change, the treatment plant has sufficient capacity remaining.
If not, describe the circumstances and plans to increase production capacity:	N/A

Water Loss Calculation

In any public water system, there is a certain percentage of the total treated water that does not reach the customer distribution system. Some of this water is used in treatment plant processes such as backwashing filters or flushing piping, but there is usually at least a small percentage unaccounted. To measure and report on this unaccounted for water, a public utility must use the same method used in the Public Service Commission's rule, *Rules for the Government of Water Utilities*, 150CSR7, Section 5.6. The rule defines unaccounted for water as "the volume of water introduced into the distribution system less all metered usage and all known non-metered usage which can be estimated with reasonable accuracy."

To further clarify, metered usages are most often those that are distributed to customers. Non-metered usages estimated include water used by fire departments for fires or training, un-metered bulk sales, flushing to maintain the distribution system, backwashing filters, and cleaning settling basins. By totaling the metered and non-metered uses, the utility calculates unaccounted for water. Note: To complete annual reports submitted to the PSC, utilities typically account for known water main breaks by estimating the amount of water lost. However, for the purposes of the source water protection contingency plan, any water lost due to leaks – even if the system is aware of how much water is lost at a main break – is not considered a use. Water lost through leaks and main breaks cannot be controlled during water shortages or other emergencies and should be included in the calculation of percentage of water loss for purposes of the source water contingency protection plan. The data in **Table 8** is taken from the most recently submitted City of Ripley PSC Annual Report.

Table 8 – Water Loss Information

Total Water Pumped (gal)		373,796,000
Total Water Purchased (gal)		–
Total Water Pumped and Purchased (gal)		373,796,000
Water Loss Accounted for Except Main Leaks (gal)	**Mains, Plants, Filters, Flushing, etc.**	692,000
	Fire Department	7,470,000
	Back Washing	–
	Blowing Settling Basins	–
Total Water Loss Accounted For Except Main Leaks		8,162,000
Water Sold- Total Gallons (gal)		284,667,000
Unaccounted For Lost Water (gal)		80,967,000
Water lost from main leaks (gal)		–
Total gallons of Unaccounted for Lost Water and Water Lost from Main Leaks (gal)		80,967,000
Total Percent Unaccounted For Water and Water Lost from Main Leaks (%)		21.66
If total percentage of Unaccounted for Water is greater than 15%, please describe any measures that could be taken to correct this problem:		Increased inspection and leak detection, and making necessary repairs.

EARLY WARNING MONITORING SYSTEM

Public water utilities are required to provide an examination of the technical and economic feasibility of implementing an early warning monitoring system. Implementing an early warning monitoring system may be approached in different ways depending upon the water utility's resources and threats to the source water. A utility may install a continuous monitoring system that will provide real-time information regarding water quality conditions. This would require utilities to analyze the data in order to establish what condition is indicative of a contamination event. Continuous monitoring will provide results for a predetermined set of parameters. The more parameters being monitored, the more sophisticated the monitoring equipment will be. When establishing a continuous monitoring system, the utility should consider the logistics of placing and maintaining the equipment and receiving output data from the equipment.

Alternately, or in addition, a utility may also pull periodic grab samples on a regular basis or in case of a reported incident. The grab samples may be analyzed for specific contaminants. A utility should examine their PSSCs to determine what chemical contaminants could pose a threat to the water source. If possible, the utility should plan in advance how those contaminants will be detected. Consideration should be given for where samples will be collected, the preservations and hold times for samples, available laboratories to analyze samples, and costs associated with the sampling event. Regardless of the type of monitoring (continuous or grab), utilities should collect samples for their source throughout the year to better understand the baseline water quality conditions and natural seasonal fluctuations. Having a baseline will help determine if changes in the water quality are indicative of a contamination event and inform the needed response.

Every utility should establish a system or process for receiving or detecting chemical threats with sufficient time to respond to protect the treatment facility and public health. All approaches to receiving and responding to an early warning should incorporate communication with facility owners and operators that pose a threat to the water quality, state and local emergency response agencies, surrounding water utilities, and the public. Communication plays an important role in knowing how to interpret data and how to respond.

The City of Ripley has analyzed its ability to monitor for and detect potential contaminants that could impact its source water. Information regarding this utility's early warning monitoring system capabilities can be found in **Table 9** on the following page and in **Appendix A**.

Table 9 – Early Warning Monitoring System Capabilities

<table>
<tr><td colspan="2">Does your system currently receive spill notifications from a state agency, neighboring water system, local emergency responders, or other facilities? If yes, from whom do you receive notices?</td><td colspan="2">The utility receives spill notifications from the WV Health Department.</td></tr>
<tr><td colspan="2">Are you aware of any facilities, land uses, or critical areas within your protection areas where chemical contaminants could be released or spilled?</td><td colspan="2">No</td></tr>
<tr><td colspan="2">Are you prepared to detect potential contaminants if notified of a spill?</td><td colspan="2">No</td></tr>
<tr><td rowspan="4">List laboratories (and contact information) on which you would rely to analyze water samples in case of a reported spill.</td><td colspan="3">Laboratories</td></tr>
<tr><td colspan="2">Name</td><td>Contact</td></tr>
<tr><td colspan="2">REI Consultants</td><td>(304) 255-2500</td></tr>
<tr><td colspan="2">WV Office of Lab Services</td><td>(304) 558-3530</td></tr>
<tr><td colspan="2">Do you have an understanding of baseline or normal conditions for your source water quality that accounts for seasonal fluctuations?</td><td colspan="2">Yes</td></tr>
<tr><td colspan="2">Does your utility currently monitor raw water (through continuous monitoring or periodic grab samples) at the surface water intake or from a groundwater source on a regular basis?</td><td colspan="2">Yes</td></tr>
<tr><td colspan="2" rowspan="2">Provide or estimate the capital and O&M costs for your current or proposed early warning system or upgraded system.</td><td>Capital</td><td>$50,000</td></tr>
<tr><td>Yearly O&M</td><td>$750</td></tr>
<tr><td colspan="2">Do you serve more than 100,000 customers? If so, please describe the methods you use to monitor at the same technical levels utilized by ORSANCO.</td><td colspan="2">No</td></tr>
</table>

SINGLE SOURCE FEASIBILITY STUDY

If a public water utility's water supply plant is served by a single-source intake to a surface water source of supply or a surface water influenced source of supply, the submitted source water contingency protection plan must also include an examination and analysis of the technical and economic feasibility of alternative sources of water to provide continued safe and reliable public water service in the event its primary source of supply is detrimentally affected by contamination, release, spill event or other reason. These alternatives may include a secondary intake, two days of raw or treated water storage, interconnections with neighboring systems, or other options identified on a local level. Note: a secondary intake would draw water supply from a substantially different location or water source.

In order to accomplish this requirement, utilities should examine all existing or possible alternatives and rank them by their technical, economic, and environmental feasibility. In order to have a consistent method for ranking alternatives, WV BPH has developed a feasibility study guide. This guide provides several criteria to consider for each category, organized in a scoring matrix. By completing the Feasibility Study, utilities will demonstrate the process used to examine the feasibility of each alternative. The Feasibility Study matrix is attached as **Appendix B**. Those alternatives that are ranked highest and deemed to be most feasible will then be the subject of a second, more in-depth, study to analyze the comparative costs, risks, and benefits of implementing each of the described alternatives. An alternatives analysis report providing these details is attached as **Appendix C**.

CONCLUSION & RECOMMENDATIONS

This report represents a detailed explanation of the required elements of the City of Ripley's Source Water Protection Contingency Plan. Any supporting documentation or other materials that the utility considers relevant to their plan can be found in **Appendix D**.

This source water protection contingency plan is intended to help prepare community public water systems all over West Virginia to properly handle any emergencies that might compromise the quality of the system's source water supply. It is imperative that this plan is updated as often as necessary to reflect the changing circumstances within the water system. The protection team should continue to meet regularly and continue to engage the public whenever possible. Communities taking local responsibility for the quality of their source water are the most effective way to prevent contamination and protect a water system against contaminated drinking water. Community cooperation, sufficient preparation, and accurate monitoring are all critical components of this source water protection contingency plan, and a multi-faceted approach is the only way to ensure that a system is as protected as possible against source water degradation.

After evaluation, the most feasible solution for Ripley to continue water service during a contingent event is the combination of existing water storage and interconnections with Mason County PSD's Letart water system and Northern Jackson PSD. Ripley currently maintains 1.32 days of water storage based on maximum production. Taking into account, Southern Jackson PSD's system storage and support from Mason County PSD in the Evans area, Ripley's water storage capacity can be re-evaluated to 1.77 days. The interconnection with Northern Jackson will provide supplemental supply, providing a sustainable water source during an emergency. Additionally, Mill Creek is fed by streams flowing through two (2) impoundments, Elk Fork Dam and Statts Mill Dam. These impoundments could be used to flush contaminants from the opposite stream in the event Mill Creek is detrimentally affected by a contamination event. It is also recommended that the Ripley install an early warning monitoring system upstream of the surface water intake on Mill Creek as described in **Appendix A**, as well as purchase a portatble generator to provide power to the distribution system during loss of power. The early warning system shall protect the system from potential contaminants detected in the primary surface water source.

This recommendation is based on an evaluation of the four alternatives. The evaluation consisted of operation and maintenance impacts, capital costs, environmental impacts, along with other criteria. A detailed analysis including supporting documentation is included in the Appendices of this report.

RECOMMENDATION COST ESTIMATE

Qty.		Description	Unit Price	Total Cost
1	LS	Interconnection with Northern Jackson PSD	$69,520.00	$69,520
1	LS	50 kW Portable Generator	$21,235.00	$21,235
1	LS	Early Warning Detection Equipment	$50,000.00	$50,000
1	LS	Operation & Maintenance for Early Warning System	$750.00	$750
TOTAL				$141,505

EARLY WARNING MONITORING SYSTEM INFORMATION

Proposed Early Warning Monitoring System Worksheet – Surface Water Source

Describe the type of early warning detection equipment that could be installed, including the design.
The early warning detection equipment that could be installed includes a level controller, display module, back panel, level & trough (see cost estimate by Hach Company in **Appendix D**) along with conductivity, oil-in-water, ORP, and pH sensors.
Where would the equipment be located?
The early warning monitoring systems would be located on the Mill Creek raw water intake line prior to where surface water would enter the treatment facility.
What would the maintenance plan for the monitoring equipment entail?
The proposed maintenance plan for the monitoring equipment shall consist of annual cleaning and/or exchanging of the probe(s) for the controller. Periodic calibration of the unit may also be required.
Describe the proposed sampling plan at the monitoring site.
Sampling of water quality data occurs every fifteen minutes. Ripley would need to retrieve data from the "History" of the controller data collector twice per month.
Describe the proposed procedures for data management and analysis.
Data management for the early warning monitoring system consists of data points (up to 500 points or approximately six months per probe) being recorded in the "History" of the controller data collector. To access the "History", the probe has to be plugged into the controller. Data is able to be removed via USB or through a local SCADA system.

Literature related to the development and design of early warning systems is provided on the following pages courtesy of the American Water Works Association

.

BY RICHARD W. GULLICK, LEAH J. GAFFNEY, CHRISTOPHER S. CROCKETT, JERRY SCHULTE, AND ANDREW J. GAVIN

Developing regional early warning systems FOR US SOURCE WATERS

REGIONAL EARLY WARNING SYSTEMS HELP IMPROVE MONITORING CAPABILITIES, FACILITATE COMMUNICATION AMONG UTILITIES, AND REDUCE RISKS TO PUBLIC HEALTH.

Early warning systems (EWSs) are used by water utilities to detect sudden changes in source water quality and are intended to provide information necessary to implement appropriate responses such as closing intakes or changing treatment methods. Rivers with several intakes over some distance are good candidates for multiple monitoring stations and coordinated data management and communication systems. In the United States, experience with such regional EWSs has largely been limited to the Ohio River and Lower Mississippi River. That situation has changed, however, with the recent development (or impending development) of regional systems on several other US rivers, including the Upper Mississippi, Schuylkill, Delaware, Allegheny, Monongahela, and Susquehanna. This article discusses the characteristics and ongoing development of these systems and the lessons learned through that process. These lessons may be applied to establish new regional EWSs on other rivers in the United States and elsewhere.

EWS OPERATIONS HAVE COMMON FUNCTIONS AND CHARACTERISTICS

Why EWSs are needed. Most raw drinking water sources are susceptible to disruptions in quality as a result of accidental, intentional, or natural contamination. To protect consumers from potentially harmful contaminants, avoid treatment process upsets, and ensure compliance with environmental regulations, utilities must respond rapidly to spills and other sudden pollution events and make appropriate adjustments in drinking water treatment and operations. The timely information provided by an EWS can help guide utility response decisions and ensure that such decisions reflect actual data and circumstances. EWSs are used mostly on riverine systems where water quality can change rapidly (as a result of a barge spill near an intake, for example); the systems are used less frequently for impoundments and rarely for groundwater.

Systems take various forms, serve several purposes. EWSs comprise a combination of frequent or continuous monitoring, other detection mechanisms, institutional arrangements, analysis tools, and response protocols. Certain components are common to all capable EWSs and include the following:

- *Detection:* a monitoring mechanism to detect pollution events and/or a public or self-reporting program.
- *Characterization:* a means to confirm and more completely characterize the event.
- *Communication:* the dissemination of data and other information to utility personnel and other decision-makers and response actions to the public and other stakeholders.
- *Response:* actions taken to minimize the potential effect of the contamination event. Responses could include source containment and/or cleanup, closure of water intakes and use of alternate sources or storage, and treatment process modifications.

Early warning monitoring can be used to detect rapid deterioration in water quality resulting from accidental or intentional discharges of toxic and hazardous chemicals near an intake. Such events as large-scale boat spills, pipeline breaks, industrial accidents, and terrorist attacks may be low in probability but can have significant consequences for water supplies. EWSs are also useful for monitoring during extreme natural events (such as heavy rains and flooding and algal blooms) and somewhat predictable events (such as seasonal runoff of herbicides).

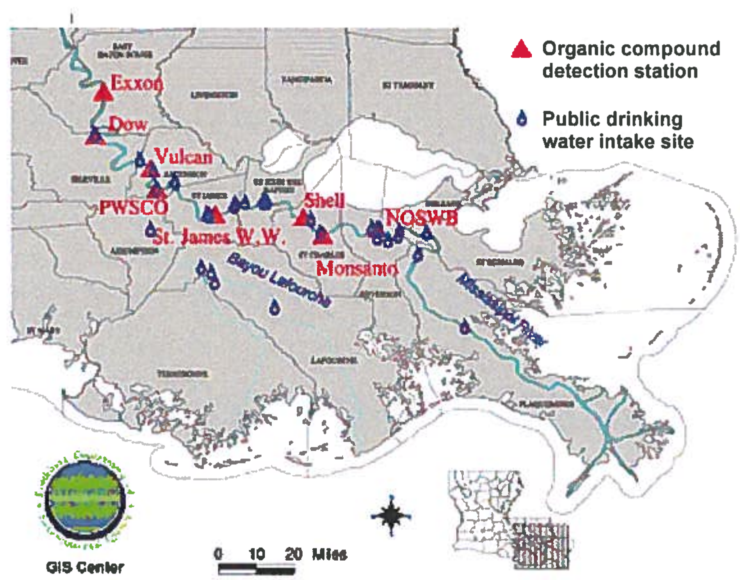
Furthermore, EWSs can serve as a pollution prevention tool by tracking spill events and garnering information (to warrant followup activities and actions by agencies or prevention activities at similar sites), detecting unauthorized waste discharges, and serving as a sentinel of river water quality. In this last capacity, EWSs may tend to increase the number of spills reported but decrease the total number of spills, perhaps because of greater diligence on the part of potential dischargers.

EWS scope depends on site-specific characteristics. Onsite early warning monitoring may be conducted by a single water supplier (e.g., a single instrument at an intake). However, source waters used by multiple water utilities (e.g., a large river) offer opportunities for cooperation and pooling of resources for development of integrated regional EWSs, including multiple monitoring stations, centralized data management and assessment, and coordinated information communication systems. This article uses the term "regional EWS" to refer to a system with multiple users and/or monitoring stations.

FIGURE 1 ORSANCO Organics Detection System stations on the Ohio River

ORSANCO—Ohio River Valley Water Sanitation Commission

FIGURE 2 Lower Mississippi River Early Warning Organic Compound Detection System



Source: Louisiana Department of Environmental Quality

Most regional EWSs are developed in a phased approach that incorporates additional monitoring capability over time. Monitoring techniques range from relatively simple online measurements (e.g., pH, turbidity) to video surveillance to advanced analytical instrumentation to the use of living organisms as bioalarms. Gullick and colleagues (2003) discuss EWS design for water utilities and the types of monitoring methods available; other references provide additional detail (Grayman et al, 2001; Gullick, 2001; Foran & Brosnan, 2000; ILSI, 1999). The sidebar on page 72 summarizes benefits provided by regional EWSs.

EXISTING SYSTEMS PROVE VALUE OF EARLY WARNING MONITORING

On many rivers, there is no systemic monitoring for sudden water quality changes, and no coordinated communication or central reporting system currently exists. Around the world, relatively few regional EWSs exist using monitoring, modeling, and communications in an integrated system to provide warning of contaminants in the source water. Several prominent systems (most of them located in Europe or Asia) were described in detail by Grayman and coworkers (2001) and summarized by Gullick and colleagues (2003). Many of these systems were developed in response to a specific contamination incident.

These systems are diverse but share some characteristics. They may vary greatly in their degree of complexity and in terms of the frequency of analysis and degree of automation. The more sophisticated networks include a coordinated monitoring, modeling, communication, and response program for an extended stretch of river. In all cases, some form of institutional structure coordinates efforts and communicates information so that appropriate actions can be taken.

Ohio River Organics Detection System. The most established regional EWS in the United States is led by Ohio River Valley Water Sanitation Commission (ORSANCO) on the Ohio River. The Ohio River is a source of drinking water for about 3 million people, and more than 25 million people live in the watershed. The river is also heavily industrialized in sections, serves a significant amount of commercial barge traffic, and has hundreds of municipal, industrial, and combined sewer overflow discharges. The EWS includes 15 gas chromatograph stations at various locations to detect and monitor organic chemical spills (Figure 1). Data management and communications are coordinated by a single central office that communicates to utilities the nature of any detected spills or other changes in river water quality.

EWSs alert utilities of contaminants and allow them to initiate cleanups such as this one along the Schuylkill River following a chemical spill caused by a train derailment.

PHOTO CHAD PINDAR, PHILADELPHIA (PA) WATER DEPT.

Most of the monitoring stations are operated by water utilities at their intakes; others are run by industrial facilities. These organizations provide labor and space for sampling and analysis stations; analytical instruments are purchased and maintained by ORSANCO. All stations analyze at least one sample a day. Using a centralized data-analysis system and state-of-the-science contaminant transport models, ORSANCO is often able to provide utilities with specific estimates regarding the concentration–distance–time profile of chemicals spilled in the river. This information helps water utilities decide when to close their intakes and/or how to respond with modifications in treatment processes.

Lower Mississippi River early warning organic compound detection system. Another regional EWS is located in Louisiana on a 128 mi (206 km) stretch of the Lower Mississippi River from Baton Rouge to New Orleans (Figure 2). The system includes eight gas chromatographs (operated by three water utilities and five industries) monitoring for volatile organic chemicals. Although there is no central coordinating agency, the system is overseen by the Louisiana Department of Environmental Quality, which also provided financial support to purchase and maintain the gas chromatographs, accessories, and data-transmitting devices. The utility and industrial monitoring sites provide lab space and workers to analyze the samples. This system was inspired by the ORSANCO example and helps to protect the 1.5 million Louisiana residents who depend on the river for their drinking water supply (Grayman et al, 2001).

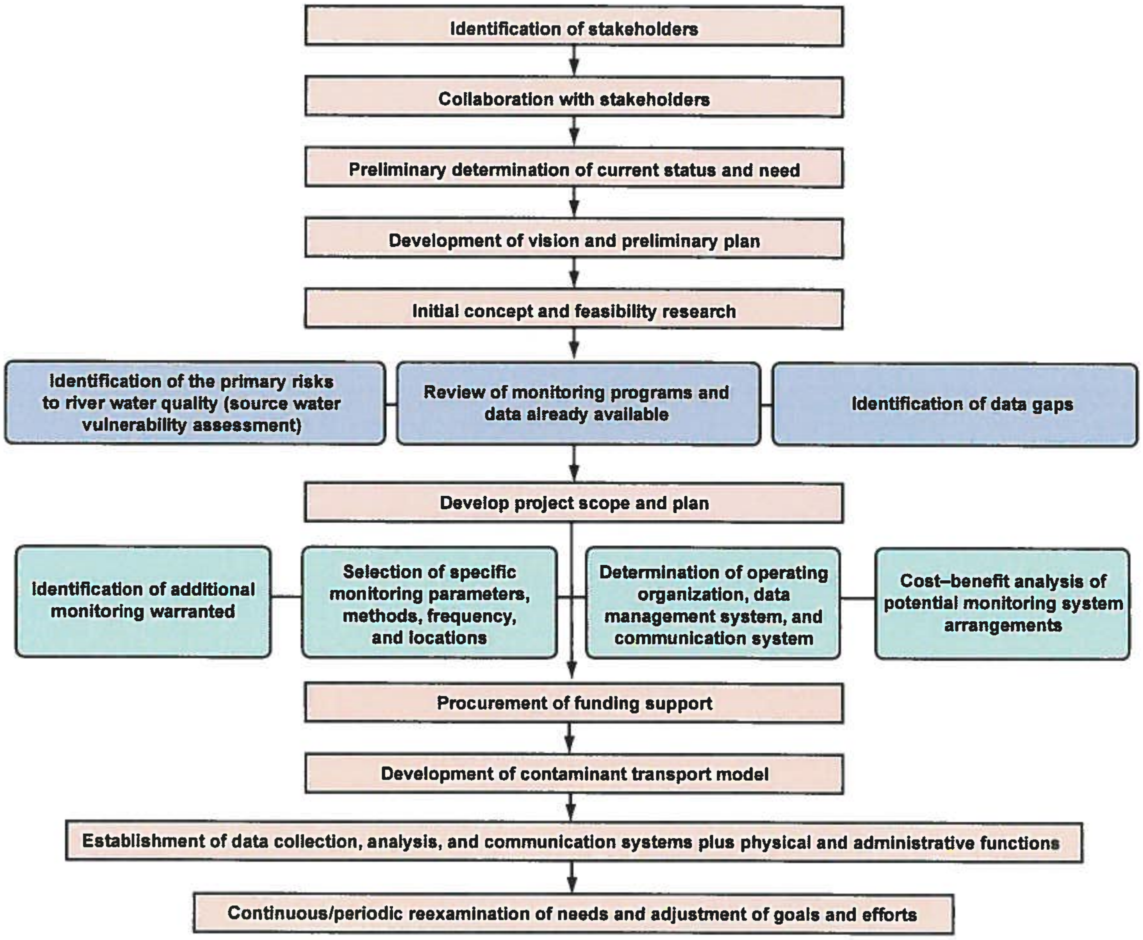
EARLY WARNING MONITORING IS ON THE RISE IN THE UNITED STATES

Interest in regional EWSs has increased in recent years, with systems currently in development for the Upper Mississippi, Schuylkill, Delaware, Allegheny, Monongahela, and Susquehanna rivers (Gullick, 2003). These systems are being designed to answer system-specific needs, and they reflect their individual locations and participating entities. However, the regional EWSs also have some characteristics in common. To some degree, each EWS was modeled after parts of the ORSANCO system, and each aspires to achieve these shared goals:

- Provide prompt notification of significant watershed events to downstream users.
- Provide information and tools to aid water suppliers in making decisions.
- Develop a framework to share information about water quality.
- Improve communication among water suppliers about water quality events.
- Improve communication between water suppliers and emergency responders.

The primary processes involved in the development of a typical regional EWS are shown in Figure 3. The following sections describe the monitoring and communication systems being developed as of April 2004 for the Delaware Valley, Upper Mississippi River, Allegheny and Monongahela rivers, and Susquehanna River.

FIGURE 3 Processes involved in the development of a typical regional early warning system



Delaware Valley (Schuylkill and Delaware rivers). The Delaware River Basin (Figure 4) drains an area of 13,300 sq mi (34,447 km^2) in the states of New York, Pennsylvania, New Jersey, and Delaware. The Delaware River is the longest undammed river east of the Mississippi, stretching 330 mi (531 km) from its headwaters in New York state to the mouth of the Delaware Bay (PWD, 2002). The Schuylkill River is 130 mi (209 km) long and is the largest tributary to the Delaware River. Its basin drains an area of 1,900 sq mi (4,921 km^2) in Pennsylvania.

The Delaware and Schuylkill rivers serve as the source water for more than 3 million people in southeastern Pennsylvania and southwestern New Jersey. Although both rivers originate in rural areas, their confluence in the Delaware Estuary promoted the development of the urban, industrial, and shipping center that is the Philadelphia–Camden metropolitan area. Their location and upstream activities render the rivers highly vulnerable to water quality contamination events and ideal candidates for a source water EWS.

Utility spearheaded EWS development. The Philadelphia Water Department (PWD) operates the three drinking water treatment plants farthest downstream on the Delaware and Schuylkill rivers. The utility gained familiarity with both watersheds during development of the Source Water Assessment Program (PWD, 2002). While working with neighboring water suppliers, PWD identified the need and gathered support for the development of a watershedwide EWS. In the aftermath of Sept. 11, 2001, and after five years of campaigning, PWD received a one-year, $725,000 grant from the Pennsylvania Department of Environmental Protection (PADEP) to develop an EWS. Although the monetary resources were significant, the one-year time frame posed a significant challenge.

PWD sought stakeholder input. From the beginning, stakeholder involvement was an integral part of the EWS development. Even before the grant was awarded, PWD approached a select group of water utilities to gain their support, identify the overall goals of the EWS, and develop the basis for a proposal. After PADEP awarded the grant and

POTENTIAL BENEFITS OF REGIONAL EARLY WARNING SYSTEMS

A regional early warning system shared and supported by a group of water providers offers numerous benefits.

- Improved monitoring can detect sudden changes in river water quality.
- Identification of spills/releases that are unknown to the dischargers may help them to prevent similar releases in the future.
- Communication of contamination events to water utilities is improved.
- Better information on contamination events allows for better response decisions.
- The overall risk to the public from spill events is reduced.
- Water providers share more kinds of information, and communication among utilities is increased.
- Monitoring efforts on the river are better coordinated.
- The system can serve as a monitoring sentinel, thus promoting greater diligence on the part of potential dischargers.
- Public confidence in potable water quality is improved.
- Additional information provided by the system can help in responding to the press during spill events.
- A central data warehouse may be beneficial to researchers studying the river.
- Source water protection of a large river is complex and may not be feasible. Time, energy, and money may be better spent on reliable early notification systems and installation of water treatment processes to deal with potential contamination events.

Adapted from Gullick et al, 2003

the project was formally under way, PWD approached a broader group of stakeholders through a series of meetings, site visits, and surveys. This group included representatives from 14 water utilities along the main stem of the Schuylkill and Delaware rivers, county emergency management agencies, and regulatory agencies (e.g., PADEP) the New Jersey Department of Environmental Protection, and the US Environmental Protection Agency (USEPA), as well as other organizations such as the US Geological Survey (USGS), the Delaware River Basin Commission, and the US Army Corps of Engineers (USACE). This diverse group brought a wide array of experiences, capabilities, priorities, and needs to the EWS development process. This in turn created both greater opportunities and significant challenges in meeting the varied expectations.

Input from the stakeholders helped to identify their needs and resources and enabled the design of an EWS that complemented existing emergency notification and response protocols. In addition, the stakeholder process identified the need for a system that could provide information and tools useful in the daily operation of a water treatment plant. This provision increases the overall value of the system and encourages users to become acquainted with the system as part of their routine operations.

System developed quickly. The Delaware Valley EWS was designed to provide the infrastructure for a notification, communication, monitoring and data-management system that could expand and develop over time. The objectives during the first year of the project were to build a framework that would support emergency notifications, promote routine information-sharing, and demonstrate the potential for a watershedwide water quality EWS. The resulting EWS is a fully integrated computer-based system that includes three major components: a telephone-based notification system, a website and data-management system, and a water quality-monitoring network (Figure 5).

The telephone notification system is an off-the-shelf application that was customized for the Delaware Valley EWS. The telephony system accepts calls from emergency responders or water utility personnel, records event information provided via touch-tone responses to a standard question-and-answer process, and makes telephone and e-mail notifications. The telephony system is integrated with the EWS server and can forward event information to the EWS database and website.

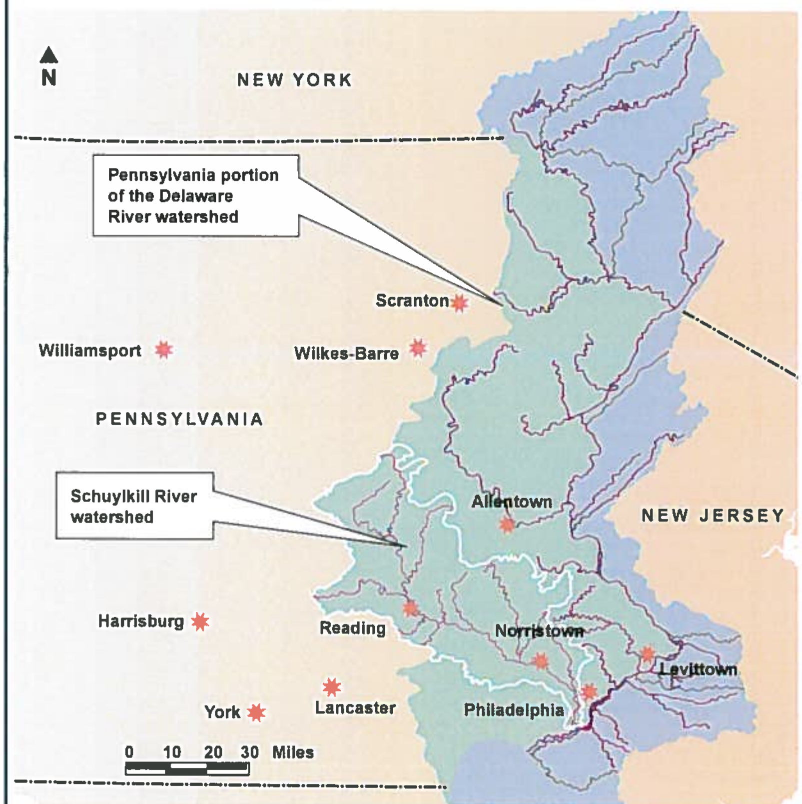
The computer server, which houses the website, data-management system, and telephony system, is the core of the Delaware Valley EWS and the central location for all EWS information. The data-management system stores and organizes information about contamination events, water quality, and plant operational characteristics in an accessible format. The result is a unique and powerful tool that sets this EWS apart from others currently in operation.

The Delaware Valley EWS website provides a dynamic and interactive user interface to the database, allowing users to access and share event and water quality information in a centralized and secure location. Various user interface formats are available, including forms for reporting and viewing the details of a water quality event (Figure 6), maps to identify the location of an event (Figure 7), graphs that show water quality data (Figure 8), and a time-of-travel estimator (Figure 9). The estimator uses real-time flow data from USGS gauging stations to provide plug-flow travel time estimates for each intake based on river conditions at the time of the event. To provide additional boundaries on this rough estimate, the historical highest flow and lowest flow on record at the gauging stations are used with a hydrodynamic water quality model to provide estimates of the earliest and latest times it would take for the spill to reach a downstream intake.

The water quality monitoring network compiles both near real-time and historic water quality data. The near real-time portion of the network uses simple and readily available technology to transmit data from remote monitors to the EWS server on a set time interval. Continuous monitors are located at select water treatment plant intakes and USGS gauging stations. Real-time monitoring was initially limited to simple water quality parameters such as turbidity and pH, but the network will be expanded in future years as monitoring technologies advance and additional monitoring needs are identified. In addition to the near real-time data, utilities will submit the results of their routine operational monitoring, creating a historical database that can be compared with real-time data.

Automation was essential to system design. One of the great challenges in designing this system was meeting the requirement that it operate essentially unstaffed. This is a different approach from that taken by many existing systems, which use an organization to oversee the monitoring and notification process 24 hours a day, seven days a week. With the Delaware Valley EWS, once an event is reported via telephone or the Internet, the system automatically performs the time-of-travel estimations and notifies downstream users. System users then supplement the event description by reporting updates and additional information to the website. This inherent reliance on the users places the success of the Delaware Valley EWS firmly in their hands.

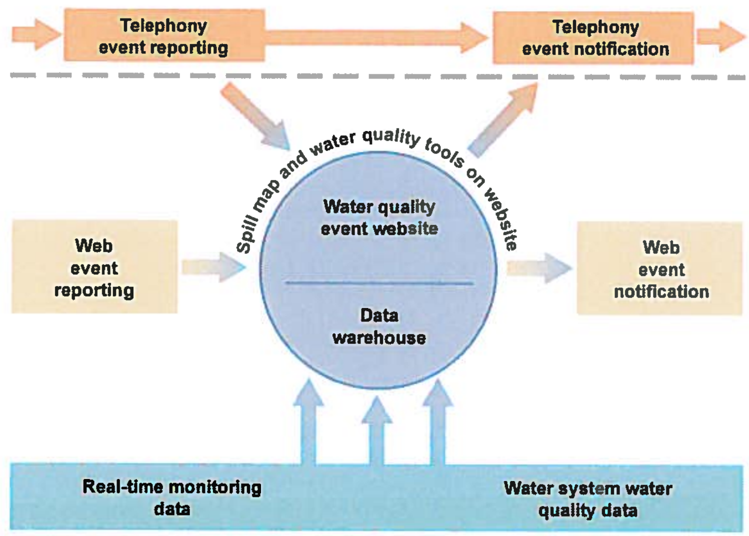
FIGURE 4 Delaware River Basin



Steps were taken to ensure organizational sustainability. Maintaining stakeholder partnership will be crucial to the long-term success of the Delaware Valley system. A steering committee was formed to act as the EWS governing body and to promote sustainability by giving stakeholders a more active role in defining the future of the system to meet their needs. The steering committee will identify issues and make decisions to guide the system's future development and maintenance, as well as locate and allocate funding. The steering committee comprises the nine voting seats of participating utilities (Table 1). Government agencies and other organizations do not have voting seats but participate by serving in an advisory role. Steering committee meetings are open to all stakeholders.

Implementation demonstrated system's value. During the first three months of EWS operation, seven water quality events of varying types and magnitudes were reported. Three events were associated with algal blooms or taste-and-odor events and their effects. One was related to high ammonia concentrations from road salt runoff affecting water treatment, and another was attributable to sewage main breaks spilling into the river. The final two events were related to spills—one a fuel spill of unknown origin and the other a tanker truck accident. The tanker truck accident in particular demonstrated the value of the Delaware Valley EWS. Initially the tanker truck was reported to have overturned on a bridge over the river just 3 mi (5 km) upstream of an intake, releasing approximately 100 gal (379 L) of diesel fuel into the river. During this event, the EWS was able to assist emergency response personnel and provide timely notification and pertinent data to downstream water sup-

FIGURE 5 Delaware Valley early warning system schematic



pliers so they could initiate their respective responses to the event with the best available information.

As system uses multiply, support for the Delaware Valley EWS grows. The response and enthusiasm for participation in the Delaware Valley EWS have been positive, and more industrial users, water suppliers, and organizations are participating in the system as word spreads and users are trained. For example, a county health department requested that the system be expanded to include its entire county. The growing support for the EWS is due primarily to the potential of the system's alternative uses that indirectly benefit the day-to-day activities of participants. Examples of indirect uses being explored include: health departments turning to the EWS for help with investigating disease clusters related to recreational waterborne outbreaks, food and beverage manufacturers obtaining advance warning of potential water quality changes that might affect processing, water suppliers obtaining official reports to justify additional chemical costs (e.g., carbon addition) during events, emergency responders using EWS data to assist in documenting accidents, and recreational events and users relying on the system for forecasts of water quality. As these potential multiple uses evolve, the usefulness and the long-term success and sustainability of the system increase.

Upper Mississippi River. The Upper Mississippi River refers to the approximately 1,300 mi (2,092 km) stretch of the Mississippi River from the headwaters to the confluence with the Ohio River at Cairo, Ill. (Figure 10). This definition excludes the Missouri River, the river's largest tributary. Other significant tributaries of the Upper Mississippi include the Illinois, Minnesota, St. Croix, Wisconsin, and Kaskaskia rivers (UMRBA et al, 2004).

A vital economic link for America's heartland, the Upper Mississippi River supports commercial navigation, water supply, recreation, wildlife, and waste-discharge assimilation. The river is a major transportation artery, and land use along its banks ranges from major metropolitan areas to rural farmland. A system of 29 locks and dams maintains a 9 ft (3 m) deep channel, allowing navigation as far upstream as Minneapolis, Minn. (UMRBA et al, 2004). The drainage area for the Upper Mississippi River is approximately 189,000 sq mi (489,510 km^2), primarily from the five states bordering the river (Minnesota, Wisconsin, Iowa, Illinois, and Missouri). The average flow of the river as it approaches Cairo is approximately 121 bgd (458 GL/d).

The Upper Mississippi River has 26 drinking water suppliers with a total of 29 intakes over an 874 mi (1,407 km) stretch from Minnesota to Missouri. Of these suppliers, 23 are community systems, and the remainder are industrial facilities (noncommunity systems). These 26 water suppliers combined provide approximately 360 mgd (1,363 ML/d) of potable water to almost 3 million people. There are three drinking water intakes between St. Cloud and the Twin Cities of Minneapolis and St. Paul in Minnesota. Then for a stretch of 370 mi (595 km) there are no drinking water intakes downstream until the Quad Cities (Davenport, Rock Island, Molina, and Bettendorf) of Illinois and Iowa.

Regional organization assumes project leadership. Initially the work to develop a regional EWS on the Upper Mississippi River was led by American Water, a privately owned water supplier with four intakes on the river (Gullick, 2001). With the support of Region 5 of the USEPA, the Upper Mississippi River Basin Association (UMRBA), an organization representing the five states bordering the river, eventually took over the lead for assessing the potential for a regional EWS. UMRBA then formed an official Upper Missouri River EWS scoping group to help explore design and operational issues. The group includes representatives of drinking water suppliers and state and federal response and drinking water programs.

Key stakeholders contribute to EWS development. Following American Water's first efforts to assess the potential for a regional EWS on the Upper Mississippi River, other entities have made important contributions to this collaborative effort. In addition to the water suppliers, UMRBA has been instrumental throughout the project. UMRBA coordinates the efforts of the Upper Mississippi River Hazardous Spills Coordination Group, composed of state and federal agencies that have various response-related roles on the river. Discussions were also held with many of the individual agency members of the spills group, including USEPA and USACE. Representatives from ORSANCO and a research project sponsored by the AWWA Research Foundation (Grayman et al, 2001) served as consultants and provided significant advice and input.

Coalition of water suppliers formed. Realizing that the support of the water suppliers on the river would be crucial to development of a regional EWS, American Water initiated steps early on to organize these providers into a coalition to better represent their collective interests. The first meeting of the Upper Mississippi River Water Suppliers Coalition was held in October 2001 in Davenport, Iowa. The primary goals of the coalition are to establish a formal communication network for the water suppliers on the river, develop a regional EWS, promote source water protection practices, provide educational opportunities for the membership and their consumers, develop working relationships with other river stakeholders, and serve as a resource clearinghouse for river water quality and related information.

Coalition members can include both public and privately owned water utilities as well as industries and other organizations that operate noncommunity water systems using the Upper Mississippi River as a source. State and federal agencies responsible for drinking water, river pollution, and spills response also participate in the coalition's meetings, although they are not official members of the coalition and have no voting powers.

A series of meetings and conference calls was held to initiate the project. More stakeholders have become involved at each step of the process and particularly at each of the meetings. One primary focus for the water suppliers was to encourage the spills group and the relevant state and federal agencies (public water supply and hazardous spill–response divisions) to support development of a monitoring network. On more than one occasion, the water suppliers coalition and the spills group have met jointly, providing opportunities to exchange experiences, perspectives, and concerns.

Existing monitoring programs identified. One important early step in the process was to identify and describe the existing river water quality monitoring programs conducted by the water suppliers as well as federal, state, and local agencies to ascertain what information would be useful for early warning monitoring. This investigation showed that despite the existence of numerous water quality monitoring programs on the Upper Mississippi River, little monitoring was being performed that would be applicable to an EWS because of the types of parameters monitored (primarily oriented toward Clean Water Act compliance or measurement of ecological health), the relatively low frequency of monitoring (e.g., once every two weeks or monthly), and the location of most of the monitoring stations substantial distances away from the water supply intakes (Gullick, 2001).

A survey of the water suppliers was used to identify the type and frequency of source water monitoring already being performed, as well as the primary risks to river water quality. Oil and petroleum products, bacteria, algae, ammonia, and pesticides (herbicides and/or insecticides) were identified as the most common contaminants of the source water. According to the water suppliers, the leading sources of contaminants on the river were barge and boat spills, industrial spills, low flows, wastewater treatment plants, and runoff. Transportation accidents were viewed as by far the biggest threat.

Despite these risks to water quality, however, the same survey indicated that little monitoring was being performed to provide advance warning of many of these contaminants.

FIGURE 6 Sample Delaware Valley early warning system user interface screen for a hypothetical spill event—water quality event report form

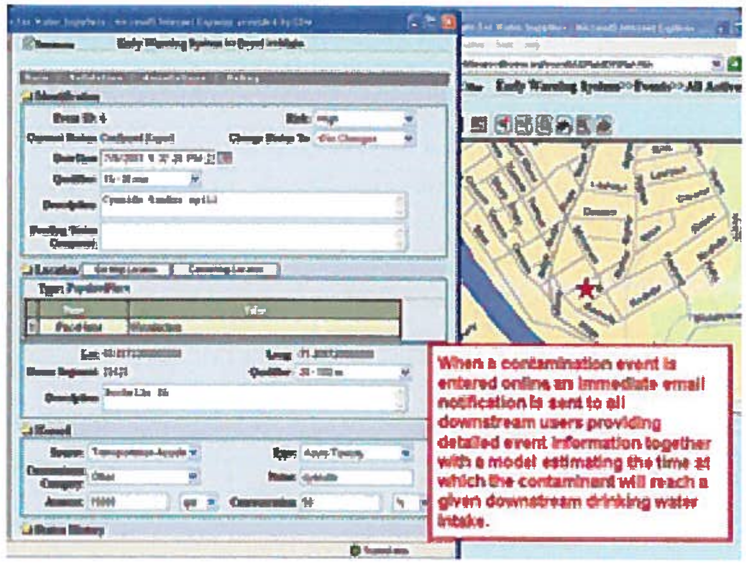
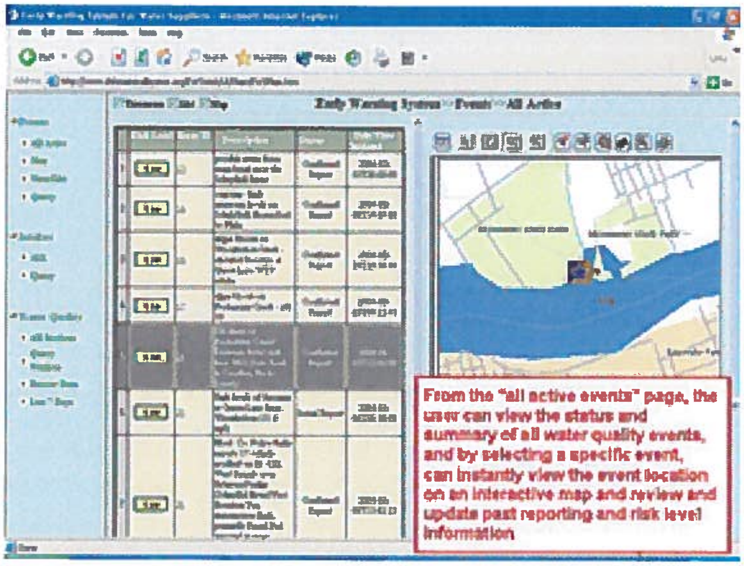


FIGURE 7 Delaware Valley early warning system user interface for a hypothetical spill event—all active events screen



Daily or frequent monitoring by intake operators was generally limited to basic physical and chemical parameters such as pH, turbidity, nutrients, and suspended solids. Turbidity and pH were the only two parameters that all of the survey respondents measured at least once a day, and only eight suppliers had continuous monitors for one or both of these parameters. Sampling frequencies for other parameters varied greatly and were typically low. In summary, the water quality data being collected were insufficient to support a regional EWS, and no central reporting system existed to track water quality data produced by the suppliers.

Funding draws on a range of sources. Initial financial support came from American Water and UMRBA, primarily in terms of personnel to perform the first exploratory work. More recently, USEPA Region 5 has provided up to $75,000 through a cooperative agreement with UMRBA to support the scoping effort and acquire monitoring equipment for a pilot station; USEPA has also provided additional contractor assistance in designing the system. Additional support has come from in-kind contributions of time from various members of the scoping group and water suppliers coalition.

Work proceeds on data collection, analysis, and dissemination system. Data-management and communication-system options are still being developed as part of the scoping effort. In April 2003, the scoping group surveyed members of the suppliers coalition concerning information dissemination and spill notification. Seventeen of the 23 organizations with intakes responded, generally expressing strong interest in a secure, web-based system that would notify them of contamination, provide ongoing information during an incident, and afford an opportunity to exchange information concerning routine operations. Most respondents indicated a willingness to share their own monitoring and testing results with other participants in the system, assuming a reasonable level of security could be ensured. This would allow the utilities to exchange data on parameters for which they test either routinely or seasonally but that may not be part of the EWS protocol; such parameters include bacteria, oxidant demand, and atrazine. The EWS scoping group is considering the results of this survey, as well as the experience of other EWSs, in identifying the key components of a data collection, analysis, and dissemination system. Particular attention will be paid to the potential to build off of one or more of the frameworks already in use or under development by the other regional EWSs discussed in this article.

Pilot program launched for Upper Mississippi River EWS. The EWS scoping group is currently coordinating implementation of a pilot monitoring station that is slated to include a multiparameter probe[1] for pH, turbidity, chlorophyll, conductivity, dissolved oxygen, temperature, and oxidation–reduction potential, as well as a continuous online fluorescence detector[2] for oil and petroleum products. The multiparameter probe was deployed in October 2003, and the initial experience with this equipment has generally been positive. Efforts are ongoing to address site and operating requirements related to the fluorescence detector. The scoping group's intent is to operate the pilot station for a sufficient period to gain operating experience over different conditions (winter temperature and ice conditions in the region can be particularly severe), identify threshold values for the various parameters, and evaluate alternative data-transmission options. Initially, the pilot station is transmitting data via satellite to a USACE website.

The pilot monitoring station is located at one of the USACE lock and dam sites where a municipal water supply intake for the city of Rock Island, Ill., is located. This location allows the scoping group to pilot an interagency, cooperative approach to operation of an EWS station. Corps personnel have provided extensive technical support concerning equipment installation and data transmission while also assisting Rock Island city personnel in maintaining and calibrating the equipment. If this interagency approach for the pilot is successful, it may prove to be a model for the final design of a regional EWS for the Upper Mississippi River.

Potential monitoring locations considered. Facilities that may serve as monitoring locations for the Upper Mississippi EWS include the water treatment plants, existing USGS and state monitoring stations, USACE lock and dam locations, and industrial facilities such as power plants. Factors determining the selection of monitoring sites will include the locations of potential contamination sources in relation to the location of water supply intakes, the risk these sources pose, and the willingness of various entities to participate.

Cost estimates vary. One proposed network of nine monitoring locations was estimated to cost about $550,000–$600,000 in capital expenses, $40,000–$50,000 for system startup, and $280,000–$340,000 in annual operating costs (Gullick, 2001). This estimate included purchase of monitoring (multiparameter probe and fluorescence detector) and telemetry equipment, daily analysis of oxidant demand, seasonal daily immunoassay analyses for atrazine, sheds for housing equipment, operating costs for the data-management and communication systems, and other items. It also assumed in-kind support from the water suppliers with monitoring stations to perform analyses and report results. The EWS scoping group will develop a refined estimate that reflects experiences with the pilot station, recommended monitoring locations, desired information system features, and other factors.

Project moves forward. Bringing the EWS to fruition involves the following steps: (1) complete pilot program, (2) develop institutional structure (data-management center and communications system), (3) complete full-scale system design (including finalizing monitoring parameters, methods, locations, and frequency), (4) develop contaminant transport model, (5) obtain long-term funding, and (6) launch system setup and operation. Several of these efforts will take place concurrently.

Allegheny and Monongahela rivers. The Allegheny and Monongahela rivers converge at Pittsburgh, Pa., where they form the Ohio River. The Allegheny River is 325 mi (523 km) long and drains 11,700 sq mi (30,303 km^2). There are 16 water suppliers on the Allegheny River serving 637,000 people. The Monongahela River is 128 mi (206 km) long and drains 7,400 sq mi

FIGURE 8 Example of Delaware Valley early warning system user interface screen—water quality data query results

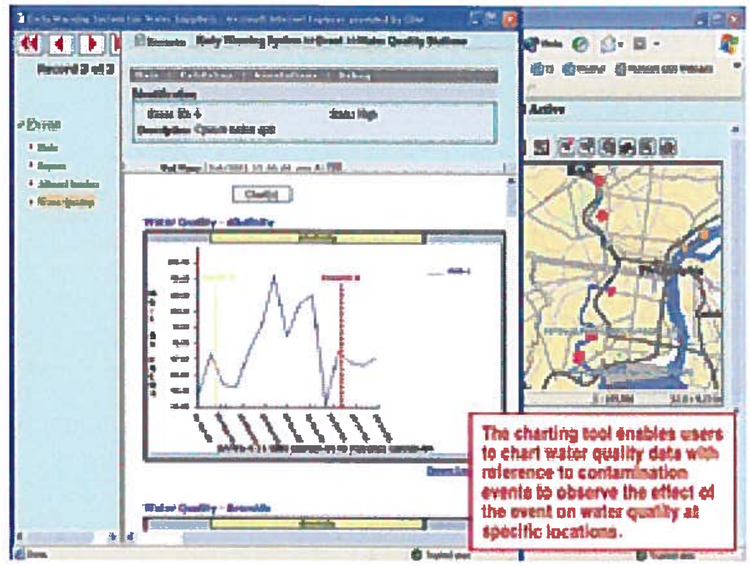
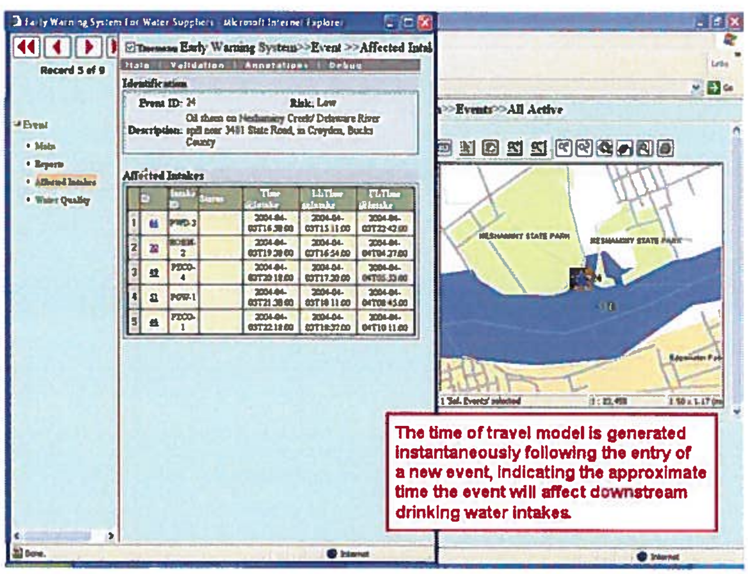


FIGURE 9 Example of Delaware Valley early warning system user interface screen for a hypothetical spill event—time-of-travel results



(19,166 km^2). The 15 water suppliers on the Monongahela main stem serve approximately 771,000 people, and 4 water suppliers on the Youghiogheny River tributary serve 201,000 people. A system of locks and dams on the rivers supports commercial navigation; reservoirs located in the watersheds provide flood control storage. Figure 11 shows the Ohio River Basin area with the Allegheny and Monongahela rivers highlighted.

As noted previously, ORSANCO has operated a regional EWS on the Ohio River for many years. This Organics Detection System, however, provides organics monitoring only on the extreme lower reaches of these two Ohio River tributaries (the Allegheny and Monongahela rivers). In January 2002, the PADEP approached ORSANCO requesting assistance in establishing regional EWSs on these rivers, and PADEP provided $800,000 funding for system design and startup. Meetings held with drinking water utilities drawing from the Allegheny and Monongahela rivers found overwhelming support for the development and operation of a regional EWS.

System had to fit regional resources, capabilities. Initially envisioned as an expansion of the ORSANCO Organics Detection System, the Allegheny and Monongahela EWS evolved into an integrated source water monitoring network that would consider multiple parameters and host a secure website for the distribution of near real-time source water quality data. As part of the initial data-gathering effort, a suitability and susceptibility analysis of the drinking water utilities was conducted to evaluate each facility's needs and resources. The utilities located along the two river systems are relatively small; approximately 70% of the Allegheny and Monongahela river utilities serve 12,000 or fewer customers, with some serving as few as 1,000. Because utility plant personnel are already multitasking in their daily work, the addition or installation of any monitoring equipment that required significant time to operate, maintain, or interpret would not be accepted or successful.

FIGURE 10 Upper Mississippi River Basin

Source: USGS, 1999

In contrast to some other developing regional EWSs, the Allegheny and Monongahela system focused on enhanced monitoring of source waters. In 2002, instrument tests evaluated available online technologies that would provide useful source water quality data, require minimal time to operate and maintain, and deliver readily interpretable results. Test results were favorable for four types of water quality monitoring instruments: (1) a multiparameter probe measuring temperature, pH, conductivity, dissolved oxygen, chlorophyll, and turbidity; (2) a fluorometer measuring hydrocarbons or chlorophyll; (3) a total organic carbon analyzer; and (4) a portable, autosampling purge-and-trap gas chromatograph with argon ionization detector. Data gathered from these instruments can be transmitted via the Internet to a project computer server, displayed near real time on the website and archived for later assessment. Operation and maintenance time for this equipment was anticipated to be less than 1 hour per week.

A key step to the acceptance of this instrumentation was a demonstration of the proposed instruments to the water utilities. This helped allay concerns regarding the technical nature of the work required and the time commitment for operation and maintenance. Utility representatives provided input about which instruments they would be interested in supporting at their facility. This information provided the basis for the location and distribution of the monitoring equipment along the two rivers. Currently the Allegheny and Monongahela EWS has 11 monitoring locations operating a total of 7 multiparameter probes, 5 gas chromatographs, 3 total organic carbon analyzers, and 1 online fluorometer.

Another key component of the project was to foster the development of communications networks among the utilities. For several years, a communications network has existed on the Monongahela River for distribution of spill reports and spill information to downstream utilities. However, no such communication network existed on the Allegheny River. To answer this need, the Allegheny River Communication Network was organized during meetings of the Allegheny River utilities. The purpose of the group is to facilitate the exchange of spill and other water quality information of interest and concern to the drinking water providers.

This project has achieved and exceeded its initial goals. A state-of-the-art regional early warning system has been established that provides enhanced source water quality monitoring for multiple parameters, a mechanism for the distribution of these data in near real time via the Internet was developed, and a new communications network was created to facilitate information exchange among drinking water utilities using a common source water.

TABLE 1 Steering Committee for the Delaware Valley early warning system

Designated Voting Seats (Permanent)	Temporary Voting Seats (Annually Voted on by Membership)	Advisory Committee (Nonvoting)
Philadelphia (Pa.) Water Department	Trenton (N.J.) Water Works	Pennsylvania Department of Environmental Protection
Pennsylvania American Water Company (Hershey, Pa.)	Morrisville (Pa.) Municipal Authority	New Jersey Department of Environmental Protection
New Jersey American Water Company (Delran, N.J.)	Middlesex Water Company (Iselin, N.J.)	US Environmental Protection Agency
Aqua America Pennsylvania (Bryn Mawr, Pa.)	New Jersey Water Supply Authority (Clinton, N.J.)	Delaware River Basin Commission (West Trenton, N.J.)
	City of Pottstown (Pa.)	US Geological Survey

Susquehanna River. The main stem of the Susquehanna River flows 444 mi (715 km) from its headwaters at Otsego Lake in Cooperstown, N.Y., to the Chesapeake Bay. More than 20 public water systems within the Susquehanna Basin depend on the river as a source of drinking water; these systems serve in excess of 2.5 million people in New York, Pennsylvania, and Maryland. Twelve of these water suppliers draw from the main stem of the Susquehanna River in Pennsylvania. Figure 12 shows the Susquehanna River Basin and the location of some water suppliers participating in the EWS.

Commission spearheaded EWS development. Development of a regional EWS for these 12 water suppliers has been led by the Susquehanna River Basin Commission (SRBC), with the majority of funding provided by PADEP. In instigating the project, SRBC has taken a relatively progressive approach; many other regional EWSs have been developed because of requests from water suppliers to a basin commission (or association), as opposed to the basin commission initiating the effort. SRBC has a history of assisting water suppliers and has worked with Pennsylvania and Maryland since 1999 to develop Source Water Assessments (SWAs) required by the 1996 Amendments to the Safe Drinking Water Act. SWAs are designed to identify the susceptibility of water supplies to a variety of potential contamination sources and can provide information useful for establishment of source water protection and monitoring programs. SRBC also receives funds from USEPA to conduct water quality monitoring within its jurisdiction and assist with program coordination related to water quality issues.

Project scope defined. Initially, the EWS will extend only through the Pennsylvania part of the Susquehanna River Basin. However, SRBC and the states of New York and Maryland are engaged in discussions to extend the EWS into those jurisdictions.

The scope of work for developing this regional EWS entailed six major tasks in the first year of development:

- Task 1—establish a steering committee of different stakeholders.
- Task 2—establish an EWS project database.
- Task 3—establish a communications network that would coordinate large spills through the Pennsylvania Incident Response System and promote data-sharing by water utilities on a secure website.

FIGURE 11 Allegheny and Monongahela rivers

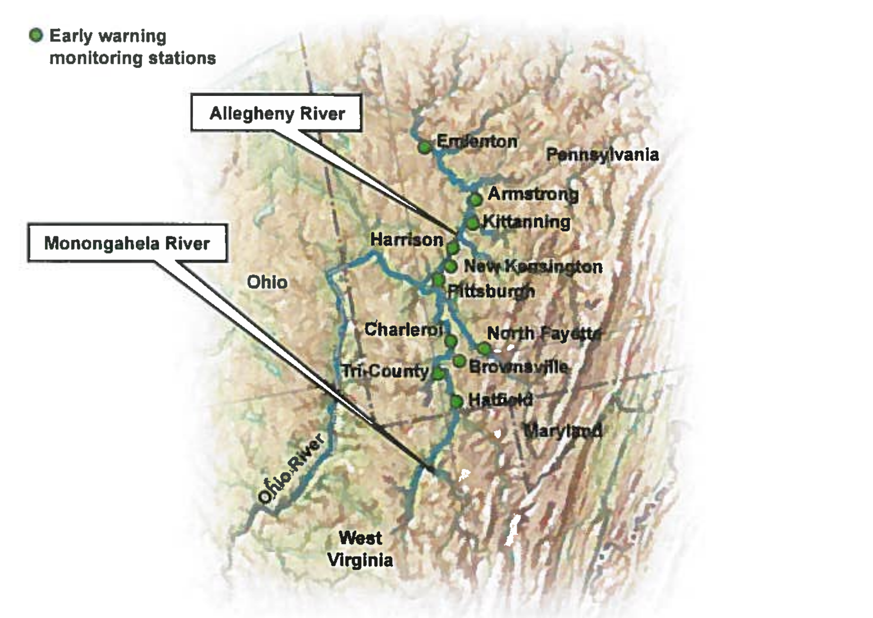
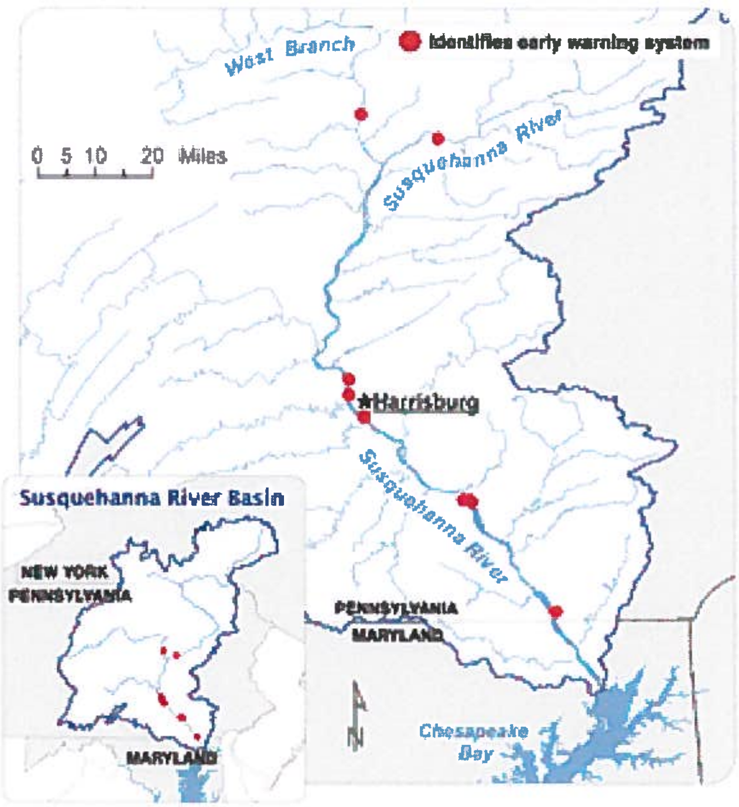


FIGURE 12 Susquehanna River Basin



• Task 4—design the full-scale monitoring system.

• Task 5—begin background work for development of a contaminant transport model.

• Task 6—assist water suppliers in connecting with other monitoring efforts (i.e., state and federal agency monitoring, citizen monitoring).

The initial phase of the project covered July 2002 through June 2003, during which time the framework for each of the six tasks was established. During the first year, three steering committee meetings were held, starting with a kickoff meeting in October 2002. Nine water suppliers have been active in the committee, assisting SRBC with decisions related to database and website design, monitoring data needs, emergency information needs, and contaminant information. Major efforts for the first year focused on establishing a website to serve as a hub for project communications and developing the monitoring resources needed to promote data exchanges and serve as indicator parameters for possible contamination events.

Communications efforts take off. A secure website was established and became operational in July 2003, allowing water suppliers to exchange water quality information and view emergency response bulletins and summaries distributed by PADEP. In addition, other information from project databases was made available through the website. Information includes stakeholder directories, contaminant inventories, project maps, Internet links to river flows and dam releases, and a time-of-travel calculator.

During the first year, development of the Susquehanna EWS focused on three baseline parameters: temperature, pH, and turbidity. By purchasing the equipment needed for online monitoring, SRBC increased the capabilities for five systems to provide real-time monitoring data for all three parameters. In addition, SRBC purchased a total organic carbon analyzer for another system that had existing online monitoring capabilities for the three base parameters. Beginning in July 2003, water suppliers started posting daily values to the website for temperature, pH, and turbidity. As of April 2004, three systems were posting data to the website at 4- to 6-hour intervals, and two more systems were expected to begin similar data posting soon.

Future plans focus on funding, system enhancement. In terms of future plans, SRBC will seek more stable funding for the operation and maintenance of the EWS and also investigate the potential for system enhancements and expansion. SRBC will be completing a study with USGS in December 2004 to characterize water quality and water velocity distributions across several transects of the Lower Susquehanna River. Because of the channel width and the presence of numerous islands and dams, the complex nature of the river presents challenges to establishing any sort of contaminant-tracking model. Study results should guide future model development efforts, as well as monitoring network enhancements.

LESSONS LEARNED OFFER ROAD MAP TO FUTURE EWS DEVELOPMENT

The development of regional EWSs in the United States has provided several lessons that can be applied to the successful establishment of similar systems on other rivers. These lessons center on securing strong water supplier involvement from an early stage, overcoming institutional constraints, obtaining initial funding for leading the project, and dealing with the sometimes very slow pace of a project of this magnitude.

Motivation for system development should not be driven by crisis. A specific chemical spill or release has been the initial impetus for development of several EWSs throughout the world. However, prudent utilities will not wait for an incident to occur on other rivers to provide incentive but instead will establish a system before occurrence of a large-scale contamination incident.

Stakeholder involvement can be the deciding factor in whether an EWS succeeds or fails. Cooperation between the affected water users, appropriate agencies, governments, and other stakeholders is critical to the development and operation of a successful regional EWS. In many instances, a variety of political jurisdictions may be involved, and EWS project leaders would do well to include input from these sectors.

Water supplier support is key. The most important collaboration within a regional EWS is that of the water providers themselves. Experience has shown that water utilities are the driving force and backbone for development of almost all regional EWSs, and their support and involvement are essential to EWS formation and operation. Without utility participation and endorsement, the project will likely not gain the necessary support from the applicable environmental agencies.

Limitations of water supplier resources must be recognized and reckoned with. Even if participating water providers offer strong conceptual support, their limitations of available time and money may prove an obstacle, and some suppliers may find it difficult to initially participate to the degree that they would prefer. The daily responsibilities of providing an adequate and safe drinking water supply for their communities keep many utilities (especially the smaller ones) fully occupied. Because of this, utility involvement in a long-term project such as a regional EWS may be sporadic. The successful EWS recognizes these limitations and makes the most of those resources that are available.

Individual leadership and institutional capacity must be developed. Someone must take the initial action to organize stakeholders and start the planning process. An organization must be identified to coordinate and manage the overall system (it often helps to have a single organization serve as the overall system coordinator). Funding must be obtained and data-management and communications systems developed. The primary obstacle to successful development of regional EWSs are often these and other institutional considerations, as opposed to the technological limitations presented by the monitoring methods currently available. Strong stakeholder support, particularly from water suppliers and other water users, can help overcome these obstacles.

Funding helps ensure project stability. Adequate resources must be available in the early stages of the process to lead and perform the initial project work. Continued progress will depend on outside funding, and as many potential sources as possible should be considered. Involvement of key environmental agencies can help identify funding sources and secure funding for continued operations.

Phased approach allows time for project to evolve. A phased approach to launching a regional EWS helps ensure that planners and users are not overwhelmed by the potential complexity of the proposed system. Instead of trying to gather support for a complete advanced system, project leaders may want to start small to showcase EWS uses and benefits. The system can then be expanded and fine-tuned over time as conditions dictate.

Salesmanship emphasizes obvious and not-so-obvious benefits of EWS. Much of the early work in developing a regional EWS involves convincing various stakeholders that the system is needed and will provide substantial benefit in comparison with expected costs. It helps to clearly define the program and its uses so that beneficiaries understand what they'll be getting and what they will need to do to participate in and benefit from the system. It can also help to emphasize less apparent advantages such as the coordinated communication and notification aspects of an EWS program.

Project team characteristics ultimately shape project outcome. If a regional EWS undertaking is to be successful, the core team leading the project must encompass certain characteristics. The numerous stakeholders participating in such a process (especially the many regulatory agencies and water suppliers) and the extensive institutional considerations involved may present challenges in resolving various views, priorities, and expectations. At times, the process of developing an EWS can be quite slow. Members of the project team must exhibit and maintain a high degree of motivation, determination, enthusiasm, patience, and perseverance. With these traits, the team can help prevent the project from coming to a standstill and lead it on a continuing course toward success.

WHAT DOES THE FUTURE HOLD FOR EARLY WARNING MONITORING?

The implementation of EWSs and regional EWSs within the United States is growing, and surveys by the AWWA Research Foundation indicate that most surface water users want these capabilities. It is anticipated that in the coming years, most major US river systems used as supplies for drinking water may develop these systems.

In the future, EWSs will likely become another part of routine activities for water systems in their multiple barrier approach. These systems will use extensively integrated information-management, data-management, and communication technologies that provide reliable and real-time information to all users as new technologies become available. The next generation of EWSs could include satellite communication, real-time monitoring technologies for pathogens as well as chemical and biowarfare agents, neural networks for predicting events based on current conditions, and web-based applications—all integrated with next-generation personal communication devices such as cell phones and personal digital assistants.

Stakeholder challenges to regional EWSs may significantly decrease as more systems are developed and demonstrate a degree of reliability, trust, cooperation, and value. Ultimately, regional EWSs that were developed individually could be tied together. For example, the systems for the Ohio River, Allegheny and Monongahela rivers, Lower Mississippi River, Upper Mississippi River, Delaware and Schuylkill rivers, and Susquehanna River could potentially be linked to create a "super-regional" EWS. This would enable individual regional systems to share relevant information, take advantage of administrative economies of scale, and work together to secure funding.

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FOOTNOTES

[1]Series 6 multiparameter probe, YSI Inc., Yellow Springs, Ohio

[2]Model TD-4100, Turner Designs Inc., Sunnyvale, Calif.

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If you have a comment about this article, please contact us at journal@awwa.org

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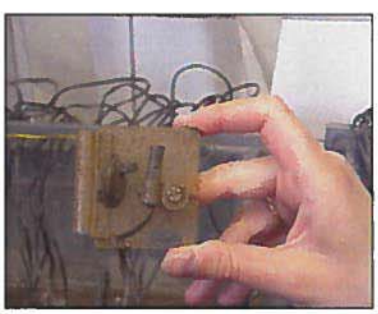
BY RICHARD W. GULLICK, WALTER M. GRAYMAN, ROLF A. DEININGER, AND RICHARD M. MALES

DESIGN OF Early Warning Monitoring Systems FOR SOURCE WATERS

WITH EARLY WARNING MONITORING SYSTEMS, WATER PROVIDERS CAN RESPOND MORE QUICKLY AND EFFECTIVELY TO CONTAMINATION OF WATER SUPPLIES.



This monitor uses a reed switch to detect whether the mussel's shell is open or closed. The mussels close their shells when sensitized by a toxicant.

Most raw drinking water sources are susceptible to a variety of disruptions in water quality as a result of accidental, intentional, or natural contamination. Rapid response to spills and other sudden pollution events is necessary to determine appropriate changes in drinking water treatment and operations in order to protect water consumers from potentially harmful contaminants, avoid treatment process upsets, and ensure compliance with environmental regulations. Early warning monitoring systems provide timely information on changes in source water quality so that knowledgeable response decisions can be made. Early warning systems can be a cost-effective mechanism for reducing risks, help boost public confidence in the water utility, and serve to encourage good practice and careful reporting on the part of dischargers.

Although the US Environmental Protection Agency (USEPA) does not mandate monitoring of raw water by water utilities, many utilities do so to some degree in order to (1) detect the existence of contaminants, (2) ascertain that existing treatment is adequate (and if not, to provide information that will help identify an appropriate improvement), and (3) provide real-time treatment process control. The monitoring data, however, are often limited regarding the number of parameters measured and the frequency of monitoring and may not be conducive to detecting spills and other sudden changes in water quality.

A 1999 survey of 153 water providers in the United States, Canada, and the United Kingdom found that a majority of utilities had experienced a significant source water contamination event in the past five years, adequate warning is not always available, the most serious perceived threats for the future are transportation accidents, and source water contamination is a significant issue that should be addressed through improved early warning systems (Grayman et al, 2001). The threats most commonly cited by drinking water utilities with intakes on rivers included spills of oil, petroleum, and chemical products from transportation accidents and pipeline and storage tank releases; insecticides and herbicides from agricultural runoff; and pathogens from untreated sewage discharges.

This article summarizes key results from two cooperative research projects (Grayman et al, 2001; Gullick, 2001). To examine the state of the art in early warning systems, these researchers surveyed utility practices and perceived needs for early warning and source water monitoring, performed a literature review of available monitoring methods, studied early warning systems around the world, examined case studies of monitoring practices at US utilities, developed a risk-based computer model for design and analysis of early warning systems, created a generic riverine contaminant transport model, and initiated development of an early warning monitoring network on the Upper Mississippi River. Though the principles of early warning monitoring apply to water quality changes from any source, this work focuses on source waters and does not directly address treated water in the distribution system or threats to the water supply infrastructure.

Multiple sampling ports on Germany's Rhine River are used to monitor water quality. The center two intakes monitor the general river water. The one close to shore represents and monitors the effluent of a large industrial complex located upstream on the same side of the river. The fourth intake is near the far shore to sample water that is primarily from an upstream tributary on that side of the river.

SYSTEM COMPONENTS AND CHARACTERISTICS DEFINED

Early warning systems include a combination of continuous or frequent monitoring, other detection mechanisms, institutional arrangements, analysis tools, and response mechanisms. They can be used to detect rapid deterioration in water quality resulting from accidental or intentional discharges of toxic and hazardous materials near an intake (e.g., low probability/high impact events such as large-scale boat spills, pipeline breaks, industrial accidents, terrorist attacks). They are also useful for monitoring during extreme natural events (e.g., heavy rains and flooding, algal blooms) and somewhat predictable events (e.g., seasonal runoff of herbicides). Early warning systems are used mostly on riverine systems where water quality can change rapidly (see example scenario in Figure 1), less frequently for impoundments, and rarely for groundwaters.

An ideal warning system features key components. The scope of an early warning monitoring program will depend on site-specific characteristics. Systems vary from a single instrument at an intake to large river systems with networks of sophisticated monitoring stations combined with coordinated data management and information communication systems. Certain components, however, are generic to all good early warning systems and include the following:

- detection—a monitoring mechanism to detect pollution events and/or a public or self-reporting program,
- characterization—a means to confirm and more completely characterize the event,
- communication—a way to disseminate data to utility personnel and other decision-makers as well as to inform the public of response actions, and
- response—actions that minimize the potential effect of the contamination event.

An ideal early warning monitor would cover all threats, monitor continuously, provide warning in suffi-

FIGURE 1 Schematic example of an early warning system

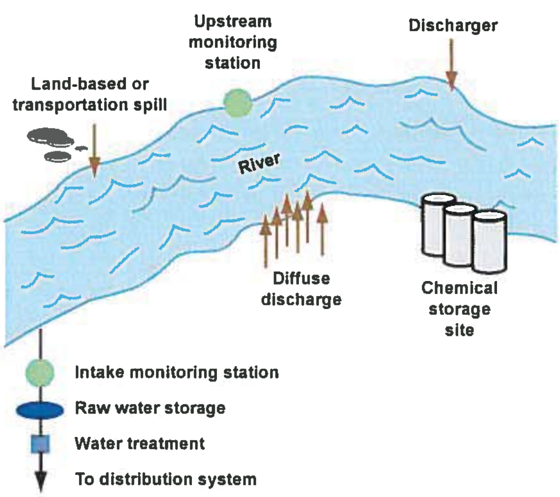
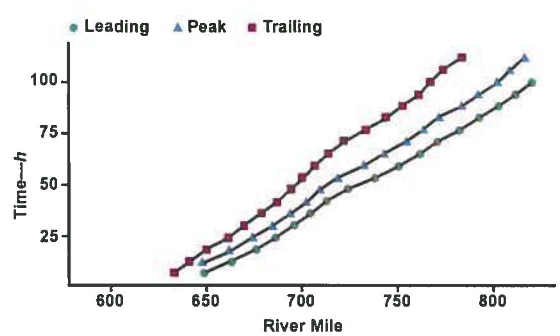


FIGURE 2 Example of riverine contaminant transport model output



Time of leading edge, peak, and trailing edge as predicted by model

Design Process and Components for Early Warning Monitoring Systems

- **Analysis of the need for early warning monitoring**
  - Preliminary vulnerability and susceptibility analysis
  - Review of available monitoring programs and data
- **Determination of program scope**
  - Selection of parameters to be monitored, monitoring methods, number and location of monitoring stations, and frequency of monitoring
  - Data management and interpretation
  - Cost–benefit analysis
- **Development of system organization and function**
  - Physical features
  - Administrative components
  - Response and communication plans
  - Funding
- **Implementation**
  - Monitoring program
  - Identification of response thresholds
  - Event confirmation procedures
  - Characterization of contamination
    - Data management, interpretation, and dissemination
    - Water quality modeling
  - Communication systems and plans
  - Response plans
- **System review and improvement**

cient time for action, give minimal false-positive or false-negative responses (such that the frequency of alarms is neither too high nor too low), be able to identify the source of contamination, be sensitive to water quality changes at regulatory levels, be reproducible and verifiable, require low skill level and training, allow remote operation, be affordable and robust, and function year-round (ILSI, 1999). Naturally, analysis of the system benefits, costs, and available resources may reduce the number of these characteristics that are applicable to specific situations, but the list provides guidance for development of such systems.

Monitoring techniques range from relatively simple online measurements of such parameters as pH and turbidity to video surveillance to advanced analytical instrumentation to the use of living organisms as bioalarms. Some methods (e.g., general water quality indicators such as bioalarms and dissolved oxygen [DO]) measure effects in the water, thus indicating that "something is not normal" but not necessarily what it is. Early warning monitors sometimes have less-sensitive detection levels than those of conventional monitoring, are often more qualitative and not compound-specific, and because they are concerned with identifying large changes in concentrations generally need less quality assurance/quality control (QA/ QC) than conventional or compliance monitoring.

DESIGN SHOULD BE INCORPORATED INTO OVERALL SYSTEM

Early warning systems should be viewed, designed, and operated as an integral part of the operation of the overall water supply system (including source water quality protection programs and monitors, as well as intake, storage, treatment, and distribution system characteristics) in order to minimize the risks associated with degraded drinking water quality under various cost and technology constraints. The key components and steps in development of an early warning monitoring system are summarized in the sidebar on this page.

The type and scope of the system to be developed should be guided primarily by the relative potential risks (source water vulnerability/susceptibility assessment), cost–benefit analysis, availability of resources and technical capabilities, and current treatment capabilities. In some water supplies, continuous monitoring of a select few parameters at, or just upstream of, the intake may be sufficient. In other cases, particularly on busy commercial rivers with numerous intakes and potential contamination sources, a more extensive and coordinated network may be appropriate. Some water utilities use early warning systems to assess the quality of multiple source waters in order to be able to continuously use the highest quality source of those available. Reducing the time between occurrence of an event and implementation of response actions is critical and is accomplished through selection of appropriate detection methods; prompt data review, confirmation, and event characterization; efficient communication infrastructure; and rapid relaying of information to decision-makers. The design of early warning monitoring systems has been discussed in the literature (Grayman et al, 2001; Gullick, 2001; Foran & Brosnan, 2000; ILSI, 1999). Sanders and colleagues (1983) examined the process for water quality monitoring system design, including statistical analyses for optimizing monitoring locations and frequency.

Vulnerability assessments help identify needs. The types of land and water uses and activities (e.g., industries, agriculture, transportation, and other commercial enterprises) located near a water source can be used to identify potential contamination scenarios, rank their relative potential occurrence and effect, and prioritize a list of pollutants of concern to be considered for monitoring. The vulnerability assessment can be used to determine not only the requirements and scope of an early warning monitoring system but also the potential need for alternate raw water sources, treatment process alternatives, increased raw water or finished water storage capacity, and other system characteristics. Vulnerability assessments are already being performed for all US public water supply systems as part of the Source Water Assessment Programs (SWAPs) required of each state by the 1996 Safe Drinking Water Act (P.L. 104-182) (see www.epa.gov/safewater/protect.html). The SWAP requirements are separate and different from the security vulnerability assessments required of many water utilities by the US Bioterrorism Act of 2002 (P.L. 107-188) (see www.epa.gov./safewater/security/security_act.pdf).

Detection mechanisms determined by site and system characteristics. The decision of what parameters to monitor should be made on a site-specific basis and take into account both watershed and water supply system characteristics. The vulnerability assessment can provide a prioritized optimal list of parameters, which is then evaluated given practical, technical (including adequacy of available monitoring methods), resource, and budgetary constraints. A review of other existing monitoring programs for the source water (e.g., by state or federal agencies, industries, and other water suppliers) should be performed to capitalize on any potential synergies.

Range of monitoring methods are available. The primary mechanisms for detecting spills and other events include water quality monitors, self-reporting by the dischargers themselves, and sighting and reporting by the observing public or by public or private agencies and organizations. The most effective early warning systems combine all three means of detecting contamination events.

Because rapid, responsible self-reporting of spill events provides the most dependable detection method, regulations and protocols should be established and enforced to strongly encourage such actions. However, the existence of and compliance with such laws vary significantly around the world. Reporting by spill-response personnel and other governmental agencies and organizations is the most common means by which many US utilities learn of source water contamination events. Public reporting is most effective with larger contamination events that have observable results (e.g., fish kills, oil sheens, odor) and events in more heavily populated areas. The effectiveness of this method depends on a population that has been sensitized to reporting such events. In Japan, for example, public reporting is the most common early warning method.

Some utilities use daily or more frequent visual inspection of source waters to monitor for gross visible pollutants such as oil sheens and algal blooms. Video cameras are sometimes used to aid in visually monitoring intake water and also to monitor upstream areas where large-scale accidents could occur (e.g., bridge abutments, highway or railway overpasses). Images can be sent directly to the treatment plant control room, and computerized image analysis technologies can be used to detect certain changes in the video images and then issue an alarm when something changes in the picture. Use of video cameras at night can be problematic, of course, and lights may be necessary to provide better 24-hour visual monitoring.

Water quality monitors include physical, chemical, radioactive, and microbiological analyses that can identify and quantify either a specific water quality parameter or a surrogate parameter selected to provide a conservative indication of the presence of a more harmful but more difficult to analyze contaminant. When surrogates are used, an adequate site-specific correlation should be established with the parameter of primary concern. In addition, biomonitoring techniques that use living organisms can be helpful in detecting general changes in water quality and toxicity. Available monitoring technologies are discussed later.

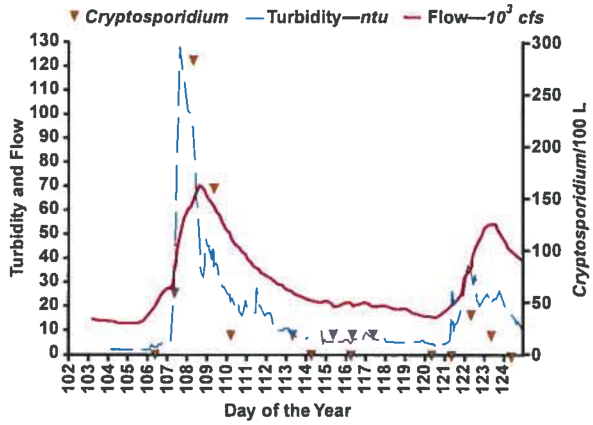
The "smell bell" test is being performed here on a sample from the River Trent in the United Kingdom. The smell bell test is an inexpensive method of physical analysis but requires trained personnel with good noses and usually is not performed more than once per shift or once per day.

Several factors influence location of monitoring stations. Monitoring systems should be installed far enough upstream from the point of water abstraction to allow for timely warning. On the other hand, monitoring stations located too far upstream will not provide coverage for pollution sources entering between the station and the intake. These somewhat conflicting considerations must be balanced with the available resources when water providers are determining the number and location of monitoring stations. If multiple water utilities use the same source (e.g., a river), they can take advantage of opportunities for cooperation and pooling of resources in terms of multiple monitoring locations.

Potential factors to consider in the selection of monitoring locations include the following:

- the location of potential contaminant sources,
- the river's flow rate (i.e., time of travel from major potential contamination sources to the intakes)
- the magnitude of mixing and dilution attributable to currents and hydrodynamic dispersion,
- consideration of all three spatial dimensions (e.g., how far upstream, where across the river, and how deep),

FIGURE 3 Variation in turbidity, river flow, and *Cryptosporidium* concentrations during spring sampling in the Delaware River



Source: LeChevallier et al, 1998

- the type of contaminants (e.g., contaminants such as floating oils may determine monitor depth),
- the monitoring instruments' response time and frequency of analysis and data review,
- the nature of the treatment process (i.e., what can the processes handle, how much time is needed to make any potential adjustments),
- precautions to protect the instrumentation from the elements,
- security to prevent vandalism,
- access to electricity,
- means of telemetry (e.g., cellular telephone or radio versus need to acquire access to telephone lines), and
- access for monitor maintenance and upkeep.

Attention must also be given to the potential for mixing (or lack thereof) of contaminants both laterally and vertically in a river. Field tracer dye studies can be used to help elucidate river-mixing patterns between potential outfalls and water supply intake(s). With a small or well-mixed system, a single monitor near the river's center or bank may be sufficient. In other instances, multiple intakes may be necessary to adequately characterize water quality across the river.

System efficacy depends on frequency of monitoring. The effectiveness of an early warning system improves as the monitoring frequency increases, and monitoring continuously via real-time online monitors is usually preferred. Longer times between samples can not only result in some short-duration events being missed but also delay the detection of the contamination event and the resulting mitigating actions. More-frequent analysis is suggested for monitors at intakes (given the lack of time between detection and entering the intake) as well as for faster rivers and rivers with lower dispersion. For upstream monitoring stations, the analysis frequency should take into consideration the contaminant travel time from the monitoring location to the intake.

System only as reliable as its data. With any monitoring system, appropriate QA/QC measures are necessary to ensure reliability of the analytical data generated and foster confidence in the appropriateness of potential responses. Because early warning monitors are concerned with identifying substantial changes in concentrations, however, they generally require less QA/QC than conventional or compliance monitoring, and precision and consistency are more important than accuracy.

Modern technology simplifies data transmission. Data from automated onsite or remote monitoring stations are usually easily transmitted for immediate use via modern electronic information transmission (telemetry) technologies such as telephone (wire and cellular), radio waves, and satellite-based communications systems. Telemetry devices are discussed in the AWWA manual for instrumentation and control (AWWA, 2001).

Risk-based models facilitate system design and analysis. Spill events are highly probabilistic occurrences, but major spills are relatively rare. Minor spills are much more common yet generally have little effect. The recommended approach to designing and evaluating early warning monitoring is a systematic method that considers the highly variable, probabilistic nature of many aspects of the system. These aspects include the probability of spills, the behavior of monitoring equipment, variable hydrology, and the probability of obtaining information about spills independent of analytical monitoring.

Spill Risk, a risk-based model using Monte Carlo (probabilistic) simulation techniques, was developed to aid in the design and analysis of early warning monitoring systems (Grayman & Males, 2002; Grayman et al, 2001). This tool uses a one-dimensional advection–dispersion contaminant transport model for a single reach of river (no tributaries). Probabilities are assigned to different types of fixed and mobile spills and discharges. Numerous simulations are run with varying inputs, and the results are used to assess the impact reduction for a single water intake (in population exposure above preset limits) provided by a variety of alternative early warning system configurations. Specifically, the model can help to determine the optimum type, number, and location of monitors; the optimum frequency of analysis; and various response scenarios.

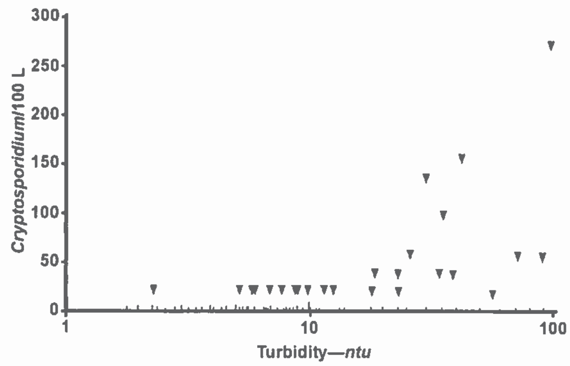
Response thresholds determined by variety of factors. Every early warning monitoring system should include predetermined response thresholds (i.e., an increase in response above normal fluctuations from baseline levels) that warrant identification as a contamination event and trigger additional action such as confirmation procedures, additional investigation and characterization of the event, and assorted prospective response actions. Selection of response thresholds should take into consideration such factors as

- historical patterns of water quality;
- the actual or perceived threat from various levels of contamination or events;
- the toxicity of the chemical or pathogen being monitored, with consideration given to regulatory limits and advisories;
- the nature and size of the population exposed;
- the ability of the treatment processes to remove the contaminant;
- the sensitivity and specificity of the monitoring method;
- the potential for false-positive or false-negative monitoring results; and
- the type and severity of action that might be taken if the trigger level is exceeded.

Response thresholds should be set at a reasonable level such that they don't occur either too frequently (too many alarms can be problematic) or too rarely (i.e., serious events are missed). A contaminant that could have severe public health effects would warrant a more stringent action trigger level than would a less harmful contaminant. Federal or state standards may be used as a guide, although in some cases, a lower value may be desirable; if existing treatment processes are efficient for that contaminant, then perhaps a concentration somewhat higher may be acceptable.

Protocol needed to confirm initial monitoring results. Initial detection results should be confirmed because false-positives may be associated with monitoring instrumentation or incorrect public reports. The confirmation process may include thoroughly checking the result's QA/QC, resampling and repeating the analysis, and performing more-accurate or more-specific alternative methods of analysis. Optimally, this step would not necessarily preclude or delay a necessary response action; any such delay should consider the immediacy of the situation, the potential magnitude of the event and corresponding possible effects (or perceived effects) on public health or the treatment systems, and the risks the water supplier is willing to take (if any), as well as other site-specific circumstances. If intakes can be closed with no substantial adverse ramifications, then it would be prudent to do so during the wait for event confirmation. To aid in confirmation, some advanced monitoring stations automatically take samples at fixed intervals and store these samples for a fixed period (e.g., 24 h); other stations are designed to take samples automatically when a monitor detects an unusual event. In either case, these samples can then be analyzed using standard tests to confirm and characterize the nature of the contaminant.

FIGURE 4 Correlation of turbidity and *Cryptosporidium* in the Delaware River



Source: LeChevallier et al, 1998

Characterization of contamination guides response. Characterization of a contamination event is imperative in order for the utility to predict with reasonable accuracy the event's effects on intake water quality over time. Contamination characterization is a six-step process:

- Step 1: Determine the specific contaminant(s) involved.
- Step 2: Identify the likely source of the contaminant (if unknown).
- Step 3: Determine the spatial and temporal variation in concentration in the source water.
- Step 4: Assess the dynamic behavior of the contaminant in the water body (mixing and decay behavior).
- Step 5: Predict the movement of the contaminant within the water body in order to predict both the time that the leading and trailing edges reach water intakes and the likely concentration.
- Step 6: Determine the effects on the waterway itself (e.g., fish kills).

Characterization of the contamination event is generally accomplished through sample collection, field and laboratory monitoring, instream tracking of the event, and use of mathematical models to predict the movement of the contaminants in the water body. Depending on the extent and severity of the event, the amount of field work and monitoring can vary significantly.

Predictions of the concentration–time–distance profile of a contaminant event can be developed to warn water users in advance of the time period when the contaminant will be at their intakes and what concentrations they will be subject to. Mathematical hydrodynamic contaminant transport models that are properly developed, calibrated, and operated can provide reasonable predictions in many cases. These models include a hydrological component that predicts contaminant transport via water flow and dispersion; often various contaminant fate processes are included as well. Models intended for use in rapid-response scenarios should be easy and quick to use, generate predictions with reasonable accuracy, and provide output that is easily interpreted. In addition to testing the model on a routine basis, water providers should establish protocols, train personnel, and set up a

General Research and Development Needs for Early Warning Monitoring Systems

- Development of a continuous monitor capable of detecting low levels of dissolved oil and petroleum products without significant limitations from chemical and physical interferences
- Continued development of rapid and automated sensors for established and emerging pathogens and biowarfare agents
- Development of sensors for simultaneous identification of multiple pathogens (combined biosensors)
- Improvements in sensor sensitivity
- Continuous, online, and remote-sensing monitors for a greater number of chemical parameters
- Improvements in electronic nose technology, especially for detecting odors in surface waters in which the complex chemical composition can create a combination of smells that make it difficult to monitor electronically
- Improvement of biological monitors through better means of sensing behavioral changes in response to sudden exposure to toxins
- Greatly improved technology exchange between the water supply industry and the many different industries developing innovative sensor technologies

fast mechanism for acquiring flow and velocity information. Current flow data for many rivers may be obtained electronically from US Geological Survey or US Army Corps of Engineers gauging stations; alternatively a flow gauge can be installed at the monitoring station.

Water quality models should be used as a guide to what may happen and are intended to supplement (but not replace) collection of actual real-time data as a source of information. Grayman and co-workers (2001) reviewed available models of varying complexity and also developed a one-dimensional Riverine Spill Modeling System that can be easily adapted for use for a wide range of rivers. An example output from such a model (Figure 2) identifies the expected time at which a spill will reach downstream locations.

Response actions and plans must be prepared ahead of time. Often, initial information about the nature and extent of a contamination event is limited. A water utility must first determine whether to act immediately or delay action pending confirmation and additional information. When the warning has been triggered by monitoring at the intake, then the need for near instantaneous decision-making is more acute. Appropriate water supplier responses to changes in source water quality depend on the type and potential extent of contamination, efficacy of existing and available treatment processes, and projected risks to public health or treatment process efficiency. General guidance and operating policies for response activities for a range of possible contamination events should be operative before an event occurs. Policies may include taking immediate action, waiting until the contaminant event has been confirmed and the nature (extent, location, arrival time, etc.) of the event determined, or opting for a more complex action plan determined by the type and location of the warning.

Responses to mitigate the effects of a spill event can include (1) closure of water intakes and use of alternate sources or storage, (2) cleanup of the spill before it can affect water intakes, (3) adjustment of existing treatment processes or use of additional ones, and (4) public notification (e.g., boil-water notices). Closure of water intakes provides the most absolute barrier; for optimum effectiveness, this action should be guided by information from the early warning system to coincide with the period of highest concentrations. If the water intake can be closed for only a limited time period (e.g., a few hours), then this places a premium on accurate predictions of concentration. The availability of raw and finished water storage capacity can help facilitate intake closure. In some cases, the intake location can be switched to draw water from different depths or lateral positions within the same source. Bank filtration and groundwater injection–recovery systems provide for additional treatment and place an additional time lag between the surface water source and the treatment plant.

Communication systems and plans are key to the efficacy of early warning monitoring. The effectiveness of an early warning system relies on accurate and timely information being communicated to those responsible for making response action decisions. The emergency response plan should include detailed instructions for communication between appropriate parties, with decision-makers, and to other stakeholders and the public, as necessary. Means of communication to the various parties can include face-to-face meetings, telephone, facsimiles, e-mail, websites, electronic bulletin boards, the media, and other methods.

Cooperative networks make the most of resources. Although onsite early warning monitoring may be conducted by a single water supplier, source waters used by multiple water utilities (e.g., a large river) offer opportunities for cooperation and pooling of resources for development

TABLE 1 Select approaches for detecting chemical and radioactive threats to drinking water*

	Approach†								
	High End			Middle			Low End		
Threats	$100,000s	Pros	Cons	$10,000s	Pros	Cons	$1,000s	Pros	Cons
Ions (salts)				IC	Fast, broad, sensitive		Ion probe	Sensitive	Selective
Metals	ICP–MS	Fast, broad ID, sensitive	Staff, lab	AAS Polarography	Fast, sensitive Fast, fairly selective	Staff, lab Selective	Ion probe	Sensitive	Selective
Polar organics	LC–MS	Broad ID	Staff, lab	LC TOC	Broad ID Broad ID	Staff, lab Lack of sensitivity	UV		Lack of sensitivity
Nonpolar organics	GC–MS	Broad ID	Staff, lab	LC	Broad ID	Staff, lab			
Volatiles, oil, hydrocarbons	GC–MS	Broad ID	Staff, lab	P&T–GC GC Fluorescence (oil, HC)	Broad ID Broad ID Broad ID	Staff, lab Staff, lab Interferences	Smell bell	Fast	Human testers
Specific compounds	GC–MS, LC–MS	Broad ID	Staff, lab				Immunoassay (pesticides)	Fast, specific	Staff
Biotoxics				Biomonitors‡	Continuous, fast	Lack of specific ID			
Radiation				Tritium Gamma detector Beta or alpha detector	Fast, specific Fast, broad ID, available online Fast	Not available online Lack of specific ID Lack of specific ID, lab, evaporation step, not available online			

*Modified from ILSI (1999)
†AAS—atomic absorption spectrometry (furnace or flame), Broad ID—can monitor for many compounds simultaneously, GC—gas chromatography, HC—hydrocarbons, IC—ion chromatography, ICP-MS—inductively coupled plasma mass spectroscopy, ID—identification, LC—liquid chromatography, MS—mass spectrometry, P&T—purge and trap, Selective—monitors for a single compound, TOC—total organic carbon, UV—ultraviolet
‡Biomonitors—fish, daphnids, mussels, algal fluorescence, and luminescent bacteria

of an integrated early warning monitoring network, including multiple monitoring stations, centralized data management and assessment, and coordinated communication systems. Case studies of such networks are reviewed later and have been discussed by other researchers (Grayman et al, 2001; AWWARF & CRS PROAQUA, 2002).

ANALYTICAL METHODS OFFER PROS AND CONS

Although the technology exists to monitor for regulated compounds in drinking water, it is neither technically nor economically feasible to monitor for all chemical and microbiological parameters. Utilities must consider the tradeoffs between costs and the range and type of monitors used. Selection of the specific methods for monitoring the parameters of concern should be based on a variety of factors, including method-response sensitivity (which should be compared with source water baseline levels), speed, desired frequency of analysis, available means of data development and retrieval, labor and maintenance requirements, initial and ongoing operating costs, and space availability. Potential water quality monitors include physical, chemical, radioactive, and microbiological analyses, as well as bioalarm systems that use living organisms to act as sensors for extreme changes in water quality. Many researchers have examined rapid or online monitoring techniques for the water industry (AWWARF & CRS PROAQUA, 2002; Frey et al, 2001; Grayman et al, 2001; Gullick, 2001; Dippenaar et al, 2000; Pollack et al, 1999; Reinhard & Debreaux, 1999). The following sections offer a brief overview of select methods for early warning.

Some of the more common physical and chemical monitoring methods used in early warning systems include simple probes measuring various parameters (e.g., turbidity, pH, temperature, conductivity, DO, chlorophyll), relatively simple batch tests (e.g., immunoassays for herbicides), and more advanced monitoring for chemicals (e.g., fluorescence for oils and chromatography for oil and petroleum constituents, volatile organic chemicals, and phenols). Some of the primary surrogates used include turbidity, DO, odor, conductivity, and general measures of organic carbon content (e.g., oxidant demand, total organic carbon). However, some of the parameters that are easily and inexpensively monitored via online probes (e.g., temperature, conductivity, pH) provide little information on detecting many spill events (e.g., oil spills). Although the more

FIGURE 5 Schematic of a commercial flow-through fish biomonitor tank

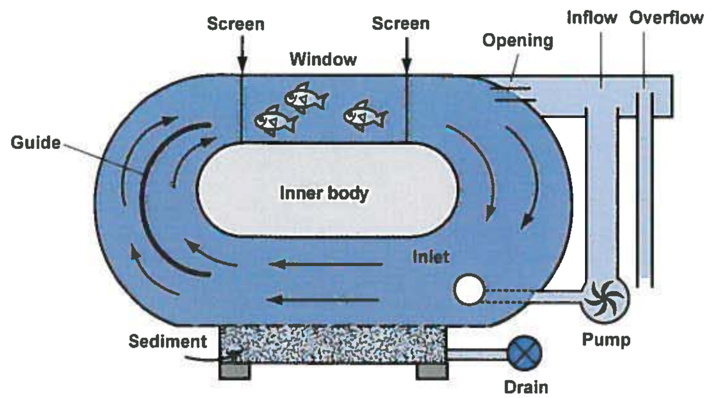
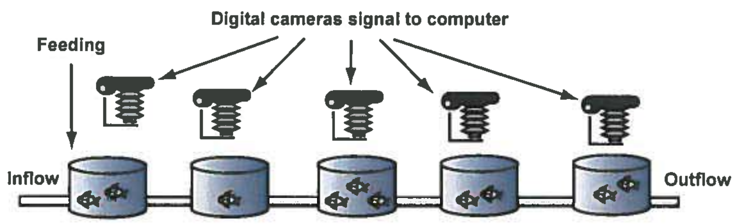


FIGURE 6 Schematic of fish-avoidance monitoring system in Osaka, Japan



advanced monitors are more expensive and require more maintenance and expertise, they are better at detecting many spill events.

Physical analyses offer speed, up-to-date information. Most physical monitoring methods are relatively rapid for most parameters (e.g., turbidity, conductivity, temperature, odor), and many can generate continuous real-time online data. Continuous online turbidity measurements are regularly used in treatment process–control application, and more expensive online particle counters are sometimes also used. Large increases in turbidity are frequently correlated with adverse changes in microbial water quality because both turbidity and microbial concentrations often increase substantially in surface waters during and after storm events because of surface runoff. Figure 3 shows an example of the correlation among increased river flow from storm events, turbidity, and the presence of the protozoan parasite *Cryptosporidium* (LeChevallier et al, 1998). High *Cryptosporidium* loadings at this location can typically be avoided by shutting an intake and using water from onsite storage when turbidity rises above a certain level (e.g., >15 ntu in Figure 4).

The presence of unusual odors can be a useful indicator for certain contamination events, including those resulting from algal by-products such as geosmin and methylisoborneol, phenols, petroleum products, and assorted volatile organics. One means for detecting odors is the "smell bell." Because it requires trained personnel with good noses, the smell bell test is not usually performed more than once per shift or once per day, thus limiting its use in early warning systems. Recent research suggests that it may soon be feasible to use electronic odor-sensing technologies ("electronic noses") that can operate continuously with less bias and greater repeatability and precision (Grayman et al, 2001).

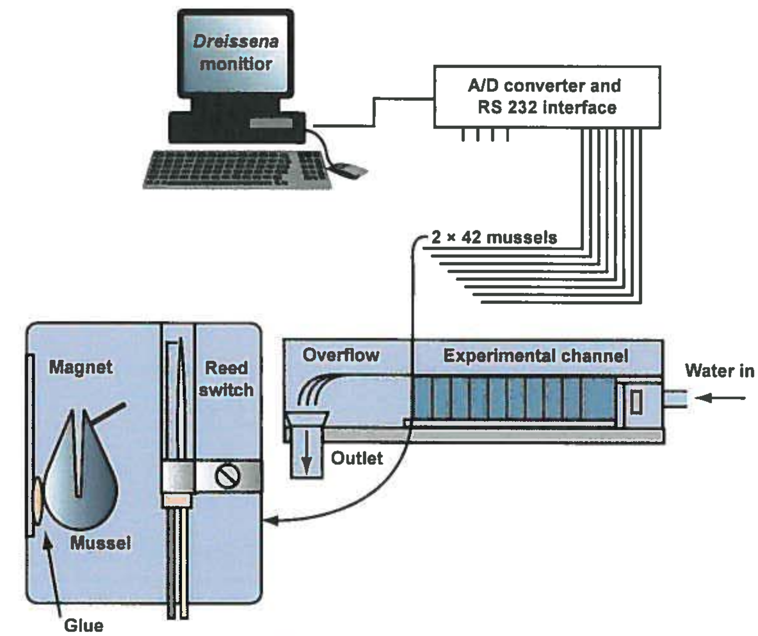
Chemical analyses come in many forms, range of costs. Many standard chemical analyses can be used for early warning monitoring, and several methods have been adapted for automated online applications and remote data access. Table 1 summarizes the relative costs as well as pros and cons for different early warning monitoring technologies for select chemical constituents.

Online analytical probes. Online analytical probes are relatively inexpensive, are easy to use, can provide continuous or nearly continuous monitoring with remote access to data, and are available from a variety of manufacturers. Ion-selective electrodes can quantify many inorganic ions including pH, elemental anions (e.g., chloride, bromide, fluoride, and iodide), ammonium, nitrite/nitrate, cyanide, certain metals (e.g., lead, cadmium, copper, aluminum, and manganese), and several other inorganic pollutants (Table 2). Probes are also available for turbidity, chlorophyll, and DO. Some manufacturers combine a variety of electrodes into one convenient and efficient multiparameter instrument. Because probes can foul in many raw water environments, some models use self-cleaning systems to reduce maintenance requirements.

DO. The DO concentration is a major parameter for the survival of aquatic life and for early warning applications is typically measured with a simple online probe. A decrease in DO can indicate the presence of organic compounds from sewage or surface water runoff. In addition, diurnal fluctuations in DO can be indicative of the presence of algae; for this reason, DO is sometimes used in conjunction with chlorophyll and turbidity measurements to monitor for algal blooms.

Nitrate and ammonia. Nitrate and ammonia/ammonium may be measured with a specific ion electrode; more sensitive but more expensive instruments for online colorimetric and ultraviolet (UV) analyses are also available. Both parameters may be indicative of agricultural pollution (i.e., fertilizers). Ammonia may come from sewage and animal waste discharges.

FIGURE 7 Schematic of a *Dreissena* monitor featuring two channels, each with 42 mussels



Metals. Ion-specific electrodes are available for certain metals, including lead, cadmium, copper, aluminum, and manganese. Anodic stripping voltametry–polarography is an excellent alternative for rapid analysis (<1–10 min) of low concentrations (nanogram-per-litre range) of certain metals and is used online at various monitoring stations in Europe. The instruments are priced in the range of $10,000–$17,000 and can detect four to six metals simultaneously; however, the method is restricted to amalgam-forming metals (e.g., cadmium, chromium, copper, lead, and zinc) and is subject to matrix interferences. Colorimetric methods are relatively inexpensive, typically apply to a single metal, and are subject to more interferences than more sophisticated methods. Atomic absorption spectrometry and plasma emission spectroscopy instruments are expensive and typically available only in commercial laboratories. One promising new technology, which has been applied to analysis of zinc, mercury, and cadmium, uses fluorescent molecules that react to specific metals in the presence of UV light (Bronson et al, 2001). Other developing methods for a variety of heavy metals include enzyme sensors and biosensors using genetically engineered microorganisms (Rogers & Gerlach, 1999).

General organic chemical parameters. Total organic carbon (TOC) and UV light absorption at 254 nm (UV_{254}) are general measures of organic content that can be performed in minutes and online. Though TOC is generally more sensitive and thus used more often for early warning, its natural variability in source waters is often greater than the concentrations of specific organics of concern. Simpler bench-scale test kits for organic carbon are also available.

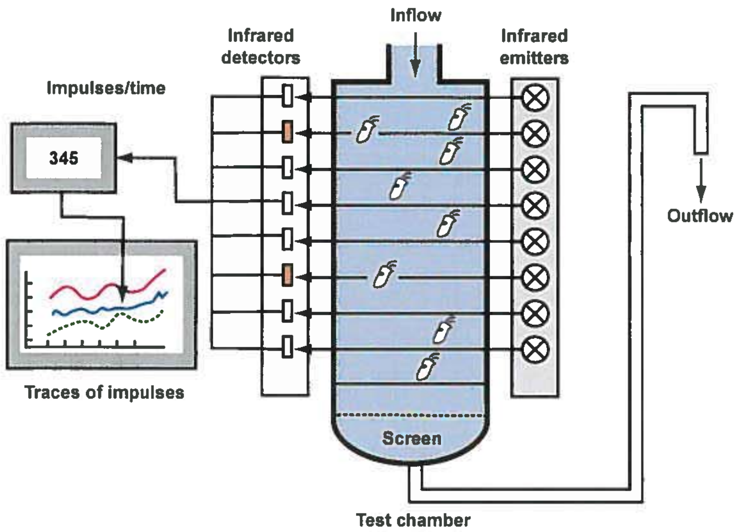
Oxidant demand and oxidant residual. Oxidant demand can be a general indicator of organic carbon content and ammonia in the source water. Because many utilities practice preoxidation (i.e., addition of chlorine, chlorine dioxide, ozone, or permanganate) and use online monitors to measure downstream oxidant residual, the oxidant demand can be calculated if the oxidant dosage and flow rates are known. Of course, oxidant residual is not applicable to raw waters but can be a useful warning measure of changes in distribution system water quality if residual disinfection is used by the utility.

Oil and petroleum. The primary techniques for online oil monitoring use light-scattering for floating oil and fluorescence for dissolved oil although each method has its limitations (He et al, 2001). Common chemical and physical interferences (e.g., particles, detergents, and floating debris) can cause frequent false alarms and make it difficult to track an oil spill during rain events that increase turbidity. Most commercial oil-in-water monitors use light-scattering techniques and thus are primarily useful only for major spills (e.g., for a 0.33 mm [0.013 in.] or greater layer of floating product).

Fluorometry can be used for dissolved gasoline, diesel, jet fuel, and oil components (such as BTEX [benzene, toluene, ethylbenzene, and xylenes]), as well as chlorophyll from algae. Continuous fluorescence oil detectors cost in the range of $12,000–$24,000, are very sensitive (low microgram-per-litre range in fairly clean water), and are used in several monitoring programs worldwide, although turbidity and humic substances can interfere. Although manual solvent extraction methods are labor-intensive, some European monitoring stations use an automated system for extraction and spectrophotometric analysis of total dissolved hydrocarbons (between 0.2 and 10 mg/L). Online monitors for low concentrations of oil need improvement. The introduction of genetically engineered microorganisms as biosensors for BTEX (Rogers & Gerlach, 1999) may prove useful in the future.

Organic chemicals. Manual and online gas chromatographs (GCs) range in cost from $30,000 to $50,000 and are used in several early warning systems worldwide to monitor for volatiles or other organic chemicals (including fuel oil components). Only a few stations use liquid chromatography, which costs in the range of $50,000–$100,000. Analyses can typically be performed in less than an hour by trained operators.

FIGURE 8 Schematic of original *Daphnia* monitor



Mass spectrometry (MS) is even more expensive and would be used primarily during the event confirmation step to provide accurate identification of organics in select samples. For some chromatography analyses, sample preparation can add significantly to the work required, and the necessary QA/QC can be more time-consuming than that for some of the simpler analyses.

Pesticides. Pesticide (herbicide and insecticide) contamination of surface waters is often seasonal because it primarily results from nonpoint source rainfall runoff from agricultural areas during periods of high pesticide application. The inexpensive batch ELISA (enzyme-linked immunosorbent assay) procedure, which is often used for the herbicide atrazine, takes approximately 40 minutes and compares reasonably well with GC–MS results for concentrations on the order of 3 µg/L, i.e., the level of the USEPA drinking water standard (Lydy et al, 1996).

Radioactivity. Early warning for radioactivity in surface waters may be applicable for facilities downstream from a nuclear power plant or other potential large source of radioactivity. Both gross radioactivity and specific radioactive substances may be measured. Tritium (hydrogen-3) may be an especially good indicator for nuclear power waste because it behaves as a conservative tracer in water and would reach an intake prior to other radioactive constituents that have larger retardation factors. Monitoring stations on the Rhine River measure for total alpha, total beta, tritium, cesium-137, and strontium-90 activity (Grayman et al, 2001).

Advances make microbiological analyses more feasible for early warning use. Conventional methods of microbial analysis require a relatively long time period (e.g., hours or days) for isolation and reproduction (amplification) of the microbial species, and many tests are specific only to a single species or class of organisms. Because of these limitations, these analyses are not often used for early warning applications. However, significant recent advances in microbial monitoring and related technology offer increased sensitivity, specificity, and more-rapid analysis, including deoxyribonucleic acid (DNA) microchip arrays, rapid DNA probes, immunologic techniques, cytometry, laser scanning, laser fingerprinting, optical technologies, and luminescence (Grayman et al, 2001; Rose & Grimes, 2001; Foran & Brosnan, 2000; Quist, 1999; Rogers & Gerlach, 1999). Most of these methods are still being developed or were only recently introduced. However, their use is likely to increase in the future. Relatively rapid existing methods for microbes are summarized in *Standard Methods* (1998) and Venter (2000).

Nucleic acid–based systems measure the genome of the organisms, which gives a high degree of specificity, but sample processing typically takes at least 2–4 hours. Several different kits are available for these tests. Rapid DNA probes are species-specific and use a robot-assisted microplate analysis of amplified samples of DNA (Quist, 1999). DNA microchip arrays are a developing technology that can detect and identify multiple microorganisms within 4 hours. Laser-scanning cytometry can be used to rapidly detect any organism for which there is a specific antibody, but the instruments are expensive.

Immunoassays use target-specific fluorescent antibodies that bind with an antigen of the target species, and test kits for a variety of pathogens are available that are relatively rapid, inexpensive, sensitive and simple to use (www.aoac.org/testkits/microbiologykits.htm).

Commercial methods[1–3] for measuring bacterial counts within 8–24 hours are readily available. Thanks to recent advances, the potential analysis time for bacteria (e.g., total coliforms, *E. coli*, or heterotrophic plate counts [HPC]) has been reduced to 4–8 hours or less. For example, a new modification of method 9211C.1 (*Standard Methods*, 1998) using adenosine triphosphate bioluminescence allows quantification of HPC within minutes (Lee & Deininger, 1999).

The conventional tests for protozoan parasites such as *Giardia* and *Cryptosporidium* (USEPA methods 1622 and 1623) require extensive training and are too time-consuming for early warning monitoring applications. Commercial instruments are available that can provide for screening of protozoan parasites in aqueous samples, but the tests still take a few hours because of sample preparation requirements.

When algae blooms are detected at their earliest stages, the algae can be treated in the reservoir before they grow out of control, thus reducing taste and odor problems and saving on treatment costs. Several commercial continuous monitors are available that rely on an online fluorescence detector to measure chlorophyll a, the principle photosynthetic pigment in all algae. Some probes costing ~$5,000 combine these measurements with those for water clarity (turbidity) and oxygen to provide early warning of algal blooms. A more expensive and sophisticated system was used in Los Angeles, Calif., to detect algae in supply reservoirs and resulted in substantial cost savings for treatment chemicals (Morrow et al, 2000).

Biomonitors track pollutants through their effect on organisms. The sheer magnitude of the number of pollutants of concern and the inability to monitor many of them continuously or at all have led to the use of online biomonitors. Biomonitors measure the changes in the behavior or properties of living organisms resulting from stresses placed on them by the presence of toxic materials. Conceptually biomonitors are analogous to the canaries used by miners to detect the presence of toxic gases. Though biomonitors do not provide information on the specific contaminant or cause of the stress on organisms, they warn that something unusual in the water is affecting the organisms, thus warranting further investigation such as specific chemical analyses (Penders & Stoks, 1999). Some biomonitors respond rapidly to elevated concentrations of a wide range of toxic compounds, and some can also be used to assess low-level chronic contamination by persistent, bioaccumulative toxins (e.g., from xenoestrogens, biocides, pharmaceuticals, and pesticides).

Examples of biomonitors include the dynamic fish (Figures 5 and 6), mussel (Figure 7), and *Daphnia* or water flea (Figure 8) tests as well as delayed algal fluorescence and luminescent bacteria response. The dynamic tests involve measuring changes (typically via electronic means) in movement or physiological responses by an organism as it tries to avoid toxic chemicals in the water. Because different species respond to different chemicals to varying degrees, the simultaneous use of different types of bioalarms (including some from different trophic levels) is often recommended (Penders & Stoks, 1999; LAWA, 1998).

The generally preferred method seems to be the *Daphnia* monitors, especially the newer ones that use digital cameras and are capable of following the behavior of each daphnid. The newer mussel tests appear to be well-suited because of the large filtering capacity of the mussels, their sensitivity, and their longevity. The simpler bacterial tests using luminescent bacteria are promising methods to determine the toxicity of the river water. Likewise, the delayed fluorescence of algae can be measured relatively easily. Although algae and bacteria monitors are not currently in wide use, and more experience with these monitors is needed, neither of these facts should deter water suppliers from using them. A report of German field experiences rated the dynamic *Daphnia* test as the first priority for developing a bioalarm station, followed in order by fluorescent algae, bacteria tests, and mussel monitors (LAWA, 1998). Fish monitors were not recommended primarily because the sensitivity was problematic and not reproducible (e.g., problems were encountered with both false alarms and the systems not responding to pollution events) (LAWA, 1998).

Very few biomonitors are in use in the United States, but dozens are operating in Europe (LAWA, 1998). Practically every station with a biomonitor uses a *Daphnia* test, but some also use fish, mussels, algae, and bacteria to test the water with organisms from different trophic levels. Japan and Korea have installed several of these systems, and the numbers are currently expanding. In the United States, USEPA research laboratories in Cincinnati, Ohio, are investigating the effectiveness of biomonitors at different trophic levels (Haught, 2000), and *Daphnia* toximeters were used for assessing source water quality during the 2002 Winter Olympics in Salt Lake City, Utah (Yates et al, 2002).

Purchase costs for these systems typically range from about $10,000 to near $50,000 and up. The manual

TABLE 2 Specific ion electrodes used in monitoring raw water

Ion	Type	Range—*mg/L*	Interferences*
Ammonium	PVC† membrane	0.1–18,000	K
Bromide	Solid state	0.4–80,000	S, I, CN
Cadmium	Solid state	0.01–11,000	Ag, Hg, Cu, Pb, Fe
Calcium	PVC membrane	0.2–40,000	Pb, Hg, Cu, Ni
Chloride	Solid state	1.8–33,000	S, I, CN, Br, OH, NH_3
Copper	Solid state	0.0006–6,350	Ag, Hg, Cl, Br, Fe, Cd
Cyanide	Solid state	0.1–260	S, I, B, Cl
Fluoride	Solid state	0.02 to saturation	OH
Iodide	Solid state	0.006–127,000	S, CN, Br, Cl, NH_3
Lead	Solid state	0.2–20,700	Ag, Hg, Cu, Cd, Fe
Nitrate	PVC membrane	0.5–62,000	I, CN, BF_4
pH	PVC membrane	1–14 (pH units)	
Surfactant	PVC membrane	1–12,000	
Hardness	PVC membrane	0.4–40,000	Cu, Zn, Ni, Fe

*Ag—silver, B—boron, BF_4—tetrafluoroborate, Br—bromine, Cd—cadmium, Cl—chlorine, CN—cyanide, Cu—copper, Fe—iron, Hg—mercury, I—iodine, K—potassium, NH_3—ammonia, Ni—nickel, OH—hydroxide, Pb—lead, S—sulfur, Zn—zinc

TABLE 3 **Summary of advanced early warning systems around the world**

River	Country	Administration	Monitoring Program	Comments	Websites
Ohio River	United States	ORSANCO (Ohio River Valley Water Sanitation Commission)	Organics Detection System (15 gas chromatographs)	Federal–state commission working with water utilities	www.orsanco.org
Mississippi River	United States	Louisiana Department of Environmental Quality	8 gas chromatographs for organics detection	Cooperative effort among the state, water utilities, and industries	www.deq.state.la.us/surveillance/ewocds/index.htm
Rhine River	Germany, Holland, Switzerland	International Commission for the Protection of the Rhine	9 international stations plus 20 national monitoring stations	Multinational early warning system; extensive use of biomonitors.	www.iksr.org
River Trent	United Kingdom	Severn Trent Water	1 station at intake	Provides real time warnings and historical database	
River Dee	United Kingdom	Hyder Lab and Sciences	3 stations	Cooperative effort among three water companies and government	
River Tyne	United Kingdom	Northumbrian Water Group	2 stations	Wide range of advanced monitors	
Llobregat River	Spain	Grupas Aguas de Barcelona	10 stations	Extensive network of automated monitors	
River Seine	France	SEDIF (Syndicat des Eaux d'Ile-de-France)	Automatic monitoring stations and samplers serving three plants	Combines sophisticated treatment, monitors, and early warning system	
North Saskatchewan River	Canada	EPCOR Utilities Inc.	2 stations located at intakes	Includes online monitors for chemical dosing decisions	
St. Clair River	Canada	ORTECH Environmental Inc.	1 monitoring station	Effective system in industrialized area since 1987	
Yodo River	Japan	Yodo River Water Quality Consultative Committee	Monitors at intakes	Cooperative effort among 10 water companies; unique monitoring systems	
River Han (and other rivers)	Korea	National Institute of Environmental Research	20 stations on four rivers	Combination of standard and advanced instruments and biomonitors	www.nier.go.kr
Danube River	Parts of 17 European countries	International Commission for the Protection of the Danube River	Mostly conventional monitors	Primarily a network for sharing spill information; 11-nation commission	www.icpdr.org
Moselle River	France and Germany	International Commission for the Protection of the Moselle and the Saar	Several advanced monitoring stations with chemical and biomonitors	Primarily agricultural area with good water quality	www.iksms-cipms.org
Elbe River	Germany and Czech Republic	International Commission for the Protection of the Elbe	17 monitoring stations	Significant improvement in water quality since the reunification of Germany	www.arge-elbe.de www.bafg.de/html/ikse/ikse.htm

batch bacteria tests can be the least expensive in terms of capital costs. The algae, *Daphnia,* and mussel tests are fairly comparable in expense (~$20,000–$40,000) and cost less than fish monitor units (LAWA, 1998; Stoks, 1998). Operating costs are fairly low for all these methods (except the luminescent bacteria test) and primarily involve replacement organisms and electricity.

False-positive results can result from interferences from a variety of environmental factors other than contaminants (e.g., temperature changes or low oxygen). Data on the sensitivity and minimum detection limits of online biomonitors are relatively limited, and the methods demonstrate a relative lack of sensitivity for some chemicals of interest. Other drawbacks include the high cost for more sophisticated biomonitors and maintenance requirements for the living systems. The interpretation of the signals from biological monitors is also an important consideration; as this improves, the value of biomonitors will likely increase.

New monitoring methods emerge, research and development needs identified. Electronic noses and rapid bacterial methods have been identified as areas in which developments are taking place, and the use of these as early warning systems is likely to increase. Selected general research and development needs are summarized in the sidebar on page 64. Numerous research projects by the AWWA Research Foundation and the Water Environment Research Foundation are investigating rapid and online monitoring technologies. Generally speaking, however, many of the advances in monitoring technologies occur from research in other scientific fields (e.g., the food and beverage industry, analytical chemistry, the sensor industry, and the military); these advances include biosensor and biochip technology, fiber optics, genetically engineered organisms, immunoassays, and microelectronics. Research on rapid and online monitoring systems for a variety of contaminants is being conducted by a number of US government organizations including the USEPA (Panguluri et al, 1999; Rogers & Gerlach, 1999) and the US Army's Joint Service Agent Water Monitor program (ILSI, 1999).

SUCCESS OF EXISTING SYSTEMS MAY WIN NEW USERS

Case studies provide snapshots of monitoring applications. There are relatively few advanced early warning systems around the world that are extensive in size and scope, employ significant online state of the art monitoring equipment, and utilize monitoring, modeling, and communications in an integrated system to warn of contaminants in source water. Table 3 summarizes 15 prominent systems described by Grayman and colleagues (2001); taken together, these installations provide a fairly complete picture of the potential for early warning systems. Other research has documented case studies of online monitoring, some of which focus on early warning (AWWARF & CRS PROAQUA, 2002). These references include an evaluation of the successes and limitations of the systems.

There are both significant commonality and diversity among the systems. All of the systems depend on a combination of monitors, self-reporting, and/or public reporting. The monitoring systems used range from simple probes (e.g., pH, turbidity, conductivity) to advanced instruments such as GCs and UV monitors to biomonitors. Many of the systems employ mathematical models to predict arrival times for a spill at downstream intakes. In all cases, some form of institutional structure coordinates efforts and communicates information so that appropriate actions can be taken. The impetus for several of these systems and networks has been an unfortunate large spill or release of a toxic or hazardous chemical.

Systems vary in their degree of complexity (Table 3). For example, the system on the River Rhine has nine international monitoring stations and 20 national stations monitoring for numerous parameters, including general water quality parameters, organic carbon indicators, nutrients, inorganics and metals, organic compounds (pesticides and volatile organics), and radioactivity. Other systems may contain only a single monitoring station. Systems also vary in terms of the frequency of analysis and degree of automation. Many of the systems are highly automated, with both alarm signals and maintenance performed remotely. The more sophisticated networks include a coordinated monitoring, modeling, communication, and response program for an extended stretch of river.

With a few notable exceptions (e.g., the Ohio River and Lower Mississippi River), US experience with advanced early warning monitoring systems and networks is limited, and many US water suppliers have little or no early warning system in place. However, interest in early warning monitoring networks has increased in recent years, and such systems are currently being developed for the Upper Mississippi, Schuylkill, Delaware, Allegheny, Monongahela, and Susquehanna rivers (Gullick, 2003).

Future holds developments for early warning systems. A vision for the future of early warning monitoring systems would address the reduction of contamination events and a plan to mitigate the effects of unexpected discharges. Key elements would include (1) an active program for reducing the likelihood of the discharges, (2) an enforced set of regulations that strongly encourages self-reporting of any nonroutine discharges, (3) a monitoring system for detecting contaminants in the source waters, (4) a mathematical tool (model) for predicting the movement of a contaminant from its source to the water intakes, (5) a communications and organizational infrastructure for coordinating and disseminating information on the contaminant event, and (6) effective means for reducing the effects of the contaminant on the water system through intake closure, treatment, and use of raw or finished water storage or alternative sources.

This vision is looking brighter but has not yet been fulfilled. In some instances, early warning systems that include many of these elements have been implemented. However, most raw water sources continue to be vulnerable to contamination, and the water community still has far to go to safeguard water supplies. Ongoing research is expected to produce substantial advances in monitoring technologies in the near future.

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SINGLE SOURCE FEASIBILITY STUDY

Feasibility Matrix | City of Ripley | PWSID#: WV 3301811 | Date: January 2016 | Completed By: Project Engineer - The Thrasher Group, Inc.

Alternative Strategy Description	Economic Criteria					Technical Criteria							Environmental Criteria						Final Score	Total Capital Cost	Comments
	Operation & Maintenance Costs	Capital Costs	**Total**	**Total %**	**Weighted Total**	Permitting	Flexibility	Resilience	Institutional Requirements	**Total**	**Total %**	**Weighted Total**	Environmental Impacts	Aesthetic Impacts	Stakeholder Issues	**Total**	**Total %**	**Weighted Total**			
Backup Intake	2.3	2.0	**4.3**	**72.2%**	**28.9%**	2.0	3.0	2.7	2.7	**10.3**	**86.1%**	**34.4%**	3.0	3.0	2.3	**8.3**	**92.6%**	**18.5%**	**81.9%**	**$3,484,737.50**	100% backup to the primary water source, environmental Impacts addressed at intake site, majority of construction in rights-of-way
Interconnect	3.0	3.0	**6.0**	**100.0%**	**40.0%**	3.0	3.0	2.7	2.7	**11.3**	**94.4%**	**37.8%**	3.0	3.0	2.7	**8.7**	**96.3%**	**19.3%**	**97.0%**	**$69,520.00**	100% backup to the primary water source with majority of construction in rights-of-way
Treated Water Storage	3.0	2.7	**5.7**	**94.4%**	**37.8%**	3.0	2.5	2.3	2.7	**10.5**	**87.5%**	**35.0%**	3.0	3.0	2.7	**8.7**	**96.3%**	**19.3%**	**92.0%**	**$514,250.00**	Supplement existing storage to meet two (2) day requirement stated in Senate Bill 373.
Raw Water Storage	3.0	2.7	**5.7**	**94.4%**	**37.8%**	3.0	2.5	2.3	2.7	**10.5**	**87.5%**	**35.0%**	3.0	3.0	2.7	**8.7**	**96.3%**	**19.3%**	**92.0%**	**$514,250.00**	Supplement existing storage to meet two (2) day requirement stated in Senate Bill 373.
Other	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Scoring:

0 - Not feasible. Criterion cannot be met by this alternative and removes the alternative from further consideration.

1 - Feasible but difficult. Criterion represents a significant barrier to successful implementation but does not eliminate it from consideration.

2 - Feasible. Criterion can be met by the alternative.

3 - Very Feasible. Criterion can be easily met by the alternative.

ALTERNATIVES ANALYSIS

The City of Ripley currently does not have an alternative water source to fully support the entire system in the event Mill Creek would become contaminated or degraded.

1. Backup Intake

The Ripley water treatment facility obtains water from Mill Creek. Mill Creek, a tributary of the Ohio River, is comprised of three (3) streams upstream of the treatment plant, Little Mill Creek, Elk Fork, and Tug Fork. The flow of Mill Creek is regulated by two dams, Elk Fork Dam and Statts Mill Dam. The Elk Fork Dam impedes the Elk Fork before converging with Little Mill Creek to form Mill Creek, while the Tug Fork is pooled behind the Statts Mill Dam prior to discharging into Mill Creek further downstream.

Ripley does not have an alternative water intake source in close proximity. An upstream location on the Ohio River, located 13 miles west of Ripley, is the nearest employable water source that does not influence nor is influenced by Mill Creek. The size and span of a water line from the Ohio River to the existing treatment facility is not practical, and therefore was not considered as an alternative for Ripley.

Currently, Ripley’s raw water intake is influenced by all three (3) of Mill Creek’s upstream tributaries. The only tenable option would be to construct a backup intake on Mill Creek upstream of the Tug Fork, eliminating one (1) tributary as a possible source of contamination.

Little Mill Creek does not sustain ample flow to allow discernable quantities to be withdrawn and does not have an existing dam. The Elk Fork forms a 278 acre impoundment that is Elk Fork Lake. With an average depth of eighteen (18) feet, it can be estimated that Elk Fork Lake retains approximately 5,000 acre feet of water, an amount capable of supporting Ripley’s water demand. Based on land use, Little Mill Creek is not heavily susceptible to contamination and would not pose a threat to an intake constructed after the convergence with the Elk Fork and formation of Mill Creek. This allows for a potential intake on an upstream location of Mill Creek, significantly closer than if constructed solely on the Elk Fork.

An intake constructed on Mill Creek upstream of the Tug Fork to the existing treatment facility would require approximately 23,000 feet of 12” water line. The construction of a backup intake on Mill Creek was evaluated in the feasibility analysis.

2. Interconnection

In 2008, Ripley acquired facilities previously operated by Evans Public Service District. Prior to 2008, Evans PSD received water service from Mason County Public Service District's Letart system. The existing interconnection between the former Evans PSD and Letart systems is existing and the Letart system is capable of providing service to the Evans area in an emergency.

Ripley is not capable of back feeding water from Evans to the parent system. The City of Ripley would require an additional 450 feet of 6" water main for an interconnection along County Route 21 to supply the remaining population from Northern Jackson PSD. Northern Jackson purchases all water from the City of Ravenswood. Ravenswood maintains seven (7) groundwater wells capable of yielding upwards of five (5) million gallons per day (MGD) as reported in the most recently filed PSC Annual Report. Ravenswood currently produces an average of 1.27 MGD serving the City of Ravenswood and Northern Jackson PSD. The proposed required production by Ravenswood is shown below.

$$1.27\ MGD + .95\ MGD = 2.22\ MGD$$

Therefore, Ravenswood is capable of satisfying Ripley's water demand. This conclusion is based on a preliminary evaluation of the Ravenswood, and Northern Jackson systems. Further development may be required within these systems for an adequate flowrate to reach Ripley from Ravenswood.

The existing interconnection with Mason County PSD along with the construction of an interconnection with the City of Ravenswood via the Northern Jackson PSD system was evaluated in the feasibility analysis.

3. Treated Water Storage

Ripley's total system storage is 2,002,000 gallons, consisting of seven (7) treated water storage tanks. According to the most recent monthly operating reports provided by the utility, the water treatment facility produces an average of 952,358 GPD and the maximum quantity produced in a twenty-two (22) hour period was 1,521,331 GPD.

Senate Bill 373 requires utilities to maintain a minimum system storage capacity equal to two (2) days of system plant's maximum level of production experienced within the past year. The minimum required storage capacity for the system would be:

$$\frac{1{,}521{,}331\ gallons}{day} \times 2\ days = 3{,}042{,}662\ gallons$$

Therefore, the system currently does not meet the minimum required water storage capacity. This evaluation includes water provided to Southern Jackson PSD which retains 975,000 gallons of treated water storage, respectively. The required storage can be re-evaluated to address only customers dependent on Ripley's water storage. Below is a demonstration of Ripley's adjusted requirement.

City of Ripley	Storage Capacity	Max. Produced Per Day	Required Storage	Remaining	Days of Storage
	Gallons				Max. Produced
	2,002,000	1,521,331	3,042,662	1,040,662	1.32

Southern Jackson PSD		Av. Purchased Per Day			Days of Storage
	Gallons				Av. Purchased
	975,000	405,881			2.40

City of Ripley Adjusted	Storage Capacity	Max. Produced Per Day	Required Storage	Remaining	Days of Storage
	Gallons				Max. Produced
	2,002,000	1,115,450	2,230,901	228,901	1.79

Furthermore, the Evans area can be fully supported by Mason County PSD, so the average demand of Evans can also be excluded from Ripley's maximum production. In this case, the storage used to supply the Evans area would also need to be separated from the total Ripley system storage. The Evans area is served by two (2) water storage tanks totaling 199,700 gallons of treated water storage. Ripley's required minimum storage after this adjustment is shown on the following page.

City of Ripley	Storage Capacity	Max. Produced Per Day	Required Storage	Remaining	Days of Storage
	Gallons				Max. Produced
	2,002,000	1,521,331	3,042,662	1,040,662	1.32

Evans					
	199,700	95,000			2.10

Southern Jackson PSD		Av. Purchased Per Day			Days of Storage
	Gallons				Av. Purchased
	975,000	405,881			2.40

City of Ripley Adjusted	Storage Capacity	Max. Produced Per Day	Required Storage	Remaining	Days of Storage
	Gallons				Max. Produced
	1,802,300	1,020,450	2,040,901	238,601	1.77

Although separating the Evans portion of the Ripley system increases the required storage amount, this scenario is more advantageous considering Mason County PSD can fully supply the Evans area. The addition of treated water storage was evaluated during the feasibility analysis.

4. Raw Water Storage

As described above the treated water storage capacity of Ripley is 2,002,000 gallons. After evaluation of the Ripley and Southern Jackson systems, Ripley requires a minimum of 229,000 gallons of additional water storage to satisfy the two (2) day system storage requirement described in Senate Bill 373. The addition of raw water storage to satisfy the minimum system storage requirement was considered during feasibility analysis.

Matrix Explanation

The alternative analysis matrix evaluates the utility's ability to implement each of the additional sources outlined. Alternative sources are evaluated for economic, technical and environmental feasibility. The matrix uses a zero (0) to three (3) rating system, with three (3) being very feasible and zero (0) being not feasible. Each category has sub questions to develop an average for the alternative. Once all areas are evaluated, a final feasibility score is given for each of the alternatives for use in determining which option will best suit the utility's needs.

Economic factors evaluated in the matrix include all information needed to fund the alternative source. The matrix considers the current utility budget available per the latest annual report, operation and maintenance costs for each alternative, and the capital cost needed to construct each alternative. Supporting documentation is included in **Appendix D** of the report which provides a breakdown of costs for each alternative that are used as capital costs in the matrix. The economic feasibility of each alternative is compared on a cost per gallon ratio. This ratio is determined by dividing the capital cost of the improvements by the total number of gallons of water produced per year. An average of the economic feasibility factors is then calculated and entered into the overall feasibility matrix found in **Appendix B**.

Technical criteria evaluated include permitting, flexibility, institutional and resilience factors. Permitting costs are included in all supporting documentation for each alternative source. The permitting factors included the permits that would be needed to construct the alternative source for the utility. An additional environmental factor is the feasibly of obtaining each permit. Permits were rated from zero (0) to three (3) based on the difficulty of obtaining the permits for the project. Depending on the project area, some permits may be very difficult and costly to obtain. Flexibility factors evaluate the ability of the alternative to be used as a permanent source of water or if it can only be used on a temporary basis. The intake and interconnections can be used as both temporary and permanent sources. The alternatives' ability to help the utility during seasonal or population increases is also evaluated in the resilience factors. The alternatives that can produce additional water were rated very feasible. Additional criteria evaluated are easements and right of ways that will need to be acquired to construct the alternative source. For interconnections and intakes right of way would be needed to lay the new water line. The feasibility of attaining the rights-of-way was evaluated. All technical criteria was averaged and also entered into the feasibility summary in **Appendix B**.

Environmental aspects for each alternative include impacts, aesthetics and stakeholders. Environmental impacts included any areas in the proposed alternative source area that are protected. Areas that are protected would have a low feasibility because the impacts could be large if the project were constructed. Aesthetics factors include noise, visual impacts, and mitigation measures that could affect the projects feasibility. The aesthetic factors relate to the stakeholder factors. The stakeholders' portion of the environmental criteria involves the community and their acceptance of the new source alternative and the structures that will be constructed.

Feasibility Matrix **City of Ripley** **PWSID#: WV 3301811** **Date: January 2016** **Completed By: Project Engineer - The Thrasher Group, Inc.**

Criteria	Question	Backup Intake	Feasibility	Interconnect	Feasibility	Treated Water Storage	Feasibility	Raw Water Storage	Feasibility	Other	Feasibility
Economic Criteria											
What is the total current budget year cost to operate and maintain the PWSU (current budget year)?		$1,144,853.00		$1,144,853.00		$1,144,853.00		$1,144,853.00		$1,144,853.00	
O and M Costs	Describe the major O&M cost requirements for the alternative?	Labor, power, materials for maintenance	1	Labor, power, materials for maintenance	3	Labor, materials for maintenance	3	Labor, materials for maintenance	3	N/A	–
	What is the incremental cost ($/gal) to operate and maintain the alternative?	$0.00	3	$0.00	3	$0.00	3	$0.00	3	–	–
	Cost comparison of the incremental O&M cost to the current budgeted costs (%)	0.00%	3	0.00%	3	0.00%	3	0.00%	3	–	–
O and M-Feasibility Score			**2.3**		**3.0**		**3.0**		**3.0**		–
Describe the capital improvements required to implement the alternative.		Construction of raw water pump station and water line		Construction of water line		Construction of additional treated water storage		Construction of a additional raw water storage		–	
Capital Costs	What is the total capital cost for the alternative?	$3,484,737.50	0	$69,520.00	3	$514,250.00	2	$514,250.00	2	–	–
	What is the annualized capital cost to implement the alternative, including land and easement costs, convenience tap fees, etc. ($/gal)	$0.01	3	$0.00	3	$0.00	3	$0.00	3	–	–
	Cost comparison of the alternatives annualized capital cost to the current budgeted costs (%)	0.00%	3	0.00%	3	0.00%	3	0.00%	3	–	–
Capital Cost-Feasibility Score			**2.0**		**3.0**		**2.7**		**2.7**		–
Technical Criteria											
Permitting	Provide a listing of the expected permits required and the permitting agencies involved in their approval.	WV DEP, WV DNR, ACOE, WV SHPO, US FWS, WV DOH and County Floodplain	2	WV DEP, WV DNR, ACOE, WV SHPO, US FWS, WV DOH and County Floodplain	3	WV DEP, WV DNR, ACOE, WV SHPO, US FWS, WV DOH and County Floodplain	3	WV DEP, WV DNR, ACOE, WV SHPO, US FWS, WV DOH and County Floodplain	3	–	–
	What is the timeframe for permit approval for each permit?	WV DEP (90 days), WV DNR (60 days), ACOE (90 days), WV SHPO (60 days), US FWS (60 days), WV DOH (90 days) and County Floodplain (90 days)	2	WV DEP (90 days), WV DNR (60 days), ACOE (90 days), WV SHPO (60 days), US FWS (60 days), WV DOH (90 days) and County Floodplain (90 days)	3	WV DEP (90 days), WV DNR (60 days), ACOE (90 days), WV SHPO (60 days), US FWS (60 days), WV DOH (90 days) and County Floodplain (90 days)	3	WV DEP (90 days), WV DNR (60 days), ACOE (90 days), WV SHPO (60 days), US FWS (60 days), WV DOH (90 days) and County Floodplain (90 days)	3	–	–
	Describe the major requirements in obtaining the permits (environmental impact studies, public hearings, etc.)	Environmental impact studies, water sampling	1	Environmental impact studies.	3	Environmental impact studies.	3	Environmental impact studies.	3	–	–
	What is the likelihood of successfully obtaining the permits?	Fair	2	Good	3	Good	3	Good	3	–	–
	Does the implementation of the alternative require regulatory exceptions or variances?	No	3	No	3	No	3	No	3	–	–
Permitting-Feasibility Score			**2.0**		**3.0**		**3.0**		**3.0**		–
Flexibility	Will the alternative be needed on a regular basis or only used intermittently?	Intermittently, but can be used permanently	3	Intermittently, but can be used permanently	3	Intermittently	2	Intermittently	2	–	–
	How will implementing the alternative affect the PWSU's current method of treating and delivering potable water including meeting Safe Drinking Water Act regulations? (ex. In the case of storage, will the alternative increase the likelihood of disinfection byproducts?)	No impact	3	Current treatment methods will not be required	3	No impact	3	No impact	3	–	–
Flexibility-Feasibility Score			**3.0**		**3.0**		**2.5**		**2.5**		–
Resilience	Will the alternative provide any advantages or disadvantages to meeting seasonal changes in demand?	No	3	No	3	No	3	No	3	–	–
	How resistant will the alternative be to extreme weather conditions such as drought and flooding?	Drought may limit availability of water	2	Drought may limit availability of water	2	Drought may limit availability of water	2	Drought may limit availability of water	2	–	–
	Will the alternative be expandable to meet the growing needs of the service area?	Yes	3	Yes	3	Limited	2	Limited	2	–	–
Resilience-Feasibility Score		0	**2.7**		**2.7**		**2.3**		**2.3**		–
Institutional Requirements	Identify any agreements or other legal instruments with governmental entities, private institutions or other PWSU required to implement the alternative.	None	3	Northern Jackson PSD Mason County PSD City of Ravenswood	2	None	3	None	3	–	–
	Are any development/planning restrictions in place that can act as a barrier to the implementation of the alternative.	No	3	No	3	No	3	No	3	–	–
	Identify potential land acquisitions and easements requirements.	Property acquisition for pump station and easements for waterline	2	Water line will be installed in DOH right-of-way.	3	Property acquisition for tank site	2	Property acquisition for tank site	2	–	–
Institutional Requirements-Feasibility Score			**2.7**		**2.7**		**2.7**		**2.7**		–
Environmental Criteria											
Environmental Impacts	Identify any environmentally protected areas or habitats that might be impacted by the alternative.	None	3	None	3	None	3	None	3	–	–
Environmental Impacts-Feasibility Score			**3.0**		**3.0**		**3.0**		**3.0**		–
Aesthetic Impacts	Identify any visual or noise issues caused by the alternative that may affect local land uses?	Fencing and control panel for pump station	3	None	3	Water tank on a hill	3	Water tank on a hill	3	–	–
	Identify any mitigation measures that will be required to address aesthetic impacts?	Clearance from Culture and History and Local Zoning Commission will be obtained	3	N/A	3	Clearance from Culture and History and Local Zoning Commission will be obtained	3	Clearance from Culture and History and Local Zoning Commission will be obtained	3	–	–
Aesthetic Impacts-Feasibility Score			**3.0**	0	**3.0**		**3.0**		**3.0**		–
Stakeholder Issues	Identify the potential stakeholders affected by the alternative.	Water Customers	3	Water Customers	3	Water Customers	3	Water Customers	3	–	–
	Identify the potential issues with stakeholders for and against the alternative.	Rate Increase may be needed to implement construction	1	Rate Increase may be needed to implement construction	2	Rate Increase may be needed to implement construction	2	Rate Increase may be needed to implement construction	2	–	–
	Will stakeholder concerns represent a significant barrier to implementation (or assistance) of the alternative?	No	3	No	3	No	3	No	3	–	–
Stakeholder Issues-Feasibility Score			**2.3**		**2.7**		**2.7**		**2.7**		–
Comments		100% backup to the primary water source, environmental Impacts addressed at intake site, majority of construction in rights-of-way		100% backup to the primary water source with majority of construction in rights-of-way		=Alternatives!G42		Supplement existing storage to meet two (2) day requirement stated in Senate Bill 373.		–	

SUPPORTING DOCUMENTATION

EARLY WARNING MONITORING COST ESTIMATE

Qty.		Description	Unit Price	Total Cost
1	EA	Back Panel / Trough / Level (required)	$4,350.00	$ 4,350
1	EA	Probe Module SC1000 (6 sensors)	$ 1,344.00	$ 1,344
1	EA	Internal Card SC1000 (4 mA inputs)	$ 879.00	$879
1	EA	Display Module SC1000	$ 2,770.00	$ 2,770
1	EA	Conductivity Sensor	$ 860.00	$860
1	EA	FP360 SC Sensor, 500 ppb, SS, 1.5 m Cable	$ 17,480.00	$ 17,480
1	EA	ORP Sensor	$ 880.00	$ 880
1	EA	pH Sensor, Ryton	$ 800.00	$ 800
1	LS	Installation	$ 20,637.00	$ 20,637
			TOTAL=	**$ 50,000**

OPERATION & MAINTENATNCE COST ESTIMATE

Qty.		Description	Unit Price	Total Cost
1	LS	Annual O&M Cost	$750.00	$ 750
			TOTAL=	**$ 750**

In addition to the early warning system, City of Ripley should establish a baseline water quality for their sources.

BACKUP INTAKE

Intake Pricing Parameters	Cost per GPM
If the GPM needed is Greater than or Equal to 1,000 GPM (12" Pipe)	$ 1,500.00
If the GPM needed is between 700 GPM to 999 GPM (8" Pipe)	$ 1,750.00
If the GPM needed is less than 700 GPM (6" Pipe)	$ 2,000.00
Intake pricing includes acreage, pumps, screens, concrete, raw water well, electricity, etc.	**$ 1,701,000.00**

Utility Information		
Existing Capacity	972	GPM
Footage Needed	29,170	LF

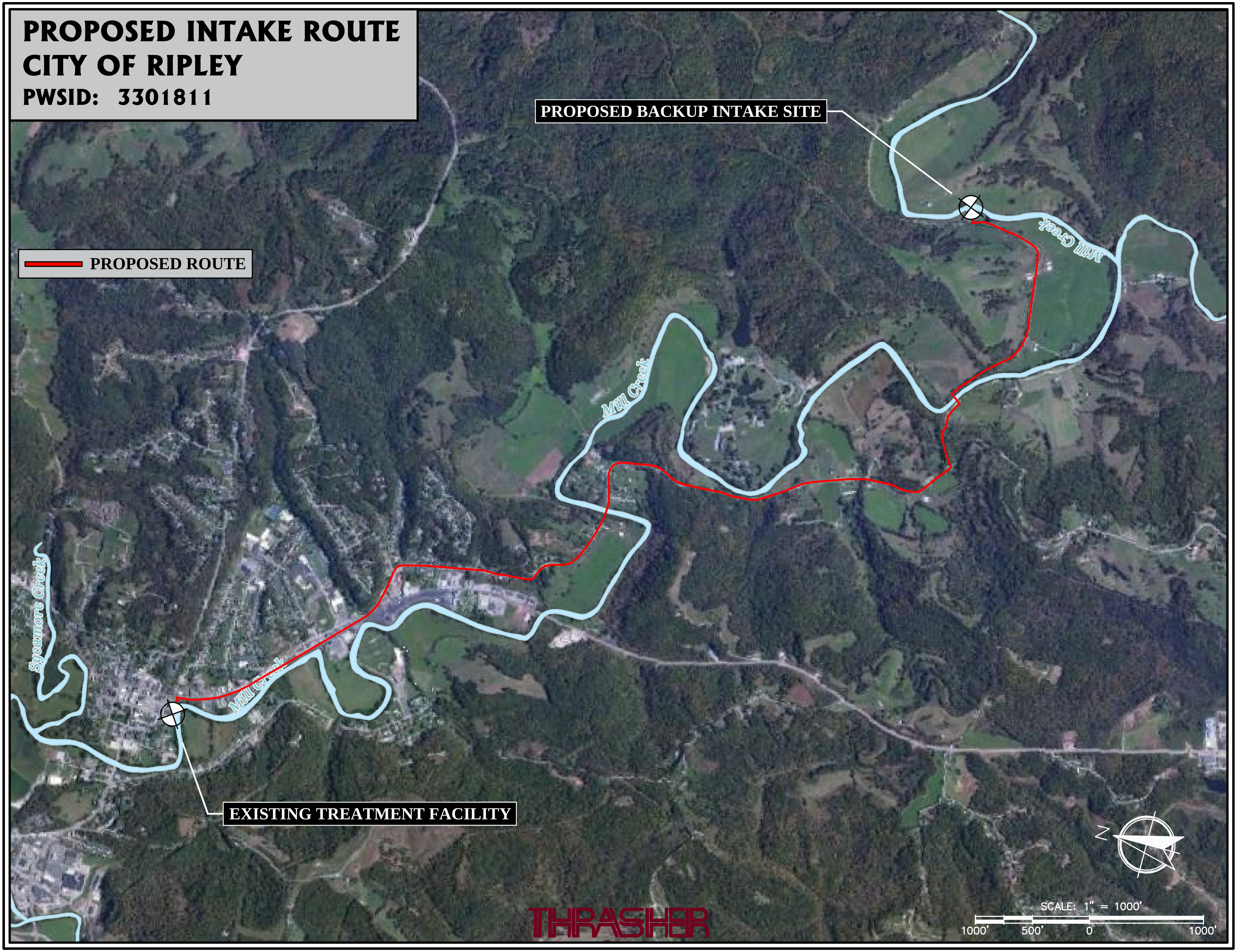
Piping Size	Cost per Foot	Footage	Totals
12" Pipe	$ 60.00	-	$ -
8" Pipe	$ 37.00	29,170	$ 1,079,290.00
6" Pipe	$ 34.00	-	$ -
			$ 1,079,290.00

Assumptions
Water will be taken from Mill Creek. According to the WVDNR, Mill Creek is not a mussel stream and will not require a survey to be completed during permitting. Permits required would include WV DEP, WV DNR, ACOE, WV SHPO, US FWS, WV DOH and County Floodplain. Additional fees are predicted to be 25% of overall cost. The fees include legal, engineering and accounting needs.

Additional Environmental Costs		
Mussel Survey	No	$ -
Permits	Yes	$ 7,500.00
		$ 7,500.00

Totals	
Intake	$ 1,701,000.00
Piping	$ 1,079,290.00
Permitting	$ 7,500.00
Additional Fees	$ 696,947.50
Total Cost	**$ 3,484,737.50**

The piping route is included on the following page.

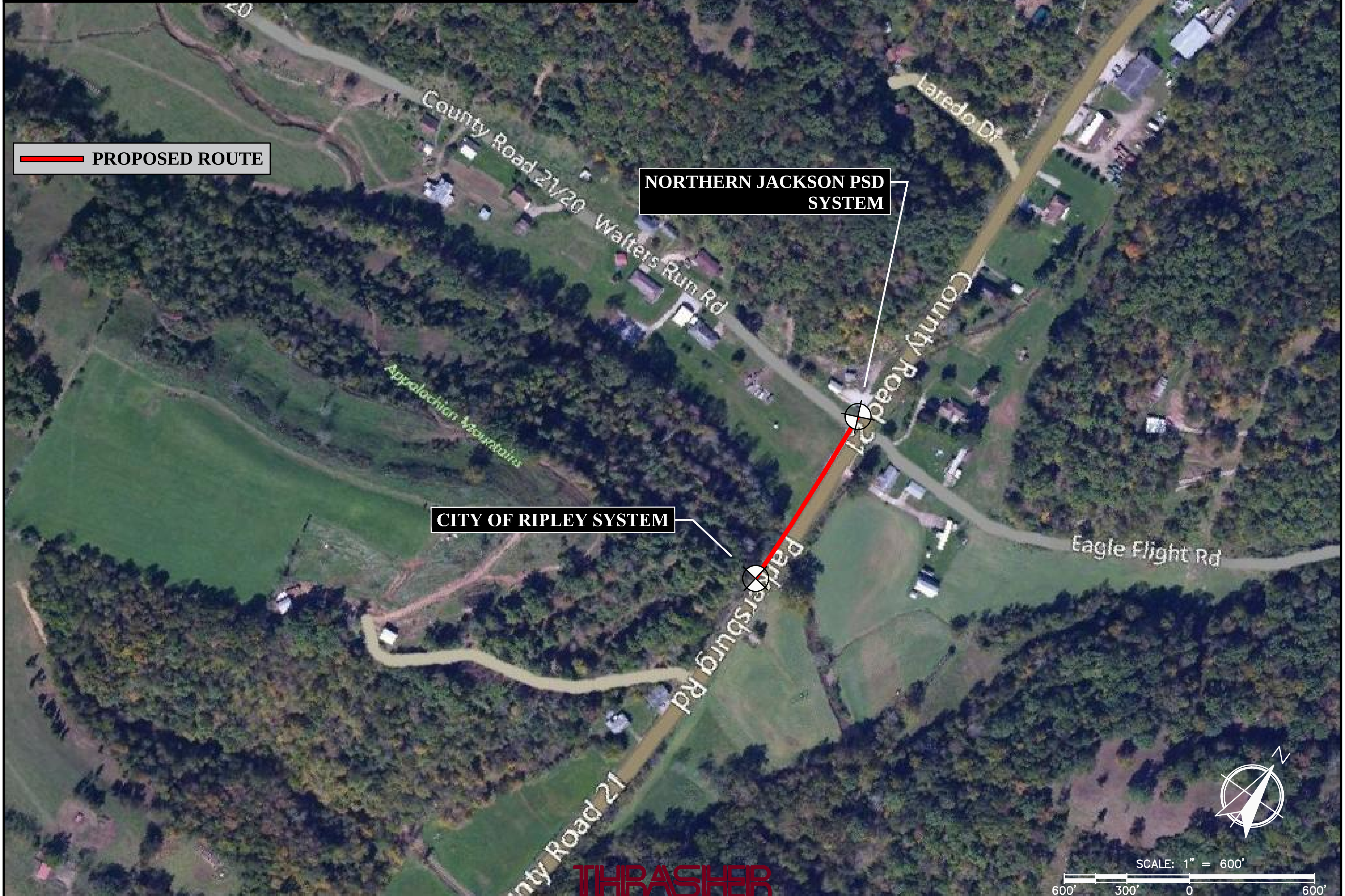

PROPOSED INTAKE ROUTE
CITY OF RIPLEY
PWSID: 3301811
PROPOSED ROUTE
PROPOSED BACKUP INTAKE SITE
Mill Creek
Mill Creek
Mill Creek
Sycamore Creek
EXISTING TREATMENT FACILITY
N
SCALE: 1" = 1000'
1000' 500' 0 1000'
THRASHER

INTERCONNECTION COST ESTIMATE

DESCRIPTION	QUANTITY		UNIT PRICE		TOTAL PRICE
Mobilization/Demobilization	1	LS	$7,500.00	/LS	$7,500.00
Video Taping of Project Area	1	LS	$1,200.00	/LS	$1,200.00
Erosion and Sediment Control Measures	1	LS	$1,000.00	/LS	$1,000.00
6" DR-18 C-900 PVC Water Line	400	LF	$30.00	/LF	$12,000.00
6" Ductile Iron Pipe	50	LF	$60.00	/LF	$3,000.00
6" M.JT. Gate Valve w/ Box and Lid	2	EA	$1,880.00	EA	$3,760.00
4" Master Meter	1	EA	$10,000.00	EA	$10,000.00
Tie-Into Existing 6" Water Line, Complete	2	EA	$3,000.00	EA	$6,000.00
Northern Jackson PSD Initial Tap Fee	1	EA	$100.00	EA	$100.00
Gravel Street/Driveway Repair	150	LF	$10.00	/LF	$1,500.00
Reclamation of Disturbed Area	500	LF	$2.00	/LF	$1,000.00
Stream Bank Slope Protection	50	LF	$70.00	/LF	$3,500.00
Construction Sub-Total					$50,560.00
Construction Contingency @ 10%, +/-					$5,056.00
Construction Total					**$55,616.00**
Additional Fees					$13,904.00
Total Cost					**$69,520.00**

These values are based on preliminary evaluation and are not design cost estimates. Actual construction cost will vary. Additional fees predicted to be 25% of overall construction cost. The fees include legal, engineering, and accounting requirements.

PROPOSED INTERCONNECTION ROUTE
CITY OF RIPLEY
PWSID: 3301811



WATER TANK COST				
Gallons	**Tank Dimension**	**Model Number**	**Cost**	**Cost Per Gallon**
105,000	25.17'dia. x 28.43' sidewall height	AQUASTORE tank Model 25 28 - SSWT	$ 155,000	$ 1.48
248,000	30.77'dia. x 37.59' sidewall height	AQUASTORE tank Model 31 38 - SSWT	$ 230,000	$ 0.93
297,000	33.56'dia. x 37.59' sidewall height	AQUASTORE tank Model 39 33 - SSWT	$ 285,000	$ 0.96
438,000	47.55'dia. x 33.01' sidewall height	AQUASTORE tank Model 48 33 - SSWT	$ 345,000	$ 0.79
491,000	50.35'dia. x 33.01' sidewall height	AQUASTORE tank Model 50 33 - SSWT	$ 365,000	$ 0.74
607,000	55.95'dia. x 33.01' sidewall height	AQUASTORE tank Model 56 33 - SSWT	$ 425,000	$ 0.70
691,000	64.34'dia. x 28.43' sidewall height	AQUASTORE tank Model 64 28 - SSWT	$ 470,000	$ 0.68
816,000	69.93'dia. x 28.43' sidewall height	AQUASTORE tank Model 70 28 - SSWT	$ 510,000	$ 0.63
948,000	69.93'dia. x 33.01' sidewall height	AQUASTORE tank Model 70 33 - SSWT	$ 555,000	$ 0.59
1,025,000	72.73'dia. x 33.01' sidewall height	AQUASTORE tank Model 73 33 - SSWT	$ 595,000	$ 0.58
1,260,000	72.73'dia. x 33.01' sidewall height	AQUASTORE tank Model 73 33 - SSWT	$ 695,000	$ 0.55
1,453,000	97.91'dia. x 28.43' sidewall height	AQUASTORE tank Model 98 28- SSWT	$ 790,000	$ 0.54
1,601,000	97.91'dia. x 28.43' sidewall height	AQUASTORE tank Model 98 28- SSWT	$ 870,000	$ 0.54
1,789,000	103.5'dia. x 28.43' sidewall height	AQUASTORE tank Model 104 28- SSWT	$ 945,000	$ 0.53
2,026,000	120.29'dia. x 23.84' sidewall height	AQUASTORE tank Model 120 24- SSWT	$ 1,052,000	$ 0.52

COSTS OF ADDITIONAL ITEMS AND ASSUMPTIONS	
Access Road and Site Preparation	$ 75,000
Yard Piping and Vault	13%
Bonds/Permits	$ 20,000
Fencings	$ 35,000
Engineering/Accounting/Legal Fees	25%
Level-Sensing and Measuring Equipment	$ 10,000
Rock Excavation of Foundation (if encountered)	5%

ASSUMPTIONS: *Cost are based on a standpipe glass lined tank. Price includes access roads and site preparation (assuming land would need to be purchased for the tank site), telemetry, excavation in rock (% of Tank Cost), valve vault and piping (% of tank Cost), fencing. Price does not include additional waterline from site to water system. Fees for engineering, legal and accounting services will be 25% of the overall project cost.*

TOTAL COST OF WATER STORAGE				
Gallons	**Tank Dimension**	**Model Number**	**Cost**	**Cost Per Gallon**
105,000	25.17'dia. x 28.43' sidewall height	AQUASTORE tank Model 25 28 - SSWT	$ 403,625	$ 3.84
248,000	30.77'dia. x 37.59' sidewall height	AQUASTORE tank Model 31 38 - SSWT	$ 514,250	$ 2.07
297,000	33.56'dia. x 37.59' sidewall height	AQUASTORE tank Model 39 33 - SSWT	$ 595,375	$ 2.00
438,000	47.55'dia. x 33.01' sidewall height	AQUASTORE tank Model 48 33 - SSWT	$ 683,875	$ 1.56
491,000	50.35'dia. x 33.01' sidewall height	AQUASTORE tank Model 50 33 - SSWT	$ 713,375	$ 1.45
607,000	55.95'dia. x 33.01' sidewall height	AQUASTORE tank Model 56 33 - SSWT	$ 801,875	$ 1.32
691,000	64.34'dia. x 28.43' sidewall height	AQUASTORE tank Model 64 28 - SSWT	$ 868,250	$ 1.26
816,000	69.93'dia. x 28.43' sidewall height	AQUASTORE tank Model 70 28 - SSWT	$ 927,250	$ 1.14
948,000	69.93'dia. x 33.01' sidewall height	AQUASTORE tank Model 70 33 - SSWT	$ 993,625	$ 1.05
1,025,000	72.73'dia. x 33.01' sidewall height	AQUASTORE tank Model 73 33 - SSWT	$ 1,052,625	$ 1.03
1,260,000	72.73'dia. x 33.01' sidewall height	AQUASTORE tank Model 73 33 - SSWT	$ 1,200,125	$ 0.95
1,453,000	97.91'dia. x 28.43' sidewall height	AQUASTORE tank Model 98 28- SSWT	$ 1,340,250	$ 0.92
1,601,000	97.91'dia. x 28.43' sidewall height	AQUASTORE tank Model 98 28- SSWT	$ 1,458,250	$ 0.91
1,789,000	103.5'dia. x 28.43' sidewall height	AQUASTORE tank Model 104 28- SSWT	$ 1,568,875	$ 0.88
2,026,000	120.29'dia. x 23.84' sidewall height	AQUASTORE tank Model 120 24- SSWT	$ 1,726,700	$ 0.85