PRELIMINARY ENGINEERING REPORT
FOR THE
UPPER VILLAGE WATER SYSTEM

TOWN OF NEW GLOUCESTER

JULY 2012

WRIGHT-PIERCE
Engineering a Better Environment

NEW GLOUCESTER WATER DISTRICT
NEW GLOUCESTER, MAINE

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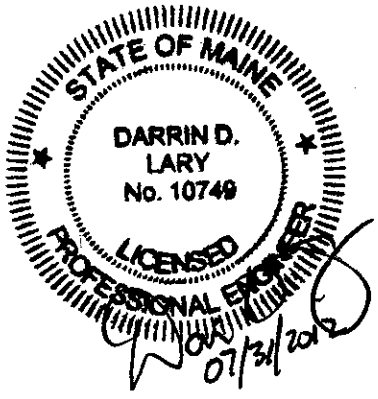
JULY 2012



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SECTION 1

PROJECT PLANNING AREA

1.1 LOCATION

The town of New Gloucester is a community of approximately 5,500 people located on the northern border of Cumberland County. The Upper Village section of town is located in the northerly end of the town at the intersections of Route 100/4 and Route 231. Currently, the Upper Village is served by individual water supplies. The new facilities proposed for the Upper Village are illustrated on Figure 1-1.

1.2 ENVIRONMENTAL RESOURCES PRESENT

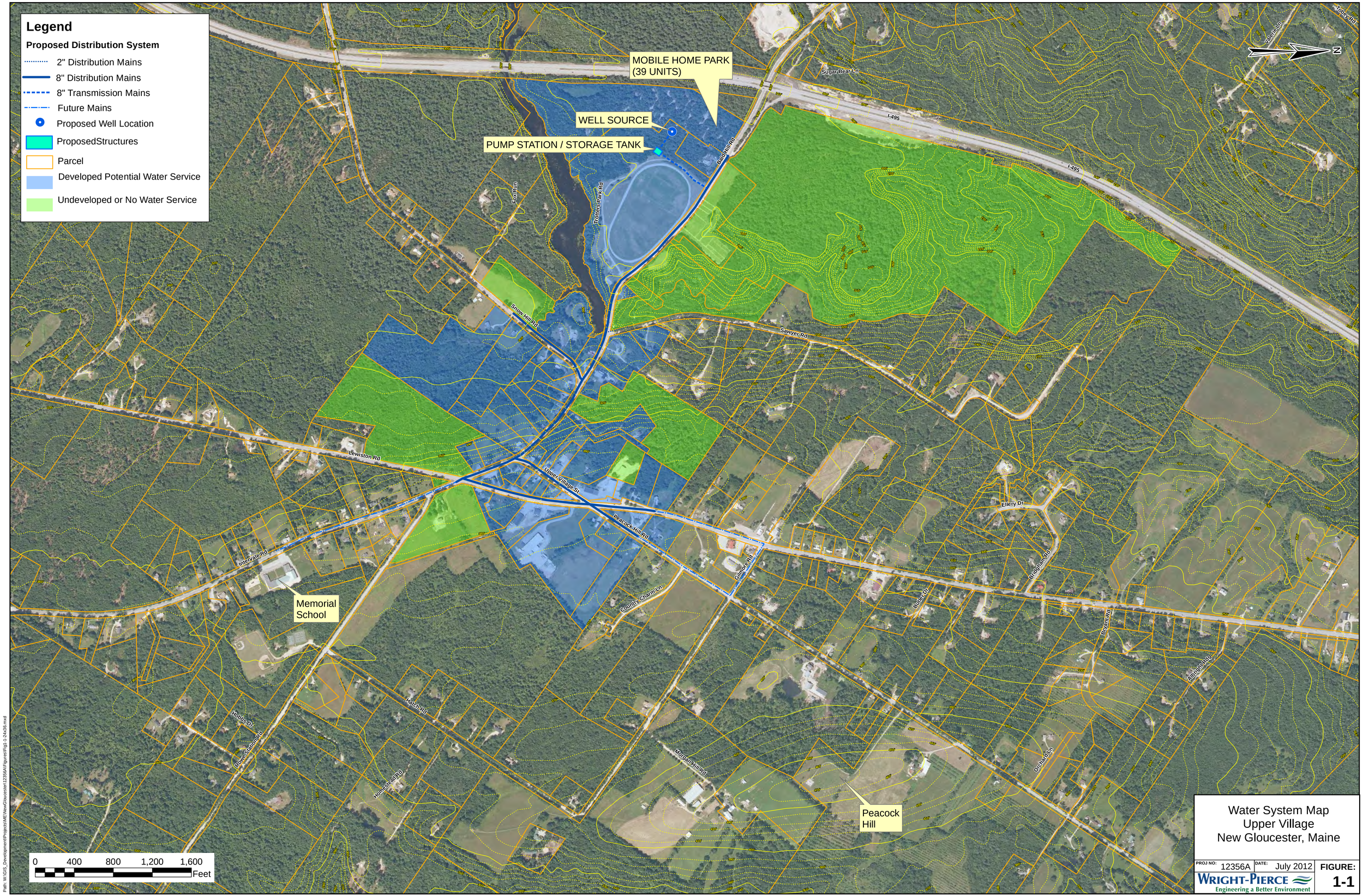
There are no important environmental resources that will be affected as part of the proposed project area. For additional information, refer to the *Environmental Report for the Upper Village Water System, dated July 2012*.

1.3 GROWTH AREAS AND POPULATION TRENDS

The town of New Gloucester has a population of approximately 5,500 people. The Maine State Planning Office (MSPO) projects the population for New Gloucester to increase to about 6,400 by 2023. This equates to a growth rate of approximately 16% over the planning period. However, the Upper Village section of Town is the historical business and commercial area of town and has been designated as the portion of town where denser development is encouraged. Based on this strategic planning, the potential growth in this area could exceed 35-50% over the planning period. The water system will be designed with sufficient capacity to provide service for the anticipated average daily flow of 30 gpm with the initial build-out and reserve capacity to deliver up to 60 gpm average daily flow. This reserve capacity is anticipated being sufficient to deliver water to the system over the planning period.

The area delineated to be served under this phase of the project will allow up to 87 existing users to be served by the new municipal water system. These users consist of 78 residential users (including the 39 unit mobile home park), 8 commercial establishments, and one governmental facility.

To ensure affordable rates and the sustainability of the capital investment, the Town of New Gloucester will pass an ordinance that requires all users located on the extents of the water system to hook-up to the system within a reasonable time period.



Water System Map
Upper Village
New Gloucester, Maine

PROJ NO: 12356A | DATE: July 2012 | FIGURE: 1-1

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SECTION 2

EXISTING INFRASTRUCTURE

2.1 WATER INFRASTRUCTURE

Currently, there is no existing water distribution infrastructure in the Upper Village area of New Gloucester. Residences and businesses are served by individual ground water supplies; both surficial dug wells and drilled bedrock wells.

The town and the Maine DEP have been working with residents and businesses in the Upper Village for more than 20 years to address petroleum and salt contamination of the groundwater supplies. For systems with significant contamination, individual filter units have been installed to address both the petroleum and salt contamination. These individual filters are difficult to adequately maintain, costly in maintenance and power usage, and not a viable long term solution to providing reliable clean and safe drinking water to the residents of the Upper Village. In addition, the point-of-use filters do not provide any remediation to the water in the wells, and the elevated salt concentration significantly reduces the lifespan of the submersible well pumps, sometimes requiring costly replacement on an annual basis.

To facilitate the growth of a centralized water system in the Upper Village, the New Gloucester Water District was created as an operating entity to own and manage the proposed water system in the Upper Village. The District, with Trustees elected by the residents of the District, will have authority over the water system pursuant with Maine PUC regulations.

SECTION 3

NEED FOR PROJECT

3.1 HEALTH, SANITATION AND SECURITY

The purpose of the project is to provide clean, reliable water to the residents and businesses in the Upper Village section of the town of New Gloucester. Sampling in the Upper Village has detected the presence of petroleum in existing water supplies. The source of contamination is assumed to be historic underground fuel tanks at service stations and automobile repair shops in the Upper Village. In addition, the presence of sodium and/or chloride in water supplies has been detected. The source of sodium and chloride is not conclusive, but likely the historical uncovered storage of salt on the town of New Gloucester Public Works facility property, formerly a MDOT maintenance facility.

To alleviate the issues, the town and Maine Department of Environmental Protection (Maine DEP) provide individual household filtering systems as a temporary solution. The filtering systems are both costly to maintain and prone to malfunction. The contaminated water supplies also contribute to a lack of investment in the Upper Village since there is no assurance of the availability of clean drinking water. This contributes to an inability to complete real estate transactions or acquire financing for development for properties in this area.

As a result, the town and Maine DEP intend to install a public drinking water supply in order to provide clean, safe drinking water to the Upper Village.

Multiple wells within the proposed water system area are contaminated with petroleum related compounds including MTBE, Benzene, Toluene, and Xylenes. Multiple properties exceed the Safe Drinking Water Act Maximum Contaminant Levels (MCL's) for Benzene and Ethyl benzene. In one case, a two-family rental house measures Benzene levels at least 10 times the MCL. As Benzene is a known carcinogen, these exceedances of public health standards are alarming.

The salt contaminated wells have sodium levels exceeding 300-400 mg/l and chloride levels exceeding 1,500-2,000 mg/l, far in excess of the Secondary MCL of 250 mg/l for chloride. High salt levels can be problematic for residents on sodium restricted diets. Figure 3-1 summarizes analytical testing for contaminates performed between 2006 and 2010.

In all, more than 20 properties have been identified with either petroleum products or salt contaminates. Historical values for multiple sampling events are detailed on the attached Figure 3-1. Figure 3-2 delineates the well locations and the petroleum and salt contaminated wells. According to MEDEP 10 wells are contaminated or at significant risk of contamination from Benzene levels that exceed drinking water standards. The Water District considers 9 wells to be contaminated or at risk from sodium and chloride levels that exceed drinking water standards. Figure 3-2 details the existing well locations and relative contamination levels.

The Median Household Income of the properties served by the proposed water system is $28,840. The income survey results have been certified by Rural Development.

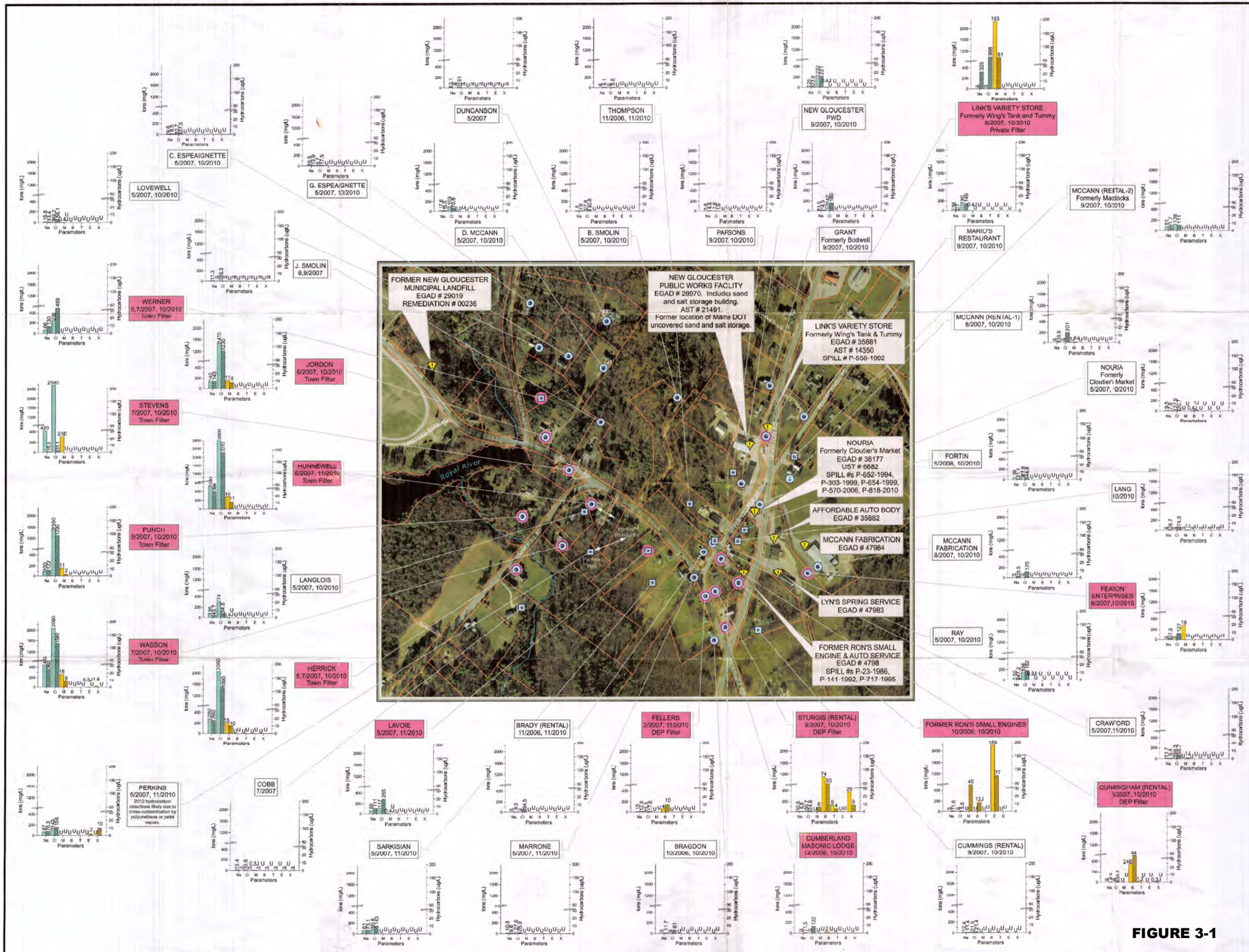


FIGURE 3-1

DEPARTMENT OF ENVIRONMENTAL PROTECTION STATE OF MAINE

COMPARISON of ANALYTICAL RESULTS 2006-2008 and 2010

UPPER VILLAGE, NEW GLOUCESTER

N

0 300 600 Feet

1 inch = 300 feet

MAP LEGEND

- MAINE DEP SITE LOCATION
- DRILLED WELL
- DUG WELL
- WELL POINT
- IMPACTED WELL

GRAPH LEGEND

- Ion Concentration 2006-2008 (mg/L)
- Ion Concentration 2010 (mg/L)
- Petroleum Hydrocarbon Concentration 2006-2008 (ug/L)
- Petroleum Hydrocarbon Concentration 2010 (ug/L)

SAMPLE LOCATION
SAMPLE DATE(S)

IMPACTED WELL — Contaminated or At Risk of Contamination by petroleum hydrocarbons or road salt.

NOTES:

Maine DEP Statewide Drinking Water Remediation Guidelines for Petroleum Related Compounds

MTBE (M): 35 ug/L
Benzene (B): 4 ug/L
Toluene (T): 600 ug/L
Ethylbenzene (E): 30 ug/L
Xylenes (X): 1,000 ug/L

Maine DEP Action Level Concentrations in Drinking Water Supply Wells

MTBE (M): 30 ug/L
Benzene (B): 3 ug/L
Toluene (T): 400 ug/L
Ethylbenzene (E): 20 ug/L
Xylenes (X): 800 ug/L

Secondary Drinking Water Standards

Sodium (Na): 100 mg/L or 20mg/L for individuals on a low-sodium diet.
Chloride (Cl): 250 mg/L

Other Abbreviations

E: Compound Exceeded Upper Level of Calibration Range
J: Associated Value is Estimated
nt: Not Tested
U: Not Detected Above the Associated Quantitation Limit

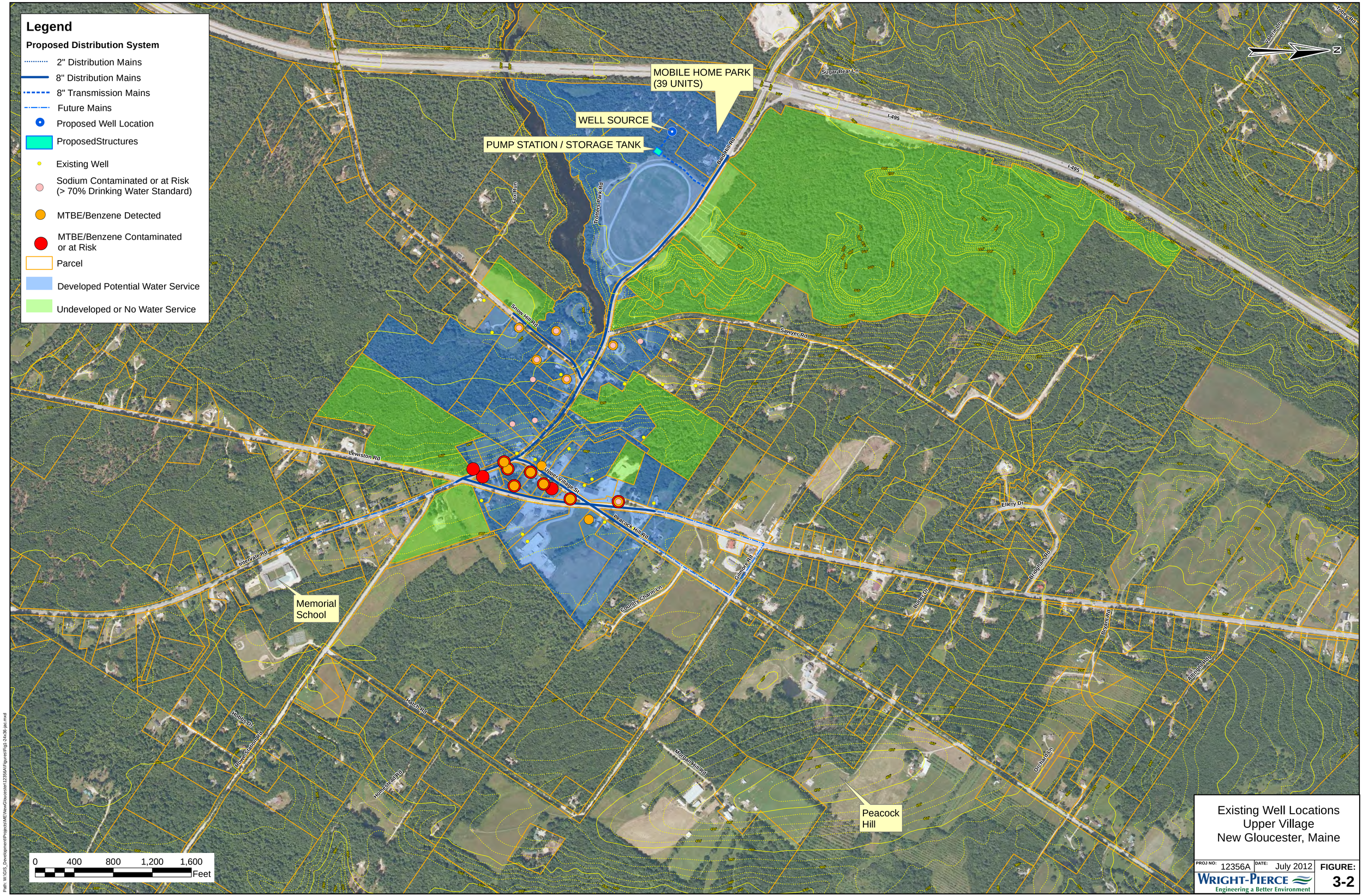
Supply wells were located by Maine DEP personnel using a Trimble GeoXH Global Positioning System with sub-meter accuracy.

2006 Sodium and Chloride Concentrations for the Jordon, Hunnewell, Punch, Stevens, and Wasson supply wells were provided by the Town of New Gloucester. Supply wells were first sampled by the Maine DEP for Sodium, Chloride and Petroleum Hydrocarbons between October 2006 and May 2008. The second round of sampling was completed in October and November 2010.

Maine DEP Site Locations represent sites in the Environmental & Geographic Analysis Database (EGAD). Response Division Spill Locations, Remediation Division sites, or registered aboveground or underground storage tanks.

The Background Image is the Cumberland_Co_09 layer from the Web Mapping Service http://geolibportal.maine.gov/wms/mapserv.exe?map=c:/wms/orthos.map&; Service Name: Maine_orthos. Hydrography and parcels are from the MEGIS data layers.

Prepared by Mark Woodruff
Maine Certified Geologist, GE503
Maine DEP, BRWM
Division of Technical Services
December 2010
Revised April 2011



Existing Well Locations
Upper Village
New Gloucester, Maine

PROJ NO: 12356A | DATE: July 2012 | FIGURE: 3-2

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3.2 SYSTEM OPERATION AND MAINTENANCE

The proposed water system will result in a centralized municipal grade water supply, treatment, distribution and storage system with operation and maintenance at facilities owned and operated by the District or located within the public right-of-way, and not requiring frequent access to private properties as is currently required for the individual filter units.

3.3 GROWTH

The proposed project is designed to provide reliable, high quality drinking water to current and future residents, businesses and town facilities in the vicinity of Upper Village. The Town inventory of land uses and water demand tables were consulted in the preliminary design to estimate the expected future demand to the area. In addition, improved fire protection will result with the addition of a new storage tank, high flow pump, and hydrants throughout the system.

The system is delineated to include connection to the 39 unit mobile home community directly adjacent to the proposed well site, thus eliminating the small private community water system and providing water to the residents via the municipal water system.

The system will also be designed with the expectation that extensions can be added in the future to connect a local elementary school with water quality concerns and extend the mains radially beyond the current planned installation to provide water to future users as required.

SECTION 4

ALTERNATIVES CONSIDERED

4.1 ALTERNATIVES

Alternatives were considered and evaluated for the proposed project and are described below along with the No Action Alternative. For each alternative, preliminary construction, total project and O&M costs were developed. Total project costs include engineering (preliminary and final design, bidding, construction administration, inspection, and post construction services), construction, administration (legal, bonding, interim financing, permit fees and miscellaneous administration fees) and contingency costs. Contingency costs are estimated at approximately 10% of the sum of the total costs.

4.1.1 Alternative 1 - New Gloucester Source - Pumped Storage Fire Protection

Extensive investigations and testing was completed by Drumlin Environmental, LLC to determine the best area to develop the well source, which was found to be in the deep aquifer lying beneath the Town's Fairgrounds property. It was also determined that the water from this aquifer will only need minimal treatment to remove radon and that it can produce more than 60 gpm over the long term - enough to allow for significant growth in the future.

A wood-framed booster pump station building, measuring approximately 24' x 24', is anticipated in order to accommodate all the required pumps, aeration system and equipment. The exact size and layout of the pump station will be determined during the final design stage. A detailed description of the proposed pump station building is included in, "Upper Village Water System Preliminary Basis of Design Memorandum", Dated December 2011 attached in Appendix A.

The transmission and distribution piping consists of approximately 9,800 linear feet of new 8-inch and 2-inch diameter pipe will be installed on the following streets:

- Bald Hill Road
- Snow Hill Road
- Sawyer Road (2-inch)
- Lewiston Road
- Intervale Road
- Upper Village Street
- Peacock Hill Road

Ductile iron pipe was selected as the most resistant material to potential petroleum contaminated soils. Petroleum resistant gaskets will be specified for the pipelines passing through any contaminated areas or areas potentially at-risk for contamination. Both PVC pressure pipe and HDPE pressure pipe were preliminarily reviewed for applicability for this project, however, concerns with the potential for permeation of the petroleum based contaminants through the pipe wall of the plastic pipes, the possibility of the solvents weakening the pipe walls, and the potential need for more extensive bedding and backfill requirements preclude the recommendation of PVC or HDPE pipe for the new distribution system in the Upper Village. A 2002 report prepared for EPA by the AWWA (included as Appendix B) indicated that 98% of permeation incidents were linked to plastic pipes and that no incidents of permeation were reported for metal pipes. Petroleum range contaminants, similar to those existing in New Gloucester accounted for 89% of the permeation incidents. We believe this constitutes a risk factor for the distribution piping that is designed to be a long-term asset and is expected to be in the ground for 100 years. A more detailed evaluation can be performed during final design when more information is available regarding the potential contamination concentrations in the soils where the distribution piping is anticipated and additional research becomes available from AWWARF regarding installation of plastic pipes in petroleum contaminated soils.

For areas with potential of elevated salt, the pipeline will be polyethylene encased for added corrosion protection. New copper water services will be installed to residential and business buildings and new hydrants included for fire protection and flushing and maintenance of the distribution system.

As a potential cost saving alternative to the construction of a more typical gravity water storage tank, the alternative of providing limited fire protection utilizing an increased size clearwell

(buried cast-in-place concrete tank at the pump station) and a high capacity pump to provide high flow to the system in the event of a fire was reviewed. The intent would be to add a gravity storage tank to the system at a future time as the water system grows and the demand and fire protection needs increase in the future.

We reviewed three options for providing pumped fire flow; 500 gpm, 750 gpm, and 1,000 gpm, all for 2 hour duration. The cost differentials are detailed on Table 4-2.

The majority of the structures within the Upper Village distribution system are 1 and 2 family dwellings not exceeding 2 stories in height. The Insurance Services Office (ISO) defines needed fire flow for this type of structure as follows:

TABLE 4-1
ISO FIRE FLOW REQUIREMENTS
1-2 FAMILY DWELLINGS < 2 STORIES TALL

Distance between Buildings	Needed Fire Flow (gpm)
Over 100'	500
31-100'	750
11-30'	1000
10' or less	1500

Based on the size and average spacing of the existing structures, the District is anticipating the need for between 500-750 gpm for 2 hours to meet the ISO standards.

To include a larger clearwell tank and a high flow pump to provide pumped fire storage the following additional elements are required:

- Additional concrete, excavation and backfill for the larger buried tanks.
- Large high flow pump, 50-75 hp.
- Larger emergency generator to power the large pump. We are assuming the large pump would need to be powered by the generator and not by line power as 3-phase power is not available onsite. We have priced two propane generators in parallel to power the pump as this is the most cost effective method to power the large pump. Pump is anticipated to be a municipal grade high flow vertical turbine pump and not a fire-rated pump due to cost concerns.
- Possibly larger building to house additional pump and equipment.

TABLE 4-2
UPPER VILLAGE WATER SYSTEM
Preliminary Alternatives Cost Estimate - Updated 07-24-2012

Scenario	Basic Area Without Fire Protection			Pump Station w/20x40 Clearwell (500 gpm for 2 hrs)			Pump Station w/20x60 Clearwell (750 gpm for 2 hrs)			Pump Station w/20x80 Clearwell (1000 gpm for 2 hrs)			Basic Area w/Tank Option A			Basic Area w/Tank Option B			Basic Area w/Tank Option C		
	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$
	4-inch			8-inch			8-inch			8-inch			8-inch			8-inch			8-inch		
Distribution System	Main			Main			Main			Main			Main			Main			Main		
Road	Length			Length			Length			Length			Length			Length			Length		
Peacock St & Upper Village St	1500	$79	$118,500	1500	$94	$141,000	1500	$94	$141,000	1500	$94	$141,000	1500	$94	$141,000	1500	$94	$141,000	1500	$94	$141,000
Lewiston Rd, Rt 202/100	2000	$79	$158,000	2000	$94	$188,000	2000	$94	$188,000	2000	$94	$188,000	2000	$94	$188,000	2000	$94	$188,000	2000	$94	$188,000
Bald Hill Rd	4700	$79	$371,300	4700	$94	$441,800	4700	$94	$441,800	4700	$94	$441,800	4700	$94	$441,800	4700	$94	$441,800	4700	$94	$441,800
Snow Hill Rd	1000	$79	$79,000	1000	$94	$94,000	1000	$94	$94,000	1000	$94	$94,000	1000	$94	$94,000	1000	$94	$94,000	1000	$94	$94,000
Sawyer Rd	0	$79	$0	0	$94	$0	0	$94	$0	0	$94	$0	0	$94	$0	0	$94	$0	0	$94	$0
River Crossing	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000
Distribution Subtotal:			**$776,800**			**$914,800**			**$914,800**			**$914,800**			**$914,800**			**$914,800**			**$914,800**
Water Service Connections	Pipe			Pipe			Pipe			Pipe			Pipe			Pipe			Pipe		
Service Piping	Length			Length			Length			Length			Length			Length			Length		
2" HDPE in Road ROW	650	$60	$39,000	650	$60	$39,000	650	$60	$39,000	650	$60	$39,000	650	$60	$39,000	650	$60	$39,000	650	$60	$39,000
2" HDPE on Private Property	250	$60	$15,000	250	$60	$15,000	250	$60	$15,000	250	$60	$15,000	250	$60	$15,000	250	$60	$15,000	250	$60	$15,000
2" Corporation	1	$200	$200	1	$200	$200	1	$200	$200	1	$200	$200	1	$200	$200	1	$200	$200	1	$200	$200
2" Curb Stop W/ Box	1	$400	$400	1	$400	$400	1	$400	$400	1	$400	$400	1	$400	$400	1	$400	$400	1	$400	$400
3/4" Copper Pipe in Road ROW	1500	$50	$75,000	1500	$50	$75,000	1500	$50	$75,000	1500	$50	$75,000	1500	$50	$75,000	1500	$50	$75,000	1500	$50	$75,000
3/4" Copper Pipe on Private Property	4200	$50	$210,000	4200	$50	$210,000	4200	$50	$210,000	4200	$50	$210,000	4200	$50	$210,000	4200	$50	$210,000	4200	$50	$210,000
3/4" Corporation	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000
3/4" Curb Stop W/ Box	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000
Internal Plumbing Connection w/Meter	19	$3,000	$57,000	19	$3,000	$57,000	19	$3,000	$57,000	19	$3,000	$57,000	19	$3,000	$57,000	19	$3,000	$57,000	19	$3,000	$57,000
Meter only installation	29	$500	$14,500	29	$500	$14,500	29	$500	$14,500	29	$500	$14,500	29	$500	$14,500	29	$500	$14,500	29	$500	$14,500
Water Services Subtotal:			**$426,100**			**$426,100**			**$426,100**			**$426,100**			**$426,100**			**$426,100**			**$426,100**
Well Source/Pump Station																					
Pump Station																					
Architectural																					
Clearwell Under Building Only	1	$176,000	$176,000										1	$176,000	$176,000	1	$176,000	$176,000	1	$176,000	$176,000
Oversized Clearwell for Fire Storage				1	$210,000	$210,000	1	$323,000	$323,000	$1	$411,000	$411,000									
Process Equipment																					
Service Pump-5hp (30gpm)	2	$8,000	$16,000	2	$8,000	$16,000	2	$8,000	$16,000	2	$8,000	$16,000	2	$8,000	$16,000	2	$8,000	$16,000	2	$8,000	$16,000
High Flow Pump-50-75hp (500-1000gpm)				1	$30,000	$30,000	1	$35,000	$35,000	1	$40,000	$40,000									
Aeration System	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000
Chemical Feed-Disinfection	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000
Electrical/VFD/Instrumentation	1	$20,000	$20,000	1	$40,000	$40,000	1	$40,000	$40,000	1	$40,000	$40,000	1	$20,000	$20,000	1	$20,000	$20,000	1	$20,000	$20,000
Emergency Power Generator	1	$20,000	$20,000	1	$70,000	$70,000	1	$70,000	$70,000	1	$70,000	$70,000	1	$20,000	$20,000	1	$20,000	$20,000	1	$20,000	$20,000
Misc. Equipment	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000
Well																					
Well Construction	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000
Pitless Adapter	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000
Well Pump & Drop Pipe	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000
Discharge Pipe to Pump Station	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000
Additional Source Investigation	1	$35,000	$35,000	1	$35,000	$35,000	1	$35,000	$35,000	1	$35,000	$35,000	1	$35,000	$35,000	1	$35,000	$35,000	1	$35,000	$35,000
Well Source/Pump Station Subtotal:			**$376,000**			**$510,000**			**$628,000**			**$721,000**			**$376,000**			**$376,000**			**$376,000**
Gravity Tank													12-inch			12-inch			8-inch		
Additional Main													4225	$120	$507,000	3300	$120	$396,000	600	$99	$59,400
Tank Cost													1	$190,000	$190,000	1	$220,000	$220,000	1	$370,000	$370,000
Site Cost													1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000
Tank Mixer													1	$15,000	$15,000	1	$15,000	$15,000	1	$20,000	$20,000
Tank Subtotal:						**$0**			**$0**			**$0**			**$762,000**			**$681,000**			**$499,400**
Other Costs:																					
Legal	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000
Interim Financing	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000
Admin	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000
Engineering	1	$140,000	$140,000	1	$140,000	$140,000	1	$140,000	$140,000	1	$140,000	$140,000	1	$150,000	$150,000	1	$150,000	$150,000	1	$150,000	$150,000
Construction Inspection - full time	1	$80,000	$80,000	1	$80,000	$80,000	1	$80,000	$80,000	1	$80,000	$80,000	1	$80,000	$80,000	1	$80,000	$80,000	1	$80,000	$80,000
Permits (MDEP & MDOT)	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000
Other Subtotal:			**$290,000**			**$290,000**			**$290,000**			**$290,000**			**$300,000**			**$300,000**			**$300,000**
Subtotal Estimate:			$1,868,900			$2,140,900			$2,258,900			$2,351,900			$2,778,900			$2,697,900			$2,516,300
Contingency 10%			*$186,890.0*			*$214,090.0*			*$225,890.0*			*$235,190.0*			*$277,890.0*			*$269,790.0*			*$251,630.0*
Total Estimate			**$2,055,790**			**$2,354,990**			**$2,484,790**			**$2,587,090**			**$3,056,790**			**$2,967,690**			**$2,767,930**
Estimated Number of Users - 87																					
Total Estimated Cost Per User			**$23,630**			**$27,069**			**$28,561**			**$29,737**			**$35,136**			**$34,111**			**$31,815**

It should be noted that a high flow pump system is not quite as reliable as a gravity tank for providing fire flows. The pumped systems, while generally reliable and frequently used, do have several avenues for failure including the pump and generator, where the gravity tank will reliably provide water to the system as long as there is water in the tank.

4.1.2 Alternative 2 - New Gloucester Source - Gravity Storage Tank

This alternative consists of the construction of a new groundwater source (gravel/bedrock well) and treatment plant / pump station, distribution system, and a gravity water storage tank in the Upper Village area of the Town.

To best assess the alternatives for installing a gravity tank to provide a stable hydraulic gradeline for the project, locations within and adjacent to the proposed distribution area were reviewed for viability for the construction of a water storage tank. Based on discussions and guidance provided by the Town, three possible storage tank site locations were reviewed for providing gravity storage to the distribution system as follows:

Option A - This option considers the tank located at the top of Peacock Hill adjacent to the existing cell phone tower. The ground elevation at this location is approximately EL. 475' so the tank would need to be about 20-feet tall to achieve the required storage. Advantages of this option are that the tank would be the smallest volume because the entire tank volume is available for fire storage, it is the least expensive tank to construct, and the lower tank height will be favorable to neighbors due to the fact that it will be the least conspicuous. Disadvantages include the site being on private property and will require an easement or purchase of land, this location requires the longest transmission main, it is a remote location and is more prone to vandalism, and it is the highest cost option.

Option B - This option considers a tank near the high point on Peacock Hill Road. The ground elevation is 420-feet so the tank would be about 65-feet tall to achieve the required storage. Advantages to Option B are that the shorter transmission main will be required than in Option A and that there are no issues or interference with the cellular tower. Disadvantages are that the

site is on private property and will require and easement or purchase of land, the length of the transmission main to the peak of Peacock Hill Road is still significant, and the tank is taller and closer to the road and would therefore be more visible.

Option C - This option considers construction of the tank in the middle of the Upper Village behind the Town Garage on Municipally owned land. The ground elevation at this location is EL. 390-feet so the tank would be about 90 to 100-feet tall to achieve the required gradeline. Advantages to Option C are that the length of the transmission main is the shortest of all options and the property is owned by the Town and will not require an easement or purchase of land. Disadvantages include this location will be visible as it is in the center of the village, a larger tank is required in order to provide fire flow and a minimum pressure of 20 psi at this location (lowest elevation), the tank will require mixing due to its size and storage volume, and the larger volume may contribute to water quality concerns due to low tank turnover.

These elevations listed above would equate to system pressures of approximately 40 psi and 45 psi, respectively, in the central section (highest elevation of all options) of the village area. This provides a good working pressure for all the properties in the distribution area as well as the required 20 psi residual pressure under fire flow conditions.

Several materials are available for the construction of the new water storage tank. Options reviewed include above-grade or buried cast-in-place concrete, above-grade or buried pre-cast wire-wound concrete tanks, or welded steel tanks and glass-fused-to-steel bolted tanks.

There are no long term environmental impacts associated with this alternative.

Detailed cost estimates for all the proposed Alternatives are included in Table 4-1.

4.1.3 Alternative 3 – No Fire Protection

Installation of a water system sized to provide required domestic flows only was reviewed. Based on results of the hydraulic modeling, a minimum of 4-inch water mains would be required

to accommodate the peak hourly demand in the system. Installation of 4-inch mains would preclude the installation of hydrants per MEDWP standards. Not installing the ability to combat fires in the Upper Village still incurs a capital cost to construct the water system of over $2,000,000 and does not offer the benefits of fire protection, reduced insurance rates for residents, and additional dense growth in the village area. The differential cost between installing 4-inch mains and 8-inch mains is likely in the $150,000 range, roughly 5% of the overall project cost to provide a system that does not lend itself to expansion based on future flows.

4.1.4 Alternative 4 - Auburn Water District Source

This alternative consists of supplying the Upper Village water system through a connection to the Auburn Water District (AWD). The AWD draws from Lake Auburn, which supplies its customers throughout its service territory.

Currently, the AWD distribution system extends south on Route 100/202 to the vicinity of Kittyhawk Avenue in Auburn. In order to provide water to the Upper Village, a transmission main would need to be extended across the railroad and south along Route 100/202 to the Auburn border with New Gloucester. A booster station would be constructed in this area and the transmission main would be extended along Route 100/202 in New Gloucester and connected to the Upper Village water system at Gilmore Road.

The long water main coupled with the currently unfiltered supply from AWD may contribute to water quality and disinfection residual concerns, especially for systems with minimal daily usage. Similar projects have required the installation of a water bleeder at the end of the distribution system to reduce the age of the water in the system and improve water quality.

There are no long term environmental impacts associated with this alternative. The estimated cost to construct the water system improvements is approximately $4,800,000.

Refer to Table 4-3 for a breakdown of the estimated project costs for Alternative 4.

TABLE 4-3
ALTERNATIVE 4 - AUBURN WATER DISTRICT SOURCE
PRELIMINARY CONSTRUCTION COST

Item Description	Amount
Transmission Main (Auburn to Upper Village)	$1,608,000
Railroad Bridge Crossing	$150,000
Booster Station	$250,000
Distribution System	$1,377,000
Storage Tank	$735,000
Subtotal	**$4,120,000**
Technical Services	$150,000
Administration & Legal	$50,000
Permits	$30,000
Subtotal	**$4,350,000**
Contingency (10%)	**$435,000**
TOTAL	**$4,785,000**

4.1.5 No Action Alternative

The No Action Alternative would be to continue the use of the individual filtering systems provided by the Town and Maine DEP. The systems are costly to operate and maintain, are prone to malfunction, and are not a viable long term solution to the contamination issues. A result of this no action alternative is continued costs for the Town and Maine DEP to operate and maintain the individual treatment systems, required continued access to private residences to operate and maintain the filters, long-term continued unsatisfactory water quality and depressed property values, and lack of development due to lack of sustainable water supply to the Upper Village. This alternative does not provide a long-term sustainable solution to the petroleum and salt drinking water contamination issues that have troubled the Upper Village for over 20 years.

SECTION 5

SELECTION OF ALTERNATIVES

Based on the evaluation for each of the infrastructure alternatives, Alternative 1 - New Gloucester Source with Pumped Storage Fire Protection is the preferred option for the proposed project. The evaluation consisted of initial construction costs, total project costs (including technical services, legal, administration, and interim financing), and operation & maintenance cost on a life cycle basis. A description of the proposed project along with the estimated total project and projected O&M costs are presented in the following paragraphs:

5.1 PROPOSED PROJECT

The proposed project consists of construction of the New Gloucester Source Well, Pump Station/Treatment Plant/Buried Concrete Storage Tank, and Distribution system. This most cost effective option offers the Upper Village the best available water source, reliability, and significant available fire flow.

The source construction will include construction of a cased and screened borehole with a grouted sanitary seal per MEDWP construction standards, construction of the pump station / treatment facility, buried concrete water storage tank, pumps, chemical feed, aeration, and associated piping and equipment.

The distribution system will consist of approximately 9,800 linear feet of new 8-inch and 2-inch diameter water main installed on the following streets:

- Bald Hill Road
- Snow Hill Road
- Sawyer Road (2-inch)
- Lewiston Road
- Intervale Road
- Upper Village Street
- Peacock Hill Road

In addition, small diameter copper service pipe shall be installed to connect to existing service piping or water service connections. Water meters will be provided for each individual service. A large, bulk water meter is anticipated for the mobile home park.

Hydrants will be installed at appropriate intervals to provide access for fire protection as well as providing required locations to perform flushing and maintenance services on the water system.

For the proposed improvements, the total project cost is estimated to be approximately $2.4 million. Refer to Table 5-1 for a breakdown of the total project costs.

TABLE 5-1
UPPER VILLAGE WATER SYSTEM
ESTIMATED TOTAL PROJECT COSTS

Item Description	Amount
Construction Costs	
• Distribution System	$914,800
• Water Service Connections	$426,100
• Pump Station / Treatment Plant / Storage Tank	$411,000
• Well Source	$99,000
Subtotal	**$1,850,900**
Technical Services	$145,000
Construction Inspection	$80,000
Administration & Legal	$25,000
Interim Financing	$30,000
Permits	$10,000
Subtotal	**$290,000**
Contingencies (10%)	$214,090
Total Project Costs	**$2,354,990**

Notes:
1. Administration Costs include legal, bond council, accounting and material testing.
2. Permits are anticipated to be required for Maine DEP and MDOT submission.

5.2 PROJECTED OPERATION AND MAINTENANCE COSTS

With the proposed project, the O&M costs include labor costs associated with part-time operation of the system, hydrant maintenance and meter reading. It is anticipated that an experienced contract operations firm will be contracted to operate the new water system. The costs also include materials and expenses associated with the operation of the new booster pump station (electric usage and building heat), chemical costs, and miscellaneous expenses. The estimated annual O&M cost for the proposed water improvements is $19,900. Refer to Table 5-2 for a breakdown of the estimated costs.

TABLE 5-2
PROJECTED ANNUAL WATER O&M BUDGET

Description	Amount
LABOR	
Operations	$8,100
Hydrant Maintenance	$500
Meter Reading	$600
MATERIALS & EXPENSES	
Building Electric Charge	$5,500
Telephone Service	$800
Building Heat & Back-Up Power	$1,000
Chemical Costs	$400
Repairs	$500
Insurance	$4,000
Miscellaneous Expenses	$800
Contingency / Capital Reserve (10%)	$2,200
Total	**$24,400**

5.3 PROJECT FINANCING

The project is anticipated to be a collaborative effort between the Town of New Gloucester, the New Gloucester Water District, and the Maine DEP to provide project financing to develop a successful municipal water supply project. The Town and the MEDEP have invested significant time, effort, and money over many years to ensure the right solution is presented to solve the long-term contamination issues that have plagued this area for a long time. To leverage all

available funding alternatives, the Town and District have applied for funding from all available resources. This additional project funding includes;

- MEDEP has committed to providing $379,827.00 and also to cover the cost of installing the water services from the water main to the meter for the 10 properties that are designated contaminated or at-risk. This cost is estimated to be approximately $78,000.
- CDBG has committed to providing $233,000 to the project out of the Cumberland County CDBG program.
- The District will have an Interlocal Agreement with the Town requiring the Town to provide $189,601 to construct the water service connections on private property.

The remaining project funding is expected to be requested from USDA Rural Development as a grant/loan package. Table 5-3 summarizes the expected breakdown of the project funding.

TABLE 5-3
UPPER VILLAGE WATER SYSTEM
ESTIMATED PROJECT FUNDING SOURCES

Funding Agency	Amount
MEDEP	
• Committed Percentage Funding	$379,827
• Water Service Connections (Estimated for 10 properties)	$78,000
Cumberland Co CDBG	
• Committed Project Funding	$233,000
Town of New Gloucester	
• Private Property Service Connections	$189,601
USDA Rural Development	
• Loan/Grant package	$1,474,562
Estimated Total Project Cost	**$2,354,990**

Due to the limited size of the first phase of the water district service area and the limited number of connections expected, the Town of New Gloucester is anticipating the users will fund the operations and maintenance costs for the District through water rate charges, and the Town will need to provide the financial assistance for loan repayment.

The District will have an Interlocal Agreement with the Town requiring the Town to the debt service on the loan portion of the award. The Town will also provide hydrant rental fees which the District will apply toward annual operating expenses.

To ensure affordable rates and the sustainability of the capital investment, the Town of New Gloucester will pass an ordinance that requires all users located on the extents of the water system to hook-up to the system within a reasonable time period.

The District understands that USDA funds will not be utilized for construction of water services on private property and intends to use matching funds for this portion of the work.

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

Based on our evaluation, we have concluded the following:

- The temporary household filters placed at each resident's supply to remove the existing contaminants in the Upper Village are costly for the Town and Maine DEP to maintain and replace and are prone to malfunction. It is not recommended that the Town continue use of the filters.
- Creation of a new water system in the Upper Village will address long-term economic disinvestment in the historical business and commercial section of this rural community.
- Financing of the project will be partnership with the Water District, The Town of New Gloucester, and the Maine DEP.

Based on our evaluation, we recommend the following improvements:

- The construction of a new groundwater source (gravel/bedrock well) and treatment facility / pump station / buried storage tank in the Upper Village area of the town,
- The installation of approximately 9,800 linear feet of new 8-inch and 2-inch water main on the following streets:
    - Bald Hill Road
    - Snow Hill Road
    - Sawyer Road (2-inch)
    - Lewiston Road
    - Intervale Road
    - Upper Village Street
    - Peacock Hill Road

- The installation of new small diameter copper water services to residential and business buildings,
- The installation of new hydrants to provide fire protection and required locations for flushing and maintenance of the distribution system.

APPENDIX A
Preliminary Basis of Design Memorandum

UPPER VILLAGE WATER SYSTEM
PRELIMINARY BASIS OF DESIGN MEMORANDUM
for the
TOWN OF NEW GLOUCESTER

December 2011

STATE OF MAINE
DARRIN D.
LARY
No. 10749
LICENSED
PROFESSIONAL ENGINEER
12/27/2011

WRIGHT-PIERCE
Engineering a Better Environment

WRIGHT-PIERCE
Engineering a Better Environment

MEMORANDUM

TO:	Paul First, Director of Planning	**DATE:**	December 27, 2011
FROM:	Darrin D. Lary, P.E.	**PROJECT NO.:**	12356A
SUBJECT:	Upper Village Water System Preliminary Basis of Design Memorandum		

The memo summarizes the proposed basis of design for the construction of a new water system in the Upper Village area of New Gloucester.

PROJECT BACKGROUND

The Town of New Gloucester, in conjunction with the Maine Department of Environmental Protection has studied the feasibility of constructing a public water system to provide clean, reliable water to the residents and businesses in the Upper Village section of the Town of New Gloucester.

The Town contracted with Drumlin Environmental, LLC to perform a feasibility study to determine the feasibility and relative costs of delivering public water to the Upper Village. The feasibility report was submitted and approved in June 2011. The report detailed the following:

- Groundwater contamination derived from historic releases of several small gasoline stations; sodium and chloride contamination from historic storage of road salt in several locations; uranium derived from granitic bedrock present in the water supply at the Memorial School that exceeds primary drinking water standard.
- Gravel/bedrock source located on the fairgrounds property with sufficient capacity and quality to meet the current and future needs of the Upper Village. Aquifer test indicated well capacity of 60 gpm +/-. Radon detected at 8,220 piC/L.
- Distribution system limits were developed to encompass contaminated areas and areas of potential growth for the Upper Village.
- Water system alternatives reviewed, including; new well source and distribution system, or connection to the end of the existing Auburn Water District system. Analysis of relative costs indicated that development of a new well source was most cost effective.
- New well source alternative was selected by the New Gloucester Selectboard on May 23, 2011.

The Town advertised an RFP for preliminary engineering services in July 2011. Wright-Pierce was selected in August 2011 to assist with preliminary engineering and limited funding assistance.

HYDRAULIC ANALYSIS

To better understand the impact of various options in the development of a new water system, we created a computerized hydraulic model of the proposed Upper Village water distribution system. The model incorporates transmission piping, distribution piping, and gravity storage or pumped storage tank location options to calculate system pressures and available fire flows under each of the selected scenarios. Development of the hydraulic model allows scenarios to be analyzed for different gravity tank locations and different pipe sizes to determine the effects to the available fire flows and system pressures. Piping extents, tank option locations and model nodes are detailed in Figure 1.

In the development of the model, we reviewed the system demand estimates developed by Drumlin Environmental. Earlier in 2011, Drumlin estimated the average daily flow for the system to be approximately 25 gpm. We concur that this is a valid projection of the domestic use in Upper Village. To provide a conservative estimate of the flow rates in the system we made the following assumptions for the mathematical calculations:

- Average Daily Flow (ADF) 30 gpm
- Maximum Daily Flow (MDF) 60 gpm (a factor of 2xADF is standard for MDF)
- Peak Hour Flow (PHF) 120 gpm (a factor of 4xADF is standard for PHF)

It should be noted that these flows exhibit very little friction losses to the pipeline when the pipeline is designed around an 8-inch or 12-inch pipe. The differences in flow rates due to pipe size restrictions are generally related to much higher "fire flow" rates, and the domestic flows for small systems such as this one normally are not affected by pipe size.

The graphical results of these model run scenarios are detailed in Figure 2. The junction locations shown in Figure 1 represent approximate locations where future hydrants could be located. In addition hydrants will be located, during the design phase, to meet the recommendations of ISO spacing and to facilitate construction and maintenance of the system.

DISTRIBUTION SYSTEM DESIGN

Based on discussions with the development team, we reviewed several options for the distribution system. The most important question which drives cost is that much larger pipes are needed to provide fire flows.

We considered several options for pipe size and pipe material.

In general, pipe materials for potable water can be divided into two categories; ductile iron (metallic) pipe and plastic pressure pipe.

There are two commonly used materials for plastic pipe for pressurized potable water systems; PVC (poly-vinyl chloride) or HDPE (high-density polyethylene). Both types of plastic pipe are commonly used for water mains; however, additional care must be taken during construction and

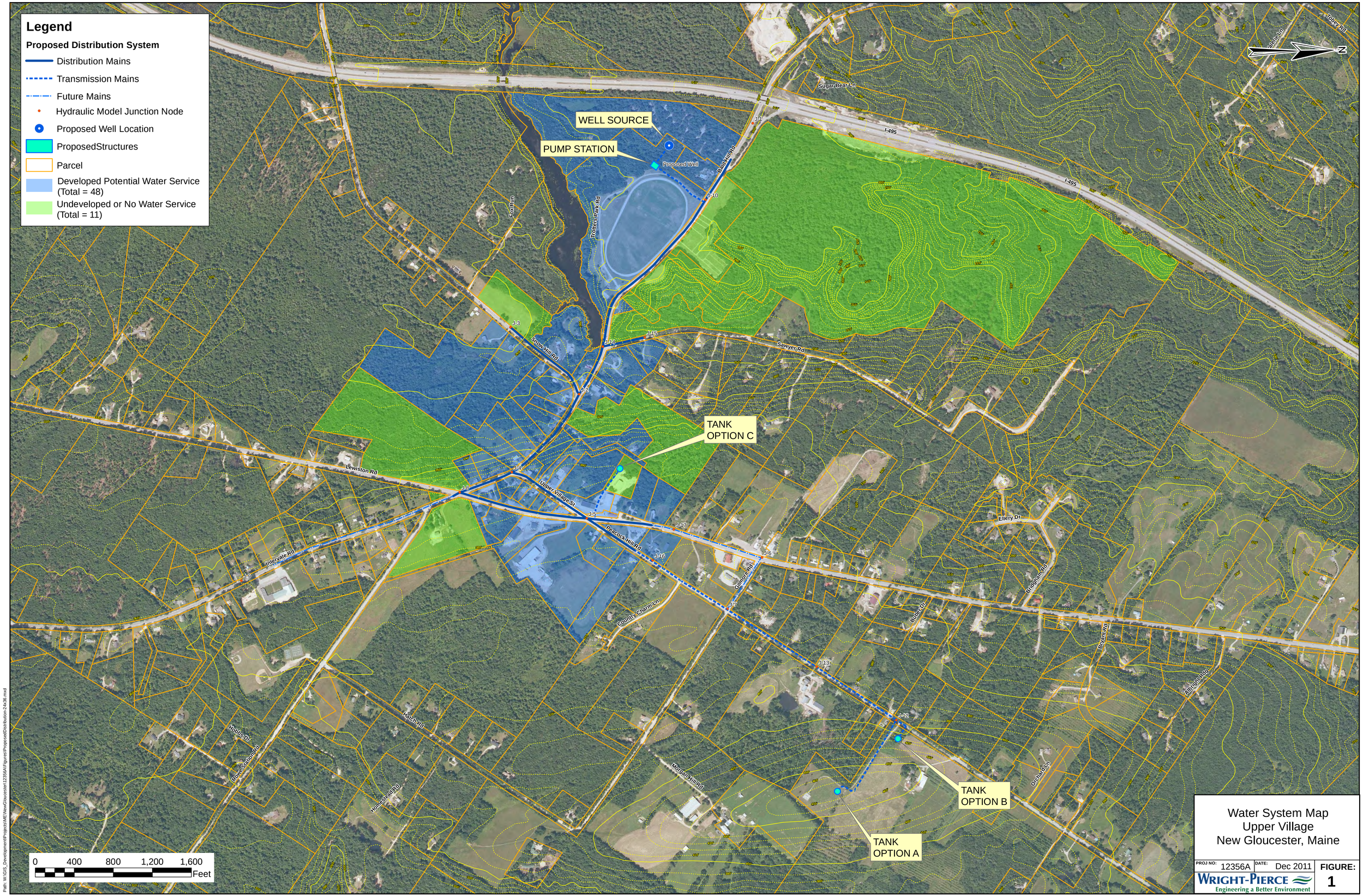

Legend
Proposed Distribution System
Distribution Mains
Transmission Mains
Future Mains
Hydraulic Model Junction Node
Proposed Well Location
ProposedStructures
Parcel
Developed Potential Water Service (Total = 48)
Undeveloped or No Water Service (Total = 11)
WELL SOURCE
PUMP STATION
Proposed Well
TANK OPTION C
TANK OPTION B
TANK OPTION A
Sugar Bear Ln
I-495
Bald Hill Rd
Fox Run
Trotters Park Rd
Snow Hill Rd
Sawyer Rd
Lewiston Rd
Upper Village St
Peacock Hill Rd
Intervale Rd
Gilmore Rd
County Charm Ln
Ellery Dr
Bartlett Hill Rd
Butler Dr
Byram Rd
Hatch Rd
Morgan Hill Rd
Honeycrest Rd
Rowe Station Rd
Houle Dr
Orchard Ln
J-1
J-2
J-3
J-4
J-5
J-6
J-7
J-8
J-9
J-10
J-11
J-12
J-13
J-14
J-15
J-16
J-17
0 400 800 1,200 1,600 Feet
Water System Map
Upper Village
New Gloucester, Maine
PROJ NO: 12356A
DATE: Dec 2011
FIGURE: 1
WRIGHT-PIERCE
Engineering a Better Environment
Path: W:\GIS_Development\Projects\ME\NewGloucester\12356A\Figures\ProposedDistribution-24x36.mxd

FIGURE 2
Hydraulic Model Output
Upper Village Water System
New Gloucester, ME

Average Day 30gpm

		No Tank
Location	Elev. (ft)	Pres. 4"
J-1	300	91
J-2	305	89
J-3	280	99
J-4	382	55
J-5	385	54
J-6	375	58
J-7	375	58
J-8	385	54
J-9	370	60
J-10	300	91
J-12	395	49
J-13	390	52
J-14	280	100
J-15	250	113
J-16	385	54
J-17	385	54
J-18	390	52

All 8" mains

	Tank Option A El.475		Tank Option A El.490		Tank Option B El.475		Tank Option B El.490		Tank Option C El.475		Tank Option C El.490	
Location	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"
J-1	76	600	82	700	76	600	82	750	76	1100	82	1200
J-2	74	600	80	700	74	600	80	750	74	2000	80	2150
J-3	84	600	91	700	84	600	91	750	84	1650	91	1750
J-4	40	600	47	700	40	600	47	750	40	2150	47	2500
J-5	39	600	45	700	39	600	45	750	39	3200	45	3500
J-6	43	550	50	700	43	600	50	700	43	1100	50	1300
J-7	43	750	50	900	43	850	50	1000	43	900	50	1100
J-8	39	600	45	700	39	600	45	750	39	2000	45	2350
J-9	45	600	52	650	45	600	52	650	45	950	52	1100
J-10	76	600	82	700	76	600	82	750	76	1250	82	1300
J-12	35	1500	41	1800	35	2250	41	2750	35	600	41	750
J-13	37	1000	43	1200	37	1150	43	1400	37	700	43	850
J-14	84	600	91	700	84	600	91	750	84	1750	91	1850
J-15	97	600	104	700	97	600	104	750	97	1750	104	1850
J-16	39	650	212	800	39	700	45	850	39	1300	45	1550
J-17	39	550	212	700	39	600	45	700	39	1400	45	1650
J-18	37	550	43	700	37	600	43	700	37	2150	43	2600

*Tank=20'h, 41.5'd
50' to min water level
Tank=65'h,23'd
87' to min water level
Tank=102'h,18.5'd

12" Tank to J-5

	Tank Option A El.475		Tank Option A El.490		Tank Option B El.475		Tank Option B El.490	
Location	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"
J-1	76	1000	82	1050	76	1000	82	1050
J-2	74	1100	80	1300	74	1100	80	1350
J-3	84	1100	91	1300	84	1100	91	1350
J-4	40	1100	47	1300	40	1100	47	1350
J-5	39	1150	45	1400	39	1200	45	1450
J-6	43	900	50	1000	43	900	50	1000
J-7	43	2300	50	2700	43	2450	50	2950
J-8	39	1100	45	1300	39	1100	45	1300
J-9	45	800	52	900	45	800	52	900
J-10	76	1100	82	1150	76	1100	82	1150
J-12	35	3500	41	3500	35	3500	41	3500
J-13	37	3000	43	3500	37	3450	43	3500
J-14	84	1100	91	1300	84	1100	91	1350
J-15	97	1100	104	1300	97	1100	104	1350
J-16	39	1950	45	2350	39	2100	45	2500
J-17	39	950	45	1100	39	950	45	1150
J-18	37	1050	43	1300	37	1100	43	1300

*Tank=20'h, 41.5'd
50' to min water level
Tank=65'h,23'd

Max Day 60gpm

		No Tank
Location	Elev. (ft)	Pres. 4"
J-1	300	91
J-2	305	86
J-3	280	97
J-4	382	52
J-5	385	51
J-6	375	55
J-7	375	55
J-8	385	51
J-9	370	57
J-10	300	91
J-12	395	46
J-13	390	49
J-14	280	98
J-15	250	111
J-16	385	51
J-17	385	51
J-18	390	49

All 8" mains

	Tank Option A El.475		Tank Option A El.490		Tank Option B El.475		Tank Option B El.490		Tank Option C El.475		Tank Option C El.490	
Location	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"
J-1	76	550	82	650	76	600	82	700	76	1100	82	1150
J-2	73	550	80	650	73	600	80	700	74	2000	80	2100
J-3	84	550	91	650	84	600	91	700	84	1650	91	1750
J-4	40	550	47	650	40	600	47	700	40	2100	47	2450
J-5	39	550	45	700	39	600	45	700	39	3150	45	3500
J-6	43	550	50	650	43	600	50	700	43	1100	50	1300
J-7	43	750	50	900	43	800	50	950	43	900	50	1100
J-8	39	550	45	650	39	600	45	700	39	1950	45	2300
J-9	45	550	52	650	45	600	52	650	45	950	52	1100
J-10	76	550	82	650	76	600	82	700	76	1250	82	1300
J-12	35	1450	41	1800	35	2250	41	2750	35	600	41	750
J-13	37	1000	43	1200	37	1150	43	1350	37	700	43	850
J-14	84	550	91	650	84	600	91	700	84	1750	91	1850
J-15	97	550	104	650	97	600	104	700	97	1750	104	1850
J-16	39	650	45	750	39	650	45	800	39	1300	45	1550
J-17	39	550	45	650	39	600	45	700	39	1400	45	1650
J-18	37	550	43	650	37	600	43	700	37	2150	43	2550

*Tank=20'h, 41.5'd
50' to min water level
Tank=65'h,23'd
87' to min water level
Tank=102'h,18.5'd

12" Tank to J-5

	Tank Option A El.475		Tank Option A El.490		Tank Option B El.475		Tank Option B El.490	
Location	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"
J-1	76	1000	82	1050	76	1000	82	1050
J-2	74	1050	80	1300	74	1100	80	1300
J-3	84	1050	91	1300	84	1100	91	1300
J-4	40	1050	47	1300	40	1100	47	1300
J-5	39	1150	45	1400	39	1200	45	1400
J-6	43	850	50	1000	43	850	50	1000
J-7	43	2250	50	2700	43	2450	50	2950
J-8	39	1050	45	1250	39	1100	45	1300
J-9	45	800	52	900	45	800	52	900
J-10	76	1050	82	1150	76	1100	82	1150
J-12	35	3500	41	3500	35	3500	41	3500
J-13	37	2950	43	3500	37	3400	43	3500
J-14	84	1050	91	1300	84	1100	91	1300
J-15	97	1050	104	1300	97	1100	104	1300
J-16	39	1950	45	2300	39	2050	45	2450
J-17	39	950	45	1100	39	950	45	1100
J-18	37	1050	43	1250	37	1050	43	1300

*Tank=20'h, 41.5'd
50' to min water level
Tank=65'h,23'd

Peak Hour 120gpm

		No Tank
Location	Elev. (ft)	Pres. 4"
J-1	300	88
J-2	305	78
J-3	280	88
J-4	382	42
J-5	385	40
J-6	375	44
J-7	375	44
J-8	385	40
J-9	370	47
J-10	300	88
J-12	395	36
J-13	390	38
J-14	280	90
J-15	250	103
J-16	385	40
J-17	385	40
J-18	390	38

*Res =480'

All 8" mains

	Tank Option A El.475		Tank Option A El.490		Tank Option B El.475		Tank Option B El.490		Tank Option C El.475		Tank Option C El.490	
Location	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"
J-1	75	500	82	600	75	550	82	650	76	1100	82	1150
J-2	73	500	79	600	73	550	79	650	73	1950	80	2100
J-3	84	500	90	600	84	550	90	650	84	1650	91	1750
J-4	40	500	46	600	40	550	46	650	40	2100	47	2450
J-5	38	500	45	650	38	550	45	650	39	3100	45	3500
J-6	43	500	49	600	43	550	49	650	43	1100	50	1250
J-7	43	700	49	850	43	750	49	900	43	900	50	1100
J-8	38	500	45	600	38	550	45	650	39	1950	45	2300
J-9	45	500	51	600	45	550	51	600	45	950	52	1050
J-10	75	500	82	600	75	550	82	650	76	1200	82	1300
J-12	34	1400	41	1750	35	2150	41	2650	35	600	41	700
J-13	37	900	43	1100	37	1050	43	1300	37	700	43	850
J-14	84	500	90	600	84	550	90	650	84	1700	91	1800
J-15	97	500	103	600	97	550	103	650	97	1700	104	1800
J-16	38	600	45	700	38	600	45	750	39	1250	45	1550
J-17	38	500	45	600	38	550	45	650	39	1400	45	1650
J-18	36	500	43	600	36	550	43	650	37	2100	43	2500

*Tank=20'h, 41.5'd
50' to min water level
Tank=65'h,23'd
87' to min water level
Tank=102'h,18.5'd

12" Tank to J-5

	Tank Option A El.475		Tank Option A El.490		Tank Option B El.475		Tank Option B El.490	
Location	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"	Pres. 8"	Fire 8"
J-1	76	950	82	1000	76	950	82	1050
J-2	73	1000	80	1250	73	1050	80	1250
J-3	84	1000	91	1250	84	1050	91	1250
J-4	40	1000	47	1250	40	1050	47	1250
J-5	39	1100	45	1350	39	1150	45	1350
J-6	43	850	50	950	43	850	50	1000
J-7	43	2200	50	2650	43	2400	50	2850
J-8	39	1050	45	1200	39	1050	45	1250
J-9	45	750	52	850	45	800	52	900
J-10	76	1000	82	1100	76	1050	82	1100
J-12	35	3500	41	3500	35	3500	41	3500
J-13	37	2900	43	3450	37	3350	43	3500
J-14	84	1000	91	1250	84	1050	91	1250
J-15	97	1000	104	1250	97	1050	104	1250
J-16	39	1850	45	2250	39	2000	45	2400
J-17	39	900	45	1050	39	900	45	1100
J-18	37	1000	43	1200	37	1000	43	1250

*Tank=20'h, 41.5'd
50' to min water level
Tank=65'h,23'd

All Pressure values in psi
All Fireflow values in gpm
Updated: 10/26/2011

future maintenance of the mains. PVC water main, commonly referred to as "blue brute" is a thermo-setting plastic resin pipe, installed in segments with rubber gaskets between each length of pipe. This pipe is not frequently used in water systems in New England, primarily due to the additional care required during the installation of the pipe and deep frost penetration. Quality bedding material must be used around the pipe to assure the integrity of the pipe is not compromised by sharp or heavy objects in contact with the pipe. This pipe may also have some porosity that would preclude it from being recommended for use in contaminated soils.

HDPE pipe is an extruded plastic pipe that is joined using heat fusion to create a seamless pipeline. This style of pipeline is used extensively for horizontal directional drilling (HDD) installations or other installations where long lengths of pipeline can be assembled prior to burying in the trench. HDPE pipe is not recommended for areas with hydrocarbon contaminated soils, so we are not recommending this type of pipe for the majority of the distribution area. There may be sections of the system where HDPE would be the best and most cost effective pipe for the Upper Village distribution system; in particular, the Royal River crossing may be most cost effective if it can be installed by HDD. In general, due to the greater wall thickness for HDPE pipe, the pipe needs to be sized up to the next available size verses DI or PVC to achieve the same internal flow area. For example, an 8-inch DI distribution pipeline has roughly the same hydraulic capacity as a 10-inch HDPE pipe.

Ductile Iron (DI) pipe is the most frequently used pipe material in New England for potable water. Ductile/cast Iron has been in use in New England for over 150 years, with many pipes installed over 100 years ago still in active service. DI pipe is a centrifugally cast iron pipe (primarily recycled materials) with a cement-mortar lining to reduce corrosion and tuberculation. The pipe is installed in segments, generally 18-20 feet in length, with rubber gaskets to create the pressurized seal. DI pipe is very non-porous and is acceptable in most areas with hydrocarbon contaminated soils. Gaskets can be selected that are designed to be resistant to the constituents in the contaminated soils. In areas with significant salt contamination, it is recommended that the pipe be installed with the plastic wrap over the pipe to reduce any cathodic corrosion potential.

Based on the superior characteristics of the ductile iron pipe, we recommend the system be primarily designed around class 52 cement-lined ductile iron during this preliminary design phase. Class 52 DI is the industry standard in New England and has an extensive track record for successful pipeline installations. There are some possibilities for cost savings that can be reviewed during the design phase, including; utilizing pressure class ductile iron - a slightly thinner wall thickness pipe, or by HDD installation of HDPE pipe for specific areas including the river crossing.

With regards to pipe sizing, we reviewed several options utilizing hydraulic modeling. First, we looked at the size of pipe required to install a distribution system without fire protection flows. Hydraulic modeling indicated that the friction losses at PHF were too great in any pipeline less than 4-inches in diameter. We therefore would recommend that a non fire protection system be constructed with 4-inch diameter mains. This is also a commonly available size for DI pipe, and anything smaller would require a different material of construction.

The majority of the structures within the Upper Village distribution system are 1 and 2 family dwellings not exceeding 2 stories in height. The Insurance Services Office (ISO) defines needed fire flow for this type of structure as follows:

Table 1 - ISO Fire Flow Requirements - 1-2 Family Dwellings < 2 Stories Tall

Distance between Buildings	Needed Fire Flow (gpm)
Over 100'	500
31-100'	750
11-30'	1000
10' or less	1500

Based on these criteria, we performed several model runs. First we developed a model run scenario with all mains in the distribution system sized to be 8-inch. Details on available pressures and available fire flows are shown in Figure 2. The model indicates that even with all 8-inch main, the system will provide the minimum 500 gpm to all nodes (potential hydrant locations) in the system. This would meet the minimum required fire flows under the ISO guidelines. However, since many of the buildings in the center of the village area are closer than 100' apart, we recommend a larger pipe from the tank to the intersection in the center of the village (node junction J-5). We developed the next model run scenario with a 12- inch transmission main from each of the tank sites on Peacock Hill down to the intersection in the center of the village. When this model scenario was calculated, the flows increased to greater than 1,000 gpm for most locations in the system. This fire flow rate most closely fits the needs of the majority of the structures in the distribution system. This 1,000 gpm flowrate is also the criteria used when sizing the storage capacity of the gravity water storage tanks. ISO requires the system to provide the required flowrate for a minimum of 2 hours. For the Upper Village area, 2 hours x 1,000 gpm = 120,000 gallons of water would be required for fire storage.

GRAVITY TANK OPTIONS

Based on discussions and guidance provided by the Town regarding possible tank site locations, we have reviewed three possible tank locations as options for providing gravity storage to the distribution system. Ultimately, the object of a large storage tank is to provide sufficient water to meet both domestic and fire flow needs to the system such that the system operates from a relatively constant pressure or "hydraulic gradeline". This hydraulic gradeline is the elevation of water required to provide adequate pressure to the highest elevation users on the system without providing pressure that is too high in the lowest portion of the system. For our analysis we modeled two specific hydraulic gradeline elevations; EL. 475' and EL. 490'. These elevations equate to system pressures of approximately 40 psi and 45 psi respectively in the central section of the village area (EL. 380' - the highest elevation area in the Upper Village). This provides a good working pressure for all the properties in the distribution area as well as the required 20 psi residual pressure under fire flow conditions.

In order to provide this hydraulic gradeline the tank needs to be tall enough to store water up to the selected elevation. This means the ground elevation at each selected tank site will determine the required height of the tank in order to achieve the required gradeline. In addition, to meet

fire flow requirements and provide the required residual pressure of 20 psi under flowing conditions, tanks built at lower elevations will need to have greater volume to compensate for the dead storage of water in the tank at pressures less than 20 psi. Figure 3 details the segments of tank storage. In the case for Upper Village, the low domestic flows make the Operational System and Equalizing Storage volumes very small, so the tank is essentially divided into Emergency/Fire Storage and Dead Storage. The dead storage volume will vary with the base elevation of the tank, from no dead storage for the higher elevation tank, to significant dead storage in the lower elevation tanks.

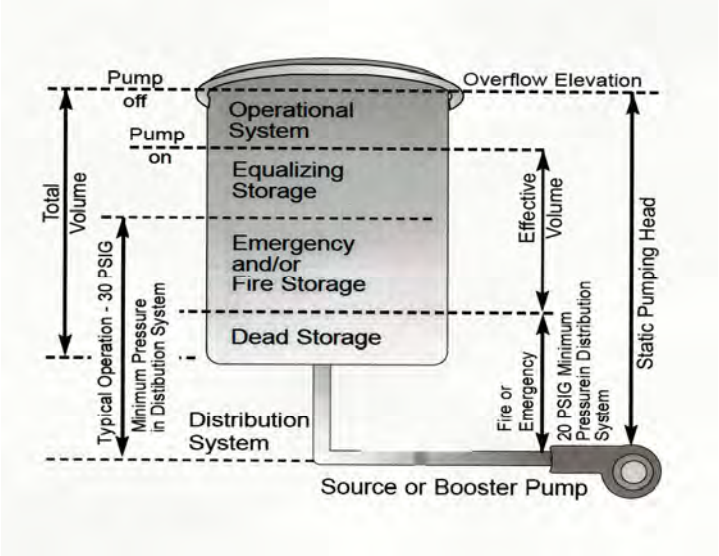


Figure 3 - Representative Storage tank Detail

Figure 1 shows the three selected tank option locations that were reviewed for this memorandum. These locations offer a good indication as to the differences inherent with locating a shorter tank at a higher elevation further from the system verses a taller tank at a lower elevation closer to the system. The relative construction cost ramifications for each location are detailed in a later section.

Tank Option A - This option considers a tank located at the top of Peacock Hill adjacent to the existing cell phone tower. The ground elevation at this location is about EL. 475 so the tank only needs to be about 20' tall. To achieve the required 120,000 gallons of fire storage the tank dimensions are 20'high x 41.5'diameter.

Advantages

- Smallest volume tank because entire tank volume is available for fire storage
- Least expensive tank to construct
- Lower height tank means least conspicuous to public and neighbors

Disadvantages

- Site is on private property - will require easement or purchase
- Longest transmission main - 4,000'
- Remote location more prone to vandalism
- Highest cost option

Tank Option B - This option considers a tank near the high point on Peacock Hill Road. The ground elevation at this location is about EL. 420 so the tank needs to be about 65' tall to achieve the required gradeline. To achieve the required 120,000 gallons of fire storage the tank dimensions are 65'high x 23'diameter.

Advantages

- Shorter transmission main than Option A (3,300')
- No issues/interference with cellular tower

Disadvantages

- Site is on private property - will require easement or purchase of land
- Fairly long transmission main to the crest of Peacock Hill Road
- Tank is taller and closer to the road so more visible

Tank Option C - This option considers construction of a tank in the middle of Upper Village behind the Town Garage on Municipally owned land. The ground elevation at this location is about EL. 390 so this would need to be the tallest tank at about 90-100' tall to achieve the required gradeline. To achieve the required 120,000 gallons of fire storage the tank dimensions are 90'high x 18.5'diameter.

Advantages

- Short transmission main (600') reduces overall cost
- Built on Town owned property so no easement or land purchase requirements

Disadvantages

- Highest visibility tank in the center of the village
- Requires larger tank to store fire flow above the elevation required to provide 20 psi residual pressure to highest service - greatest volume of dead storage
- Largest volume tank will definitely require mixing to reduce icing issues
- Largest volume tank may contribute to water quality concerns due to low tank turnover

Municipal water storage tanks are generally fabricated of either concrete or steel construction. Concrete construction can be either above-grade or buried cast-in-place concrete or more commonly, above-grade or buried pre-cast wire-wound concrete storage tanks. Concrete generally offers benefits over steel tanks in longevity and minimal maintenance, however, this generally comes at the cost of significantly higher capital construction costs.

Recognizing the Town's funding limitations we did not develop detailed evaluations for the concrete tank options. Option A is the only location where a pre-cast style below grade tank could be considered. A wire-wound tank could be considered for Options B, but the height of the tank at the location of Option C precludes the use of concrete tanks. Based on discussions with the concrete tank manufacturers, a concrete tank is likely not cost competitive for the Upper Village distribution system.

Example of Bolted Steel Tank - 65' Tall

This leaves the most common remaining options of welded steel tanks and glass-fused-to-steel bolted tanks. We briefly researched pre-formed fiberglass panel tanks and bolted stainless steel tanks as viable alternatives, but neither option was feasible or cost effective for this proposed project. Recent project experience has seen the quoted prices for welded steel tanks significantly higher than the bolted tank prices and welded tanks have seen significant lead time issues with getting materials to construct the tanks. In addition, many utilities have been less enthusiastic about welded steel tanks due to the expensive maintenance required every 20-30 years to repaint the tank. The glass-fused-to-steel bolted tank does not require painting and has an expected lifespan of 50 years or more.

Based on these constraints, we recommend specifying the tank around a bolted tank but allowing a welded tank be submitted as an "or equal," to meet USDA Rural Development procurement practices.

Due to the expected small domestic demand for the system, it is likely a mixing system would need to be installed in the tank. This would be recommended for two reasons. First, a mixing system would keep the water in the tank from becoming stagnant due to low usage and long detention times, and second, an active mixing system would reduce the potential for ice build-up on the sidewalls and in the top of the tank. Ice build-up can cause significant damage to the tank and bolted steel tanks are particularly susceptible to potential ice damage. During the design phase, tank mixing systems will be reviewed to determine the best alternative for providing the required mixing. Available systems include; solar operated, "SolarBee" type systems; internally piped, check valve, "Tideflex" style systems; or mechanical mixers.

PUMP STATION BUILDING DESIGN

We reviewed several options for construction of the pump station for Upper Village. Again, recognizing the budget constraints, we would not recommend the construction of a masonry pump station building to house the pumping equipment for the system. Wright-Pierce has had good success with wood-framed construction for municipal buildings to reduce the overall construction costs for the project.

We anticipate the pump station building will need to be approximately 24' x 24' to accommodate all the required pumps, aerations system, and equipment. A concept drawing of potential layout for the pump station is detailed in Figure 4. The exact size and layout of the building will be determined in a collaborative process during the design phase. There are options to use higher quality vinyl shingles to make a wood framed building more appealing

Example of Wood Framed Municipal Building, 14'x18'

As a basis for developing preliminary costs for the pump station, we have anticipated the following components for the building;

Site Development

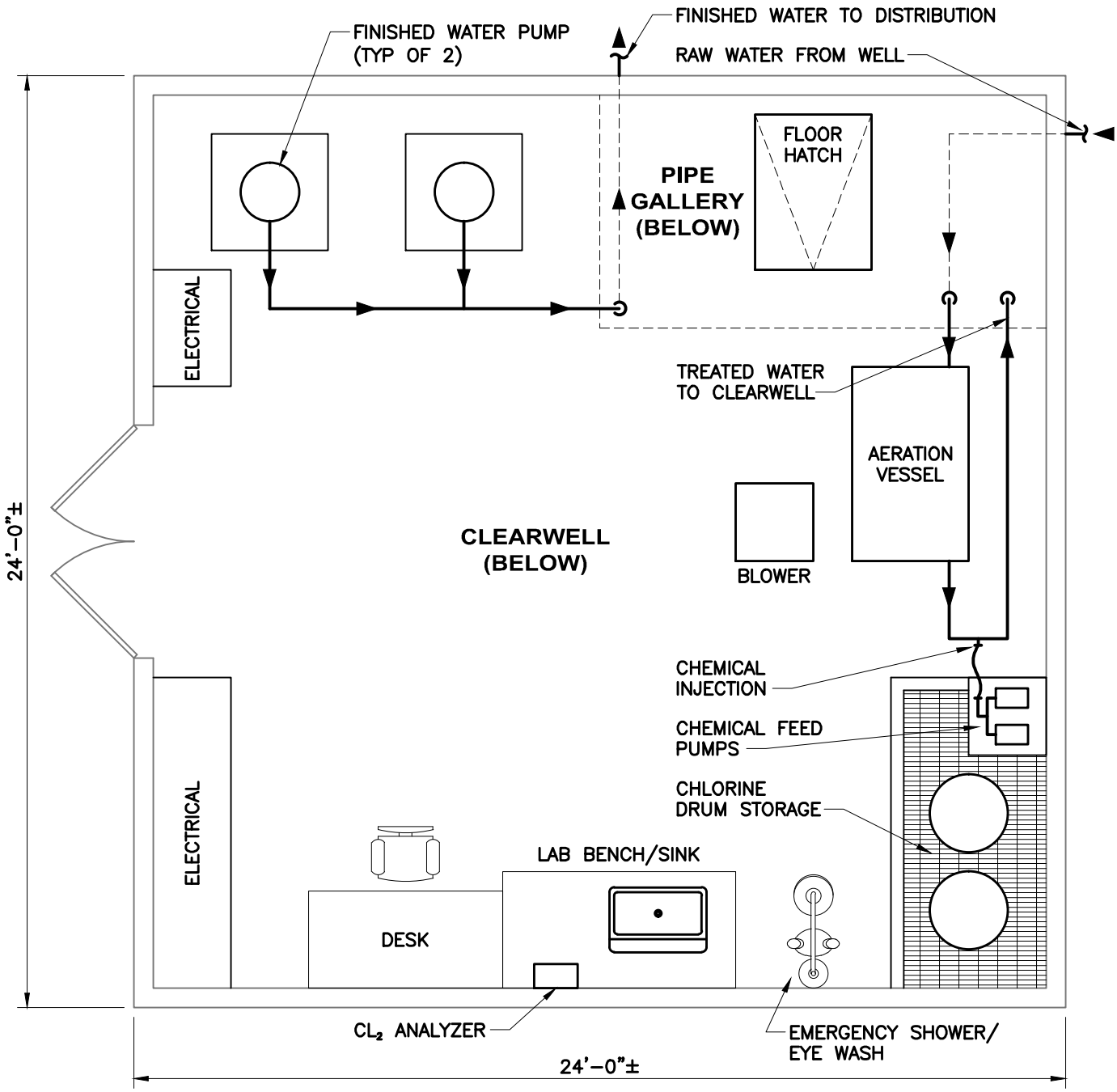
- New well, pitless adapter, and piping to the pump station.
- Building excavation and backfill.
- Gravel access drive to building.
- Small security fence surrounding the well.

Building Structure

- Concrete clearwell below and elevated concrete slab floor.
- Small pipe gallery accessed by floor hatch and ladder.
- Wood framed walls and wood truss roof framing.
- Fiberglass insulation.
- FRP coated plywood panels for interior wall and ceiling finish.
- Commercial grade insulated metal door.
- Vinyl clad exterior siding with aluminum clad fascia and trim.
- Provide desk and file cabinet space.

Process Equipment

- Variable Frequency Drive (VFD) controlled well pump and finished water pumps. The VFD will be used for phase conversion as 3-phase power is not available onsite.
- Deep Bubble aeration system based on Lowry DB-32 unit for radon removal.
- Sodium Hypochlorite (chlorine) disinfection fed from supplied drums.
- Small laboratory bench with sample sink. Sink waste to onsite tight tank.
- Online chlorine analyzer.



UPPER VILLAGE WATER SYSTEM PUMP STATION CONCEPT PLAN		
PROJ NO: 12356A	DATE: 11/2011	SCALE: 1/4"=1'-0"
WRIGHT-PIERCE Engineering a Better Environment		FIGURE: 4

Electrical and Controls

- PLC based Control Panel to accept alarms and signals from building intrusion, pump condition, chemical feed condition, water storage tank level, and environmental conditions (i.e. building temperature).
- Radio Telemetry to transmit tank level data and alarms back to Pump Station.
- Propane fired back-up power generation in outside separate sound attenuated enclosure.
- Intrusion alarm contacts at door and windows.
- Automatic temperature sensor to detect building temperature alarm.
- Motion detector lights for operator safety when accessing the site and facility at night.

HVAC

- Propane fired unit heater.
- Automatic louver and ventilation fan to control internal building temperature in warmer weather.

PUMPED STORAGE FIRE PROTECTION

Based on discussion with the Town, we reviewed to alternative of providing limited fire protection utilizing an increased size clearwell (buried cast-in-place concrete tank at the pump station) and a high capacity pump to provide high flows to the system in the event of a fire.

We reviewed three options for providing pumped fire flow; 500 gpm, 750 gpm, and 1,000 gpm, all for 2 hour duration. The cost differentials are detailed in Table 2.

The differences required to include a high flow pump and additional buried tank storage in the design of the pump station include the following:

- Additional concrete, excavation and backfill for the larger buried tanks.
- Large high flow pump, 50-75 hp
- Larger emergency generator to power the large pump. We are assuming the large pump would need to be powered by the generator and not by line power as 3-phase power is not available onsite. We have priced two propane generators in parallel to power the pump as this is the most cost effective method to power the large pump.
- Possibly larger building to house additional pump and equipment.

It should be noted that a high flow pump system is not as reliable as a gravity tank for providing fire flows. The pumped systems, while very reliable, do have several avenues for failure including the pump and generator, where the gravity tank will reliably provide water to the system as long as there is water in the tank.

TABLE 2
UPPER VILLAGE WATER SYSTEM
Preliminary Cost Estimate

Scenario	Basic Area Without Fire Protection			Basic Area w/Tank Option A			Basic Area w/Tank Option B			Basic Area w/Tank Option C			Pump Station w/20x40 Clearwell (500 gpm for 2 hrs)			Pump Station w/20x60 Clearwell (750 gpm for 2 hrs)			Pump Station w/20x80 Clearwell (1000 gpm for 2 hrs)		
	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$	Quantity	Unit$	Total$
Distribution System	**4-inch Main Length**			8-inch Main Length			8-inch Main Length			8-inch Main Length			8-inch Main Length			8-inch Main Length			8-inch Main Length		
Road																					
Peacock St & Upper Village St	1500	$79	$118,500	1500	$99	$148,500	1500	$99	$148,500	1500	$99	$148,500	1500	$99	$148,500	1500	$99	$148,500	1500	$99	$148,500
Lewiston Rd, Rt 202/100	2000	$79	$158,000	2000	$99	$198,000	2000	$99	$198,000	2000	$99	$198,000	2000	$99	$198,000	2000	$99	$198,000	2000	$99	$198,000
Bald Hill Rd to Royal River	2500	$79	$197,500	2500	$99	$247,500	2500	$99	$247,500	2500	$99	$247,500	2500	$99	$247,500	2500	$99	$247,500	2500	$99	$247,500
Snow Hill Rd	1000	$79	$79,000	1000	$99	$99,000	1000	$99	$99,000	1000	$99	$99,000	1000	$99	$99,000	1000	$99	$99,000	1000	$99	$99,000
Sawyer Rd	450	$79	$35,550	450	$99	$44,550	450	$99	$44,550	450	$99	$44,550	450	$99	$44,550	450	$99	$44,550	450	$99	$44,550
Bald Hill Rd to Pump Station & Wayfarer	2700	$79	$213,300	2700	$99	$267,300	2700	$99	$267,300	2700	$99	$267,300	2700	$99	$267,300	2700	$99	$267,300	2700	$99	$267,300
River Crossing	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000
Distribution Subtotal:			**$851,850**			**$1,054,850**			**$1,054,850**			**$1,054,850**			**$1,054,850**			**$1,054,850**			**$1,054,850**
Water Service Connections	Pipe Length			Pipe Length			Pipe Length			Pipe Length			Pipe Length			Pipe Length			Pipe Length		
Service Piping																					
3/4" Copper Pipe in Road ROW	1650	$50	$82,500	1650	$50	$82,500	1650	$50	$82,500	1650	$50	$82,500	1650	$50	$82,500	1650	$50	$82,500	1650	$50	$82,500
3/4" Copper Pipe on Private Property	2470	$50	$123,500	2470	$50	$123,500	2470	$50	$123,500	2470	$50	$123,500	2470	$50	$123,500	2470	$50	$123,500	2470	$50	$123,500
3/4" Corporation	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000	50	$100	$5,000
3/4" Curb Stop W/ Box	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000	50	$200	$10,000
Internal Plumbing Connection w/Meter	19	$2,000	$38,000	19	$2,000	$38,000	19	$2,000	$38,000	19	$2,000	$38,000	19	$2,000	$38,000	19	$2,000	$38,000	19	$2,000	$38,000
Meter only installation	31	$300	$9,300	31	$300	$9,300	31	$300	$9,300	31	$300	$9,300	31	$300	$9,300	31	$300	$9,300	31	$300	$9,300
Water Services Subtotal:			**$268,300**			**$268,300**			**$268,300**			**$268,300**			**$268,300**			**$268,300**			**$268,300**
Well Source/Pump Station																					
Pump Station																					
Architectural																					
Clearwell Under Building Only	1	$176,000	$176,000	1	$176,000	$176,000	1	$176,000	$176,000	1	$176,000	$176,000									
Oversized Clearwell for Fire Storage													1	$234,000	$234,000	1	$323,000	$323,000	$1	$411,000	$411,000
Process Equipment																					
Service Pump-5hp (30gpm)	2	$9,000	$18,000	2	$9,000	$18,000	2	$9,000	$18,000	2	$9,000	$18,000	2	$9,000	$18,000	2	$9,000	$18,000	2	$9,000	$18,000
High Flow Pump-50-75hp (500-1000gpm)													1	$30,000	$30,000	1	$35,000	$35,000	1	$40,000	$40,000
Aeration System	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000
Chemical Feed-Disinfection	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000
Electrical/VFD/Instrumentation	1	$20,000	$20,000	1	$20,000	$20,000	1	$20,000	$20,000	1	$20,000	$20,000	1	$50,000	$50,000	1	$60,000	$60,000	1	$70,000	$70,000
Emergency Power Generator	1	$20,000	$20,000	1	$20,000	$20,000	1	$20,000	$20,000	1	$20,000	$20,000	1	$80,000	$80,000	1	$80,000	$80,000	1	$80,000	$80,000
Misc. Equipment	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000
Well																					
Well Construction	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000	1	$37,000	$37,000
Pitless Adapter	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000	1	$5,000	$5,000
Well Pump & Drop Pipe	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000	1	$10,000	$10,000
Discharge Pipe to Pump Station	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000	200	$60	$12,000
Additional Source Investigation	1	$40,000	$40,000	1	$40,000	$40,000	1	$40,000	$40,000	1	$40,000	$40,000	1	$40,000	$40,000	1	$40,000	$40,000	1	$40,000	$40,000
Well Source/Pump Station Subtotal:			**$383,000**			**$383,000**			**$383,000**			**$383,000**			**$561,000**			**$665,000**			**$768,000**
Gravity Tank	12-inch			12-inch			12-inch			8-inch											
Additional Main	0	$120	$0	4225	$120	$507,000	3300	$120	$396,000	600	$99	$59,400									
Tank Cost	0	$190,000	$0	1	$190,000	$190,000	1	$220,000	$220,000	1	$330,000	$330,000									
Site Cost	0	$50,000	$0	1	$50,000	$50,000	1	$50,000	$50,000	1	$50,000	$50,000									
Tank Mixer	0	$15,000	$0	1	$15,000	$15,000	1	$15,000	$15,000	1	$15,000	$15,000									
Tank Subtotal:			**$0**			**$762,000**			**$681,000**			**$454,400**			**$0**			**$0**			**$0**
Other Costs:																					
Legal	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000
Admin	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000	1	$25,000	$25,000
Engineering	1	$150,000	$150,000	1	$150,000	$150,000	1	$150,000	$150,000	1	$150,000	$150,000	1	$150,000	$150,000	1	$150,000	$150,000	1	$150,000	$150,000
Permits (MDEP & MDOT)	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000	1	$30,000	$30,000
Other Subtotal:			**$235,000**			**$235,000**			**$235,000**			**$235,000**			**$235,000**			**$235,000**			**$235,000**
Subtotal Estimate:			$1,738,150			$2,703,150			$2,622,150			$2,395,550			$2,119,150			$2,223,150			$2,326,150
Contingency 15%			*$260,722.5*			*$405,472.5*			*$393,322.5*			*$359,332.5*			*$317,872.5*			*$333,472.5*			*$348,922.5*
Total Estimate			**$1,998,873**			**$3,108,623**			**$3,015,473**			**$2,754,883**			**$2,437,023**			**$2,556,623**			**$2,675,073**

Updated 12/20/2011

PRELIMINARY COST ESTIMATES

Table 2 details the estimated costs for the various options for gravity tanks and the different sizes for pumped fire flows. The alternatives range in price from almost $2.4M for the smallest pumped fire flow system up to $3.1M for the gravity tank at the top of Peacock Hill. These costs include a 15% overall project contingency.

With regards to the gravity tank options, the greatest unknown is the potential cost to acquire land to build a tank on. Land acquisition costs are extremely variable and have not been factored into the preliminary cost estimate.

In addition to the project construction costs we have reviewed the operation and maintenance costs for the facility. These annual operating costs include the electrical usage, chemical costs, building heat, and miscellaneous clerical expenses and are detailed in Table 3. Per discussion with the Town, labor expenses are not included in this evaluation.

Table 3 - Projected Annual Operating Costs.

Cost Component	Estimated Annual Cost
Building Electric Charge @$0.15/kwh	$5,500
Building Heat & Back-up Power	$1,000
Telephone Service	$800
Chemical Costs	$400
Miscellaneous Expenses	$1,000

SUMMARY

We have presented multiple options for providing a clean reliable supply of water to the residents and businesses of the Upper Village area of New Gloucester. The best solution will be a collaborative approach to determine what options best fit the needs of the Upper Village area and still fit within the budget designated for the project.

APPENDIX B
Permeation and Leaching

United States
Environmental Protection
Agency

Office of Water (4601M)
Office of Ground Water and Drinking Water
Distribution System Issue Paper

Permeation and Leaching

August 15, 2002

PREPARED FOR:

U.S. Environmental Protection Agency
Office of Ground Water and Drinking Water
Standards and Risk Management Division
1200 Pennsylvania Ave., NW
Washington DC 20004

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AWWA
With assistance from
Economic and Engineering Services, Inc

Background and Disclaimer

The USEPA is revising the Total Coliform Rule (TCR) and is considering new possible distribution system requirements as part of these revisions. As part of this process, the USEPA is publishing a series of issue papers to present available information on topics relevant to possible TCR revisions. This paper was developed as part of that effort.

The objectives of the issue papers are to review the available data, information and research regarding the potential public health risks associated with the distribution system issues, and where relevant identify areas in which additional research may be warranted. The issue papers will serve as background material for EPA, expert and stakeholder discussions. The papers only present available information and do not represent Agency policy. Some of the papers were prepared by parties outside of EPA; EPA does not endorse those papers, but is providing them for information and review.

Additional Information

The paper is available at the TCR web site at:

http://www.epa.gov/safewater/disinfection/tcr/regulation_revisions.html

Questions or comments regarding this paper may be directed to **TCR@epa.gov.**

Permeation & Leaching

1.0 General Description of Topics

Distribution system infrastructure and appurtenances, including piping, linings, fixtures, and solders, can react with the water they supply as well as the external environment. These interactions can result in degradation of the distributed water. Permeation of plastic pipes and leaching from linings and metal appurtenances are known pathways for water quality degradation.

Permeation of piping materials and non-metallic joints can be defined as the passage of contaminants external to the pipe, through porous, non-metallic materials, into the drinking water. The problem of permeation is generally limited to plastic, non-metallic materials.

Leaching can be defined as "the dissolution of metals, solids, and chemicals into drinking water" (Symons et al, 2000). Leaching can result in elevated levels of metals, organic contaminants, or asbestos in water consumed at the tap. Health effects and mitigation techniques related to leaching of lead and copper from lead service lines or household plumbing materials are addressed in the Lead and Copper Rule (USEPA, 1991). Health effects associated leaching of asbestos fibers from asbestos-cement piping is currently addressed under the Phase II National Primary Drinking Water Regulations (USEPA, 1991). Thus, this White Paper will focus on leaching and permeation of organic contaminants and other metals.

1.1 Permeation of Piping and Non-Metallic Joints

Permeation is a physicochemical mass transfer phenomenon involving diffusion of a solute through a porous medium. The driving force for mass transfer is the presence of an activity (e.g., concentration) gradient with respect to the solute. The rate of permeation can be generalized in simple mathematical terms shown in Equation 1.

(1) $N = UA \cdot (\Delta a)$

where:
N = Mass Permeation Rate
U = Overall Mass Transfer Coefficient
A = Transfer Area
a = Solute Activity

The overall mass transfer coefficient (U) is a complex function of the following variables:

- Solute properties (composition, phase)
- Medium properties (composition, pore structure, swollenness)
- Solute-medium interaction (equilibrium partitioning, diffusion coefficient)
- Pipe flow hydrodynamics (Reynolds number)
- Transfer geometry (medium thickness)
- Environmental conditions (temperature)

Permeation of potable water mains and distribution system fittings by external contaminants can be viewed as a three-step process. First, the solute partitions between the external bulk phase (e.g., pore water, soil) and the pipe wall exterior. Next, the solute diffuses through the pore structure of the pipe or fitting. Finally, upon penetration the solute partitions between the internal bulk phase (e.g., pipe water) and the pipe wall interior.

Permeation can occur either from the vapor or aqueous phase. With respect to permeation of potable water mains, the contaminants of interest include highly volatile hydrocarbons and organic solvents. Therefore, both water mains and fittings installed in the vadose and saturated zones are susceptible to contamination by permeation (DWI0441, 1992).

1.2 Metals and Chemical Leaching

Leaching is a broad category that includes the dissolution of a variety of metals and chemicals into drinking water. In some instances, it is difficult to differentiate between corrosion and leaching. Studies have been conducted to determine the rate and extent of leaching from metallic, plastic, and concrete pipes, as well as various coatings, linings, and sealants. Coatings and linings are often employed to prevent corrosion of water mains and mitigate red water problems. Among the more common linings are epoxy resins, cement-mortar, asphalt (bituminous), and concrete.

2.0 Description of Potential Water Quality Problems

Table 1 provides a summary of potential water quality problems associated with permeation and leaching.

Table 1
Summary of Potential Water Quality Problems

Permeation	Leaching
Increased VOC content of distributed water[2]	Increased lead and copper levels[1]
Vinyl Chloride formation[2]	Increased asbestos levels[1]
Aesthetic issues (taste, odor, film formation)	Increased organic contaminants from PE pipe[2]
	Increased metals levels from cement pipe or linings[2]
	Increased organic contaminants from organic linings[2]
	Aesthetic issues (taste, odor, color)

(1) Health effects associated with these parameters have already been addressed by USEPA through existing Safe Drinking Water Act Regulations.
(2) Potential direct public health impact.

The following discussion focuses on the issues listed in Table 1 that can directly impact public health (denoted by a number 2) but have not been addressed through existing Safe Drinking Water Act Regulations within the distribution system.

2.1 Permeation Occurrences and Health Impacts

2.1.1 Dilution Effect

The movement of water through mains acts to dilute contaminants that have permeated the pipe wall. In a simplified hypothetical model involving clean water flowing unidirectionally through a pipe section surrounded by contaminated media (of uniform activity), the solute activity in the pipe water is related to the flow rate (Q) according to equation 2. This is referred to as convective dilution.

(2) $$a \propto 1 - e^{(-UA \cdot Q^{-1})}$$

The rate and extent of permeation is greatest for small-diameter mains and service lines (DWI0772, 1997). These water lines contain the highest ratio of mass transfer surface area to pipe volume, and are often associated with stagnant or low flow conditions (poor convective dilution). This effect is exacerbated by the greater likelihood of accidental releases of organic contaminants such as petroleum products on a customer's property and consequently, closer to the point of withdrawal or consumption.

2.1.2 Case Studies

More than 100 incidents of drinking water contamination resulting from permeation of subsurface mains and fittings have been reported in the United States (Glaza and Park, 1992). The majority of these incidents were associated with gross soil contamination in the area surrounding the pipe. The occurrence of permeation incidents was equally split between high-risk locations such as: industrial areas; former sites of fuel stations; and near underground storage tanks; and low-risk locations such as residential areas. The sources of contamination for the low-risk areas included disposal and accidental leaking of gasoline, oil, and paint thinner products (Holsen et al., 1991a).

Figure 1 illustrates the distribution system materials involved in the reported permeation incidents. Pipes composed of polymeric materials (i.e., plastics) were involved in 98% of the incidents. These materials include polybutylene, polyethylene, polyvinyl chloride (PVC), and acrylonitrile-butadiene-styrene (ABS). No reported incidents of permeation through metal-based pipe were identified.

Figure 2 illustrates the contaminants involved in reported incidents. The contaminants most likely to permeate plastic are lipophilic and non-polar in nature. Diesel and petroleum products (gasoline-range organics) were involved in 89% of the incidents, while volatile chlorinated solvents accounted for 5% of the incidents. Other contaminants that exhibit high rates of permeation include (simple) chlorinated aromatics, chlorinated and unchlorinated straight-chain aliphatic hydrocarbons, and phenolic compounds (Holsen et al., 1991a; Holsen et al., 1991b). Strongly polar pesticides (e.g. paraquat, malathion, and atrazine) and long-chained (high molecular weight) hydrocarbons were not permeation threats (DWI0032, 1990; Park et al., 1991).

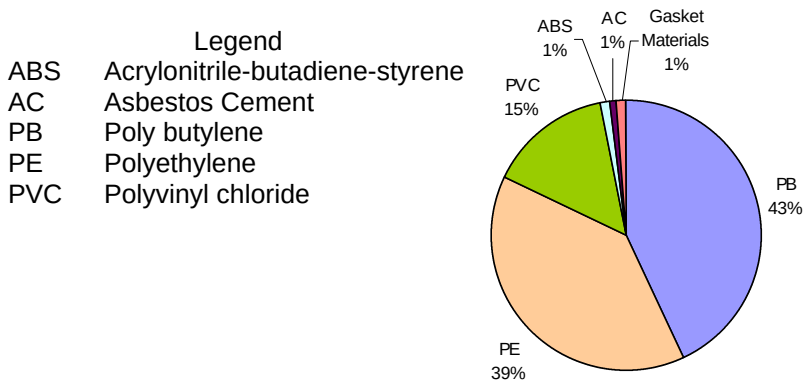

Figure 1
Pipe materials involved in U.S. water system permeation incidents (Holsen et al., 1991a)

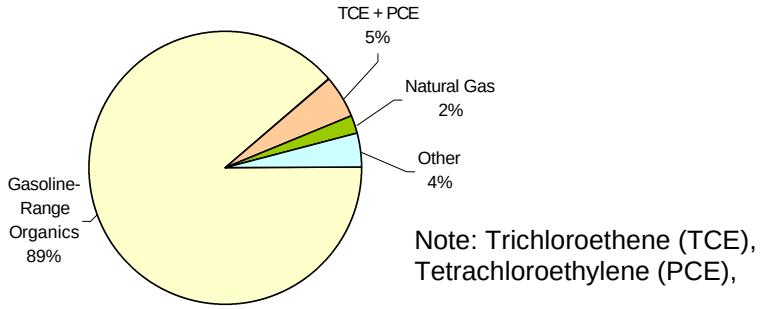

Figure 2
Contaminants involved in U.S. water system permeation incidents (Holsen et al., 1991)

The occurrence of contamination was generally identified by the customer, and indicated by an unusual taste and odor in the tap water. For many highly toxic substances incorporated in Figure 2, including benzene, vinyl chloride, and dichloromethane, the taste and odor threshold is well above the drinking water Maximum Contaminant Level (MCL) (DWI0441, 1992; Glaza and Park, 1992).

Holsen et al. (1991a) calculated the frequency of permeation incidents for both service connections (Table 2) and water mains (Table 3). The results further indicate that polymeric pipelines are most susceptible to permeation.

Table 2
Frequency of Permeation of Service Connections
(incidents per 10^6 connection-year)

Metal	Polyethylene	Polybutylene	Polyvinyl Chloride
0	3.6	16.5	2.2

Table 3
Frequency of Permeation of Water Mains
(incidents per 10^5 mile-year)

Metal	Concrete	Asbestos Cement	Polyvinyl Chloride
0.1	0	0.3	4.6

Holsen et al. (1991a) conducted an investigation of seven sites where plastic pipe permeation had been reported. All seven incidents involved polybutylene and polyethylene service connections and were associated with gross contamination of the soil surrounding the pipe. In one instance where the cause of contamination was determined to be a 10-gallon gasoline leak onto the road surface, water quality samples were collected from the service line (after 40 hours of stagnation) and analyzed for benzene, toluene, ethylbenzene, and xylene (BTEX). The results, which are presented in Table 4, indicate that the concentrations reached were higher than the numeric value of two drinking water MCLs (MCL violation would be based on annual average exceeding numeric value).

Table 4
Analytical Results from a Gasoline Permeation Incident

Contaminant	MCL (mg/L)	Water Sample (mg/L)
Benzene	5	1,300
Toluene	1,000	4,300
Ethylbenzene	700	< 500
Xylene	10,000	< 500

In March 2000, the Montana DEQ presented water quality results from another incident involving gasoline-contaminated soil. Benzene permeated a 30-inch black polyethylene service line to a concentration of 527 µg/L, over 100 times the drinking water MCL. The contact time between the pipe and contaminant was unknown.

Selleck and Marinas (1991) identified another permeation incident involving a polybutylene service connection. In this case, soil adjacent to the connection had been contaminated with chlorinated aromatics. The results of soil and service line water samples, which are provided in Table 5, indicate that contaminants were capable of permeating to concentrations above health action levels.

Table 5
Analytical Results from a Solvent Permeation Incident

Contaminant	Level of Concern (µg/L)	Water Sample (µg/L)	Wet Soil Sample (g/kg)
1,2-Dichlorobenzene	600[1]	2,500	< 0.010

(1) Numeric value of drinking water MCL; compliance with MCL is based on annual average.

2.1.3 Laboratory Studies

Laboratory studies have been conducted to determine the rate of permeation and time to penetration for several different combinations of contaminants and pipe materials. The primary limitation of these studies is the use of stagnant water columns, and the corresponding lack of convective dilution.

Park et al. (1991) presented the results of pipe-bottle studies using various mixtures of organic chemicals at varying activities. The findings (Table 6) support an important conclusion about the synergistic effects of organic mixtures. The addition of a readily permeable organic chemical to a mixture of relatively non-permeable organic chemicals increases the overall rate of permeation. This consideration is important because most chemical spills and contamination events involve mixtures of similar components (Glaza and Park, 1992).

Table 6
Penetration Times for Organic Solutions Through Polybutylene Pipe

Contaminant	Relative Concentration	Penetration Time[1] (days)	
		Pure	Mixture
Toluene	0.26	38 – 60	16
1,2-Dichlorobenzene	0.19	> 140	16
Toluene	0.24	40 – 60	9
Trichloroethylene	0.21	20	9
Trichloroethylene	0.31	9	9
1,2-Dichlorobenzene	0.24	> 80	10

(1) Defined as the time required to reach 1 mg/L in the pipe water

Joint gaskets have a high intrinsic permeability, but usually are not the primary pathway for permeation. The most common gasket materials include styrene-butadiene-rubber (SBR), chlorinated rubbers, fluorinated rubbers, nitrile rubbers, and ethylene-propylene-diene-monomers. Gaskets and seals are routinely used to join both iron and plastic pipes. According to Park et al. (1991), organic chemicals are approximately 5 to 100 times more permeable in gasket materials compared to polybutylene pipe. However, there are two reasons why most permeation events do not involve gaskets. First, the mass transfer area associated with gaskets is considerably smaller than that associated with pipelines (DWI0772, 1997). Second, gaskets are usually installed in areas where flow is continuous and flow velocities are high, which increases the dilution effectiveness (Holsen et al., 1991a).

2.1.4 Desktop Studies

The large pool of variables and boundary conditions complicate the task of quantifying pipeline permeation. Selleck and Marinas (1991) developed and presented analytical solutions for the permeation of hydrophobic contaminants through plastic water mains. The following two boundary conditions were considered:

Case 1. New pipe installed in soil subject to gross contamination
Case 2. Previously contaminated pipe flushed with clean water

The analytical solutions were used to calculate penetration times for ¾-inch polybutylene water mains exposed to a variety of organic contaminants. The results are presented in Table 7. The penetration times for the previously contaminated pipe were small, on the order of minutes. Conversely, the penetration times for the new pipe were on the order of weeks. This phenomenon has been laboratory-verified for PVC and polyethylene pipes as well. Organic chemicals and solvents promote swelling of polymeric materials, which in turn increases the rate of diffusion by several orders of magnitude (Selleck and Marinas, 1991).

Table 7
Penetration Times[1] for Polybutylene Service Lines

Contaminant	Case 1[2]	Case 2[3]
Toluene	36 days	54 minutes
1,2-Dichlorobenzene	53 days	20 minutes
1,3-Dichlorobenzene	65 days	24 minutes
Tetrachloroethylene[5]	13 days	5.5 minutes

(1) Time to: toluene ≥ 100 μg/L, 1,2-dichlorobenzene ≥ 10 μg/L, 1,3-dichlorobenzene ≥ 10 μg/L, tetrachloroethylene ≥ 5 μg/L
(2) New pipe
(3) Previously contaminated pipe flushed with clean water

These results indicate that a contamination incident cannot be corrected by simply flushing the line with clean water for a protracted period of time. Although contaminants may be removed from the internal surface, the pipe will retain its status as a swollen, highly permeable medium (Selleck and Marinas, 1991).

New PVC pipes exhibit lower permeation rates than new polyethylene or polybutylene pipes, primarily due to differences in the material matrices (DWI0772, 1997). PVC is an amorphous glassy polymer, while polyethylene and polybutylene are semicrystalline rubber. At low solute activities, PVC is virtually impermeable (penetration time of 10^5 years). However, when exposed to high activity (e.g., saturated) organic conditions, such as those that would occur during gross chemical spillage, PVC pipe is softened to the point of failure. As a result, permeation rates increase dramatically (Selleck and Marinas, 1991; DWI0772, 1997).

Thermodynamic theory indicates that hydrostatic pressure within the pipeline provides negligible resistance to permeation at the pressure range commonly found in the distribution system (Selleck and Marinas, 1991).

2.1.5 Health Impacts

Many of the contaminants involved in permeation events are regulated by federal and state drinking water standards because of known health risks. These include the Phase I, II, IIb, and V Rules of the Safe Drinking Water Act. Maximum Contaminant Levels have been established

and apply at the point of entry to the distribution system. These water quality standards are established based on risks associated with the ingestion (consumption) pathway and typically reflect health consequences resulting from long-term exposures. However, it is important to note that serious acute and chronic health effects can also occur through other pathways, including inhalation and dermal sorption (direct contact). Examples of non-consumptive water use where inhalation and dermal absorption risks may be incurred including showering and hand washing (Argonne National Laboratory Environmental Assessment Division, 2002). Potential health risks associated with these routes of exposure include skin rashes and respiratory distress.

The Chemical Health Effects Tables (U.S. Environmental Protection Agency, 2002a) provides a summary of potential adverse health effects from high/long-term exposure to hazardous chemicals in drinking water.

2.2 Leaching Occurrences and Health Impacts

ANSI/NSF Standard 61: Drinking Water System Components – Health Effects (NSF International, 2001) establishes minimum health effects requirements for the chemical contaminants and impurities that are indirectly imparted (via leaching) to drinking water from products, components, and materials used in drinking water systems. This standard does not establish performance, taste and odor, or microbial growth support requirements for drinking water system products, components, or materials.

The products and materials covered under ANSI/NSF 61 relevant to this White Paper include protective materials (coatings, linings, solvent additives, etc.), joining and sealing materials (solvent cements, welding materials, gaskets, etc.), and pipes and related products (pipes, tanks, fittings, etc.). The NSF Drinking Water Additives Program started with cooperative agreement from the USEPA in 1985. Thus, there are many distribution system materials and components that were installed prior to the adoption of NSF standards. Despite the availability of NSF-approved materials and standards, it is not possible to ensure continuous adherence to existing standards under all circumstances.

A limited survey of 7 states (OR, CA, CO, FL, WA, TX, and NY) suggests that NSF Standard 61 certification is commonly required by State Health Departments for the components of drinking water distribution systems. All seven of the primacy agencies interviewed mandate the use of materials approved under NSF 61.

The overall and general method for certifying a particular product is described herein. First, product-specific information is reviewed "to determine the appropriate analytical testing and to ensure that the potential health effects of products or materials are accurately and adequately identified". This information includes but is not limited to complete formulation information for each water-contact material (e.g. percent or parts by weight for each chemical in the formulation), the total volume of water that the product can hold when filled to capacity, the maximum temperature to which the product, component, or material is exposed during its intended end use, and a list of published and unpublished toxicological studies relevant to the chemicals and impurities present in the product, component, or material.

Appropriate analytical testing of the exposure water includes a "minimum test battery" established for a material of common formulation and/or formulation-dependent analysis for uncommon or non-standard formulations.

The extraction procedures used to generate exposure water varies by product category (e.g. pipes and related products, barrier materials, joining and sealing materials, mechanical devices and others), by application (hot or cold etc.) and by configuration, size and material composition of the individual product as applicable. Some of the variables to be selected and/or adjusted include surface area-to-volume ratio, conditioning (e.g. cleaning and pre-soaking), exposure time, and single vs. multiple time point sampling protocols, filling, emersion or other contact arrangement and initial test-water quality characteristics.

Four extraction waters are specified and available for exposure:

(1) pH = 5, with 2 mg/L available chlorine and 100 mg/L hardness;
(2) pH = 6.5, with 2 mg/L available chlorine and 100 mg/L hardness;
(3) pH = 8 (organic analysis), with 0 mg/L available chlorine and 100 mg/L hardness;
(4) pH = 10, 2 mg/L available chlorine.

Methods of preparing these waters are specified and the water or waters to be used for testing are either specified by material (e.g. the pH 6.5 water and the pH 10 water for copper and copper alloy pipe and tubing), or by formulation-specific selection criteria. Several entries within the standard direct the use of a conservative approach, for example:

> "Products or materials whose intended uses fall under more than one section of this Standard shall be evaluated under the section having the most rigorous evaluation conditions. NOTE – Rigorous conditions are typically associated with shorter conditioning periods, longer exposure periods, higher surface-to-volume ratios and higher exposure temperatures."

The results of the laboratory analysis on the exposed extraction water are normalized to determine the level of contaminants projected "at the tap". The normalized contaminant concentrations are then compared to various criteria. The water quality criteria used to evaluate the normalized concentrations come from several sources. There are normative criteria based on the contaminants regulated by the USEPA and established by Health Canada or addressed by USEPA guidance. The single product allowable concentration (SPAC) utilized by NSF Standard 61 is one tenth of the regulatory (or guidance) MCL (or MAC), except for radionuclides for which the values are the same. There are six additional substances for which a SPAC has been established by NSF International and peer-reviewed. There are over 300 additional substances listed in NSF Standard 61 as threshold-of-evaluation chemicals, for which too little data exists to determine a SPAC and for which "a comprehensive literature search for the particular substance and consideration of structure-activity relationships" must be undertaken if certain threshold concentrations are exceeded.

NSF 61 also applies "informational drinking water criteria" which includes over 60 additional compounds with SPACs that have not been peer reviewed.

2.2.1 Plastic Water Mains

Polyvinyl chloride (PVC) mains manufactured prior to 1977 contain elevated levels of vinyl chloride monomer, which are prone to leaching (Flournoy, 1999). Vinyl chloride is a toxic chemical with known carcinogenic effects; the drinking water MCL is 2 μg/L, enforceable at the point of entry to the distribution system.

Water quality samples collected from a rural water system in Kansas, which had installed over 100 miles of pre-1977 PVC, contained as much as 14 μg/L of VC. Of the 53 samples collected (from 4 unique sites) over a 6-year period, 55% exceeded the VC MCL. This finding motivated other states with pre-1977 PVC to monitor for VC within the distribution system. Other VC MCL exceedances were identified in Missouri, Iowa, Arkansas, and Texas. The study identified the following factors which promoted VC leaching:

- Small-diameter pipes (i.e., ≤ 2 inches)
- High temperature (i.e., ≥ 50 ^{o}F)
- High contact times with pre-1977 PVC pipe (i.e., ≥ 1 day)

No instances of MCL violations associated with leaching from PVC mains manufactured post-1977 were cited in the literature. Additional research is required to estimate the quantity of pre-1977 PVC mains still in use.

According to "The Handbook of PVC Pipe" (Uni-Bell, 3rd Edition) PVC pipe and fittings are immune to nearly all types of corrosion that could result in the leaching of corrosion products. The Handbook provides detailed data regarding the resistance of PVC pipe to numerous chemicals and states that PVC pipe and fittings are resistant to chemicals generally found in water and sewer systems.

Advantages and drawbacks of using plastic water mains are summarized in Table 8.

Table 8
Features of Plastic Pipe

Advantages	Drawbacks
• Resistant to chemical corrosion and tuberculation	• Vulnerable to permeation by organics
• Do not require linings	• May leach organic chemicals
• Low relative cost	• More frequent mechanical failure
• Ease of handling and installation	• Reduced strength and flexibility (kinking)

2.2.2 Cement Materials

Cement-based materials include reinforced or pre-stressed concrete pipes, cement-mortar linings, and asbestos-cement pipe. Two general components of cement-based materials include the aggregates and the binder. The binder consists of calcium silicates and calcium aluminates in various proportions depending on the type of the cement (Leroy, Schock, Wagner, and Holtschulte, 1996).

Several types of degradation of cement materials can occur in the presence of acid waters or waters aggressive to calcium carbonate (Leroy, Schock, Wagner, and Holtschulte, 1996). Waters that have a very low ion content are aggressive to calcium hydroxide contained in hydrated cements (ACIPCO, 2002). These waters will also attack calcium silicate hydrates, which form the larger portion of cement hydrates. Although calcium silicate hydrates are nearly insoluble, soft waters can progressively hydrolyze them into silica gels, resulting in a soft surface with reduced mechanical strength. Calcium hydroxide will also leach from cement-mortar linings exposed to soft waters. The extent of leaching increases with the aggressiveness of the water and its residual time in the pipe and is inversely proportional to the diameter of the pipe.

Douglas and Merrill (1991) studied the deterioration of new cement-mortar linings under various water quality conditions. Field-testing demonstrated that aggressive water is capable of leaching cement compounds from these linings, causing significant increases in bulk solution pH, alkalinity, and calcium. The pH of stagnant water held in contact with cement-mortar lined pipes for one week increased from an initial value of 7 upwards as high as 12. While convective dilution reduced the magnitude of these water quality changes, it also resulted in a greater overall extent of leaching, as indicated by the depth of the linings calcium loss. Asphaltic seal coats significantly reduced cement-mortar deterioration.

Cement materials contain a variety of regulated inorganic chemicals, many of which are prone to leaching. Guo et al. (1998) conducted laboratory tests to determine the extent of leaching from ductile iron pipes lined *in situ* with portland cement (type I) mortar. The pipes were lined and cured in accordance with ANSI/AWWA Standard C602-89, and subsequently disinfected according to ANSI/AWWA C651-92. The test water was standard faucet water from a New Jersey utility. Under static conditions, arsenic, barium, cadmium, and chromium leached from the lining to maximum values roughly 10-20% of their respective drinking water MCLs. Further, the acid-soluble contents of arsenic, barium, cadmium, and chromium in the cement coating applied were only 3, 1.9, 13, and 6.6 percent of the cement industry maximum, respectively. Therefore, the extent of leaching could have been higher if an alternate cement lining had been applied. Additional research is necessary to understand the fate of heavy metals associated with cement leaching, and the degree of accumulation within distribution systems.

According to Berend and Trouwborst (1999), the application of cement-mortar lining can also lead to aluminum leaching. The aluminum content in cement-mortar linings varies, as shown in Table 9. One of the predominant crystalline phases in cement is tricalcium aluminate, which is believed to dissolve according to the following reaction:

(3) $Ca_3Al_2O_6 + 6H_2O \rightarrow 3Ca^{2+} + 2Al^{3+} + 12OH^-$

Table 9
Aluminum Composition of Common Cement Linings (% as Al_2O_3)

Blast Furnace Cement	Pozzolanic Metallurgical Cement	High-Alumina Cement	Portland Cement	Berend and Trouwborst Study Cement
13%	13%	36%	5%	18.7%

Aluminum poses serious health risks to hemodialysis patients. The European Union defines a maximum aluminum concentration of 30 µg/L in water used for hemodialysis. The USEPA has established a Secondary MCL range for aluminum of 50-200 µg/L.

In the study by Berend and Trouwborst (1999), the installation of 7,200 feet of cement-mortar lined ductile iron pipe caused aluminum levels in a water supply to increase from 5 µg/L to 690 µg/L over the course of 2 months. More than two years later, aluminum continued to leach from the lining and produce water with over 100 ìg/L of aluminum. This was attributed to several illnesses and a 32% mortality rate at a receiving dialysis center. The water in contact with the pipe was seawater that had been desalinated and subsequently treated with coal-filtration, fluoridation, and UV disinfection. The water was aggressive (maximum Langelier Index between –0.5 and –1.5), soft (hardness 15-20 mg/L as $CaCO_3$), of low alkalinity (no data) and high pH (8.5 to 9.5). The pipe had been lined with cement mortar at the factory by a rotary centrifugal process.

Aggressive, soft, and poorly buffered (i.e., low alkalinity) waters promote aluminum leaching from cementitious materials. These are the same water quality conditions that are conducive to leaching of lead and copper. The Lead and Copper Rule (USEPA, 1991) specifies a minimum pH within the distribution system of 7.0, but does not specify minimum alkalinity levels. Utilities are required to maintain optimal water quality parameters at the point of entry to the distribution system and at several locations within the distribution system to minimize lead and copper leaching at the tap.

The extent of leaching is also strongly related to the contact time between the water and the cement-mortar lining. In the study by Berend and Trouwborst (1999), the average contact time was 2.3 days.

Polyphosphate corrosion inhibitors attack and soften cement linings, thereby accelerating cementitious leaching. These corrosion inhibitors can also chelate and complex with soluble calcium and aluminum.

2.2.3 Bituminous Coatings and Linings

Asphalts and coal tars are bituminous materials that occur naturally or are derived from non-destructive separation of petroleum fractions. Bituminous coatings contain a complex mixture of many chemical compounds, the exact composition of which depends upon the individual source. Historically, the use of bituminous coatings has resulted in problems when exposed to soft,

acidic waters. Among these problems are red water discoloration, extensive tuberculation, and loss of carrying capacity.

The material properties of the coating systems are enhanced by the use of additives, the most obvious of which are the solvents used as a vehicle for application. However, these additives can diffuse through the coating and into the pipe water. Elevated levels of alkyl benzenes and polycyclic aromatic hydrocarbons (PAHs) have been reported in reservoirs with new bituminous coatings and linings (Yoo et al, 1984; Krasner and Means, 1985; Alben, 1980). While few additives from coating materials are included in prioritized lists of SOCs to be monitored in drinking water, proper application, curing, and testing prior to returning coated surfaces to service will minimize subsequent exposure to solvents used in application.

Alben et al (1989) studied leaching of organic contaminants from flat steel panels lined with various coatings, including vinyl, chlorinated rubber, epoxy, asphalt, and coal tar. Emphasis was given to the rate of leachate production and leachate composition. The test water was GAC processed tap water with a pH of 8 to 9. Leaching rates (mg/m^2-day or μg/L-day) were assessed over a period of 30 days. Organic contaminants were found at parts-per-billion levels in water compared to parts-per-thousand levels in the coating.

Concentrations of total organic carbon (TOC) in leachate from asphalt were the lowest of the five coatings studied. Alkyl benzenes constituted 72% of the leachate from asphalt coating. Based on the results of 30-day laboratory experiments with asphalt-coated test panels (coating thickness 536 μm), the rates of leaching were predicted for full-scale storage tanks with volume to surface area ratios ranging from 8.2 to 37.7 ft^3/ft^2 (2.5 to 11.5 m^3/m^2). Initial rates of leaching for the semi-volatile base-neutrals were found to range from 0.4 to 1.7 μg/L-day; after 30 days the rates dropped to 0.2 to 1.0 μg/L-day.

Concentrations of TOC in leachate from coal tar were the second lowest of the five coatings studied (2 bituminous and 3 polymeric coatings). PAHs accounted for essentially all of the TOC in leachate from coal tar coating. Based on the results of 30-day laboratory experiments with coal tar-coated test panels (coating thickness 2,746 μm), the rates of leaching were predicted for full-scale storage tanks with volume to surface area ratios ranging from 8.2 to 37.7 ft^3/ft^2 (2.5 to 11.5 m^3/m^2). Initial rates of leaching for the PAHs were found to range from 2.6 to 12 μg/L-day; after 30 days the rates were similar at 2.3 to 11 μg/L-day.

There have been incidents of PAH leaching from coal tar linings that have ultimately led to taste and odor complaints. In one particular case, a butterfly valve failed while in the closed position, thus creating an artificial dead-end along a pipe stretch coated with coal tar. Upon repairing the valve and reopening it, the utility received several odor complaints. Water quality sampling revealed that anthracene, naphthalene, and other PAHs were present at concentrations in excess of 5,000 μg/L (Satchwill, 2002).

2.2.4 Epoxy Coatings and Linings

Epoxy coating starts out as a dry powder which is produced by combining organic epoxy resins with appropriate curing agents, fillers, and pigments. When heated, the powder melts and its constituents react to form complex cross-linked polymers.

Alben et al (1989) studied leaching of organic contaminants from epoxy-coated flat steel panels, with emphasis on the rate of leachate production and leachate composition. The test water was GAC processed tap water with a pH of 8 to 9. Leaching rates (mg/m^2-day or μg/L-day) were assessed over a period of 30 days and found to decay as a simple exponential.

Concentrations of TOC in leachate from epoxy resin were the highest of the five coatings studied (2 bituminous and 3 polymeric coatings). The solvents methyl isobutyl ketone (MIBK), ortho-, meta-, and para-xylene represented a major portion (51%) of leachate from the epoxy coating. Based on the results of 30-day laboratory experiments with epoxy-coated test panels (coating thickness 393 μm), the rates of leaching were predicted for full-scale storage tanks with volume to surface area ratios ranging from 8.2 to 37.7 ft^3/ft^2 (2.5 to 11.5 m^3/m^2). Initial rates of leaching for the solvents were found to range from 40 to 187 μg/L-day; after 30 days the rates dropped to 8 to 37 μg/L-day.

These findings were further supported by field studies. Solvents (MIBK, xylenes) from an epoxy coating were also detected in effluent from 2 of 3 storage tanks that were monitored one month after application of the coating (Alben et al, 1989).

The extent of leaching of organic contaminants from epoxy resin linings was found to be strongly dependent on the duration of the curing process (DWI0032). Longer curing periods produced more stable linings.

The City of Calgary performed leaching studies with pipe coupons coated with two-component epoxy resins (Satchwill, 2002). Five different NSF and AWWA approved epoxy resins were independently investigated. Application and curing of the epoxy resin involved the following steps: (1) applying the initial coating followed by verification that application meets wet film thickness specification, (2) 24 hours of air drying followed by verification that application meets dry film thickness specification, (3) applying a second epoxy coating (followed by verification), and (4) 24 hours of air drying (followed by verification.) The coupons were then filled with water and held for 72 hours prior to analysis for TOC and VOCs. The results, which are provided in Table 10, illustrate the extreme extent of leaching from new epoxy resins into stagnant water columns.

Table 10
72-Hour Epoxy Resin Leaching Results

Coating	BTEX (mg/L)	TOC (mg/L)
Epoxy 1	13.2	166
Epoxy 2	4.9	34
Epoxy 3	48.0	279
Epoxy 4	0.2	345
Epoxy 5	25.6	143

Benzyl alcohol and epoxy resin oligomers have been identified in leachate from epoxy coated water mains (Crathorne et al, 1984; Watts et al, 1983).

3.0 Prevention and Mitigation Methods

3.1 Indicators

The majority of the contaminants of concern with respect to permeation and leaching events are organic chemicals, including volatile, semi-volatile, and non-volatile substances. While many of these contaminants are regulated under national and/or state drinking water standards, and are thus monitored at the source, others fall into the class of unregulated organics. Some of these unregulated contaminants are potential health concerns and are listed on the Contaminant Candidate List (CCL) under the Unregulated Contaminant Monitoring Rule (UCMR).

Source water quality monitoring will not aid in detecting contamination events that occur within the distribution system, including permeation and leaching. However, there are other methods and indicators that can be used to prevent and identify contamination events. The following potential indicators are addressed:

- Taste and odor of tap water
- Installation inspection/Site use review
- Environmental monitoring
- Release to service monitoring

3.1.1 Taste and Odor of Water

Taste and odor (T&O) complaints have previously led to the identification of gross subsurface contamination. The key question in this regard is whether or not T&O detection is useful for identifying a contamination event *before* significant health risks are incurred (through consumption). Table 11 provides a comparison of risk thresholds versus T&O thresholds for several organic substances commonly involved in permeation and leaching events. The effect of mixing chemicals on the T&O thresholds is unknown.

Table 11
Organoleptic versus Risk Thresholds for Pure Compounds

Contaminant	MCL	Taste Threshold	Odor Threshold	Detectable Before Risk? (3)
Benzene	5 µg/L	500-4,500 µg/L	2,000 µg/L	No
Ethylbenzene	700 µg/L	29 µg/L	29 µg/L	Yes
Xylenes	10 mg/L	No Data	2.2 mg/L	Yes
Naphthalene	300 µg/L[1]	No Data	300 µg/L	No
1,2-Dichloroethane	5 µg/L	29,000 µg/L	No Data	No
Tetrachloroethylene (PCE)	5 µg/L	300 µg/L	No Data	No
Methyl Isobutyl Ketone (MIBK)	500 µg/L[2]	No Data	20,000 µg/L	No
Vinyl Chloride	2 µg/L	None	None	No
Styrene	100 µg/L	730 µg/L	No Data	No

(1) State of New Jersey MCL
(2) State of Wisconsin MCL
(3) Health risk level based on long-term exposure.

In most instances, the risk threshold is substantially lower than either the taste or odor thresholds. However, while there are contaminants for which the organoleptic thresholds are lower than the levels where long-term exposure is a concern, the most prevalent sources of contamination are events like petroleum product releases where a combination of compounds with varying organoleptic and risk thresholds will be present.

3.1.2 Installation Inspection/ Site Use Review

There are currently no certification requirements in published literature for installers or inspectors with regard to identifying potential subsurface contamination or installing pipes or fittings in regions of potential contamination. Standards ANSI/AWWA C900 through C950 cover plastic pipe and recommend consultation with the pipe manufacturer prior to selecting a material if a water main must pass through an area of gross contamination. The UPC specifies that clean soil be used as backfill around buried pipes.

Activities and procedures that are typical of construction within areas believed to be at significant risk of contamination include reviewing site use(s) and performing environmental monitoring during installation.

Historical and current site use will allow the construction team to assess the probability of contamination as well as the specific contaminants for which to look. The contamination of soil and/or groundwater by highly permeable substances can often be identified during construction activities through the use of air quality monitoring equipment and/or passive soil gas surveys. Gas chromatographic instruments, including photo-ionization detectors (PIDs) and flame-ionization detectors (FIDs), are tools that can be used to detect hydrocarbons in the vapor phase (or headspace) at the parts-per-million level. Passive soil gas sampling involves the use of specially designed sorbents to capture volatile and semi-volatile organic compounds in soil and

water. Passive soil gas sampling provides quantitative, time-integrated data of organic contamination.

3.1.3 Monitoring

Monitoring is critical to ensure that a new or rehabilitated main can be safely released to service. Some utilities have developed water quality "release to service" standards for new and repaired mains. Typical monitoring parameters include total coliform bacteria, HPC, pH, disinfectant residual, turbidity, and odor. However, monitoring for additional parameters may be warranted based on knowledge of materials used and/or site-specific water quality or environmental conditions. For example, monitoring for BTEX and MIBK following application of an epoxy coating can be used to evaluate the extent of leaching and potentially identify problems with the lining material or manufacturers defects.

3.2 Maintenance

Stagnation of water can exacerbate permeation and leaching incidents. Poor convective dilution of permeated or leached solvents is associated with stagnant areas of the distribution system. The extent of leaching of cementitious and organic material exhibits some relationship to the contact time between the pipe and internal water. Unidirectional flushing and reservoir turnover can be used to encourage fluid movement, minimize residence time, and replace stagnant water. Flushing does not suppress the process of leaching, but the movement of fluid helps to prevent the accumulation of contaminants in a localized area. Studies have demonstrated the ineffectiveness of flushing to mitigate a permeation incident. While flushing may replace the contaminated water, the pipeline retains its swollen, highly permeable state. In these instances, pipe replacement is an effective practice.

With respect to permeation, most incidents occur along service connections due to their small diameter and frequent stagnation, however, service lines are not owned by the utility (USEPA, 1999). Thus, in the event of a permeation event involving a service connection the consumer would need to flush the tap long enough to draw water from a point beyond the service line to avoid exposure to potentially contaminated water.

3.2 Design and Installation

Prevention of permeation and leaching requires proper materials selection and installation practices. The phenomena of permeation and leaching require consideration of the environments surrounding and within the pipe, respectively. From a design perspective, permeation can be precluded by identifying the area of installation and recognizing the potential for past or future gross spillage of organic chemicals and petroleum products.

ANSI/AWWA Standards C900 through C950 state that if a water main must pass through an area of gross contamination, the manufacturer should be consulted regarding the permeation of pipe walls and joint fittings prior to selecting the material. The Standards also note that research has documented that pipe materials such as polyethylene, polybutylene, polyvinyl chloride, and asbestos cement; and elastomers, may be subject to permeation by lower molecular weight

organic solvents or petroleum products. Ten State Standards (Great Lakes…1997) states that non-permeable materials shall be used for all portions of the system including water mains, service connections, and hydrant leads in areas of distribution systems where the groundwater is contaminated by organic compounds. The Uniform Plumbing Code does not discuss permeation directly. It does state that clean soil will be used as backfill around buried pipes and seems to recognize some potential for contamination from the pipe-embedment environment The UPC does not, however, specifically address installation through contaminated soils or permeation as a pathway of exposure.

To prevent leaching from cement-based pipes and linings, knowledge of water quality is necessary when determining the appropriateness of certain materials. ANSI/AWWA Standard C401-98 provides guidance on the application of asbestos cement pipes based on internal water quality characteristics, as summarized in Table 12.

Table 12
Aggressiveness of Water towards Asbestos-Cement Pipe

Water Type	pH + log(AH)	Langelier Index	Recommended Pipe Type
Highly Aggressive	< 10.0	< -2.0	*
Moderately Aggressive	10.0 – 11.9	-2.0 to –0.1	II
Nonaggressive	≥ 12.0	≥ 0	I and II

Source: ANSI/AWWA Standard C401-98
*The serviceability of pipe for such applications should be established by the purchaser in conjunction with the manufacturer
Type I – no limit on uncombined calcium hydroxide
Type II – 1.0% or less uncombined calcium hydroxide
A = Alkalinity as mg/L $CaCO_3$; H = Calcium hardness as mg/L $CaCO_3$

The rate of leaching of organic additives was found to decrease exponentially with time. Therefore, it is recommended that newly lined pipes be pre-soaked prior to release to service. Normal hydrostatic testing and disinfection activities will help remediate leaching. Extending the curing process will also help improve the stability of epoxy linings.

Additional Standards applicable to design, installation, and application of pipelines, linings, and coatings are summarized below:

- AWWA Manual M9 provides information related to design, handling, delivery, laying, field testing, and disinfection of concrete pressure pipe.
- AWWA Standard C600-606 covers pipe installation procedures
- ANSI/AWWA C104 through C153 covers ductile iron pipe, fittings, linings, coatings, gaskets, and joints.
- ANSI/AWWA C200 through 222 covers steel pipe, linings, coatings, and joints.
- ANSI/AWWA C300 through 304 covers concrete pipe.
- ANSI/AWWA C400 through C403 covers AC Pipe.
- ANSI/AWWA C800-89 covers service lines.

3.3 Source Water Treatment

Water quality plays in important role in the process of materials leaching. Key parameters in this regard include pH, alkalinity, and dissolved inorganic ions. Water quality parameter requirements for minimizing soluble lead and copper levels are provided in the Lead and Copper Rule (USEPA, 1991). Suitable water quality conditions for the installation of asbestos-cement pipe were summarized previously.

Based on a study by Brend and Trouwborst (1999), aluminum leaching from portland cement and blast furnace slag cement only occurred in low alkalinity water. Based on this study, the following recommendations were established:

- In-situ linings of ordinary portland cement should not be used if the alkalinity is less than 55 mg/L as $CaCO_3$.
- Factory-applied cement linings should not be used if the alkalinity is below 25 mg/L as $CaCO_3$.

Vik and Hedberg (1991) provided the following recommended water quality conditions to avoid leaching of cement-based materials, including AC and concrete pipes and cement mortar lining.

- pH > 7
- Alkalinity > 15 mg/L as $CaCO_3$
- Calcium > 10 mg/L
- Sulfate < 200 mg/L
- Aggressive CO_2 < 5 mg/L

4.0 Summary

Distribution system infrastructure and appurtenances including piping, linings, fixtures, and solders can react with the water they supply as well as the external environment. Permeation and leaching are two mechanisms that can result in the degradation of the distributed water. Leaching from cement linings can occur in soft, aggressive, poorly buffered waters. Under static conditions, metals such as aluminum, arsenic, barium, chromium, and cadmium can leach from cement linings, even when NSF approved materials are used and linings are applied according to AWWA standards. Current provisions of the Safe Drinking Water Act do not require monitoring for heavy metals beyond the point of entry to the distribution system, and additional research would be required to assess the degree of metals accumulation within the distribution system. Vinyl chloride can leach from pre-1977 PVC pipe. No instances of MCL violations were cited in association with post 1977 PVC pipe. Volatile organics present in the ground water or vadose zone can permeate plastic piping and gaskets. Permeation is typically most severe for small diameter, low-flow pipes. The literature cites instances where MCL violations have occurred at the point of consumption, although current provisions of the Safe Drinking Water Act do not require monitoring for volatile organic compounds beyond the point of entry to the distribution system. In most instances, the risk threshold of chemical contaminants is substantially lower than either the taste or odor thresholds, suggesting that utilities cannot rely

confidently on customers' perception of taste and odor for identifying contamination events. Unidirectional flushing can be used to rid the distribution system of stagnant, contaminated water, but additional research is needed to determine the fraction of heavy metals and organics that can be removed through flushing. Permeated plastic piping must be replaced since the piping retains its swollen porous state after permeation. NSF Standard 61 and numerous AWWA Standards have been developed to prevent the degradation of drinking water due to contact with piping materials. Materials selection, design, and installation considerations based on water quality and environmental conditions are addressed in these Standards.

Bibliography

ACIPCO. "Linings." June 12, 2002. <http://www.acipco.com/international/products/Sec13.pdf>

Alben, K., Bruchet, A., and Shpirt, E., January 1989. *Leachate from Organic Coating Materials Used in Potable Water Distribution Systems*. Denver, CO, AWWARF.

ANSI/AWWA Standard C401-98. *The Selection of Asbestos-Cement Pressure Pipe, 4 In. through 16 In. (100 mm through 400 mm), for Water Distribution Systems*. AWWA, Denver, CO.

Argonne National Laboratory Environmental Assessment Division. "Identify Potential Exposure Pathways." *The Ecological Risk Assessment Process*. June 12, 2002. <http://web.ead.anl.gov/ecorisk/process/html/ch2/2.3.6.htm>

Benjamin, M., H. Sontheimer, P. Leroy, 1996. Internal Corrosion of Water Distribution Systems. AWWARF and TZW. Denver, Co.

Berend, Kenrick and Trouwborst, Tom, July 1999, "Cement-mortar pipes as a source of aluminum, "*Journal AWWA*, Vol. 91 No. 7, pp. 91-100.

Bureau of Environmental Health Assessment and Massachusetts Department of Public Health, October 1997, "Health consultation, Duxbury Water Distribution, Duxbury, Plymouth County, Massachusetts," http://www.atsdr.cdc.gov/HAC/PHA/duxbury/dux_p1.html

Douglas, B.D., Merrill, D.T., December 1991. *Control of Water Quality Deterioration Caused By Corrosion of Cement-Mortar Pipe Linings*. Denver, CO: AWWARF.

DWI0032, March 1990, "Effect of Distribution on Organic Contaminants in Potable Water," FWR.

DWI0441, May 1992, "Effects of Organic Chemicals in Contaminated Land on Buried Services," FWR.

DWI0772, December 1997, "Permeation of Benzene, Trichloroethene and Tetrachloroethene through Plastic Pipe," FWR.

Flournoy, Ralph L., Monroe, David, Chestnut, Naima-Halim, and Kumar, Vinita, June 1999, "Health Effects from Vinyl Chloride Monomer Leaching from pre-1977 PVC pipe," 1999 AWWA Annual Conference Proceedings.

Glaza, Edward C. and Park, Jae K., July 1992, "Permeation of Organic Contaminants Through Gasketed Pipe Joints," *Journal AWWA*, Vol. 84 No. 7, pp. 92-100.

Great Lakes Upper Mississippi River Board of State Public Health & Environmental Managers. 1997. *Recommended Standards for Water Works*. Albany, NY: Health Education Services.

Guo, Qizhong, Toomuluri, Parvati J., and Eckert, James O., March 1998, "Leachability of regulated metals from cement-mortar linings," *Journal AWWA*, Vol. 90 No. 3, pp. 62-73.

Hammer, Bill, March 2000, News Release - Montana Department of Environmental Quality, http://www.dep.state.mt.us/press/press2000/PR031700.asp.

Holsen, Thomas M., Park, Jae K., Jenkins, David, and Selleck, Robert E., August 1991, "Contamination of Potable Water by Permeation of Plastic Pipe," *Journal AWWA*, Vol. 83 No. 8, pp. 53-56.

Holsen, Thomas M., Park, Jae K., Bontoux, Laurent, Jenkins, David, and Selleck, Robert E., November 1991, "The Effect of Soils on the Permeation of Plastic Pipes by Organic Chemicals," *Journal AWWA*, Vol. 83 No. 11, pp. 85-91.

Kirmeyer, G., M. LeChevallier, M. Friedman, J. Funk, K. Martel, M. Karim, and J. Harbour. 2001. *Pathogen Intrusion Into the Distribution System*. Denver, CO: AWWARF and AWWA.

Leroy, P., M. Schock, I. Wagner, and H. Holtschulte. 1996. Internal Corrosion of Water Distribution Systems. AWWARF and TZW. Denver, Co.

National Sanitation Foundation. 2001. NSF Standard 61 Drinking Water System Components—Health Effects. ANSI/NSF Standard 61. National Sanitation Foundation International.

Park, Jae K., Bontoux, Laurent, Holsen Thomas M., Jenkins David, and Selleck, Robert E., October 1991, "Permeation of Polybutylene Pipe and Gasket Material by Organic Chemicals," *Journal AWWA*, Vol. 83 No. 10, pp. 71-78.

"Plastics Contaminate Tap Water with Hormone Disruptors," ENDS Report, June 1999, Issue 293

Satchwill, Trevor. "The Impact of Pipe Coatings on Drinking Water Quality." June 12, 2002. <http://www.awwoa.ab.ca/Acrobat/PipeCoatings.pdf>

Selleck, Robert E. and Marinas, Benito J., July 1991, "Analyzing the Permeation of Organic Chemicals Through Plastic Pipes," *Journal AWWA*, Vol. 83 No. 7, pp. 92-97.

Snoeyink, V., and I. Wagner. 1996. Internal Corrosion of Water Distribution Systems. AWWARF and TZW. Denver, Co.

State of California. June 12, 2002. <http://www.swrcb.ca.gov/resdec/wqorders/1998/wqo98-10.html>

Symons, James M., L. C. Bradley, T. C. Cleveland, 2000. The Drinking Water Dictionary. AWWA, Denver, CO.

Thompson, C. and Jenkins, D., 1987. *Review of Water Industry Plastic Pipe Practices*. Denver, CO. AWWARF.

Uni-Bell PVC Pipe Association. Handbook of PVC Pipe, Third Edition. Dallas, Texas.

USEPA, "Technical Factsheet on Benzene." June 12, 2002. <http://www.epa.gov/safewater/dwh/t-voc/benzene.html>

USEPA, "Technical Factsheet on Ethylbenzene." June 12, 2002. <http://www.epa.gov/safewater/dwh/t-voc/ethylben.html>

USEPA, "Technical Factsheet on Vinyl Chloride." June 12, 2002. <http://www.epa.gov/safewater/dwh/t-voc/vinylchl.html>

USEPA, "Technical Factsheet on Styrene." June 12, 2002. <http://www.epa.gov/safewater/dwh/t-voc/styrene.html>

U.S. Environmental Protection Agency. 2002a. Chemical Health Effects Tables. http://www.epa.gov/safewater/tcrdsr.html. May 7, 2002.

USEPA, July 1998, Volatile Organic Chemicals Rule (Phase 1) (Final), Fed. Reg.

USEPA, 1994. Office of Pollution Prevention, Chemical Fact Sheet. EPA 749-F-94-021

USEPA, July 1991, Lead and Copper Rule (Final), Fed. Reg.

USEPA, 1991, Phase II National Primary Drinking Water Regulations, Fed. Reg.

Vik, E.A., and T. Hedberg. 1991. Corrosion and Corrosion Control in Drinking Water Systems. In Proc. *Of a Corrosion Workshop and Seminar in Oslo, Norway, March 19-21, 1990*. Houston, Texas: National Association of Corrosion Engineers (NACE).

Virginia Department of Health. "Petroleum Products." June 12, 2002. <http://www.vdh.state.va.us/HHControl/petrofac.pdf>

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