3-2013

Design and Construction Cost of a Water Line Underneath I-75 in Bowling Green, Ohio

V. Goduto

Alan Atalah
Bowling Green State University - Main Campus, aatalah@bgsu.edu

North American Society for Trenchless Technology (NASTT)

NASTT's 2013 No-Dig Show

Sacramento, California

TM1-T6-02

The Design and Construction Cost of a Water Line underneath I-75 in Bowling Green, OH

Victor C. Goduto, The City of Bowling Green, Bowling Green, OH

Alan Atalah, Construction Management Department, College of Technology, Bowling Green State University, Bowling Green, OH

ABSTRACT: The City of Bowling Green, OH operates a water distribution system that delivers high quality water. The system operates optimally in a grid system; larger, "trunk water mains," are installed in a grid pattern on the outer limits of the system with smaller lines branching from the larger lines. Almost all the residential, industrial, and commercial areas in Bowling Green were originally limited to the west side of I-75. However over the past few decades, these areas grew on the east side of I-75. Two 24" water mains crossed underneath I-75 at the central and south part of the city to provide water to the east side. These limit development in the north eastern section and subject the WWTP (located in that part) to an undue risk if any damage occurs in the central trunk. The installation of a 16" waterline underneath I-75 at the northern end will ensure fire protection for the existing industry and supply a second water source to the WWTP. Four construction methods are examined to cross the interstate with a new waterline: open cut with detouring traffic, postponing the installation until resurfacing the interstate to install the line by open cut, horizontal directional drilling, and auger boring. This paper examines the design and construction cost of the four potential methods of construction to install a 16" waterline underneath I-75.

1. INTRODUCTION

The City of Bowling Green located in Wood County in Northwest Ohio has a current population of approximately 29,000. The City owns and operates its public utilities systems including a water treatment plant and water distribution system as well as a wastewater collection system and wastewater treatment facility. The City treats, distributes, and releases an average of 7 million gallons of wastewater a day and has a maximum capacity of producing 10 million gallons of potable water a day(The City of Bowling Green 2010).

This paper examines a portion of the water distribution system that was constructed in less than an optimal format. Ideally, a water distribution system is set up in a grid format, which allows for optimized flow throughout the system (American Water Works Association 2003) (Alperovits and Shamir 1977). However, dead end lines occur; dead end lines have only one end connected to the grid. The City's wastewater treatment plant (WWTP) uses city water in its treatment process; however, the wastewater plant receives water from a dead end water line. There is also a large industrial park that is served by the same dead end water line. This is a weak point in the water distribution system. If the current water line that serves the WWTP or industrial park fails, the WWTP and several large factories will be without water service. This could cause an overflow of raw wastewater into the environment, which is illegal and could cause flooding in residents' homes.

The proposed water line (shown in red in Figure 1) connects the dead end line on Dunbridge Road to the water line on Mercer Road creating a loop and a second feed to the wastewater treatment plant and industrial park. The line is needed to meet increasing demands in the north east area.

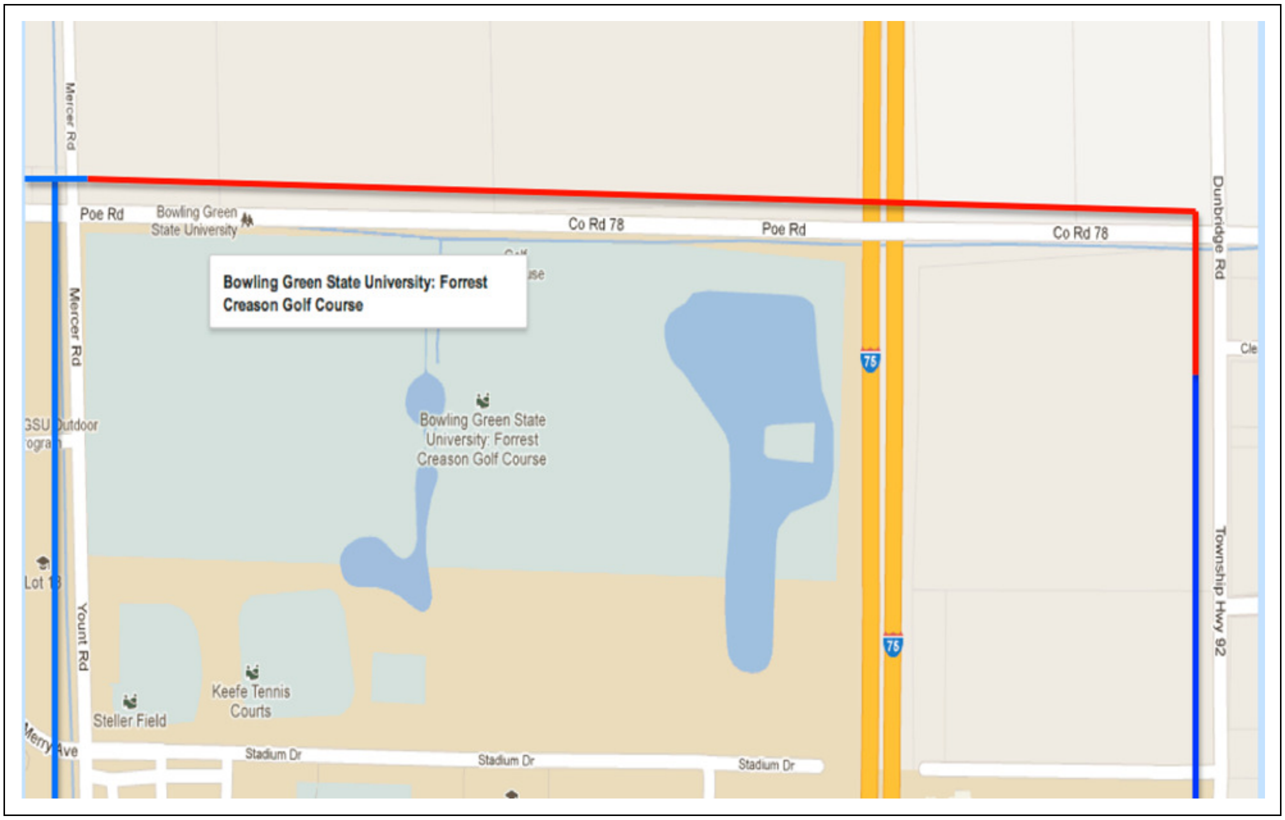

Figure 1 Proposed Water Line Design is Shown in Red(Google Maps, 2012).

This study attempts to evaluate the installation alternatives to the proposed line that close the loop and eliminate the dead end in the distribution system. Creating this loop significantly reduces the risk of interruption to water supply to theWWTP and Industrial Park, enhances the fire protection to areas currently lacking fire protection, and encourages future development in the area.

2. RESEARCH METHODOLOGY

The following steps outline the research methodology:

- Investigate Ohio Department of Transportation (ODOT) policies for crossing under interstate highways with utilities and determine the requirements.
- Calculate the size of the pipeline based on current and future water demand of the area where pipeline will be constructed.
- Research and explore the pros and cons of four potential methods of installation.
- Develop cost estimates from contractors, historical data, and estimating softwareand propose a method of installation.

Shop drawings and specifications of similar projects were obtained from the Engineering Division in the City of Bowling Green to determine an adequate and acceptable means to cross the Interstate. The authors explored and investigated the current water demands of the area and estimated possible future demands to determine the pipeline capacity. The authors acquired subsurface information in the project area from the United States Department of Agriculture Natural Resources Conservation Service and historical data from the City of Bowling Green's Engineering Division. Four potential methods of pipeline installation were examined:open cut a trench to cross the Interstate by diverting traffic, horizontal directional drilling, or auger boring and jacking, and open cut during the interstate reconstruction.

3. FINDINGS AND RESULTS

The soil in the project area consists of Hoytville Clay Loam and MermillAurand Complex. Hoytville Clay Loam is a clay type soil with limited permeability. Hoytville Clay Loam is present in nearly 92% of the project area. MermillAurand Complex is present in approximately 8% of the project area. MermillAurand Complex is also a clay type soil with limited permeability(Web Soil Survey, 2012).The soil report lists the two soil types present to eighty inches in depth. Since portions of the project may go deeper than eighty inches it would be helpful to know the soil content below that point. A review of previous projects and a visual inspection of the project site showed no presence of bedrock. (T. Sonner, Personal Communication, April 12, 2012).Using water-modeling software the City of Bowling Green's Engineering Division determined that the desired pipe size is 16 inches (T. Sonner, Personal Communication, March 21, 2012).

Requirements for Crossing an Interstate Highway

According to theODOT's Policy for Accommodation of Utilities which gives detailed guidance for the procedure of crossing state owned right of ways, horizontal directional drilling (HDD) or auger boring are acceptable methods for crossing the interstate(Ohio Department of Transportation, 2007). The final method to be approved will be a negotiated between ODOT and the City of Bowling Green.

4. INSTALLATION METHODS

The following four installation methods were considered for the project:

- Open cut a trench and cross the Interstate by diverting traffic.
- Construct and install the pipeline using trenchless technologies and cross the Interstate by means of directional drilling.
- Construct the pipeline using trenchless technologies and cross the Interstate by jacking and boring (Auger-bore).
- Postpone the project and install the pipeline when road reconstruction is occurring allowing for an open cut installation while traffic is already diverted.

Traditional Open Cut Method

The first potential pipeline method of installation is traditional open cut. The advantage of traditional open cut construction is allowing the project to progress in a continuous fashion; the laying and backfilling of pipe allows the project to progress at a steady pace. The traditional open cut method is suitable for nearly all soil conditionsexcept for oozing mud and running sands. (Washington, Trench and Excavation Support Options And Excavation Slope Design 2012)

Open cut trenching can be dangerous and the walls of the trench have to be supported or sloped. If the contractor slopes the trench, a larger work area is required, and more material has to be excavated, increasing the cost of the project (Washington, Trench and Excavation Support Options And Excavation Slope Design 2012). Returning the area to its original condition is labor intensive and may require workers to return to the site several times. Furthermore it has been documented that the cutting of asphalt paving and subsequent repairing of asphalt paving significantly reduces the lifespan of the pavement.(Shahin & Associates Pavement Engineering 2002).

Horizontal Directional Drilling

The second examined pipeline installation method was horizontal directional drilling (HDD). The entire project or portions of the project, could be installed using the HDD method. HDD was initially used in the installation of telecommunication lines but is now used to install pipelines of up to forty-eight inches in diameter(Abraham, Baik and Gokhale 2007). The advantages of HDD are many such as: no interruption of traffic flow, minimal surface and subsurface disturbance, and little if any surface restoration after project completion. HDD is a surface launched process not requiring drive pits or reception pits, which can significantly reduce project costs. However, pits may be required to connect existing utilities to newly installed utilities(Abraham et al.)
The cost of HDD is quite competitive when compared to traditional open cut installation. Consideration must be given to the depth of installation when utilizing HDD. As the depth increases the cost of HDD becomes more

competitive when compared to the cost of open cut trenching. When there is limited accessibility to the installation site, HDD can be used where traditional methods are prohibited or impractical.
HDD is not without its limitations, intersecting utilities pose problems for HDD, placing constraints on the depth of installation. If other utilities cross the path of the HDD machine, the new installation may have to be placed at an undesirable depth. There is also the possibility of surface heaving and subsidence. The installation requires high-pressure slurry to assist in constructing the borehole for pipe pullback. If the soil is of insufficient strength to withstand the pressure, surface heaving can occur. Furthermore, the pressure and high flow rates of the slurry can also cause soil to erode causing voids resulting in subsidence (Baik 2003).

Horizontal Auger Boring

The third examined method is to install the pipeline by traditional open cut and auger bore under the interstate. Auger boring is a trenchless technique, which employs a cutting head that is rotated and attached to augers within a casing. The operation requires the excavation of a jacking pit and a receiving pit. The boring equipment, which includes the auger boring machine, augers, and cutting head, is located in the jacking pit. The receiving pit accepts the casing as the auger-boring machine drives the casing under the obstruction. Vertical alignment is controlled by a water level and horizontal alignment control can be somewhat limited(Abraham et al.)

Auger boring has its advantages. Auger boring casings can range in size from four inches up to sixty inches. Typical drive lengths range between forty feet and three hundred feet. Site restoration is only required at the boring and receiving pits. Auger boring is particularly useful in unsuitable soils, cobbles and boulders as large as one-third the size of the casing can easily be handled and removed from the casing. A major advantage of auger boring over other trenchless methods is the casing acts as the borehole eliminating the possibility of cave-ins during the boring process. (Abraham et al.)

Auger boring may not be the most practical method when line and grade are important. Auger boring requires a substantial investment due to the variety of casing sizes, which require many different sized cutting heads and augers; therefore, increase costs. Setup and bore pit excavation can also be more costly than other trenchless methods due to the forces required to drive the cutting head, casing, and auger(Abraham et al.).

Postpone and Install During Road Reconstruction

Postponing the project and installing the pipeline during road reconstruction is a viable method of installation worth exploring. There is a high possibility that ODOT will reconstruct the Interstate in the near future and add a third lane in both northbound and southbound lanes of travel. The pipeline could be installed by means of open cut while the road is being rebuilt and traffic is already diverted. The pipeline could be installed and incased in a concrete casing rather than a steel casing, which is normally required. This may save a substantial amount of funds, in the initial project.

5. ESTIMATED QUANTITIES AND COSTS FOR THE PROJECT

Quantities were estimated for the project by obtaining historical bid data from the City of Bowling Green's Engineering Division. Two bid tabulations were used to obtain estimates, Gypsy Lane Water Line Extensions Phases One and Two. These two bids were used due to their similarity to the proposed project. There are few connection points and there is no asphalt cutting required. The project also has an auger-boring estimate contained in the bid. Hydrant assemblies were obtained from the Gypsy Lane Water Line Extension Phase Two.

Prices-not available from historical data-were estimated using RS Means. RS Means is a construction estimating software program that allows the user to estimate a variety of construction projects using current pricing. Projects are broken down into material, equipment, and labor. Data was also acquired by obtaining estimates from contractors.

This project requires the installation of approximately 5,700 feet of sixteen-inch water line. Sixteen-inch DR18 polyvinylchloride (PVC) pipe was the selected pipe for installation. The Interstate crossing consists of a total of three hundred linear feet with eighty linear feet of asphalt. There are also two connection points at each end of the project requiring a transition fitting to connect two differing pipe materials. A separate estimate was used to price the transition couplings and their installation.

The cost of the project is broken down into two phases: the open cut portion of the project and the crossing at the interstate. The most practical way to complete the project would be to install the pipeline by means of open cut and then perform one of the four methods discussed to cross the interstate.

Project Estimate Traditional Open Cut Installation

Since the project is in a relatively remote area, the material removed from the trench can be stored near the project and placed back in the trench. Below is an estimated cost of installing the 16-inch water line by traditional open cut. Table 1 shows the open cut portion of the project minus the open cut, backfilling, and compaction of the interstate, which was calculated using RS Means.

Table 1. Open Cut Estimate Less the Interstate Crossing

Quantity	UNIT	DESCRIPTION	Unit Cost	Total Cost
5,700	LF	16" Waterline	$66.62	$ 379,730
2,400	SY	Seeding and Mulching and Topsoil	$1.87	$ 4,490
9	EA	Fire Hydrant Assembly, Type A	$4,753.53	$ 42,780
5	EA	16" Butterfly Valve in Manhole	$7,220.00	$ 36,100
2	EA	New Waterline Connection to Existing	$11,618.00	$ 23,240
1	EA	Install Valve and Plugged Tee	$2,400.00	$ 2,400
1	EA	2-inch Blow off	$1,460.00	$ 1,460
1	LS	Dust Control	$330.00	$ 330
1	LS	Clearing and Grubbing	$4,160.00	$ 4,160
1	EA	Air Release Valve Assembly,	$2,255.35	$ 2,260
			TOTAL	$ 496,950

Table 2 shows the estimated cost of removing and re-installment of the asphalt pavement and sub-grade of the Interstate. This estimate was obtained by using RS Means.

Table 2.Removal of Asphalt and Installation of Sub-grade Estimate using RS Means.

Qty	Description	Unit Cost	Total
27.00	Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees	$8.90	$240
27.00	Demolish, remove pavement & curb, remove bituminous pavement, 4" to 6" thick, excludes hauling and disposal fees	$8.90	$240
72.00	Excavating, trench or continuous footing, dense hard clay, 1 C.Y.excavator, 6' to 10' deep, excludes sheeting or dewatering	$5.25	$380
251.00	Fill by borrow and utility bedding, for pipe and conduit, crushed stone, 3/4" to 1/2", excludes compaction	$40.50	$10,170
251.00	Compaction, 4 passes, 12" lifts, towed vibrating roller	$0.99	$250
27.00	Base course drainage layers, aggregate base course for roadways and large paved areas, stone base, compacted, 3/4" stone base, to 12" deep	$14.40	$390
27	Asphalt Paving, plant mixed asphaltic base courses for roadways and large paved areas, bituminous concrete, 10" thick	$38.50	$1,040
27	Plant-mix asphalt paving, for highways and large paved areas, wearing course, alternate method for developing paving costs, 3" thick, no hauling included	$82.50	$2,230
20	Public Storm Utility Drainage Piping, drainage and sewage, corrugated HDPE, type S, bell and spigot, with gaskets, 18" diameter, excludes excavation and backfill	$19.95	$400
		Total	$15,330

Finally, a cost estimate was developed to accommodate traffic diversion. Required distances for delineation devices and signage for single lane closures on interstate highways was determined using, “ODOT’s Manual for Uniform Traffic Control Devices” (Ohio Bureau of Traffic Engineering 1999). The unit costs in Table 3 below were acquired from Safeway of Perrysburg Ohio, who specialize in renting traffic control devices.

Table 3.Estimated Cost for Traffic Control Devices

Quantity	Item	Unit	Minimum Days	Unit Cost	Total Cost
21	Barrels	EA	7	$0.65	$96
7	Sign Stands	EA	7	$3.60	$176
2	Set up / Take down	EA		$400.00	$800
1	Arrow Board	EA	7	$20.60	$144
1	48" X 48" Sign Road Work Ahead	EA	7	$2.60	$18
1	48" X 48" Right Lane Closed Ahead	EA	7	$2.60	$18
1	48" X 48" Left Lane Closed Ahead	EA	7	$2.60	$18
1	48" X 48" Taper Graphic	EA	7	$2.60	$18
1	48"X 48" Reduced Speed	EA	7	$2.60	$18
1	Construction Zone Fines Doubled	EA	7	$2.60	$18
1	End Road Work	EA	7	$2.60	$18
				TOTAL	$1,344

The total estimated cost to perform the project by means of traditional open cut would be: $548,733.04

Project Estimate Using Horizontal Directional Drilling

In an interview with Dustin Schlachter of S & S Directional Boring Limited, a cost of $95.00 per linear foot was quoted with an additional emergency contingency charge of $30.00 per linear foot in case of road heaving or settling. Below in Table 4 is the estimated cost of the project using horizontal directional drilling to install High Density Polyethylene Pipe.

Table 4.Horizontal Directional Drilling Estimate**.**

Quantity	UNIT	DESCRIPTION	Average Unit Cost	Total Cost
5,400	LF	16" Waterline	$66.62	$359,750
2,400	SY	Seeding and Mulching and Topsoil	$1.87	$4,490
300.00	LF	Horizontal Directional Drilling HDPP Pipe	$125.00	$37,500
9	EA	Fire Hydrant Assembly, Type A	$4,753.53	$42,780
5	EA	16" Butterfly Valve in Manhole	$7,220.00	$36,100
2	EA	New Waterline Connection to Existing	$11,618.00	$23,240
1	EA	Install Valve and Plugged Tee	$2,400.00	$2,400
1	EA	2-inch Blow off	$1,460.00	$1,460
1	LS	Dust Control	$330.00	$330
1	LS	Clearing and Grubbing	$4,160.00	$4,160
1	EA	Air Release Valve Assembly,	$2,255.35	$2,255
			TOTAL	$514,460

For comparison purposes an estimate of the directional drilling portion of the project was developed using RS Means. Below in Table 5 are the unit costs and total costs for horizontal directional drilling. Boring pits are included in the estimate in case the desired angle of drilling cannot be obtained.

Table 5. Directional Drilling Estimate developed through RS Means.

Qty	Description	Unit	Unit Cost	Total
1	Directional drilling, mud trailer per day	Day	$885.00	$885

Qty	Description	Unit	Unit Cost	Total
1	Directional drilling, large equipment to 1000', minimum charge, clay & soft sandstone, up to 12" dia, excluding cost of conduit	Ea.	$995.00	$995
1	Directional drilling, large equipment to 1000', not to exceed 12" dia, large unit setup per drill, excluding cost of conduit	Ea.	$775.00	$775
2	Directional drilling, large equipment to 1000', not to exceed 12" dia, large unit mobilization to site, excluding cost of conduit	Ea.	$1,550.00	$3,100
300	Directional drilling operation, large equipment to 1000', per linear feet, gravel, sand & silt, up to 12" dia, 100' minimum, excluding cost of conduit	L.F.	$13.81	$4,142
320	Water supply distribution piping, piping HDPE, butt fusion joints, 40' lengths, 16" diameter, SDR 21	L.F.	$63.50	$20,320
		Totals	$100.72	$30,217

RS Means will only estimate the cost of directional drilling of a twelve-inch pipe. In order to convert the price to 16-inch pipe, the cost of the directional drilling operation is increased by 78% ($16^2/12^2$) based the area ratios of the two diameters; i.e. the cost /LF for the drilling operation is increased from $7.80/LF to $13.81/LF.The subtotal cost is $30,217. If we add $30.00 /LF emergency contingency, the total cost to perform the directional drilling is $130.7/LF. And total cost of $39,217.

In order to obtain drilling fluid costs, the Baroid Industrial Drilling Company was consulted. In order to accommodate a 16-inch pipe several back reaming passes must be made. Below in Table 6 are the costs calculated for drilling fluid materials.

Table 6.Drilling Fluid Mix Needed for Directional Drilling Operation.

Size of Hole in Inches to be Bored	Water needed in Gallons for 300'	Pounds of Bentonite per 100 Gallons of Water	Cost of Bentonite $10.00 per 50 lb	Cost of Easy Mud Gold at $150.00 per 10lb.	Cost of Penetrol per Half Quart per 100' at $60.00 a Gallon
6	432	194	$38.88	$64.80	$22.50
12	1,296	583	$116.64	$194.40	$22.50
20	1,728	778	$155.52	$259.20	$22.50
28	4,608	2,074	$414.72	$691.20	$22.50
16" pipe	810	365	$72.90	$121.50	$22.50
Subtotals	8,874	3,993	$725.76	$1,331.10	$90.00
				Total Cost	$2,146.86
				Total Unit Cost	$7.16

The total estimated cost from bid tabulations, contractors estimate, and drilling fluid = $514,459.12 + $2.146.86 = $516,605.9

Project Estimate Auger Boring

The project estimate for crossing the interstate by means of auger boring was calculated in the same manner as the previous two methods. Table 7 shows the estimated cost of the interstate crossing performed by the auger-boring method using Bid Tabulations.

Table 7. Auger Boring Estimate from Bid Tabulations

Quantity	Unit	Description	Unit Cost	Total Cost
5,400	LF	16" Waterline	$66.62	$359,750
2,400	SY	Seeding and Mulching and Topsoil	$1.87	$4,490
300	LF	30" Steel Casing Pipe, Jack and Bore	$604.50	$181,350
9	EA	Fire Hydrant Assembly, Type A	$4,753.53	$42,780
5	EA	16" Butterfly Valve in Manhole	$7,220.00	$36,100
2	EA	New Waterline Connection to Existing	$11,618.00	$23,240
1	EA	Install Valve and Plugged Tee	$2,400.00	$2,400

1	EA	2-inch Blow off	$1,460.00	$1,460
1	LS	Dust Control	$330.00	$330
1	LS	Clearing and Grubbing	$4,160.00	$4,160
1	EA	Air Release Valve Assembly,	$2,255.35	$2,255
			TOTAL	$658,310

Below in Table 8, is the estimated cost of auger boring using RS Means. The estimate includes driving and receiving pits as well as dewatering and sheet piling.

Table 8.Cost of Auger Boring RS Means Estimate.

Qty	Description	Unit	Unit Cost	Total
110	Excavating, trench or continuous footing, common earth, 1 C.Y. excavator, 10' to 14' deep, excludes sheeting or dewatering	B.C.Y.	$5.10	$560
110	Backfill, structural, common earth, 80 H.P. dozer, 50' haul, from existing stockpile, excludes compaction	L.C.Y.	$1.31	$140
300	Horizontal boring, roadwork, 1/2" thick wall, 36" diameter casing, includes casing only, 100' minimum, excludes jacking pits or dewatering	L.F.	$560.00	$168,000
10	Dewatering, pumping, 8 hr., attended 8 hours per day, 3" centrifugal pump, includes 20 L.F. of suction hose and 100 L.F. of discharge hose	Day	$885.00	$8,850
500	Sheet piling, steel, 22 psf, 15' excavation, per S.F., left in place, excludes wales	S.F.	$26.50	$13,250
	Totals		$636.02	$190,810

The slight difference in the cost per linear foot for the auger bore using RSMeans is due to the slightly larger casing.

The total cost to install the project by auger boring from bid tabulations = $658,309.12

Postpone the Project

Postponing the project and having the water line incorporated into the design of the highway reconstruction may lower the overall cost. If ODOT were to pick up the cost of traffic diversion and remove the asphalt and sub-grade, the City may pay the cost to install the water line across the highway. Once the water line was installed, it could be encased in concrete. Below in Table 9 is the open cut portion of the project including the highway crossing minus the asphalt and road sub-grade estimate.

Table 9. Open Cut Estimate Less the Interstate Crossing.

Quantity	UNIT	DESCRIPTION	Unit Cost	Total Cost
5,700	LF	16" Waterline	$66.62	$379,730
2,400	SY	Seeding and Mulching and Topsoil	$1.87	$4,490
9	EA	Fire Hydrant Assembly, Type A	$4,753.53	$42,780
5	EA	16" Butterfly Valve in Manhole	$7,220.00	$36,100
2	EA	New Waterline Connection to Existing	$11,618.00	$23,240
1	EA	Install Valve and Plugged Tee	$2,400.00	$2,400
1	EA	2-inch Blow off	$1,460.00	$1,460
1	LS	Dust Control	$330.00	$330
1	LS	Clearing and Grubbing	$4,160.00	$4,160
1	EA	Air Release Valve Assembly,	$2,255.35	$2,260
			TOTAL	$496,945

An RS Means estimate was developed to establish the cost of encasing the water line in concrete and filling the trench with a suitable granulated fill. Compaction is also included in the estimate. Below in table 10 is the estimate to install the concrete and fill the trench with granulated fill.

Table 10. Estimate to Install Concrete Casing and Backfill.

Qty	Description	Unit	Unit Cost	Total
85	Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments	C.Y.	$99.55	$8,460
167	Compaction, 4 passes, 12" lifts, riding, sheeps foot or wobbly wheel roller	E.C.Y.	$0.77	$130
167	Compaction, riding, vibrating roller, 4 passes, 12" lifts	E.C.Y.	$0.53	$90
			Total	$15,440

The total cost to postpone the project would be: $512,387.47

6. CONCLUSION

Table 11 shows the total costs of all methods and the total cost per linear foot and the cost per foot to cross under the highway.

Table 11.Total of all Methods Estimated.

Method	Total Cost	Cost per Foot	Total Cost per foot to Cross I-75
Auger Boring	$658,309.12	$115.49	$604.50
Horizontal Directional Drilling	$516,605.98	$90.63	$134.50
Postpone the project	$512,387.47	$89.89	$57.47
Open Cut	$512,286.51	$89.87	$173.44

The total cost of a project is difficult to predict; there are many different variables that can and do occur between the prediction of a future project and the bid award. These estimates give a good indication of what a project of this scope might cost to complete at present time using one of the four methods discussed.

7. CHAPTER 5 CONCLUSION AND RECOMMENDATION

The purpose of the project was to analyze and examine the design and installation of a water line project for the City of Bowling Green Engineering Division. The installation of the new water line is a viable project that can be completed and will improve the quality of water and improve the water distribution system's performance.

Recommendation

The least expensive method of installing the water line is the open cut method. However, open cutting across Interstate 75 does not seem likely. The next least expensive method at $89.89 per linear foot is to postpone the project and install the water line when the highway is being reconstructed. The timing of this method may not coincide with the needs of the community. It has recently been discovered that the construction of a new water tower is being designed near the project area. Therefore, this project may be expedited, which makes the horizontal directional drilling more attractive. Horizontal directional drilling across the interstate is the next least expensive method at $90.63 per linear foot. Furthermore, when indirect costs, such as Social Costs, which this paper does not address, are considered a trenchless method is more desirable. ODOT may be convinced to allow the water line to be constructed without a casing making this the most economical way to complete the project.

8. REFERENCES

- A Decision Support System for Horizontal Directional Drilling*Tunneling & Underground Space Technology,* 200318 (1), 99.
- American Water Works Association*Water Transmission and Distribution (3rd ed.)*Denver, COAmerican Water Works Association2003
- Design of optimal water distribution systems.*Water Resources Research*1977Vol 13 (6) 885-900

- *Development of a Decision Support System for Selection of Trenchless Technologies to Minimize Impact of Utility Construction on Roadways*Lafayette, INPurdue University2007
- Google Maps*Google Maps*2012http://maps.google.com/maps?hl=en&tab=wl.
- Ohio Bureau of Traffic Engineering *Ohio manual of uniform traffic control devices for streets and highways*Columbus, OhioOhio Bureau of Traffic1999
- Ohio Department of TransportationPolicy for Accommodation of Utilities*Policy for Accommodation of Utilities*2007http://www.dot.state.oh.us/districts/D10/Right_of_Way_Permits/Documents/Manuals/Utilities%20 Manual.pdf
- Shahin & Associates Pavement Engineering*Analysis of Impact of Utility Cuts on Rehabilitation Costs In Santa Cruz County, CA*http://www.dpw.co.santa-cruz.ca.us/Operations/trenchcutfeereport.pdf
- The City of Bowling Green*Water Distribution & Wastewater Collection - Water Distribution*2010http://www.bgohio.org/departments/utilities-department/water-distribution-wastewater-collection/water-distribution
- *Trench and Excavation Support Options And Excavation Slope Design* http://www.pdhcenter.com/courses/g111/g111.htm
- *Trench and Excavation Support Options And Excavation Slope Design*2012http://www.pdhcenter.com/courses/g111/g111.htm
- Web Soil Survey*Web Soil Survey*2012http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx