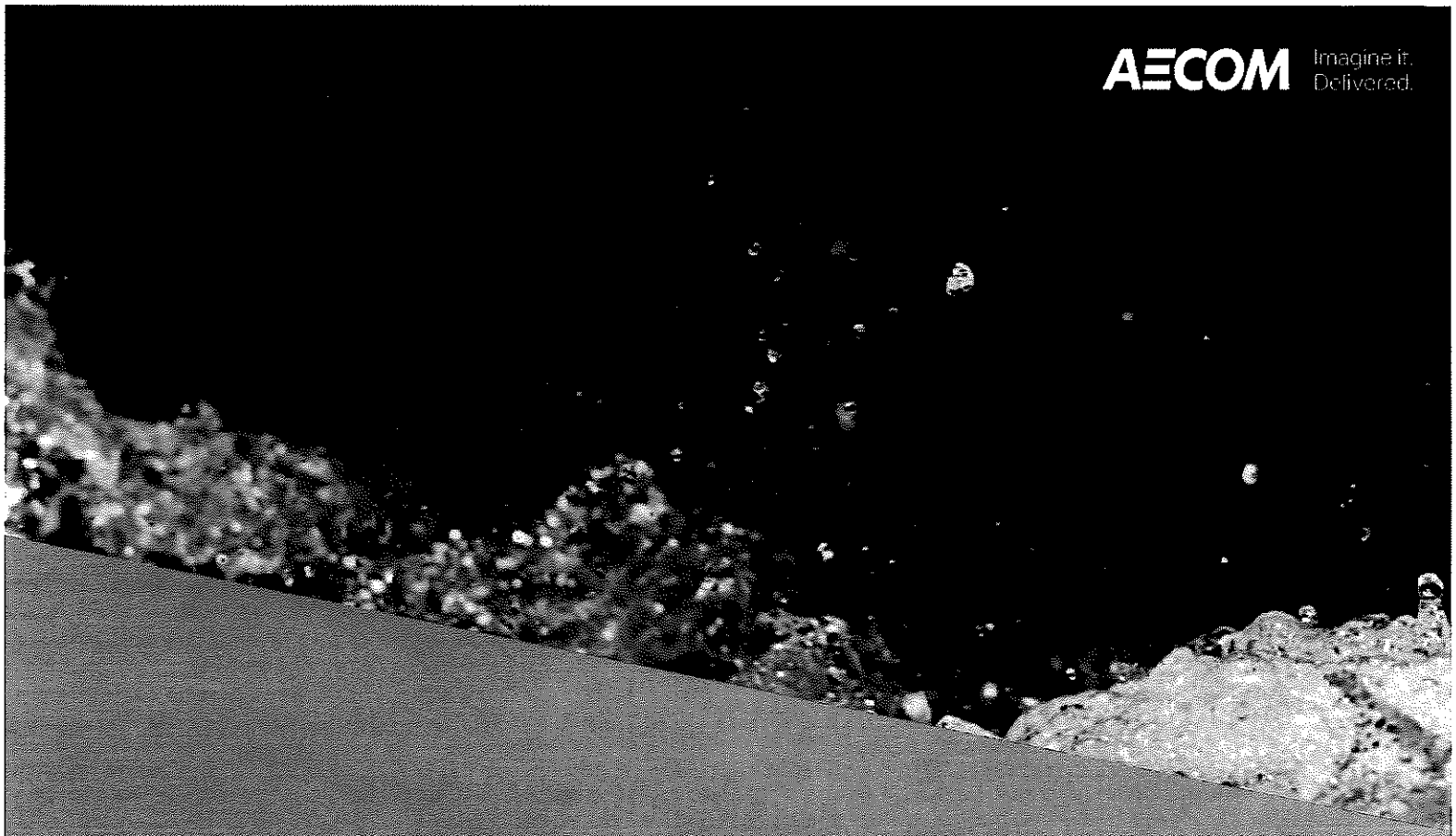

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Emergency Water Supply Interconnections Evaluation and Conceptual Design

Bethlehem Authority

Project number: 60637597

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Executive Summary

Background

The previous Emergency Water Supply Feasibility Study (Study) conducted for the Bethlehem Authority (Authority) recommended improving existing interconnections and installing new interconnections so that, if the Authority's water supply was compromised, a maximum demand of up to 15 mgd could be reliably provided from its neighboring utilities. For dates when system demands would normally exceed 15 mgd, available storage within Bethlehem's system would be utilized. However, demand restrictions are recommended during periods when Bethlehem is relying on neighboring utilities' supply. The supplying utilities are Lehigh County Authority (LCA), Easton Suburban Water Authority (ESWA), Northampton Borough Municipal Authority (NBMA), Upper Saucon Water & Sewer, Hellertown Borough Authority, Bath Borough Authority, and Salisbury Township. This Interconnection Evaluation and Concept Design memo identifies improvements needed to make the interconnections viable and provides concept designs for the recommended improvements. The evaluation included flow testing at the interconnections, associated distribution system modeling and development of interconnection system concepts. Interconnection improvements recommended by the previous Study were evaluated further by comparing the feasibility and cost effectiveness of the following four scenarios:

1. Existing piping with the Bethlehem Water Treatment Plant (WTP) supplying the demand.
2. Existing piping with the neighboring interconnections supplying the demand without the WTP.
3. Proposed piping improvements with the WTP supplying the demand.
4. Proposed piping improvements with the interconnections supplying the demand without the WTP.

Flow and Pressure Testing

Water distribution system flow and pressure data were collected via hydrant flow tests to assess how the Authority's and neighboring utility's water system would react under conditions with interconnections active. Pressure and flow tests involve opening one or more hydrants to flow while measuring pressure at one or more nearby hydrants. Test plans are provided in Appendix A and test results are provided in Appendix B. Data from these tests were used to calibrate the hydraulic model and assess improvements needed for effective interconnections.

Model Calibration

Bethlehem's WaterGEMS water distribution system model was calibrated to better match the results of 10 hydrant flow tests conducted near or at the interconnections. To calibrate the model, scenarios were set-up to match conditions of the flow tests including flow demands, tank levels, and valve settings, and model input was modified to reach closer agreement with the measured pressures. The model was calibrated to match the measured static pressures within +/-3-4 psi and residual pressures within +/- 5-7 psi, respectively.

Interconnection Evaluation

There are several options for upgrading or improving Bethlehem's interconnections with its neighboring utilities, depending on the existing conditions at the interconnections. Ideally, pressure loss on either side of the interconnections would be minimal to maintain an acceptable level of service. To minimize service reduction, water mains carrying flows to and from the interconnections would be sized to convey flows with limited pressure loss. In some cases, the hydraulic grades on the supplying side of interconnections would be high enough to deliver the average day demand to Bethlehem without infrastructure improvements, but this would result in significant pressure loss and would therefore only be recommended for shorter duration outages.

The calibrated Bethlehem system model was run under the four evaluation scenarios to assess the emergency supply capacity from existing interconnections and potential improvements needed to meet Bethlehem's demands while maintaining an acceptable level of service for its customers. Impacts to other utilities' distribution system when activating interconnections were evaluated through desktop analysis of water main friction loss from the nearest storage facility to the interconnection at the target interconnection flow. The results of these analyses were used to estimate the hydraulic gradeline (HGL) at the interconnection locations for both utilities and identify whether pumping or pressure reduction would be required. With the exception of NBMA-1, all other interconnections were found to require pumping to lift the water from the serving utility to the HGL that would be required in Bethlehem to maintain acceptable system pressures and flows. Some of the interconnections may be feasible without piping improvements but would require greater pumping horsepower. In addition, the possibility of partial supply at limited pressures without pumping was considered.

Based on the results of the flow testing and hydraulic modeling, the final target supply for interconnections from the LCA and ESWA system differ from the values recommended in the previous Study. A maximum demand of up to 15 mgd can be supplied to the Authority's system, with 13.5 mgd supplied through improved or new interconnections with LCA, ESWA, NBMA and Upper Saucon and 1.5 mgd supplied via interconnections with Bath, Hellertown and Salisbury (assuming additional infrastructure improvements). These differ from the values recommended in the previous study because a review of the system hydraulics found limitations on the amount that could be supplied from the Upper Saucon Quarry source. Accordingly, the Upper Saucon supply was reduced and the amounts recommended from LCA, ESWA, and NBMA were incrementally increased.

Final Recommended Interconnection Flows

ID	Study ID	Connection	Final Recommended Supply (mgd)
IC 1	LCA-1	Allentown: Central Park W.	1.1
IC 2	LCA-2	Allentown: W Broad and	1.6
IC 3	LCA-3	Allentown: Club and	2.6
		Total LCA	**5.3**
IC 4	ESWA-1	Easton: Interconnection	1
IC 5	ESWA-2	Easton: Interconnect Green	1.25
IC 6	ESWA-3	Easton: Scherman Blvd at	0.625
IC 7	ESWA-4	Easton: Tamarind Dr and	0.625
IC 8	ESWA-5	Easton: Sapphire Lane and	1.1
IC 9	ESWA-6	Easton: Shannon Ave	1
		Total ESWA	5.6
IC 10	NBMA-1	Northampton Borough	1.6
IC 11	US-1	Upper Saucon	1
IC 12	HE-1	Hellertown Connection	0.5
IC 13	BA-1	Bath Interconnects	0.5
IC 14	SA-1	Salisbury Twp. Interconnect	0.5
		Total Supply All Utilities	**15**

For dates when system demands would normally exceed 15 mgd, available storage within Bethlehem's system would be utilized. However, demand restrictions are recommended during periods when Bethlehem is relying on neighboring utilities' supply. Salisbury and Hellertown each have existing interconnections with Bethlehem and Bath Borough serves a portion of Bethlehem that is not connected to the remainder of the distribution system so additional infrastructure improvements not developed herein would be required for these utilities.

Comparisons were made of the water quality characteristics including the disinfectant and corrosion control chemicals used, constituents that could impact disinfectant residual and like pH, TOC, alkalinity. In addition, the impact of larger mains at the periphery of the distribution system was considered.

Interconnection Concept Design

The duration of Bethlehem's raw water supply outage is uncertain and would be affected by many factors. A short-term outage of a few days might be weathered with customers experiencing lower pressures and degraded water quality. Where interconnections don't already exist, short-term interconnections could be as simple as connecting temporary piping between hydrants in Bethlehem and the supplying utility. Some interconnections would require additional water mains to make these new connections feasible. This simplified approach may result in reduced pressures and available fire flows. A longer-term outage might require additional infrastructure such as meter vaults and temporary pumping and/or chemical feed. Catastrophic loss of the raw water supply conduits might extend for several months or longer and the interconnections would need to be fully developed to help keep operations in Bethlehem and the supplying utilities as close to normal as possible. In this report, the concept designs and opinions of probable cost are based on full developed interconnections.

All interconnections were evaluated for one-way flow from the connected utility into Bethlehem. It may be determined that Bethlehem could supply flows in the opposite direction in case of an emergency in the other utility. Flow meters are available that can measure flows in two directions and totalize these flows for revenue purposes. The cost differential for bidirectional meters compared with unidirectional meters is estimated to be about 50% per meter or about $3,500 for a 6-inch meter and $2,500 for a 4-inch meter.

Concept designs were developed for each interconnection including water main improvements, meter vaults, pumping facilities (where required), pressure reducing facilities (where required), and chemical feed facilities (where required). Concept design drawings for each interconnection are located in Appendix D. Appendix E provides a closer scale view into potential locations for the proposed interconnection facilities. Quantities were estimated for each of the recommended interconnection improvements and are tabulated below.

Water Main and Appurtenance Improvements for Interconnections

Connection ID	Bethlehem Infrastructure Improvements				Connecting Utility Infrastructure Improvements			
	Water Main (ft)	Hydrants	Gate Valves	Fittings	Water Main (ft)	Hydrants	Gate Valves	Fittings
LCA-1	3,122 (R)	1	26	16	980 (R)	1	11	5
LCA-2	2,229 (R)	1	15	8	0	1	1	0
LCA-3	0	1	1	0	0	1	1	0
LCA Subtotal:	**5,351**	**3**	**42**	**24**	**980**	**3**	**13**	**5**
ESWA-1	0	1	1	0	0	1	1	0
ESWA-2	0	1	1	0	395 (R)	1	3	1
ESWA-3	0	1	1	0	189 (N)	1	2	1
ESWA-4	946 (R)	1	6	3	230 (N)	1	2	1
ESWA-5	749 (N)	4	3	2	0	0	1	0
ESWA-6	2,815 (R)	24	1	11	2,940 (N)	10	2	1
ESWA Subtotal:	**4,510**	**32**	**13**	**16**	**3,754**	**14**	**11**	**4**
NBMA-1	0	0	1	0	0	0	1	0
Upper Saucon-1	4,154 (R)	0	13	8				
Sub-Total:	**9,861**	**35**	**56**	**40**	**4,734**	**17**	**25**	**9**
Total:	**14,595**	**52**	**81**	**49**				

Note **(N) – New Pipe**
(R) Replacement pipe

Proposed Interconnection Vaults

Utility	Number of Vaults	Includes Pressure Reducing Valve?
LCA	3	No
ESWA	5	No
NBMA	1	Yes

Recommended Booster Pump Stations

Connection ID	Location	Pumping Requirements Capacity mgd (gpm)	Pump Suction Pressure (psi)	Pump Station Head (ft)	Pump Station Power (HP)
Easton Suburban Water Authority					
ESWA-1	Easton Interconnection Hecktown Rd.	1 (694)	19	95	25
ESWA-2	Easton Interconnect Green Pond Rd	1.25 (868)	27	59	20
ESWA-3	Easton: Scherman Blvd at Wm Penn Hwy (potential)	0.625 (434)	19	78	15
ESWA-4	Easton: Tamarind Dr. and Scherman Blvd (potential)	0.625 (434)	49	79	15
ESWA-5	Easton: Sapphire Lane and Carter Road (potential)	1.1 (764)	33	87	25
ESWA-6	Easton: Shannon Ave/Farmersville	1 (694)	38	89	20
Lehigh County Authority					
LCA-1	Allentown: Central Park West & Florence Interconnect	1.1 (764)	23	179	50
LCA-2	Allentown: W Broad and Hanover Interconnect	1.6 (1111)	32	107	50
LCA-3	Allentown: Club and Tremont Interconnect	2.6 (1806)	32	77	50
Upper Saucon Authority					
US-1	Upper Saucon: Camp Meeting Rd. Quarry	1 (694)	0	135	35
	Upper Saucon: Saucon Valley PRV Booster PS	0.5 (347)	40	101	15
Other Utilities					
HE-1	Hellertown: Main Street near Kichline Avenue	0.5 (347)	Unknown	100	15
BA-1	Bath: Jacksonville Rd.	0.5 (347)	Unknown	100	15
SA-1	Salisbury: Emmaus Avenue near South Fairview Road	0.5 (347)	Unknown	100	15

Chemical Feed Systems by Interconnection

ID	Connection	Proposed Supply (mgd)	$Ca(OCl)_2$ System			Corrosion Inhibitor System
			Tablet Feed 1 mg/l			Liquid Feed 0.5 mg/l
			Req Chlorine (lb/day)	Req Rate (lb/hr)	Design Rate (lb/hr)	gal/day
LCA -1	Central Park West and Florence Interconnect	1.1 (764)	9.17	0.38	0.5	11.0
LCA-2	W Broad and Hanover Interconnect	1.6 (1111)	13.34	0.56	0.5	16.0
LCA-3	Club and Tremont Interconnect	2.6 (1806)	21.68	0.90	1	26.0
ESWA-1	Hecktown Rd.	1 (694)	8.34	0.35	0.5	10.0
ESWA-2	Green Pond Rd	1.25 (868)	10.43	0.43	0.5	12.5
ESWA-3	Scherman Blvd at Wm Penn Hwy (potential)	0.625 (434)	5.21	0.22	0.5	6.3
ESWA-4	Tamarind Dr and Scherman Blvd (potential)	0.625 (434)	5.21	0.22	0.5	6.3
ESWA-5	Sapphire Lane and Carter Road (potential)	1.1 (764)	9.17	0.38	0.5	11.0
ESWA-6	Shannon Ave (future)	1 (694)	8.34	0.35	0.5	10.0
NBMA-1	Northampton Borough Interconnect - Savage Rd.	1.6 (1111)	13.34	0.56	1	16.0
Upper Saucon-1	Upper Saucon	1 (694)	8.34	0.35	0.5	10.0
HE-1	Hellertown: Main Street near Kichline Avenue	0.5 (347)	4.17	0.17	0.5	5.0
BA-1	Bath: Jacksonville Rd.	0.5 (347)	4.17	0.17	0.5	5.0
SA-1	Salisbury: Emmaus Avenue near South Fairview Road	0.5 (347)	4.17	0.17	0.5	5.0

Engineer's Opinion of Probable Costs

Quantities were estimated for each of the recommended fully developed interconnections in terms of water mains and appurtenances required for both utilities. Probable costs were broken down by water mains and appurtenances in Bethlehem, water mains and appurtenances in the other utilities, interconnection vaults, and pump stations that include chemical feed equipment. These probable costs (detailed in Appendix F) include estimated contractor overhead and profit and a contingency as tabulated below:

Description	Cost Opinion
Bethlehem Watermains LCA	$3,530,000
Bethlehem Watermains ESWA	$2,340,000
Bethlehem Watermains NBMA	$18,000
Bethlehem Watermains US	$1,480,000
Bethlehem Watermains HE	$0
Bethlehem Watermains BA	$0
Bethlehem Watermains SA	$0
SUBTOTAL	**$7,368,000**
Connecting Utility Watermains LCA	$600,000
Connecting Utility Watermains ESWA	$1,850,000
Connecting Utility Watermains NBMA	$20,000
Connecting Utility Watermains US	$0
Connecting Utility Watermains HE	$0
Connecting Utility Watermains BA	$0
Connecting Utility Watermains SA	$0
SUBTOTAL	**$2,470,000**
Interconnection Vault LCA (3)	$110,000
Interconnection Vault ESWA (5)	$180,000
Interconnection Vault Watermains NBMA (1)	$37,500
Interconnection Vault Watermains US (1)	$0
Interconnection Vault Watermains HE (1)	$37,500
Interconnection Vault Watermains BA (1)	$37,500
Interconnection Vault Watermains SA (1)	$37,500
SUBTOTAL	**$440,000**
Booster PS's Allentown (3 PS's) w/Chemical Feed System	$895,000
Booster PS's ESWA (6 PS's) w/Chemical Feed System	$1,632,000
Booster PS's US (2 PS's) w/Chemical Feed System	$531,000
Booster PS's HE (1 PS) w/Chemical Feed System	$267,000
Booster PS's BA (1 PS) w/Chemical Feed System	$267,000
Booster PS's SA (1 PS) w/Chemical Feed System	$267,000
SUBTOTAL	**$3,859,000**
TOTAL	**$ 14,137,000**

Temporary Interconnection Evaluation

The interconnection concept designs above assume the installation of permanent interconnections with the recommended upgrades. A second analysis was conducted to assess temporary interconnections for short term outages. One immediate short term outage scenario would be a shutdown of the raw water supply to allow for inspection of the raw water tunnels and assess their condition and vulnerability.

The analysis matches available interconnection flow with available system storage by pressure zone and compares these values to the demand in each zone (and hydraulically connected zones). It is assumed that the raw water tunnel inspection would occur during low demand and would require a period of up to 24 hours. Temporary pumping would be provided as required to maintain pressures in Bethlehem near existing levels. Interconnections were grouped based on whether they currently exist, whether they are in close proximity and could be activated through hose connections, or if they are more distant and would require additional construction:

Pressure Zone	LCA-1, LCA-2, LCA-3, ESWA-1, ESWA-2, NBMA-1 (mgd)	ESWA-3, ESWA-4, HE-1, SA-1 (mgd)	ESWA-5, ESWA-6, US-1, BA-1 (mgd)	Total
	Existing	Close	Distant	
Main	7.55	1.25	2.1	10.9
Howerton South	1.6	0	0	1.6
Saucon Valley	0	0	1	1
Main-Southside	0	0.5	0	0.5
East Allen	0	0	0.5	0.5
Southside High	0	0.5	0	0.5
Total	9.15	2.25	3.6	15

Bethlehem's pressure zones were grouped according to the interconnection supplies available and the storage available in each zone. Zones without storage or interconnection supply were grouped with the zones that normally supply them. The following table lists the assumed demands for these zone groups as derived from the base demands in the hydraulic model:

Zones	Available Storage (MGal)	Accumulated Demand (mgd)	Supply Through Existing Inter-connections, (mgd)	Excess Supply/ Deficit, (mgd)	Supply Through Existing and Temporary Inter-connections, (mgd)	Excess Supply/ Deficit, (mgd)	Supply Through All Inter-connections, (mgd)	Excess Supply/ Deficit, (mgd)
Howertown South + LVIP III	0	0.21	1.6	1.39	1.6	1.39	1.6	1.39
Main + East Allen + Spring Lake Vlg + Main - Southside + Applebutter + Steel City	0.16	8.65	7.55	-0.94	9.3	0.81	11.9	3.41
Southside Low	15.38	1.02	0	14.36	0	14.36	0	14.36
Southside High + Saucon Valley + Lower Saucon + Stonesthrow + Bingen + Weil St + Kohler + Saucon Meadows	1.52	1.77	0	-0.25	0.5	0.25	1.5	1.25
Southeast Low + Society Hill	0.49	0.23	0	0.27	0	0.27	0	0.27
South Mountain + University Heights	0.48	0.12	0	0.37	0	0.37	0	0.37
Total	18.04	12.0	9.15		11.40		15.0	

This table indicates that with the existing interconnections and temporary hose connections, the system should function for at least 24 hours during any temporary shutdown of the raw water facilities. However, without the recommended interconnection improvements, the pipes leading to the temporary interconnections would experience increase head loss that would temporarily lower service pressures by the approximate amounts tabulated below:

Interconnection	Status	Additional Pressure loss in Bethlehem (psi)	Additional Pressure loss in Supplying Utility (psi)
ESWA-1	Existing	0	0
ESWA-2	Existing	0	15
ESWA-3	Requires temporary hose connection (hose head loss excluded)	0	0
ESWA-4	Requires temporary hose connection (hose head loss excluded)	1	0
LCA-1	Existing	13	29
LCA-2	Existing	18	0
LCA-3	Existing	0	0
NBMA-1	Existing	0	0

1. Introduction

The Bethlehem Authority (Authority), Emergency Water Supply Feasibility Study (Study) evaluated a number of alternatives to address known and potential vulnerabilities in the Authority's raw water supply system; most notably if one of the vulnerabilities were compromised and this caused an outage of raw water supply. In that case, the Authority would not have an alternative supply to meet the system demands. The Study evaluated the following four alternatives to provide up to 15 million gallons per day (mgd) to the Authority's water distribution system under an emergency condition: (1) improving existing and adding new interconnections with neighboring systems; (2) bypassing the Wild Creek Reservoir; (3) constructing redundant tunnels through Blue Mountain and Wire Ridge; and (4) providing new water supply sources including groundwater wells, the Lehigh River, and Beltzville Reservoir.

Of the options identified, emergency water supply interconnections were identified as the preferred alternative. AECOM recommended improving existing interconnections and installing new interconnections so that up to 15 mgd could be provided reliably from its neighboring utilities: Lehigh County Authority (LCA), Easton Suburban Water Authority (ESWA), and the Northampton Borough Municipal Authority (NBMA). For dates when system demands would normally exceed 15 mgd, available storage within Bethlehem's system would be utilized. However, demand restrictions are recommended during periods when Bethlehem is relying on neighboring utilities' supply. This Emergency Water Supply Interconnection Evaluation and Concept Design identifies improvements needed to make the interconnections viable and provides concept designs for the recommended improvements. The evaluation includes flow testing at the interconnections, associated distribution system modeling, and development of interconnection system concepts.

1.1 Interconnection Components

At a minimum, water supply interconnections would include pipes in each utility close enough to each other to be connected through temporary or permanent piping. Temporary piping may include running hoses or above-ground piping between hydrants in each utility. Permanent piping would entail underground piping connecting each utility and installation of an isolation valve. Flow meters could also be installed on the permanent or temporary piping to measure the amount of water supplied to Bethlehem. In many of the interconnection locations, system pressures may be considerably different. Where the pressures in the supplying utility are significantly lower than in Bethlehem, the distribution system pressure in Bethlehem would drop unless pumping is provided at the interconnection. These lower pressures might be acceptable for a short-term outage but likely not for a longer period. Where pressures in the supplying utility are significantly higher than in Bethlehem, pressure reduction would likely be required to prevent damage within Bethlehem.

For the purposes of this report, full development of each interconnection including piping, pump stations, and interconnecting vaults was assumed. The minimum level of infrastructure improvement recommended