



**Donald L. Plusquellic**  
Mayor  
**Gerald Holland**  
Director of Public Service

## **City of Akron**

### **Ohio Canal CSO Alternatives Advanced Planning Study**

**Date: October 17, 2006**



Akron Engineering Bureau  
Environmental Division

**Ohio Canal CSO Alternatives  
Advanced Planning Study**

Prepared by:

Metcalf & Eddy of Ohio, Inc.  
159 South Main Street, Suite 312  
Akron, Ohio 44308

Project Manager: Mr. Bradford A. Beckert, P.E., P.S.

October 17, 2006

**Ohio Canal CSO Alternatives  
Advanced Planning Study**

TABLE OF CONTENTS

	<u>Page No.</u>
<b>1. EXECUTIVE SUMMARY</b>	1-1
<b>2. INTRODUCTION</b>	
2.1 EVALUATION SCOPE AND REPORT ORGANIZATION	2-1
2.2 BACKGROUND INFORMATION AND ASSUMPTIONS	2-2
<b>3. ANALYSIS</b>	
3.1 GEOTECHNICAL INFORMATION	3-2
3.2 TUNNELING EVALUATION	3-2
3.3 ENVIRONMENTAL PRE-SCREENING	3-11
3.4 RIGHT OF WAY AND PROPERTY ISSUES	3-15
3.5 OHIO CANAL INTERCEPTOR SEWER EVALUATION	3-18
3.6 OHIO CANAL ENCLOSURE HYDRAULIC ASSESSMENT	3-22
3.7 CSO TREATMENT TECHNOLOGIES	3-25
<b>4. DESIGN CRITERIA</b>	
4.1 TUNNEL BORING MACHINE SELECTION	4-1
4.2 TUNNEL BORING CONSTRUCTION ISSUES	4-5
4.3 RISK ASSESSMENT AND ALTERNATIVE METHODS	4-10
4.4 CRITERIA FOR MATRIX ANALYSIS	4-12
<b>5. PROJECT COSTS</b>	
5.1 CONSTRUCTION COST ESTIMATING	5-1
5.2 ALTERNATIVE DESCRIPTIONS AND COSTS	5-3
5.3 MATRIX EVALUATION APPROACH	5-57
5.4 MATRIX EVALUATION RESULTS	5-59
<b>6. CONCLUSIONS AND RECOMMENDATIONS</b>	
6.1 RECOMMENDED ALTERNATIVE	6-1
6.2 PRELIMINARY DESIGN CONSIDERATIONS	6-4

**APPENDICES**

APPENDIX A – BACKGROUND GEOTECHNICAL STUDY (BBC&M)  
APPENDIX B – GEOTECHNICAL DATA REPORT (BBC&M)  
APPENDIX C – ENVIRONMENTAL SCREENING REPORTS (EDR)  
APPENDIX D – OHIO CANAL INTERCEPTOR DEFICIENCY SUMMARY  
APPENDIX E – OHIO CANAL ENCLOSURE PROFILE  
APPENDIX F – TUNNELING TECHNICAL REPORT

## **1.0 EXECUTIVE SUMMARY**

The City of Akron has developed a comprehensive Long Term Control Plan (LTCP) to address Combined Sewer Overflows (CSOs) from the sewer system. The original LTCP was submitted to the Ohio EPA in 1998, and was subsequently revised in 2000 and 2005, to reflect improvements in CSO control technology and changes in construction economy.

As part of the LTCP, the Ohio Canal Interceptor Tunnel (OCI Tunnel) was proposed to convey, store, and release CSO flow from the CSO racks adjacent to the Ohio Canal in downtown Akron. The OCI Tunnel concept was intended to achieve three (3) primary goals, consisting of:

1. Capture and store for treatment up to 15 million gallons of CSO;
2. Eliminate CSO discharges to the Ohio Canal; and
3. Provide conveyance to a consolidated overflow location to the Cuyahoga River.

To achieve these specific goals, the LTCP proposed a large-diameter storage/conveyance tunnel to intercept all flow from the downtown area rack locations and convey the flow north to a consolidated overflow location downstream of the confluence of the Ohio Canal and the Little Cuyahoga River.

The purpose of this Advance Planning Study was to evaluate alternatives for meeting the goals and objectives of the original OCI tunnel identified in the LTCP. Several alternatives were identified based on:

- < Suitability of subsurface soil and rock conditions for tunneling
- < Use of the Ohio Canal Enclosure for CSO conveyance and storage
- < Potential construction of the Ohio Canal Bypass Conduit
- < Future Innerbelt Boulevard development

Each of the alignment alternatives was developed to meet the City's previously developed CSO control and flow conveyance goals. Modifications to the level of control,

or evaluation of alternative overflow locations, were not evaluated as part of this study. The alignment alternatives evaluated as part of this study are presented in Table 1-1.

**Table 1-1. Evaluated CSO Control Alternatives**

<u>Alternative</u>	<u>Description</u>
1a	Maple Street Tunnel Alignment, with Canal Bypass Conduit
1b	Maple Street Tunnel Alignment, without Canal Bypass Conduit
2a	Main Street Tunnel Alignment, with Canal Bypass Conduit
2b	Main Street Tunnel Alignment, without Canal Bypass Conduit
3a	Ohio Canal Tunnel Alignment, with Canal Bypass Conduit
3b	Ohio Canal Tunnel Alignment, without Canal Bypass Conduit
4a	Walnut Street Tunnel Alignment, with Canal Bypass Conduit
4b	Walnut Street Tunnel Alignment, without Canal Bypass Conduit
5a	Canal Bypass Conduit, Ohio Canal Enclosure, Enclosure Extension, and Howard/Cuyahoga Street Storage Tank
6a	Canal Bypass Conduit, Ohio Canal Enclosure Storage, Enclosure Extension Storage, and Walnut/Maple Street Storage Tank
7a	Canal Bypass Conduit, Innerbelt Storage Tank and Tunnel Storage

Supporting data and background information was developed or obtained to aid the evaluation of the alternatives. This supporting information consists of:

- ◁ Geologic records and data from geotechnical investigations and testing conducted for this study;
- ◁ Inspection video for the Ohio Canal Interceptor;
- ◁ Record drawings for the CSO Rack locations and the Ohio Canal Enclosure;
- ◁ CSO flow and volume output from the City’s collection system modeling;
- ◁ Alternative alignments and cost information for the Ohio Canal bypass conduit;
- ◁ Environmental pre-screening records; and
- ◁ Land base and property information for Summit County.

A comparative matrix evaluation was performed to compare the alternatives based on capital cost and multiple non-cost criteria. Each criterion was assigned a weighting factor based on discussion with City personnel. Table 1-2 identifies each criterion and the respective weighting.

**Table 1-2. Matrix Evaluation Criteria and Weighting**

CRITERIA	RANK	WEIGHTED PERCENTAGE
Relative Cost	1	30
Constructability	2	25
Easements/Acquisitions	3	20
Clearance from Critical Structures	4	10
Maintenance Access	5	10
Odor Control and Ventilation	6	5
<b>Total</b>	-	<b>100</b>

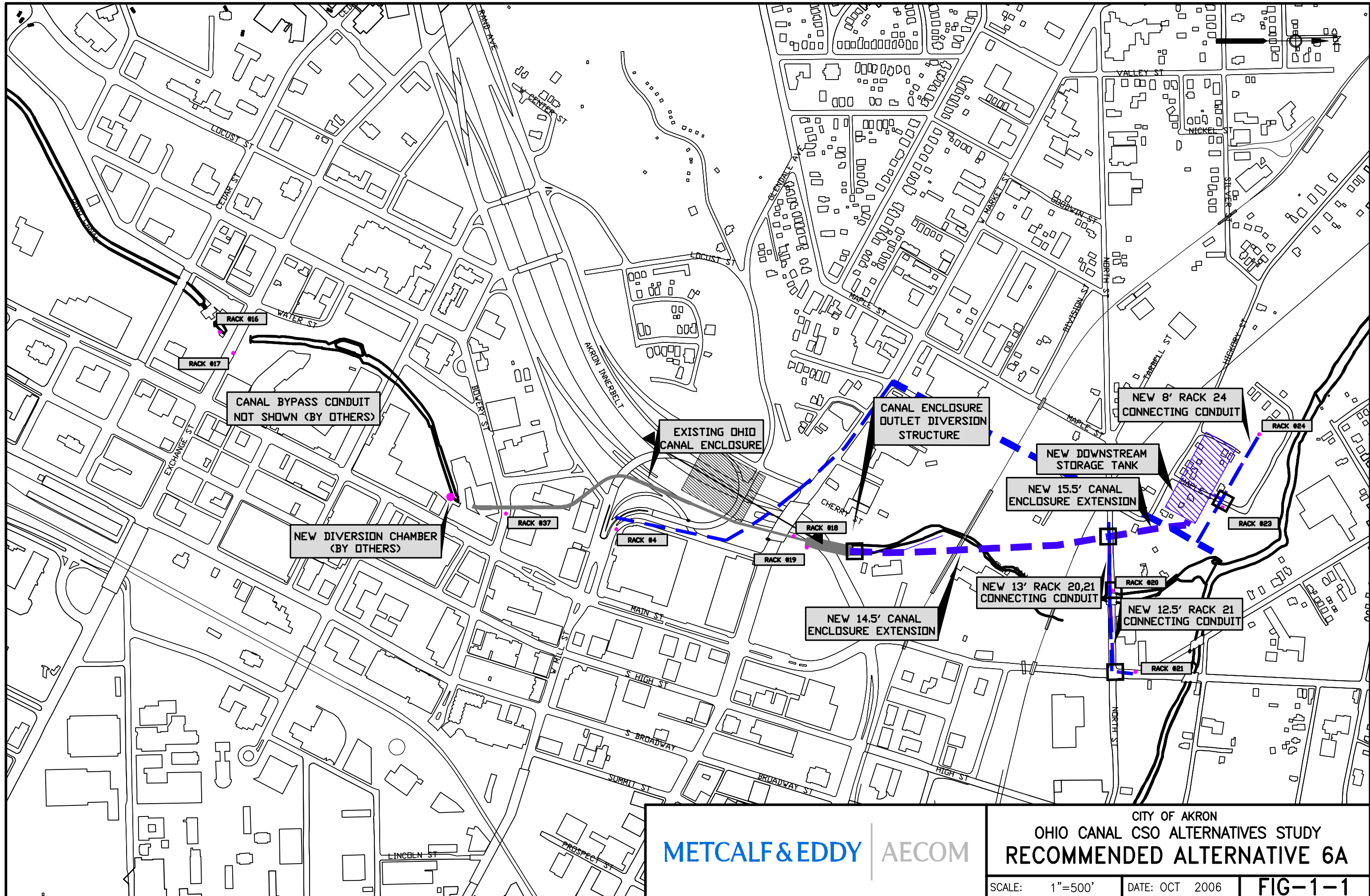
Each criterion was assigned a relative score from 1 (lowest) to 5 (highest) for each alternative, and then weighted by the factors described in Table 1-2. The alternative with the highest composite score was Alternative 6A, which includes:

- < Ohio Canal Bypass Conduit
- < CSO storage in the Ohio Canal Enclosure
- < Storage basin near Maple Street and Hickory Street
- < Tunnel segment connecting enclosure to storage basin
- < Miscellaneous connecting conduits and required improvements

Alternative 6A is illustrated in Figure 1-1.

Alternative 6A makes use of the existing Ohio Canal Enclosure for storage and a short section of tunnel conveying flow to a basin adjacent to the Cuyahoga River. The use of a storage basin at the downstream end not only provides the necessary additional storage volume, but provides the City with the flexibility to include clarification, advanced primary treatment, high-rate treatment and/or disinfection.

The cost for alternative 6A is summarized in Table 1-3.



**METCALF & EDDY** | AECOM

CITY OF AKRON  
OHIO CANAL CSO ALTERNATIVES STUDY  
**RECOMMENDED ALTERNATIVE 6A**

SCALE: 1"=500'    DATE: OCT 2006    **FIG-1-1**

**Table 1-3. Alternative 6A Cost Summary**

<u>Components of Cost</u>	<u>Cost (2006 dollars)</u>
Project Capital Costs, including: <ul style="list-style-type: none"> <li>◁ Canal Bypass Conduit</li> <li>◁ Reroute Ohio Canal through potential Innerbelt Boulevard Development</li> <li>◁ Required improvements to Canal Enclosure</li> <li>◁ Tunnel and connecting conduits</li> <li>◁ Downstream storage/treatment basin</li> <li>◁ Contractor Overhead &amp; Profit</li> </ul>	\$55 MM
Project Contingency (10% of capital cost)	\$5 MM
Canal Bypass Conduit East Alignment	\$13 MM
Engineering (25% of capital cost, plus contingency)	\$18 MM
<b>Total Cost (including contingency and engineering)</b>	<b>\$92 MM</b>

Note: A detailed cost estimate is provided in Section 5.

Many of the costs identified in Table 1-3 are based on available record information, limited field geotechnical investigation and significant professional judgment. The development of preliminary design for this concept will provide the City with a more accurate budgetary estimate and specific criteria for final design. The preliminary design should include the following:

- ◁ Detailed geotechnical field investigation, including preparation of a geotechnical data report (GDR) and geotechnical baseline report (GBR);
- ◁ Topographic survey and mapping, including the identification of property lines, existing and required easements, existing utilities, and key structures;
- ◁ Detailed hydraulic, hydrologic and surge modeling to determine level of control, pollutant reduction, design flows, critical water elevations, potential surge / transient wave formation, and operational parameters;
- ◁ Preliminary plans and section drawings, sufficiently detailed to develop a preliminary (Class III) cost estimate; and
- ◁ A preliminary design report with specific design assumptions, an outline of required specifications, and specific issues to consider during final design.

The preliminary design will provide the City with the information necessary to evaluate potential funding, schedule and project delivery options that may be advantageous to the City.

## **2.0 INTRODUCTION**

The purpose of this study is the development and evaluation of alternatives and selection of a preferred plan for the collection and storage of CSO flows based upon the original OCI Tunnel CSO control concept that was proposed in the City's LTCP in 1998. The area proposed for CSO rack collection is approximately bounded to the south by Cedar Street, to the west by Maple Street, to the north by the Little Cuyahoga River, and to the east by Main Street and Howard Street. CSO storage and conveyance will originate from the following racks: 4, 16, 17, 18, 19, 20, 21, 23, 24 and 37, as previously illustrated in Figure 1-1.

These racks currently overflow into the Ohio Canal which runs through downtown just to the west of Main Street and Howard Street. Overflows from any storm event must be captured and conveyed north to a location on the Little Cuyahoga River downstream of the Ohio Canal confluence. Captured flows can then be slowly released to the Ohio Canal Interceptor, and/or treated and overflowed to the Little Cuyahoga River.

## **2.1 EVALUATION SCOPE AND REPORT ORGANIZATION**

The scope of this evaluation consists of four (4) major tasks:

1. Development of Background Information – This task consists of a preliminary review of geologic information, a field geotechnical investigation program, tunneling evaluation, environmental pre-screening, right-of-way/property analysis, review of the Ohio Canal Interceptor condition, hydraulic assessment of the Ohio Canal Enclosure's storage capacity, and an evaluation of applicable treatment technologies that can be used in conjunction with tunnel storage and conveyance. This information is presented in Section 3 - Analysis.
2. Evaluation Criteria - Many criteria are used in the evaluation of the selected alternatives. These criteria include the development of tunneling criteria and construction issues, identification of tunnel boring machine (TBM) alternatives, and the development of comparative evaluation criteria. A discussion of these issues is provided in Section 4 – Design Criteria.

3. Alternatives and Project Costs – Each alternative developed for this study has specific advantages and disadvantages, and fundamental cost differences. A discussion of each alternative, a detailed cost estimate and a comparative matrix evaluation of the alternatives is presented in Section 5 – Alternatives and Project Costs.
4. Conclusions and Recommendations – The highest ranked alternative is discussed in more detail and preliminary design considerations are presented in Section 6 – Conclusions and Recommendations.

## **2.2 BACKGROUND INFORMATION AND ASSUMPTIONS**

### Hydraulic Requirements

The LTCP proposed that the original OCI Tunnel would be approximately 5500 feet long, 23 feet in diameter, with a total storage capacity of approximately 15 MG. The 15 MG would provide complete capture and storage of CSO for the storms up to approximately a 2-3 month, 8-hour recurrence interval. Storm flow rates and volumes exceeding this level, up to a 1-year, 8-hour storm, will be treated prior to discharge to the Little Cuyahoga River. Therefore, tunnel alternatives will be sized to meet the 15 MG storage requirement and be capable of conveying all CSO flow out of the downtown area, eliminating the current CSO Rack overflow locations. The conveyance capacity required to achieve this was determined by conveying flow from the full outlet pipe capacity from each individual rack.

The maximum capacity of the outlet pipe was determined using Manning's equation; therefore the connecting conduits to the tunnel are very large. With the use of collection system hydrologic and hydraulic modeling, these connecting conduit pipe sizes can be reduced and optimized.

### Canal Bypass Conduit

The Canal Bypass Conduit is a proposed CSO conveyance conduit that would transfer flows from Rack 16 and 17 near Exchange Street to a diversion structure behind the Akron Civic Theater south of Bowery Street. The purpose of this conduit is to convey

CSO flows around the Lock 2 and Lock 3 area downtown. The Canal Bypass Conduit is incorporated into the CSO storage/conveyance alternatives designated with the letter 'A' that are presented in this report. Cost for this conduit, as provided by the design consultant, has been incorporated in the alternatives.

#### Ohio Canal Enclosure

The portion of the Ohio Canal that runs through downtown Akron is conveyed through a large concrete box culvert that begins behind the Akron Civic Theater south of Bowery Street, and outlets just to the north of State Route 59 near Beech Street. The enclosure is approximately 2270 feet long. Rack 4 and Rack 37 currently overflow into this enclosure. Racks 18 and 19 currently overflow in a junction chamber near the enclosure outlet.

The City has proposed plans for a future Innerbelt Boulevard Development. As part of this development, base flow and upstream storm water in the existing Ohio Canal could be transferred west through the development upstream of the canal enclosure. Diverting these flows from the canal enclosure make it available for CSO conveyance and/or storage. This option of canal diversion and utilization of the canal enclosure for storage and conveyance of CSO flow is incorporated into some of the alternatives that are presented in this report. Cost for the canal diversion, as provided by the design consultant, has been incorporated in the alternatives.

The following sections of this report provide the background information, analysis criteria, evaluation and recommendations for control of the Ohio Canal CSOs.

### 3.0 ANALYSIS

The purpose of this section is to identify and develop background information that will be used to create and evaluate alternatives for controlling CSO to the Ohio Canal. This background information comes from many different sources, and addresses many separate elements that may affect or be influenced by the recommended alternative. For clarity, this section has been organized into the following subsections:

- ◁ Section 3.1 – Geotechnical Information. This subsection contains the results of a preliminary review of geologic information, the development and results of a field geotechnical investigation program. This information was required to develop tunneling costs and for the evaluation of constructability issues.
- ◁ Section 3.2 – Tunneling Evaluation. This subsection contains a tunneling evaluation, and discusses the specific tunneling equipment and issues that may be encountered.
- ◁ Section 3.3 – Environmental Pre-screening. This subsection presents a summary of environmental pre-screening work. This limited environmental review was completed to determine if environmental concerns may impact the construction work.
- ◁ Section 3.4 – Right of Way and Property Issues. This subsection identifies various right-of-way and property issues that may arise with many of the alternatives. Each alternative has various needs with respect to easements and property acquisitions that may be necessary. The number and complexity of such issues was identified as part of the analysis.
- ◁ Section 3.5 – Ohio Canal Interceptor Sewer Evaluation. This subsection provides a review of the Ohio Canal Interceptor (OCI) sewer condition. This assessment is necessary to identify specific defects within the OCI and to make recommendations if the OCI will be kept in services as part of the recommended alternative.
- ◁ Section 3.6 – Ohio Canal Enclosure Hydraulic Assessment. This subsection provides a hydraulic assessment of the storage capacity available within the Ohio Canal Enclosure. This information will be used to evaluate the potential use of the Enclosure as a storage facility as part of a selected alternatives.

- ◁ Section 3.7 – CSO Treatment Technologies. This subsection provides an evaluation of applicable end-of-pipe treatment technologies that can be used in conjunction with tunnel storage and conveyance.

These are presented in the following sections.

### **3.1 GEOTECHNICAL INVESTIGATION**

A geotechnical investigation was conducted by BBC&M Engineering, Inc. (BBCM) as part of this study to investigate the existing subsurface conditions of the downtown Akron area where tunneling is proposed. The investigation was conducted in two (2) parts:

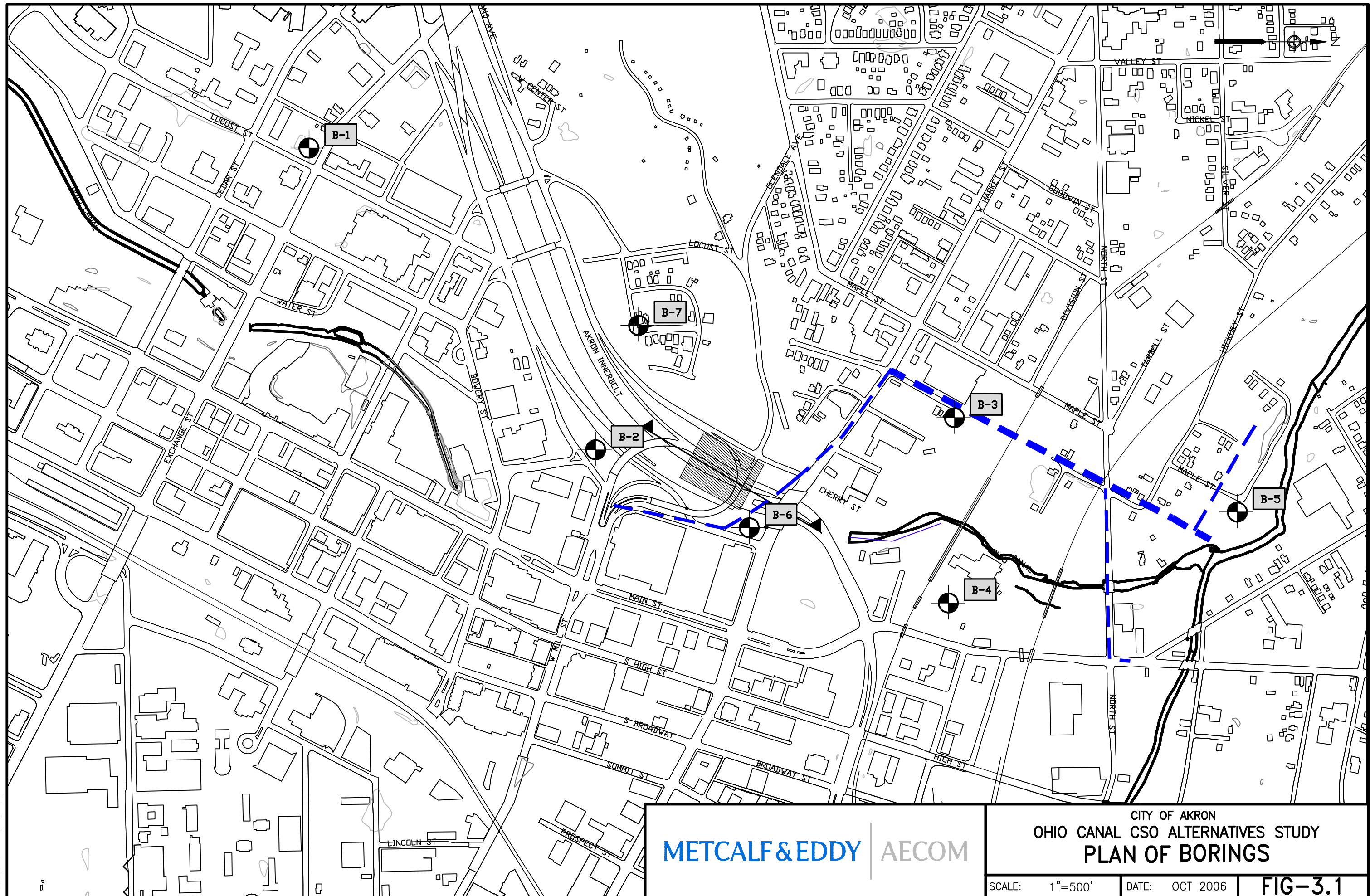
- ◁ **Existing Geotechnical Records Study** – BBC&M researched all available geotechnical data for the downtown Akron area where tunneling is proposed. This report is located in Appendix A.
- ◁ **Geotechnical Soil Borings and Laboratory Analysis** – BBC&M advanced seven (7) soil borings along two proposed tunneling routes. This Geotechnical Data Report (GDR) providing the results of this testing is located in Appendix B. The boring locations are illustrated in Figure 3-1.

### **3.2 TUNNELING EVALUATION**

The geology discussion presented in this report is intended to focus on specific geology parameters, descriptions, and assessments related to the tunneling and shaft construction conditions that could be expected within the downtown Akron area. Additional discussion on tunneling operations is provided in Appendix F.

#### **3.2.1 Geotechnical Settling and Subsurface Conditions**

The glacial history helps to evaluate the consistency of the soil overburden deposits and to predict whether the generally fine grained soils at the site are over-consolidated, which may assist in shaft construction stability and less settlement above the tunnel. Multiple glaciations of the area south of Lake Erie have resulted in such features as buried channels, and stream capture most notably demonstrated by the Cuyahoga River which changes direction north of the site and whose ancestral channel may not follow the present day drainage patterns.



**METCALF & EDDY** | AECOM

CITY OF AKRON  
OHIO CANAL CSO ALTERNATIVES STUDY  
PLAN OF BORINGS

Ohio Canal Tunnel alignments fall within the glaciated Alleghany Plateau geomorphic province and is shown on surficial geology maps within the Akron-Canton interlobate plateau, a hummocky area between two converging lobes of glacial drift. An Illinoian advance of the glacier built up an end moraine in southern Ohio and Pennsylvania creating blocked drainage and ancient lakes when Wisconsinan glaciers advanced into the area depositing the Summit County Morainic Complex immediately north of Akron. The results of the soil stratigraphy formed are complex and can only be generalized at this stage of the investigation.

Split spoon samples from 6 of the 7 test borings taken from Elevation 996 to Elevation 918 recovered 51 to over 214 feet of predominantly sands and silts above weathered shale bedrock. An uppermost layer of brown medium dense sands and silts, including some fill soils within the highway area, is on the order of 30 to 70 feet thick. Beneath these widely graded granular soil deposits are fine grained clayey silt deposits, typically dense, interbedded with a fine to medium grained sand layer thickening towards the southwest. Permeability estimates for this range of materials can vary from  $10^{-3}$  cm/sec to  $10^{-7}$  cm/sec.

Shelby tube samples were taken in Boring B-4 where the clayey silt was recovered having a dry unit weight of 106 pounds per cubic foot (pcf) and triaxial shear strength of slightly less than 1 ton per square foot (tsf). A base level Elevation 980 appears to fill the valleys south of the Cuyahoga River which cuts to Elevation 820 where one (1) test boring was taken and found bedrock at a depth of 7 feet. At boring B-1 which reportedly did not penetrate rock at a depth of 214 feet, refusals in very dense gray silt with little clay beginning at a depth of 115 feet were noted. Weathered bedrock shale fragments are typically found within the basal section of the overburden forming a somewhat gradational contact with the top of rock.

Tunneling behavior of a wide range of fine sands, silty sands, clayey sands, and silts is difficult to predict based on the soil data to date, but can be quantified with further complete grain size analyses. Where the tunnel passes through clayey silt at depths of 100 feet, the strength to overburden ratio indicates that stand-up times for a firm ground could be obtained with pre-drainage (lowering of the water table below invert). However, sandy beds with trace to little binder as found in boring B-2 would likely behave as fast raveling ground and thick granular fill

soils in boring B-6 and if extended to tunnel depth may behave as running ground. The TBM specified would be designed to mitigate this condition.

Depth of shafts on the order of 100 feet may eliminate the use of rectangular multi-braced soldier pile and lagging walls in favor of a circular shape. Limited grouting may be required through the fill and medium dense sands and silts down to the clayey silt.

### **Bedrock**

Bedrock is mapped as Mississippian and Pennsylvanian clastic sandstones, siltstones, and shales lying on the northern slope of the Appalachian basin, strata gently dipping towards the southeast. Pre-glacial drainage patterns dissected the bedrock surface into elongate hills of younger sandstones separated by several northwest-southeast trending valleys flowing northward which cut deeper into older shales. Age relationships are problematical in the non-fossiliferous shales, but important due to the presence in the region of older black shales (known as the Huron member of the Ohio Shale of late Devonian age) which can contain methane gas, radon, and occasionally uranium. Scouring removed and re-worked much of the bedrock to unknown depths within the ancient stream channels, sometimes cutting deep into older deposits creating what is known as a geologic unconformity or time gap in the strata.

Top of rock is soft gray shale gradational with the overlying gray sandy silt overburden in a 5 to 15 feet thick zone consisting of standard penetration test blow count refusals and/or rock quality designation (RQD) of 0% where core was recovered in 6 of the 7 borings. Presence of nodules, likely calcareous, in the gray shale were noted in the 6 core borings tentatively identified as either the Cuyahoga Group of early Mississippian age or the Bedford Shale of latest Devonian age. However, pyrite was also noted as lenses in the cores suggesting that the older black shales may be below the tunneling horizon.

Bedrock was classified as soft shale, medium hard siltstone, hard siltstone, and hard shale, all generally known as mudstone where massive and not fissile. Calcite cementation was noted in some of the cores. A total of 16 unconfined compressive strength tests were made on the mudstones within the proposed vertical alignment, invert elevation 825. The average strength

was 3281 psi with a maximum of 8566 psi in a thick siltstone bed; minimum strengths of slightly less than 1000 psi were noted in soft shales near the top of rock. Slake durability tests were conducted on 6 samples indicating the rock is not particularly susceptible to decomposition with alternate wetting and drying cycles. Minimum slake durability of 63% was recorded in the soft shale with 5 tests in the 90% to 99% range. Mineralogical studies of the clays immediately above the shales within the Cuyahoga River valley have identified predominantly illite clay minerals which is not swelling clay.

A total of 42 RQD measurements were made on typical 5 feet core runs showing a mean RQD of 49% (fair rock) for alignment groups generally east of the Innerbelt, and an RQD of 63% (good rock) for alignments generally west of the Innerbelt. Predominant fractures are bedding plane separations essentially horizontal, occasionally formed by very thin clay or silt interbed fillings. Some vertical fractures were noted in cores, and occasional diagonal fractures were noted dipping 75 degrees. Slightly rough joints spaced less than 8 inches apart and assumption of wet groundwater conditions results in a preliminary estimate of empirical rock mass rating, RMR=41 to 51 for the tunneling horizon. The meaning of this Class III rock mass is an empirical prediction of the average stand up time of one (1) week for a moderate diameter span, perhaps 4000 psf in cohesion, a 25 degree angle of internal friction, and a height of rock load for tunnel supports on the order of 14 feet for a 25 feet wide tunnel. These parameters are only intended for use in the preliminary design and require confirmation.

Tunneling behavior of weak rock (1000 psi to 3500 psi) is generally favorable in terms of stand-up time for placing tunnel supports, such as pre-cast segmental liners required for large diameter tunnels. The ground does not appear to be intensely fractured or under high stress conditions which would lead to a squeezing condition. Furthermore, the gradual transition from the weathered shale and basal till at the top of rock into a weak rock would likely provide a fairly smooth mixed face condition which would not deflect the alignment of the tunnel off its course.

### **Ground Water**

Ground water levels were obtained during the drilling of seven test borings at the site. Stabilized ground water is typically between Elevation 890 and Elevation 910 with higher readings in boring B-1 up on the southern drift and lower readings in boring B-5 down near the Cuyahoga

River. This amounts to 75 feet of head above tunnel invert Elevation 825. Ratio of joint water pressure to major principal stress, a parameter used in the RMR empirical classification discussed in the Bedrock section above, is estimated at 0.3 from an overburden pressure up to Elevation 935.

During the drilling, several of the boreholes were dry until after the bedrock had been penetrated. This indicates that the top of rock may be sealed by the presence of weathered shale and the densely compacted silts and clays which have been overridden by the glacial ice sheet. It is likely that the tunnel will be wet to dripping perhaps on the order of 6 gallons per minute per 30 linear feet, but that flows will not be under pressure since there are no lakes above the area and the tunnel is generally above river and flood level.

A loose zone was found in Boring B-1, 5 feet thick, at a depth of 45 feet. The water content is a little higher and this may represent a perched water zone or an isolated lens of groundwater within the erratic glacial drift. Pre-drainage of this zone by means of well points for construction of a shallow soil alignment east of the Innerbelt requires further investigation including packer tests to determine the extent of this aquifer.

Ground water concerns are most likely to be associated with construction of the river side shaft excavation where the presence of granular deposits is directly connected to the Cuyahoga River by a buried channel following the valley southwards. Further study of existing water wells in the area and possibly pump tests would be required to define these conditions and better define the risks in either the shallow soil alignment east of the Innerbelt, or the mixed face portion of the deeper rock alignment west of the Innerbelt.

### **3.2.2 Design and Construction Issues**

#### **Tunnel Boring Machine (TBM) Method**

The bored tunnel will pass through both the fine-grained clayey alluvial/lacustrine soils and coarser gravely/sandy glacial soils. Clayey soils are low strength, relatively impermeable material, whereas gravely soils are high strength, highly permeable soils. Presence of ground water and nature of gravely soils exclude utilization of an open-face shield. Therefore, tunneling

will need to be performed using Earth Pressure Balance (EPB) or Slurry Pressurized TBM methods. One major advantage of a bored tunnel is that adjacent ground water lowering is not required.

An EPB tunneling machine is generally more suited to fine-grained soil whereas a slurry machine is preferable in coarse-grained soils (which are present at the site). However, EPB tunneling may become feasible in all expected soils if some ground conditioning (treatment) is also performed. If the soil cover above the tunnel becomes less than the normally required thickness equal to one tunnel diameter it is possible to stabilize the overburden of lesser thickness by treating the ground with grout. The grouting can be performed in advance of the tunneling from the ground surface. Alternatively it can be performed from inside the TBM since most machines can accommodate ground stabilization techniques.

Effective measures will also be undertaken to ensure the final tunnel liner remains watertight. The water retention capabilities of such tunnels have improved significantly in recent years. The TBM tunnel section is protected with gasket type seals between precast concrete tunnel liner segments. This system has resulted in successful and acceptable level of watertightness for water carrying tunnels.

### **Launching and Extraction Shafts**

The launching and extraction shafts involve excavation to the bottom of the shaft, construction of the tunnel structure, and backfilling with compacted material. A variety of temporary retaining walls are feasible; these may include:

1. Diaphragm slurry walls with and without tie backs or internal bracing;
2. Interlocking sheet pile wall with tiebacks or internal bracing
3. Circular tunnel liner plate wall with ring wales
4. Secant pile walls
5. Top Down excavation and construction of concrete liner, supported from concrete collar.

Either wall system method is suitable to provide a rigid wall system capable of resisting groundwater penetration for the depths required on the project.

Proposed tunnel alternative east of the Innerbelt will require launch shafts approximately 125ft deep and extraction shaft of 100ft deep. Alternatives west of the Innerbelt will require launch shaft approximately 125ft deep and extraction shaft 50ft deep.

Hydrostatic pressures and minimizing water leakage into the shaft are the two major design considerations. Dewatering of the excavation and avoiding settlement of the adjacent buildings supported by shallow foundations are the primary construction considerations. This problem could be mitigated by plugging the bottom of the shaft with concrete. Moreover, all buildings are assumed to be supported by deep foundations that include concrete-filled pipe piles, driven steel H-piles, and drilled-in, cast-in-place concrete socketed shafts (caissons). All deep foundations are assumed to be bearing in bedrock; therefore, dewatering and deep excavation will have minimum impact on the foundation.

The ground water is confined to the lower granular soil stratum which has high hydraulic conductivity. Pump tests and analyses using historical data from previous well installations will be evaluated during Preliminary Engineering.

Another construction consideration that will influence the use of tie backs for temporary retaining walls is the presence of basements and deep foundations adjacent to the tunnel walls. Use of tiebacks will also require right-of-way acquisition and legal agreements.

### **3.2.3 Instrumentation Monitoring**

#### **Surface Settlement Impacts**

One of the major concerns in the construction of the tunnel and tunnel shafts will be from construction induced ground movements and their affects to buildings adjacent to the alignment, especially those which are supported by shallow foundations. An instrumentation program to be utilized during construction will be developed based on the method of tunneling.

The settlement of structures at the close proximity of shafts is insignificant due to the configuration of the shaft structure. However, the instrumentation program should be designed to monitor lateral and vertical movement of structures adjacent to the shafts. This can be accomplished by using Deformation Monitoring Point (DMP), inclinometers, and piezometers.

If the tunnel is constructed using a tunnel boring machine (EPB or slurry TBM's), construction induced ground movements of facilities both above the tunnel and on either side of the tunnel become a concern. Therefore, besides inclinometers, DMP's and piezometers, a series of multi-point extensometers may also be installed in boreholes drilled in arrays perpendicular to the tunnel alignment. Some of the boreholes should be located directly above the tunnel's centerline and some at an offset of 8 to 10 feet on each side of the tunnel. Each borehole should be finished at ground level with a secure manhole installation to prevent vandalism. Extensometers should be connected to vibrating wire displacement transducers housed in the referenced head located about 1.5 feet below ground surface. The depth of the lowest anchor points of extensometers above the tunnels will depend upon the thickness of overburden. The lowest anchor point of the extensometers in the side holes should be about 10 feet below the tunnel inverts. The exact locations, depths, installation methods, instrument type and frequency of monitoring will be developed once a tunneling method, alignment, profile, and a detailed construction method is identified and pursued into final design.

Movement adjacent to all of the buildings will be monitored; however, it is not anticipated that any of the construction methods will require mitigation efforts of the buildings founded on deep foundations. The launch and extraction shafts may utilize integral slurry wall techniques or make use of a rigid support of excavation system to limit ground movements behind the wall to acceptable limits. Limitations on groundwater drawdown will also be imposed to help minimize settlements.

### **Anticipated Surface Settlement**

Water content measurements were made in all spoon samples providing an index of the coefficient of consolidation of the fine grained soils. Out of 36 Atterberg limits tests, only 12 showed any indication of plasticity mostly plotting in the ML (silt) range with 3 samples in the CL-ML (dual clay and silt classification) and 2 in the CL (clay of low plasticity) range. Bell shaped settlement curves are anticipated based on a 1%-2% loss of ground into the tunnel (depending on the excavation method and quality of the workmanship). At depths of nearly 100 feet it is unlikely that the settlement at the ground surface will be significant. Most of the settlement and lateral movements will be associated with the construction shaft excavations where the instrumentation and monitoring efforts should be focused.

### 3.3 ENVIRONMENTAL PRE-SCREENING

A limited review of commercial environmental database records was conducted for this study. This limited environmental review was completed to determine if environmental concerns may impact the construction work.

An environmental database report was obtained from Environmental Data Resources, Inc. (EDR) for the potential alignments east and west of the Innerbelt. The EDR report contains the results of a proprietary database search of federal and state environmental databases that track activities associated with hazardous waste and incidents that have resulted in major environmental impairment or are suspected of being environmentally impaired. These databases are prepared and maintained by various federal and state environmental agencies such as the Environmental Protection Agency (EPA) and the Ohio Environmental Protection Agency (OEPA). The search distances are per ASTM Standard Practice for Environmental Site Assessments (E 1527-05). The following are descriptions of the Federal and State databases searched by EDR.

#### **Federal Records Review**

- ◁ **NPL:** The National Priority List (NPL) identifies priority hazardous waste sites for remedial actions under the EPA Superfund program.
- ◁ **CERLIS:** The EPA publishes a list of sites that may potentially pose a threat to the environment or the health of the general public. This list is known as the CERLIS list. The EPA also publishes the CERLIS-NFRAP list, which are CERLIS sites designated “no further remedial action planned” and have been removed from the CERLIS list.
- ◁ **CORRACTS:** The CORRACTS report identifies hazardous waste handlers with corrective action activity.
- ◁ **RCRA:** RCRAInfor is EPA’s comprehensive information system, providing access to data supporting the Resource Conservation and Recovery Act (RCRA) and the Hazardous Waste Amendments. The database includes selective information on sites, which generate, transport, store, treat, and/dispose of hazardous waste. The EPA also regulates the management of hazardous waste at Transportation, Storage, and Disposal (TSD) facilities; RCRA large quantity generator (LQG); and RCRA small-quantity generator (SQG) sites.

- ◁ **US BROWNFIELDS:** The EPA's listing of Brownfield properties addressed by Cooperative Agreements Recipients and Brownfield properties addressed by Targeted Assessments.

### **State and Local Record Review**

- ◁ **DERR:** The DERR database is an index of sites which Ohio EPA maintains files. It includes sites with know or suspected contamination. A site's inclusion in the database does not mean that it is now or has ever been contaminated.
- ◁ **OH MSL:** Ohio EPA no longer maintains or published the Master Sites List (MSL), which was a list of sites with know or suspected contamination. A site's inclusion in the database does not mean that it is now or has ever been contaminated.
- ◁ **SWF/LF:** The Solid Waste Facilities/landfill Sites record typically contains an inventory of solid waste disposal facilities or landfills in Ohio.
- ◁ **LUST:** The Leaking Underground Storage Tank (LUST) Incident Reports contain an inventory of reported leaking UST incidents.
- ◁ **UST List:** The Underground Storage Tank (UST) database contains registered USTs.
- ◁ **Archive UST List:** Underground Storage Tank records that have been removed from the UST database.
- ◁ **UNREG LTANKS:** A suspected or confirmed release of petroleum for a non-regulated UST.
- ◁ **VCP:** Sites listed on Ohio EPA, Voluntary Action Program Sites.

### **Summary of EDR Findings**

The target properties were not listed in any of the databases searched by EDR. However, surrounding sites were identified. A summary of the findings is listed below. Table 3-1 lists the environmental concerns identified, and the full reports are located in Appendix C.

- ◁ One RCRA-TSD was listed within 1 mile of the site.
- ◁ One RCRA-LQG was listed within ¼ mile of the site. The facility did not have any violations listed.
- ◁ Nine RCRA-SQG was listed within ¼ mile of the site.
- ◁ Three DERR sites were listed within one mile of the site.

- < One MSL site was listed within one mile of the site.
- < Twenty Five LUST sites were listed within ½ mile. Twenty two of the LUST sites are inactive and were issued no further action letters. One LUST site was listed as an active site with report of possible incident. Two Lust sites were listed as active site with no closure report received letter sent to facilities.
- < One UNREG LTANKS was listed within ½ mile of the site.
- < One UST was listed within ¼ mile of the site.
- < One VCP was listed within ½ mile of the site.

Four sites are located adjacent to the alignments. These sites are summarized below.

- < Akron City of St #60 is located at 60 W North St and south of CSO Treatment Area 3A. This facility was listed as a RCRA-LQG and as having no violations found.
- < Harrs is located at 198 N Howard, and south of CSO Treatment Area 3A. The facility was listed as an EDR Historic Cleaner in 1940.
- < Akron WWTP is located at 219 Putnum St, and north of CSO Treatment Area 4B. The facility was listed as having a spill reported in 2004 (OH Spills S106747323). No specific information was available.
- < An unknown property (UNK) is located at 222 Hickory St and south of CSO Treatment Area 4B. The facility was listed as having a spill reported in 2001 as a sheen (OH Spills S105734641). No specific information was available.

**Table 3-1: Summary of Environmental Concerns**

<b>Site Name</b>	<b>Distance (mile)</b>	<b>Database Listing</b>	<b>Environmental Issue</b>
Ozko, Inc. 317 Silver St	1/8-1/4 W	RCRA-TSD RCRA-SQG	Two violations are listed for this site from 2000, including a TSD-Closure/Post-Closure requirement violation.
Akron City of St # 60 60 W North Street	0- 1/8	RCRA-LQG	No violations listed.
Tri Star International 132 N Howard St	0-1/8 S	RCRA-SQG	No violations listed
ACM Inc 55 Furnace St	1/8-1/4 SSE	RCRA-SQG	No violations listed
Farley Chemical and Solvent Co. 309 Silver St	1/8-1/4 W	RCRA-SQG	No violations listed
City of Akron Power Plant 40 Beech St	1/8-1/4 SSW	RCRA-SQG	Two violations listed, compliance achieved.
Gusmer-Admiral Inc 305 W North St	1/8-1/4 SW	RCRA-SQG	One violation listed, compliance achieved.
Kocto Manufacturing 313 W North St	1/8-1/4 SW	RCRA-SQG	No violations listed
Erectors 20 E North St	0-1/8 E	RCRA-SQG	No violations listed
Parker Fabricating Inc 20 E North St	0-1/8 E	RCRA-SQG	No violations listed
Old Ohio Edison Steam Plant 40 Beech St	1/8-1/4 SSW	DERR	Listed as Clean Ohio Fund and Voluntary Action Program
Towell Dave Cadillac Inc Prope 111 W Market St	¼-1/2 SSW	DERR VCP	Listed as Voluntary Action Program
ABC Demolition Co 359 Harris St	½-1 E	DERR OH MSL	Site listed as Site Assessment.
Starr Transmission 155 W Market St	¼-1/2 SSW	LUST	Active site with report of possible incident
Charles Childress 214 Memorial Pkwy	¼-1/2 N	LUST	Active site, no closure report received letter sent.
Stephen Comunal 70 E North St	1/8-1/4 E	LUST	Active site, no closure report received letter sent.
Summit Co. Income Maint Facility 37 N High St	¼-1/2 S	UNREG LTANKS	Facility status DEF
Akron Switch Center 120 N Broadway	1/8-1/4 SE	UST	Diesel tank currently in use

### **Historical Topographic Map**

M&E obtained historical USGS topographic maps of the Akron 15-Minute quadrangle from 1905 and Akron West 7.5-Minute quadrangle from 1958, 1967, 1979, 1992, and 1994. These maps were used in determining prior use of the property, as required by ASTM E 1527-054. No changes were noted on the Topographic Maps.

### **Environmental Pre-Screening Conclusions**

Although several sites were identified in the EDR report, none of these sites are likely to impact the reviewed area due to their distance from the site and the topography of the area.

### **3.4 RIGHT-OF-WAY AND PROPERTY RESEARCH**

The proposed alignments for CSO conveyance and storage were laid out to maximize the use of public right-of-way. Most of the proposed tunneling is within public right-of-way, however storage tanks will require a large amount of land.

#### **Downstream Storage Tank Locations**

One area designated for a large storage tank is the northwest corner of the Howard Street and North Street intersection, as illustrated in Figure 3-2. The area is bounded by the Little Cuyahoga River to the north, the Ohio Canal to the west, Howard Street to the east, and North Street to the south. Several properties where the current ABTEC building resides would need to be purchased for land use. According to Summit County records, these properties are currently each owned by Bruce Taylor, Pamela Myers, Alisa O'Neil, and Linda Barnes.

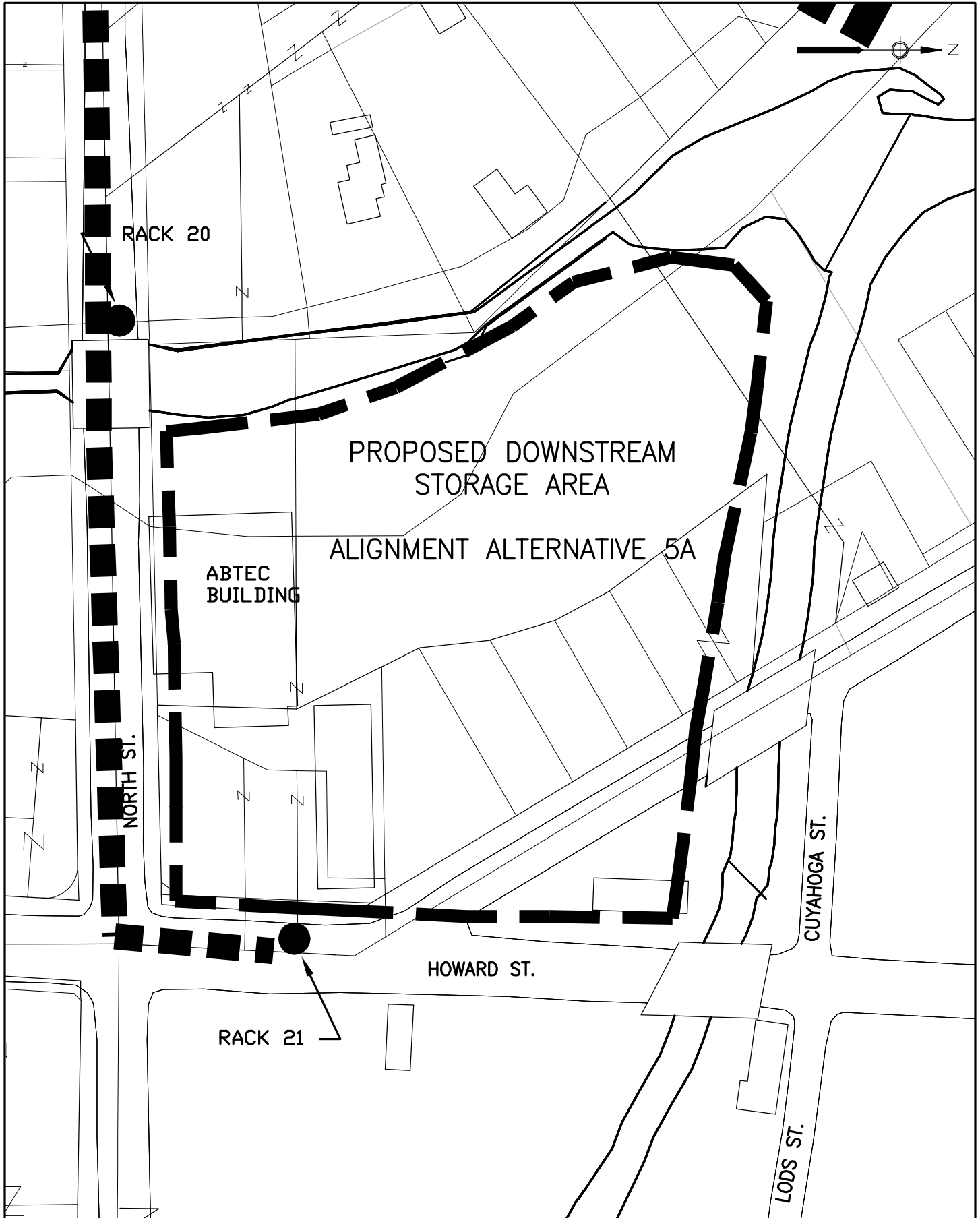
Another area designated for a large storage tank is an area bounded to the north by the Little Cuyahoga River, to the east by Walnut Street, to the south by Hickory Street, and to the west by Hubbard Street, as illustrated in Figure 3-3. Most of the properties in this area are currently owned by the City.

#### **CSO Storage Tunnel – Alignment Alternative 3A and Alignment Alternative 5A**

Alignment Alternative 3A and Alignment Alternative 5A (described in Section 5) both incorporate a large storage tunnel along the east bank of the Ohio Canal between the Innerbelt

LAST UPDATE: Monday, October 16, 2006 9:31:14 PM  
PLOT DATE: Wednesday, January 16, 2008 3:42:16 PM

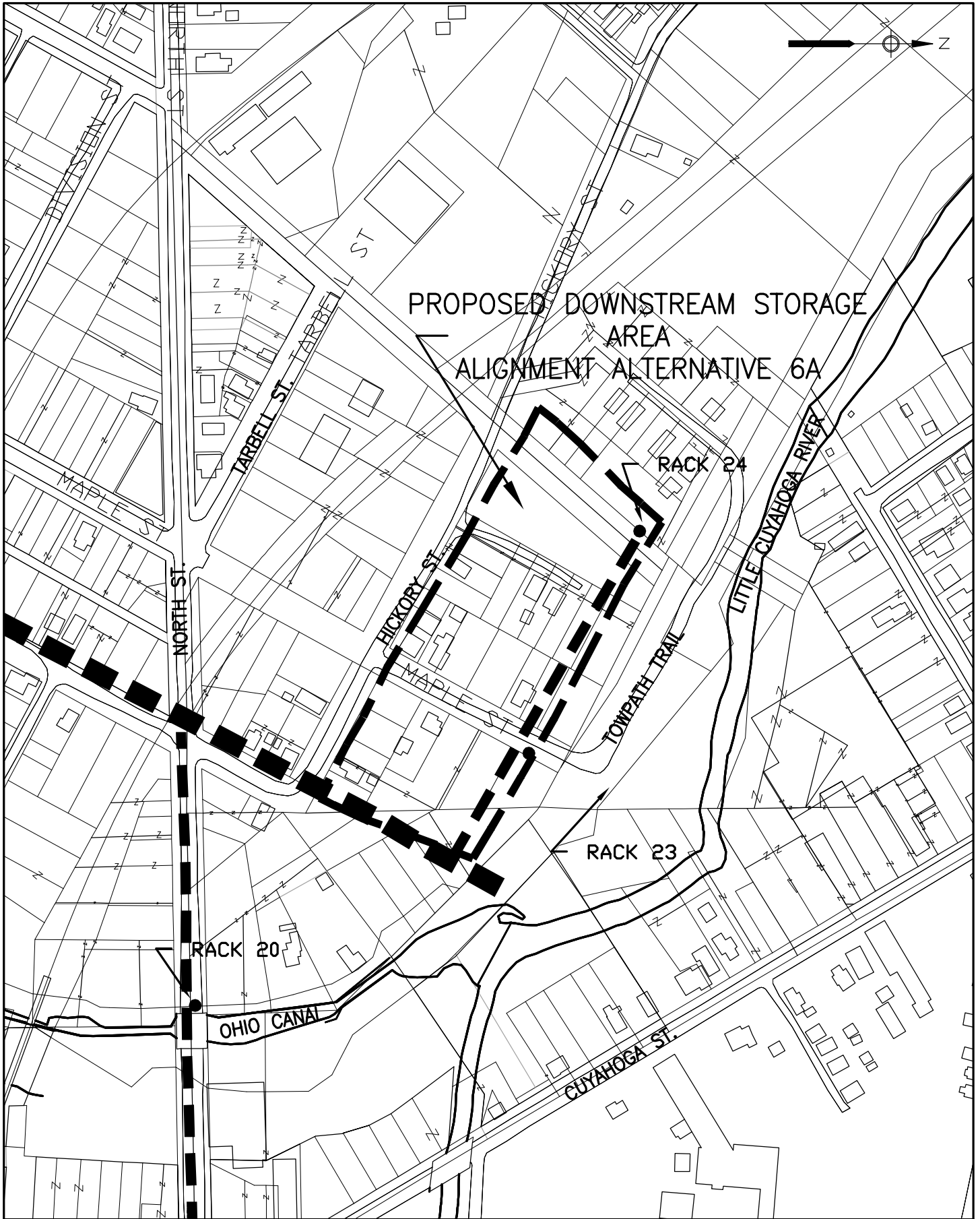
PATH/FILENAME: P:\60005637-AKR\EXHIBIT-1.DWG  
ANSI A - 3-8-05



**METCALF & EDDY | AECOM**

CITY OF AKRON  
OHIO CANAL CSO ALTERNATIVES STUDY  
DOWNSTREAM STORAGE AREA-5A

SCALE: 1"=100' | DATE: OCT 2006 | **FIG-3.2**



**METCALF & EDDY | AECOM**

CITY OF AKRON  
OHIO CANAL CSO ALTERNATIVES STUDY  
DOWNSTREAM STORAGE AREA-6A

SCALE: 1"=200'    DATE: OCT 2006    **FIG-3.3**

and North Street. The Ace Rubber building currently resides along the east bank of the Ohio Canal near the Furnace Street right-of-way. The property is currently owned by Garro Properties. The acquisition of this property will help to create a straighter alignment.

### **3.5 OHIO CANAL INTERCEPTOR SEWER ANALYSIS**

The Ohio Canal Interceptor sewer (OCI sewer) flows north through downtown Akron near the Ohio Canal. The section of the OCI sewer that flows north between Exchange Street and Bowery Street was previously inspected in 1998. Closed-circuit television (CCTV) inspection videos were provided by the City for review by the project team. The purpose of this review was to qualitatively determine the condition of the OCI sewer, and to identify the potential need for structural rehabilitation. This becomes especially significant when evaluating CSO control alternatives that require the OCI sewer to remain in service for conveyance of sanitary sewer flow.

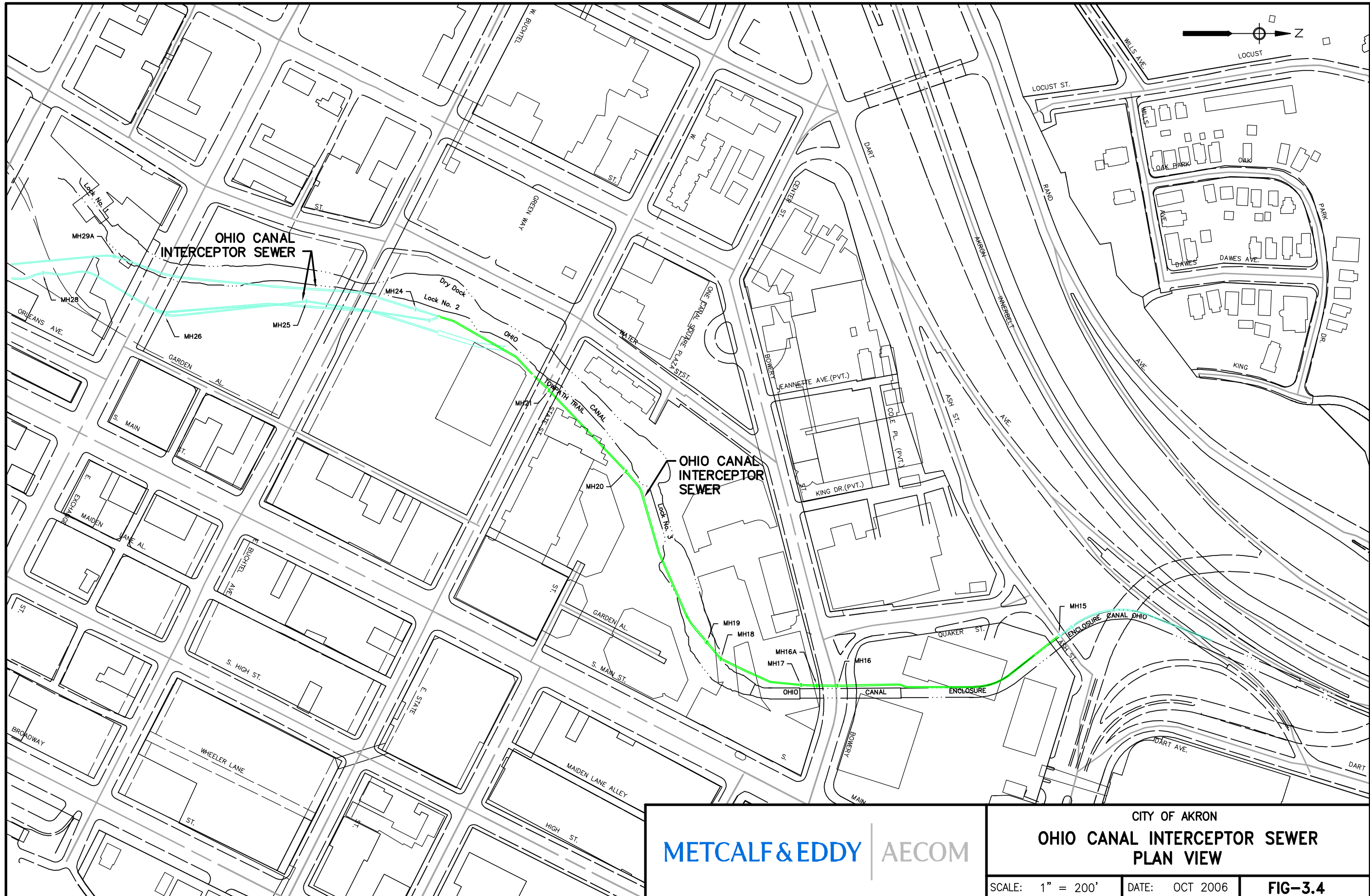
The CCTV inspection videos were reviewed and manually documented using the Pipeline Assessment and Certification Program (PACP) codes developed by the National Association of Sewer Service Companies (NASSCO). A detailed tabulation of the identified conditions and defects is presented in Appendix D. Figure 3-4 illustrates the reach of the OCI sewer that was reviewed as part of this effort. Most of the interceptor, from MH-29A to MH-15, is 30- to 36-inch diameter brick sewer. Only the most upstream section, MH-29 to MH-29A, is 8-foot by 12-foot reinforced concrete. During dry weather, flow levels exceed 30-40% of the pipe diameter in some sections, and flow velocities are generally high as well.

Throughout the length of sewer reviewed, there were several identified deficiencies that were not localized to specific areas, including:

- < Displaced or missing bricks
- < Circumferential and longitudinal cracks
- < Offset pipe joints
- < Infiltration
- < Root intrusion
- < Mineral deposits

LAST UPDATE: Monday, October 16, 2006 9:39:15 PM  
PLOT DATE: Wednesday, January 16, 2008 3:45:47 PM

PATH/FILENAME: P:\60005637-AKR\FROM ARCADIS\REFUTILITIES-BASE-RYAN.DWG  
ANSI B - 3-8-05



**METCALF & EDDY** | AECOM

CITY OF AKRON  
**OHIO CANAL INTERCEPTOR SEWER  
PLAN VIEW**  
SCALE: 1" = 200' | DATE: OCT 2006 | **FIG-3.4**

None of the identified defects appeared to be an imminent risk of collapse. However, the observation of structural defects, in conjunction with the presence of groundwater infiltration and potential internal hydrostatic loads from surcharge, present conditions that are potentially favorable for material surrounding the sewer to be washed away, leaving void space around the sewer. This scenario can cause sink holes and possibly sewer collapse.

Monitoring and assessment of critical sewer infrastructure such as the OCI sewer is recommended every 5 to 10 years. Since the OCI sewer was inspected approximately 8 years ago, the sewer should be scheduled for inspection in the near future. Following such an inspection, a comparison can be made between the observed defects to the defects identified in the 1998 inspection. If conditions appear to be worsening, specific rehabilitation options can be developed based on the long-term plan for use of the OCI sewer.

Certain alternatives for controlling CSO to the Ohio Canal discussed later in this report present the option of conveying sanitary sewer flow through a proposed conveyance/storage tunnel system, and then connecting back to the OCI sewer at a downstream location. This would allow portions of the existing OCI sewer to be abandoned, or replaced with new, smaller diameter sanitary sewers. However, other alternatives present the option of conveying the wet weather flow through surface facilities, such as the Canal Enclosure, in the downtown area. These alternatives would require the OCI sewer to remain functional as part of the CSO long-term control plan.

Several rehabilitation options are available for 30- to 36- inch brick sewers, many of which require little surface disruption. Table 3-2 presents a summary of many rehabilitation options. Cured-in-place pipe (CIPP) techniques have been used successfully in sewers similar in condition and size to the OCI sewer. Based on future inspection and assessment results, rehabilitation may be a cost-effective method to preserve the structural integrity and hydraulic capacity of the OCI sewer.

**Table 3-2. Rehabilitation Options for the Ohio Canal Interceptor Sewer**

Method:		Diameter Range (mm)	Maximum Installation (m)	Liner Material
In-Line Expansion	Pipe Bursting	100-600 (4-24 in.)	230 (750 ft.)	PE, PP, PVC, GRP
Sliplining	Segmental	100 - 4000 (4-158 in.)	300 (1,000 ft.)	PE, PP, PVC, GRP (-EP & -UP)
	Continuous	100 -1600 (4-63 in.)	300 (1,000 ft.)	PE, PP, PE/EPDM, PVC
	Spiral Wound	150 -2500 (6-100 in.)	300 (1,000 ft.)	PE, PVC, PP, PVDF
Cured-In-Place Product Linings	Inverted-In-Place	100-2700 (4-108 in.)	900 (3,000 ft.)	Theromaset Resin/Fabric Composite
	Winched-In-Place	100 -1400 (4-54 in.)	150 (500 ft.)	Theromaset Resin/Fabric Composite
	Spray-on-Linings	76-4500 (3-180 in.)	150 (500 ft.)	Epoxy Resins/Cement Mortar
Modified Cross- Section Methods	Fold and Form	100-400 (4-15 in.)	210 (700 ft.)	PVC
	Deformed/Reformed	100-400 (4-15 in.)	800 (2,500 ft.)	(thermoplastics) HDPE
	Drawdown	62-600 (3-24 in.)	300 (1,000 ft.)	(thermoplastics) HDPE, MDPE
	Rolldown	62-600 (3-24 in.)	300 (1,000 ft.)	HDPE, MDPE
	Thin-walled lining	500-1,100 (20-46 in.)	960 (3,000 ft.)	HDPE
Internal Point Repair	Robotic Repair	200-760 (8-30 in.)	N/A	Exopy Resins Cement Mortar
	Grouting/Sealing & Spray-on	N/A	N/A	Chemical Grouting
	Link Seal	100-600 (4-24 in.)	N/A	Special Sleeves
	Point CIPP	100-600 (4-24 in.)	15 (50 ft.)	Fiberglass/Polyester, etc.

Note: Spiral wound sliplining, robotic repair, and point CIPP can only be used only with gravity pipeline.  
All other methods can be used with both gravity and pressure pipeline.

EPDM = Ethylene Polypelene Diene Monomer  
GRP = Glassfiber Reinforced Polyester  
HDPE = High Density Polyethylene  
MDPE= Medium Density Polyethylene  
PE = Polyethylene  
PP = Polypropylene  
PVC = Poly Vinyl Chloride  
PVDF = Poly Vinylidene Chloride

Iseley, T. and M. Najafi, 1995. *Trenchless Pipeline Rehabilitation*. Prepared for the National Utility Contractors Association, Arlington, VA.

### **3.6 OHIO CANAL ENCLOSURE STORAGE AND CONVEYANCE ANALYSIS**

The Ohio Canal flows from the south to the north through downtown Akron, just to the west of Main Street and Howard Street. The canal flows through a rectangular concrete box enclosure that begins behind the Akron Civic Theater at the corner of Bowery Street and Main Street and outlets to open-air north of State Route 59 near Beech Street. This enclosure was built in the 1960's to allow for business development on the west side of Main Street between Bowery Street and Market Street.

If the current storm flows through the Ohio Canal are diverted westerly as part of the proposed Innerbelt Boulevard development, then that leaves the Canal Enclosure available for storage or conveyance of CSOs from the CSO Racks in the vicinity of the enclosure. This would include flows from Racks 16 and 17, as well as Racks 4 and 37 that currently overflow into the enclosure.

#### **Ohio Canal Enclosure Storage Capacity Analysis**

The original Ohio and Erie Canal Enclosure plans (Contracts 1-3, 1963-1966) as provided by the City of Akron were used in the analysis of the enclosure's storage capacity. M&E did not conduct a survey or field investigation of the enclosure, only the plans provided were used in the analysis. There are changed conditions along the length of the enclosure since the original construction, including the construction of State Route 59 (Akron Innerbelt). There are many potential storm water connections along the length of the enclosure that were not a part of the original construction plans. The location and elevations of these connections could significantly reduce the storage capacity of the structure.

The canal enclosure contains two large ogee spillways that divide the enclosure into three sections at different sloped elevations. For the purposes of the capacity analysis, the sections will be called Section A, B, and C (see Ohio Canal Enclosure Profile located in Appendix E).

#### **Section A**

Section A is the lowest section of the enclosure at the outlet near Beech Street. It starts at Sta. 13+74 (Contract 2) and ends at Sta. 4+81 (Contract 3), the outlet. Section A can be used for

storage assuming an automatic gate or other control structure is installed at the outlet. The Section can be filled to the lowest inlet into the enclosure. The manhole at Sta. 6+33.50 (Contract 3) was assumed to be the lowest inlet into the structure. The total volume capacity to elevation 895.00 was estimated to be 1.7 MG.

### **Section B**

Section B is immediately upstream of Section A. Section B spans from Sta. 7+32 (Contract 1) to Sta. 13+74 (Contract 2). Section B can be used for storage assuming automatic gates or other control structures are installed at the inlet and outlet of this section. The total volume capacity of Section B to elevation 921.50 was estimated to be 2.7 MG.

### **Section C**

Section C is located at the upstream end of the canal enclosure behind the Civic Theater. It was determined that this section of the canal enclosure would not be suitable for storage, as flow back up into the open section of the canal immediately upstream of the enclosure.

Using the existing canal enclosure for storage capacity would require installing flow control gates that would close the outlet during a storm event, and then release the stored flow to the Little Cuyahoga Interceptor as capacity is available. Additional monitoring will be required to allow automated facilities to release storm flow for severe rain events that exceed the CSO control goals. The canal enclosure storage capacity was analyzed assuming a closed outlet. The enclosure could then be filled up to the lowest inlet elevation into the structure, which is the maximum elevation the water could reach before flooding adjacent facilities. This volume is estimated to be approximately 1.7 MG. The capacity is well under the 15 MG needed to store CSO flows from the adjacent racks.

The canal enclosure above the enclosure flood elevation was then analyzed to find the capacity of the upstream section of the structure. This section could only be used for storage if automatic gates were installed at intermittent locations. The volume in this upstream section is estimated to be 2.7 MG. Therefore, the total potential volume of the canal enclosure is estimated to be 4.4 MG. This volume represents approximately 30% of the required CSO storage volume of 15 MG. Racks 20, 21, 23, and 24 are downstream of the canal enclosure. Separate facilities will be required to control CSO from these Racks.

Additional analysis of the enclosure is required to determine the presence of service connections and to evaluate structural condition. Since the canal enclosure can only potentially store 30% of the required CSO volume, the enclosure will be further evaluated in conjunction with another tunnel and/or storage facility.

The landscape has changed since the enclosure’s original construction. There are most likely many potential storm connections to the enclosure that have been made after the initial construction in the late 1960’s. Any connections would have to be eliminated or isolated from the enclosure to avoid flooding. This elimination process would require smoke testing, dye testing, and an internal survey of the structure.

Further, an analysis of the structural integrity of the canal enclosure is required. The structure must be suitable to withstand the full storage loading of combined sewer flow and the installation of automated gates.

**Ohio Canal Enclosure Conveyance Analysis**

The Ohio Canal Enclosure is also available for CSO conveyance out of the downtown area. The profile of the Ohio Canal Enclosure is shown in Appendix E. The conveyance capacity of the enclosure depends on the velocity of the flow. For calculation purposes, 10 ft/s was assumed for velocity.

Canal Sections			
Station	Dimensions	Slope	Capacity (mgd)
5+00	14'x17'	0.30%	2800
15+50	15'x14'	0.10%	1416
14+00	20'x8'	-	1034
22+00	27.6'x8.5'	-	1511

The Canal Enclosure must be able to pass the storm flows from Racks 4, 16, 17, and 37. The total flow based upon the maximum outlet capacity of each of these Racks is 1,425 mgd. The conveyance capacity of the canal enclosure can be improved by reducing the size of the concrete ogee weir located near Station 14+00.

### 3.7 CSO TREATMENT ALTERNATIVES

The City has the option of incorporating treatment at the downstream location of any of the alignment alternatives. High-rate treatment would allow for treating a 1-year, 8-hour storm event prior to discharge to the Little Cuyahoga River. Several types of treatment have already been studied by the City, and piloted at the Akron Water Pollution Control Station (WPCS). Pilot studies have been performed for the ACTIFLO, DensaDeg, and Fuzzy Filter compressed media technologies. These pilot studies were reviewed along with several other projects, including: Massachusetts Wastewater Regional Authority (MWRA) Union Park Treatment Facility, the MWRA CSO Facilities Plan, and the Nashua, NH Wet Weather Flow Treatment Facility Report.

Characteristics of typical Akron CSO flows are shown below, based upon the Akron WPCS CSO Access Database (DLZ, September 2003).

Akron CSO Flow Characteristics		
TSS (mg/l)	BOD (mg/l)	CBOD (mg/l)
182	74	52

#### **ACTIFLO**

The U.S. Filter/Kruger ACTIFLO system is a compact process that uses a microsand, called Actisand, which enhances floc formation and acts as a weight for settlement. It is recommended for storm flows and combined sewer flows. The process allows for high overflow rates of approximately 60 gpm/sf and short retention times. These characteristics greatly reduce the square foot area needed for clarification tanks.

#### **DensaDeg**

The Infilco Degremont, Inc. DensaDeg Clarifier is a high-rate solids contact clarifier that combines optimized flocculation, internal and external solids recirculation, and tube settling to maximize hydraulic loading rates and treatment. Similar to the ACTIFLO process, the area needed for clarification is greatly reduced. DensaDeg can achieve hydraulic loading rates up to approximately 40 gpm/sf.

## Compressed Media Filtration

The Wet Weather Engineering and Technology (WWETCO) compressed media filtration is a high-rate filter that does not require any mechanical instruments to process incoming wastewater. Compressed media filtration achieves hydraulic loading rates up to approximately 13 gpm/sf.

## Comparison Summary

Table 3-3 presents a comparison of treatment technologies suitable for CSO applications. The City of Akron desires to treat up to a 1-year, 8-hour storm event. The cumulative peak flow rate from the downtown Racks (4, 16, 17, 18, 19, 20, 21, 23, 24, 37) for this particular storm event, neglecting peak timing and attenuation, is approximately 413 mgd. The required size (square footage) of a treatment facility of each kind is presented in the table. All of the downstream storage areas presented in this report are of adequate size to accommodate any of these treatment facility types.

**Table 3-3. CSO Treatment Technologies**

Process	Hydraulic Load Rate (gpm/sf)	Process Size (sf)		Coagulant & Flocculant	Backwash (Air/H <sub>2</sub> O)	Treatment Performance				O & M Level ****
		Q=413 mgd	W/ Extra Disinfection*			Inf.TSS (mg/L)	TSS Removal	Disinfect	Source	
ACTIFLO	60	4,780	16,300	Yes	No	140	>90%	>90%	Pilot Test in Akron, Port Clinton, Mansfield, Toledo; WWTPs of Lawrence, Bremeron, St. Bernard	High
DensaDeg	40	7,170	18,690	Yes	No	140	>90%	>90%	Pilot Test in Akron; WWTPs of Leucadia, Breckenridge, Meru, Toledo	High
Compressed Media Filter	13	22,060	33,580	No	Yes	10~300	50~80	30%	Pilot Test in Akron, Atlanta; WWTP of Columbus	High
Fast Primary Clarifier	4	71,750	71,750**	No	No	140	50***	99.96%	MWRA Union Park Treatment Facility	Moderate

**Note:**

\* Extra disinfection process is added to meet NPDES Discharge Limit; Sizing is based on 3 minute contact time (>99.9% removal) and 10 ft depth.

\*\* The primary clarifier can reach disinfection limit when a disinfectant like NaClO is fed in the influent channel.

\*\*\* The TSS removal rate usually drops when influent TSS level decreases.

\*\*\*\* Operation and maintenance include chemical and mechanical processes, and energy consumption.

## **4.0 DESIGN CRITERIA**

The purpose of this section is to provide specific criteria that will be used to evaluate the various CSO control alternatives. Each of the alternatives presented in Section 5 will require tunneling to some extent. The following text identifies specific issues that must be considered in the selection of a preferred alternative. This section provides discussion of the following items:

- ◁ Tunnel boring machine (TBM) selection and methodology;
- ◁ Tunnel boring construction issues;
- ◁ Risk mitigation and alternative tunneling methods; and
- ◁ Criteria for matrix analysis of alternatives.

These issues are discussed in greater detail in the following text.

### **4.1 TUNNEL BORING MACHINE (TBM) SELECTION AND METHODOLOGY**

Recent developments in Tunnel Boring Machines (TBM) have brought about effective methods of building tunnels in various types of rock and mixed face conditions that have possible applications on the Ohio Canal Tunnel.

A dedicated TBM would be designed for the specific subsurface materials and conditions expected to be encountered on the project. For the purpose of this study, it is assumed that a new TBM will be designed, fabricated and purchased for the proposed alignments of the project. The Contractor does have the option of purchasing a used machine for the work. Except for acknowledging this fact, no other consideration for a used machine has been considered in this report.

Typically a TBM consists of a rotating head which excavates the material and from there the spoil enters into a chamber from which the material is transported to the surface. The complete operation requires a crew driving and running the cutting head, an excavation handling crew, and a lining installation and storage crew. The diameter of the cutting head is selected based on the required tunnel geometry and total thickness of the lining assembly.

Three types of TBM technology are predominantly used in current practice. They are referred to as Open Face, Earth Pressure Balance (EPB), and Slurry Shield. The open face shield method cannot effectively control the inflow of water or support the face consisting of poorly graded sand and gravel, and water pressure anticipated at this site. Therefore, since control of the excavated tunnel face and infiltrating groundwater during construction is vital to the success of the project, the open face shield method is eliminated from further consideration.

### **Earth Pressure Balance and Slurry TBM Methods**

The development of underground technology using tunnel boring machines in recent years has reduced the potential differences between the EPB and Slurry TBM systems. These are outlined below.

#### **Earth Pressure Balance TBM Method**

The Earth Pressure Balance (EPB) TBM operates by using the excavated soil to provide a pressure to resist the ground face loads. The face is supported by excavated material held under pressure behind the cutting head in front of the forward bulkhead. Pressure is controlled by the rate of passage of excavated material through a balance screw auger through hydraulically controlled gate valve. Material is removed from the screw conveyor onto an open conveyor to either muck wagons or by a ribbed conveyor system to the surface. To ensure the screw conveyor can operate successfully and provide a good quality material, additives such as polymers or foams can be injected to the excavated material in front of the cutting head or directly into the screw. While the use of pressurized mud injection is not normally required, the benefits of using such a system would be assessed during the design period. The EPB has traditionally been used in finer grade materials such as silts and clays but with the development of foam and polymer additives can now be used in a much wider range of soils and is even being used in mixed face and rock tunneling. Advantages for the EPB TBM include: more flexible than the slurry TBM in the chosen mode of operation, potentially cheaper machine costs than the slurry TBM, faster rate of advancement for tunnels in mixed ground conditions. Disadvantages include the difficulties associated with maintaining a good quality spoil in

coarse grained soils with high permeability, a condition likely to be encountered on this project.

### **Slurry TBM Method**

The slurry TBM operates using bentonite or polymer slurry that provides stability at the tunnel face to the soil and hydrostatic pressures. The slurry is mixed with the excavated material and pumped through pipelines to a separating plant at the surface. This method utilizes a slurry injected into the face ahead of the shield, and is hydraulically pressurized to meet the face earth and water pressure, which stabilizes the face. Excavated earth is transported through a slurry discharge pipeline to a slurry treatment facility, where the soil materials are separated for disposal and the “cleaned” slurry re-circulated.

Advantages for the slurry TBM include: the machine operates well in sand and gravel soils; tunnel spoil is pumped to the surface avoiding use of mucking cars or conveyor belt system on steep grades, benefits are greater for larger tunnels (over 32 ft internal diameter) where the potential hydrostatic pressure differential at the face is significant. Disadvantages for the slurry TBM include: higher operating and slurry handling equipment costs, potential for slurry ‘blowout’ in shallow cover areas causing environmental pollution.

### **Tunnel Boring Parameters and Design**

Two different groupings of tunnel alignments are identified for tunneling consideration: (1) Tunnels following the Ohio Canal, east of the Innerbelt; and (2) Tunnels west of the Innerbelt. Both groupings of tunnel routes proceed from the work areas adjacent to the Cuyahoga River launching shafts to extraction shafts up land from the river. A 12 inch outer pre-cast concrete liner is proposed for either grouping. The overall bore diameter proposed would be 25ft to 27ft.

The bow wave forces created by the TBM tunneling require an overburden cover to dampen the impact to the ground surface and to protect the surface from heave and soil unraveling, and impacts on foundation structures adjacent to the alignment. Based on the existing ground conditions, an adequate ground cover overburden used in this evaluation

is one (1) bored tunnel diameter. The bored tunnel alignment and profile layout is detailed in the BBC&M Geotechnical Data Report. Bored tunnels generally maintain a minimum overburden cover of one (1) diameter, as a rule of thumb. In areas where the one (1) diameter of overburden is not available special ground improvement techniques may be utilized such as, chemical grouting or deep soil mixing. Critical overburden cover occurs as the tunnel approaches the extraction shaft. The poorly graded silty gravel and sand that is present at these critical locations would need to be treated.

The soil enhancement permits a soil “arch” to form above and in-front of the advancing bore, stabilizing the face, so that the risks of a blow-out can be minimized. The use of ground improvement methods may require additional care to ensure control of the grouting material. In terms of side cover, not enough earth pressure and/or resistance may have the effect of causing the equipment to deviate towards the softer side of the cut, collapse of the soil impacting adjacent structures. Shallow building foundations would most probably need additional protection along the alignment of the bored tunnel as the tunnel operates within a diameter of the building footprint. It is anticipated that the effects on the deep foundations would be minimal.

Guidance of the TBM is controlled by operators who are typically assisted by a survey crew, the direction of the tunnel bore is maintained by using a system of lasers and targets mounted on the wall of the completed tunnel and the TBM itself. Past projects have shown high accuracy in driving the TBM using this type of guidance system. Tolerance on the centerline of bore from the beginning of the alignment to the end is expected to be within 4 inches.

### **Ground Water Control and Management**

Control of ground water during construction is an important consideration for the TBM and the shaft construction. Groundwater can be typically controlled via a reasonably watertight support of excavation system integral with sump pumping. Particularly difficult ground conditions, such as raveling sands and gravels, may require additional ground stabilization to manage excessive groundwater infiltration and associated loss of ground stability.

## **Tunnel Lining and Waterproofing**

The outer tunnel lining is anticipated to be pre-cast concrete 300mm (12”) thickness, 1.5m wide each piece having an average arc length of approximately 3m in length. The criteria for acceptable leakage would be developed during the preliminary design.

The outer liner consists of approximately 7 arc segments, which are mechanically locked to each other along the ring as well as laterally to the previously placed ring. Typically the match-up of the leading edge of adjacent segments is varied to ensure that there are not cross joints between adjacent segments, only tee joints.

In order to accommodate construction tolerances and horizontal or vertical changes in the alignment, the edges of the lining are typically not parallel, introducing a skew to those longitudinal face edges in order to fit the geometry. There is a gap between the tailskin of the shield and the installed lining that is necessary to create a seal against infiltration of groundwater and grout. This gap is sealed by providing three rows of tailseal brushes which maintain contact between the in-place lining and the tailskin, these brushes are then injected with thixotropic grease. Once the shield is pushed past the last ring built, the gap left between the placed liner and the earth is grouted with a special cementitious grout either directly from the TBM system or through grouting ports incorporated into the lining.

The tunnel liner provides structural integrity and is the primary line of defense for infiltration of groundwater. Between each segment are factory installed EPDM gasket type seals. These seals have provided acceptable levels of water tightness in past projects.

## **4.2 TUNNEL BORING CONSTRUCTION ISSUES**

### **Tunnel Spoil Handling and Removal**

The method of material removal from the face of the TBM depends on the type of equipment used for the project. Traditionally for small tunnels with profile grades up to 3%, a rail system is used for spoil removal, delivery of segments and in long tunnels, the removal of personnel. If an EPB TBM is used for this Project, a ribbed type of conveyor system or chain-drive locomotive and muck car system would be proposed to handle

steeper grades. In an EPB system in order to avoid an unacceptable level of spillage from the conveyor, additives to the spoil may be required to transform any 'wet material' to more of a "tooth paste" consistency. The chain-driven locomotives and muck cars are used to transport segments and ancillary services to the TBM and can be used as an emergency muck haulage system should the conveyor system fail. If a Slurry system is used for this project, spoil materials would be pumped from the face of the machine to a slurry desanding unit, most likely located at the Launching Shaft area. The desanding unit will separate the slurry additives from the excavated ground materials. The excavated material would be moved to trucks for disposal. The slurry would be recycled to the face and reused by the TBM. The specific system to be utilized will be selected based on economic and practical limits of the type of individual technologies, and would be determined during Preliminary Design. The construction cost estimate for this report considered a ribbed conveyor system to convey and dispose of excavated material.

### **Obstructions**

Obstructions to tunneling operations or shaft construction due to deep foundations, of retaining walls and sheet pile walls will require special design and construction considerations. Known obstructions considered are man-made obstructions and a preliminary design will be performed to remove, demolish or rework the obstructions to meet the needs of the tunneling operation. Unknown obstructions, such as randomly occurring boulders in the fill or natural soil deposits, will require the use of a specially designed rock crushing facility in the TBM. Boulders will be typically ground by disc cutters in a slower penetration rate. In the EPB TBM, the size of boulders that can be accommodated is limited by the size of the screw conveyor. In the slurry TBM, the size of boulders that can be accommodated is limited by the size of crusher. Boulders larger than which can be accommodated would likely need to be crushed or demolished by hand from inside the face of the TBM. Seismic probing may reduce the risk of encountering unforeseen obstacles.

It is anticipated that known obstructions must be removed prior to commencing a TBM operation in the area.

## **Ground Improvement Modifications**

Ground modification of several forms can be utilized on the project and primarily would likely be needed during construction of the launching and extraction shafts and along the tunnel alignment as it approaches the extraction shaft or diversion structure. These modifications range from treatments designed to help optimize the alignment, to in-situ treatments to serve as construction expedients.

Where the overburden cover of the bored tunnel is less than one tunnel diameter, stabilizing the existing soils using ground improvement methods, such as jet or chemical grouting patterns or deep soil mixing may be possible. This can provide benefits to increase the length of bored tunneling beyond the current limits chosen and utilizing grouting or in-situ soil mixing to lessen the “arch” requirements has the potential to significantly reduce the vertical grades in the alignment.

Grouting or in-situ soil mixing can be performed in advance of the tunneling from the ground surface. The in-situ silty sands and gravels would be readily groutable using chemical grouts to produce a reinforced soil mass along the proposed alignment.

Grouting “through the face” may also be performed from inside the tunnel bore, as the TBM can be equipped to provide for ground stabilization techniques.

## **Utility Relocation**

Utility relocations will primarily occur in the launching and extraction shaft areas and possibly in the defined work zone area. Coordination with local utility (water, gas, sewer, electrical, telephone, etc) is extremely important in regards to impacting construction schedules and cost. Utilities adjacent to the shafts may require monitoring and/or underpinning support.

## **Community and Business Impacts**

Shaft construction staging, the development of work areas, and muck disposal routes will have significant impacts on the local community and associated businesses. The primary impacts of traffic maintenance and utility relocations have been discussed. Additional

impacts include noise and vibration produced by construction activities. These impacts may be significant depending upon the support of excavation system provided. However, acceptable limits will be placed on noise and vibration levels. Mitigation measures for dust and rodent control will be necessary. Construction staging would be developed to minimize any detrimental impacts to the construction of the project.

### **Construction Stages and Work Zones**

Construction work zones will need to be secured throughout the project. The location of the primary work zone area should coincide with the launching shaft location. The size of the work zone will consider handling of the tunnel muck, drying and disposal, a slurry plant (in the case of a slurry TBM), truck access, loading and washing facilities, and storage of segmental concrete liner sections. A smaller work zone area will be required at the extraction shaft location.

### **Environmental Impacts**

Potential environmental impacts and permitting requirements associated with the tunnel construction will vary among the tunneling techniques. Based on the borings to date, no contaminated soil or impacts have been identified.

### **Material Disposal**

Each alternative offers its own set of considerations, which must be addressed during the project development phase. Selection of the correct disposal method must be made based on both environmental and economic factors.

Further options may exist for the re-use of the dredged materials. The gravel deposits in particular are highly sought after and could easily be sold. Alternatively, the contractor may opt to reuse the clean gravel material for tunnel backfill or stockpile the material for use on other projects.

### **Water Quality**

A permit will be required from the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act for all tunneling alignment. This section of the Act authorizes the Army Corps to regulate the discharge of dredged material into waterways such as the

river that are identified as “waters of the U.S.”. The permitting process contains the same permitting process required under the Endangered Species Act, following this hierarchy:

- ◁ Avoid the use of the resource
- ◁ If avoidance is neither feasible nor practicable, then minimization measures must be considered
- ◁ As a last resort, mitigation measures must be implemented.

A permit under Section 10 of the Rivers and Harbors Act of 1899 will also be required from the Army Corps of Engineers for all tunneling methods and for work below the Ohio Canal. Section 10 authorizes the Corps to regulate structures (except bridges) in, over or under navigable waters of the United States. As part of the permitting process, the Marine Safety Office of the U.S. Coast Guard may be asked to comment on the permit application relative to impacts of the construction activities on river navigation.

In addition, a permit will be necessary from the Ohio DEP. The permitting process generally follows the same format as that for the Section 404 permit from the U.S. Army Corps of Engineers. This permit will be required for dewatering discharge and spoil disposal work near the Cuyahoga River and the Ohio Canal and for any ground surface pretreatment or dewatering or spoil disposal conducted within or near wetlands above the tunnel alignment.

A National Pollutant Discharge Elimination System (NPDES) permit will be required for the entire project for the regulation of storm water generated from construction activities under all three tunneling techniques. If it is proposed that the storm water will be treated prior to discharge (such as discharge from a batch plant), a temporary NPDES permit for storm water associated with industrial activities may be required.

Weathering of the pyrite may cause an acid leachate containing sulfates that can be detrimental to water quality. Erosion of fine grained clay particles from the soils and weathered portions of the shale bedrock may cause a turbidity problem in the discharge water quality. A very slight hardening of the water may result from leaching the more

cemented portions of the siltstone, far less than the normal impact of tunnel lining and grouting operations.

### **Potential Gassy Ground Conditions**

Review of available boring logs and groundwater quality data, does not suggest potentially gassy geotechnical conditions. If encountered, the tunneling methods and equipment will have to be modified to meet the OSHA regulatory requirements. The current construction cost estimate does not include any contingency costs for such an occurrence.

All sedimentary rock formations, especially shale, are likely to be classified by the OSHA and the MSHA as potentially gassy. Many of the Appalachian basin rock formations, such as the Berea sandstone which is closely associated with the Bedford shale, are known producers of petroleum. Methane gas explosions have been known to occur within tunnels under the Great Lakes, and in particular in excavations founded in the black shale of the Ohio formation.

## **4.3 RISK ASSESSMENT AND ALTERNATIVE TUNNELING METHODS**

There are always some risks involved with any major civil engineering construction project. The incidents associated with either form of tunnel construction are well known and mitigation measures have been developed to deal with these potential risks. The risks involved with tunnel construction are evaluated below under the headings of cost, schedule and technical issues.

### **Cost Risks**

Unforeseen ground conditions such as higher or lower than anticipated rock elevation, buried river valleys, contaminated groundwater deposits, or the potential gassy ground conditions can be encountered. Risks can be minimized with appropriate level of site investigation and testing of deposit samples early in the design process.

Damage to existing utilities or facilities adjacent to tunnel alignment can occur. These impacts can be mitigated by establishing locations and elevations of all utilities along the tunnel alignment prior to construction, and providing measures to reroute or protect

utilities as necessary. Arranging utility work as an early start contract may also help to reduce impact on the tunnel schedule. Also, an unanticipated amount of boulders, timbers, and groundwater contamination may be associated with the canal construction and filling.

### **Schedule Risks**

Plant/equipment failure: For construction activities with a risk of plant failure, back up equipment should be made available to replace defective machinery as necessary. This would include maintaining an adequate supply of the high maintenance replacement parts to minimize any delays. Also, an unanticipated amount of boulders and groundwater contamination can lead to schedule delays.

### **Technical Risks**

The tunnel may be subject to a number of extreme load conditions over its intended design life. The probability of such load conditions is not influenced by a given tunnel construction type. The risks of extreme loads can be minimized through correct design and detailing of the tunnel structure and will not be considered as an influencing factor in the assessment of tunnel types.

However, technical issues related to construction are type specific. Risks would be identified during the design process through risk analysis and constructability review procedures and contingencies prepared for foreseeable events.

### **Alternative Tunneling Methods**

Recent TBM designs provide a cross between EPB and Slurry type machines known as a “Mixshield”. These machines are capable of operating in open face with conveyor belt (in rock), or slurry mode with bentonite (in cohesionless soil), or without bentonite and water only (in clayey soils). An advantage of the Mixsheild over an EPB is the use of a stone crusher for boulders up to 4 ft in diameter. These machines are relatively new, especially in the US and do not have the success history of more conventional machines.

Liner alternatives include an initial “junk” segmental liner. The liner is considered a temporary design constructed usually without EPDM gaskets and construction is expedited. Final cast-in-place concrete with 360 degree waterproofing membrane, or a final segmental gasketed liner follows.

New Austrian Tunneling Method (NATM) or more currently called Sequential Excavation Method (SEM) is a mined tunneling method with application of ground support, as needed creating a sub-horizontal jet-grouting umbrella. In addition, where dewatering is not allowed (due to settlements), face grouting (permeation of jet grouting) may be necessary of the core in permeable ground. The excavation is formed in segments of the final tunnel shape, usually starting at the top of the heading proceeding to the bench of the heading, followed with an initial shotcrete liner, final cast-in-place concrete with 360 deg waterproofing membrane.

Mentioned here are only a few alternative tunneling methods which may have opportunities to provide a safe and successful tunnel in specific areas of the alignment.

#### **4.4 CRITERIA FOR MATRIX ANALYSIS**

Several criteria were considered for the comparison and analysis of each alternative.

##### **1. Relative Cost**

§ *Provide a cost effective tunneling solution for CSO storage.* This was measured by the relative cost differences of the various alternatives.

##### **2. Constructability**

§ *Maximize the tunneling operation through similar geologic materials.* In order to reduce the costs of the overall tunneling operation, the tunnel alignment must maximize the amount of similar stratum through which tunneling is required. This is because different types of TBMs are required to bore through soft ground, and through rock. A change in stratum type may require an access shaft to be excavated at the point of change, and the TBM to

be exchanged or modified. These actions would significantly increase the cost of tunneling operations.

- § ***Minimize, or eliminate, sharp bends in the tunnel alignment.*** Alternatives were considered that would keep sharp bends to a minimum for better constructability, hydraulics, and reduced cost.
- § ***Facilitate handling and disposal of muck generated from tunneling and shaft excavation materials.*** Alignments were considered that would allow for a launching and spoils handling shaft at the downstream end of the OCI Tunnel alignment.

### **3. Easements**

- § ***Minimize the number and cost of temporary and permanent easements.*** Alternative alignments were compared to observe the number of easements that would be needed for construction. The cost of easements was assumed the same for all buildings and properties. The average unit cost for all easements will be based on historical information regarding easement coordination and subsequent acquisition on other City of Akron projects.

### **4. Clearance from Critical Structures**

- § ***Provide adequate clearance for tunneling and drop shafts from critical surface and underground structures.*** Alternatives were compared using relative to the distance from the tunnel and construction shafts to existing structures. This issue is of particular concern with respect to commercial structures with pile foundations along Main Street and other areas along the various alignments where pile foundations may be present.

### **5. Maintenance Access**

- § ***Provide adequate maintenance access to the storage tunnel.*** The preferred maximum spacing for tunnel system access is approximately 3,000 feet. Alternatives were compared relative to the number of shafts required to meet this objective.

## **6. Odor Control and Ventilation**

§ *Minimize odors from combined sewage.* The storage and movement of combined sewage in the OCI Tunnel poses a mild concern for odors. There will most likely be one or two access shafts along the route. Each of the proposed locations will provide an opening for sewer air release and the potential for odors.

These are discussed in detail for each alternative in the following section.

## **5.0 ALTERNATIVES AND PROJECT COSTS**

The purpose of this section is to provide discussion on the criteria, approach and results of the comparison of the identified alternatives. This section is organized into the following subsections:

- ◁ Section 5.1 – Construction Cost Estimating. Each alternative has specific costs associated with the project components. A discussion of the procedures used for developing the planning level costs is provided.
- ◁ Section 5.2 – Alternative Descriptions and Costs. Each alternative, and the associated project components, is described. Specific assumptions are made for each alternative, and an estimate of cost is provided. The cost estimates include potential capital cost, contractor overhead and profit, a 35% contingency, and 25% for engineering and legal fees. A summary of all alignment alternative costs is presented at the end of this section in Table 5.2.
- ◁ Section 5.3 – Matrix Evaluation Approach. This section describes the approach used for conducting a matrix evaluation on the alternatives. The specific criteria assumptions and weighting is described.
- ◁ Section 5.4 – Matrix Evaluation Results. This section provides the final scoring of the matrix analysis for the various CSO control alternatives.

These are discussed in greater detail in the following text.

### **5.1 CONSTRUCTION COST ESTIMATING**

Preliminary planning level cost estimates were prepared for each of the proposed Alignment Alternatives. These costs are the opinion of the Engineer based on available pricing information for labor, equipment and materials, unit prices, general knowledge of similar projects, and presently available geotechnical information. Costs are presented in Year 2006 U.S. Dollars, and are for comparison purposes.

Actual subsurface conditions may vary pending additional geotechnical data analysis during the preliminary engineering design.

Although the estimates cannot specifically breakdown labor, materials and equipment, basic data and assumptions used in preparation of these cost estimates are discussed below.

### **Construction Cost Data Assumptions**

Unit prices represent complete in-place construction costs, and include allowances for each of the items listed below.

#### **Labor**

Labor costs are based on estimated crew sizes and costs per shifts. Crew personnel include machine operators, mechanics, and laborers.

#### **Materials**

Materials included sheeting, backfill, foundations materials, and all steel, cross bracing, etc. used to construct the structure.

#### **Equipment Operations**

Equipment operation costs include fuel, oil, grease and repair parts.

#### **Plant and Equipment**

Plant and equipment includes the cost of construction equipment, construction yards and buildings, mobilization and miscellaneous items such as temporary power and utility services, ventilation equipment, and compressed air equipment. Supplies are included and comprised of miscellaneous materials (i.e. small tools and equipment).

### **Tunneling**

Tunneling costs were derived from recent projects for the Northeast Ohio Regional Sewer District and other tunneling projects in Ohio and Michigan. Therefore, construction costs were consolidated into a lineal foot unit cost for each tunnel diameter that includes TBM setup, tunnel drive, TBM maintenance, and TBM removal. These unit costs were plotted versus tunnel diameter and a “best fit line” was generated as a result. The equation **Unit**

**Cost per Lineal Foot = 266.81 \* (Tunnel Diameter) + 65.12** was used to determine the lineal foot unit costs based upon tunnel diameter.

### **Existing Canal Enclosure Modifications**

Alignment Alternatives 5A and 6A include modifications to the existing Ohio Canal Enclosure in order to use it for CSO storage and conveyance. These modifications are to be determined based upon video inspection and structural analysis. Any existing storm water connections must be removed and routed elsewhere in order to use the enclosure as a storage facility. Several line item costs are included in these estimates and are considered consistent for each alternative.

### **Overhead and Profit**

The Contractor's overhead and profit factor may approach 20% of the construction cost estimate. This factor considers the uniqueness and specialties required for the job and the percentage is considered equal for each of the alternatives in this comparison.

### **General Contingency**

At the present stage of preliminary planning and available geotechnical information, a 10% general contingency factor is added to the construction cost estimate.

### **Design Engineering & Engineering Construction Services Contingency**

These estimates include project "soft-costs", such as management, engineering and design costs, and direct expenses. These costs are assumed to be generally consistent for each alternative and are included in these evaluations as a 25% factor.

## **5.2 ALIGNMENT DESCRIPTIONS AND COSTS**

### **CSO Tunnel Alignment Alternative 1A**

Alignment Alternative 1A (illustration and cost estimate follow this alignment description) assumes that the proposed Canal Bypass Conduit would be constructed, and that a diversion structure would be constructed near Bowery Avenue, behind the Civic Theater. A connecting tunnel conveying flow from the new Rack 16/17 Diversion Chamber would be routed north along Quaker Street to Dart Avenue, then turn east on Dart Avenue (see Photo 1) to the intersection with Mill Street. At the intersection of Mill

Street, the tunnel would pick up flow from Racks 4 and 37 and would then turn westward before Market Street, passing under State Route 59. At this point the connecting tunnel would receive flow from Racks 18 and 19. The connecting tunnel would continue west to the corner of Market Street and Maple Street where it will connect to the main leg of the OCI Tunnel. In this alternative, the OCI Tunnel would begin at the corner of Market and Maple Street and would head northerly along Maple Street (see Photo 2) until the road ends near the Towpath Trail. The OCI Tunnel would be approximately 2400 feet in length, with a required diameter of 35 feet.



Photo 1. Looking north along Dart Avenue toward Mill Street intersection.



Photo 2. Looking north along Maple Street toward Norfolk-Southern Railroad.

### **Alternative 1A – Connecting Conduits.**

***Canal Bypass Conduit*** – This conduit would be constructed to transfer Rack 16 and 17 flows to a diversion chamber at Bowery Avenue behind the Civic Theater.

***Rack 37 Connecting Conduit*** – This connecting conduit would carry flows from Rack 37 to the diversion chamber where the Rack 16 and 17 Conduit ends.

***Rack 16, 17, and 37 Connecting Conduit*** – This conduit would transfer flows from Racks 16, 17, and 37 to an access chamber located along Dart Avenue near Rack 4.

***Rack 4, 16, 17, and 37 Connecting Conduit*** – This connecting conduit would carry flows from Racks 4 and 37 to an access chamber located at the southwest corner of Dart Avenue and Market Street. This access chamber would also intercept flows from Racks 18 and 19.

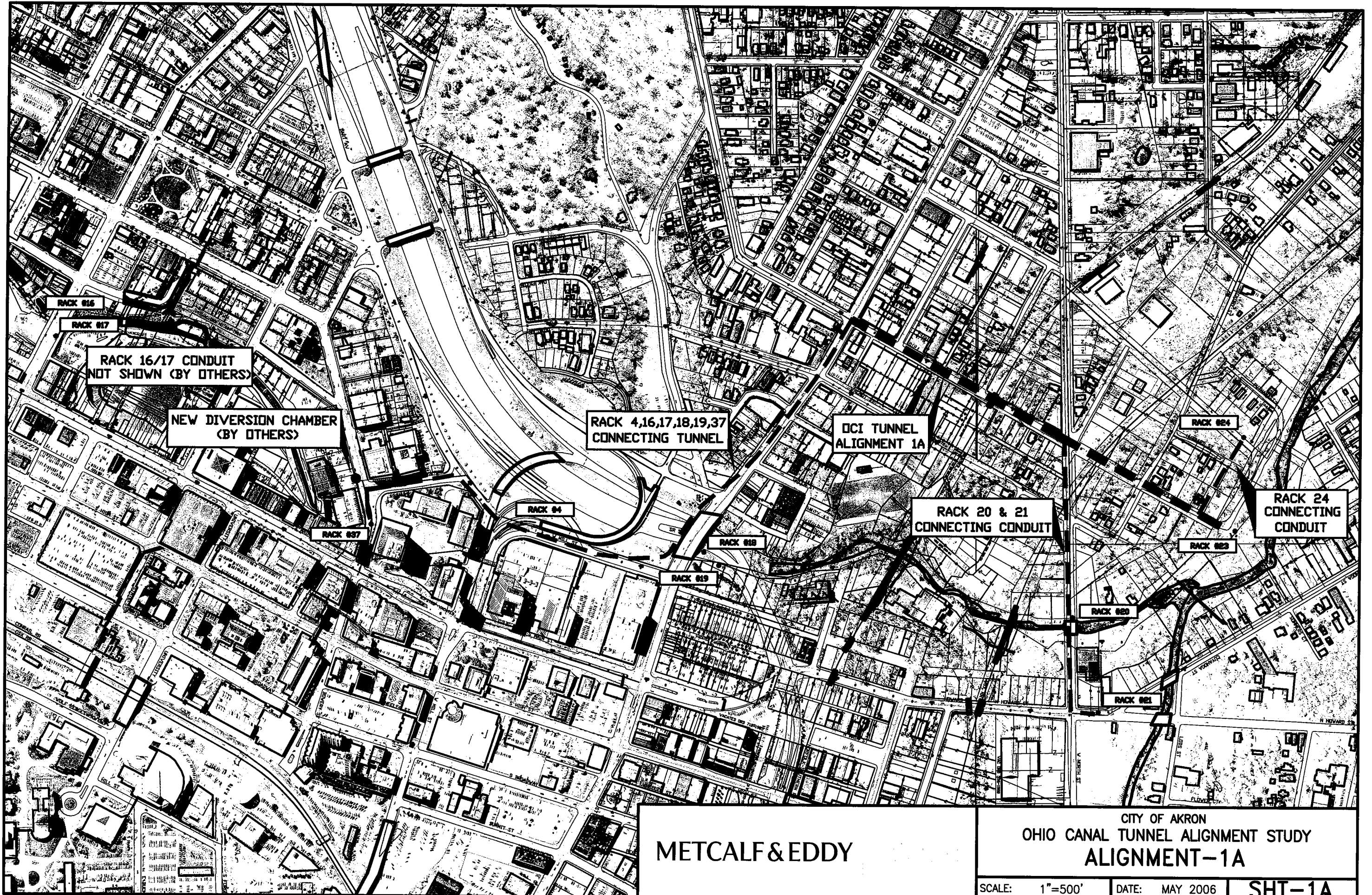
***Rack 4, 16, 17, 18, 19, and 37 Connecting Conduit*** – This connecting conduit would carry flows from Racks 4, 16, 17, 18, 19, and 37 and would meet the OCI Tunnel at the corner of Market Street and Maple Street.

***Rack 24 Conduit*** – This conduit would be built to transfer flow from Rack 24 to the OCI Tunnel along Maple Street.

***Rack 21 Connecting Conduit*** – This conduit would carry flows from Rack 21 at Howard Street west along North Street to an access chamber near Rack 20.

***Racks 20 and 21 Conduit*** – This conduit would be built from Rack 21 at Howard Street to the OCI Tunnel at the corner of Maple Street and North Street.

<b>Alignment Alternative 1A: Tunnel and Conduit Summary</b>		
<b>Description</b>	<b>Diameter (FT)</b>	<b>Length (LF)</b>
<b>OCI Tunnel</b>	<b>35</b>	<b>2400</b>
<b>Rack 37 Connecting Conduit</b>	<b>5.5</b>	<b>157</b>
<b>Rack 16, 17, 37 Connecting Conduit</b>	<b>16.25</b>	<b>800</b>
<b>Rack 4, 16, 17, 37 Connecting Conduit</b>	<b>17.25</b>	<b>1100</b>
<b>Rack 4, 16, 17, 18, 19, 37 Connecting Conduit</b>	<b>29</b>	<b>1280</b>
<b>Rack 21 Connecting Conduit</b>	<b>12.5</b>	<b>600</b>
<b>Rack 20, 21 Connecting Conduit</b>	<b>14</b>	<b>880</b>
<b>Rack 24 Connecting Conduit</b>	<b>8</b>	<b>440</b>



METCALF & EDDY

CITY OF AKRON  
OHIO CANAL TUNNEL ALIGNMENT STUDY  
ALIGNMENT-1A

SCALE: 1"=500'    DATE: MAY 2006    SHT-1A

City of Akron  
Ohio Canal Tunnel Alignment Evaluation  
Preliminary Construction Cost - Various Alternatives

Alternative 1A

	Description	Diameter (Ft)	Quantity	Unit	Unit Cost	Total Cost
1	Mobilization / Demobilization	-	1	LS	\$1,000,000	\$1,000,000
	<b>Tunnel Construction</b>					
2	Tunnel Boring Machine	-	1	EA	\$15,030,000	\$15,030,000
3	Spare Parts	-	1	LS	\$601,200	\$601,200
4	Launch Shaft	-	1	LS	\$2,204,400	\$2,204,400
5	Extraction Shaft	-	1	LS	\$5,611,200	\$5,611,200
6	Start Up and Starter Tunnels	-	1	LS	\$3,106,200	\$3,106,200
7	Spoils Handling and Muck Removal	-	1	LS	\$2,605,200	\$2,605,200
8	Final Site Clean Up	-	1	LS	\$1,182,360	\$1,182,360
	<b>Tunnels</b>					
9	OCI Tunnel	35	2400	LF	\$12,224	\$29,338,620
10	Rack 37 Connecting Conduit	5.5	157	LF	\$1,533	\$240,613
11	Rack 16, 17, 37 Connecting Conduit	16.25	800	LF	\$4,401	\$3,520,603
12	Rack 4, 16, 17, 37 Connecting Conduit	17.25	1100	LF	\$4,668	\$5,134,318
13	Rack 4, 16, 17, 18, 19, 37 Connecting Conduit	29	1280	LF	\$7,803	\$9,987,272
14	Rack 21 Connecting Conduit	12.5	600	LF	\$3,400	\$2,040,134
15	Rack 20, 21 Connecting Conduit	14	880	LF	\$3,800	\$3,344,384
16	Rack 24 Connecting Conduit	8	440	LF	\$2,200	\$967,819
	<b>Access Shafts</b>					
17	Rack 4 Access Shaft	-	1	EA	\$1,440,000	\$1,440,000
18	Rack 18, 19 Access Shaft	-	1	EA	\$1,440,000	\$1,440,000
19	OCI Tunnel Upstream Access Shaft	-	1	EA	\$1,440,000	\$1,440,000
20	Rack 20 Access Shaft	-	1	EA	\$1,440,000	\$1,440,000
21	Rack 21 Access Shaft	-	1	EA	\$1,440,000	\$1,440,000
22	OCI / Rack 20, 21 Access Shaft	-	1	EA	\$1,440,000	\$1,440,000
23	OCI Tunnel Downstream / Rack 23, 24 Access Shaft	-	1	EA	\$1,440,000	\$1,440,000
	<b>Structures</b>					
24	Tunnel Outlet Diversion Chamber	-	1	EA	\$2,400,000	\$2,400,000
	<b>Acquisitions</b>					
25	Property Easement	-	1	EA	\$30,000	\$30,000
	<b>SUBTOTAL</b>					<b>\$98,424,324</b>
	<b>Contingency (10%)</b>					<b>\$9,842,432</b>
	<b>Canal Bypass Conduit East Alignment (By Others)</b>					<b>\$13,235,880</b>
	<b>Engineering (25%)</b>					<b>\$30,375,659</b>
	<b>TOTAL PROJECT COST</b>					<b>\$151,878,295</b>

## **CSO TUNNEL ALIGNMENT ALTERNATIVE 1B**

Alignment Alternative 1B (illustration and cost estimate follow this alignment description) reflects the original OCI Tunnel alignment as proposed in the Akron Facilities Plan (1998). This alternative assumes that the proposed Canal Bypass Conduit would not be constructed. Instead, flows from Rack 16 and 17 would be routed via a connecting tunnel west along Exchange Street (see Photo 3) to the intersection with Rand Avenue. The OCI Tunnel would begin at the corner of Exchange Street and Rand Avenue, just to the west of State Route 59. The OCI Tunnel continues northerly along Maple Street until the road ends near the Towpath Trail. The tunnel would be approximately 6020 feet in length, with a required diameter of 21 feet.



Photo 3. Looking west along Exchange Street  
from Rack 16/17 vicinity.

### **Alternative 1B – Connecting Conduits.**

***Rack 16 and 17 Connecting Conduit*** – Flow from Racks 16 and 17 would be diverted to a connecting tunnel that would travel west along Exchange Street to a connection point into the OCI Tunnel at Locust Street.

***Rack 37 Connecting Conduit*** – This connecting conduit would carry flows from Rack 37 to an access chamber near Rack 4.

***Rack 4 and 37 Connecting Conduit*** – This connecting conduit would carry flows from Racks 4 and 37 to an access chamber located at the southwest corner of Dart Avenue and Market Street. This access chamber would also intercept flows from Racks 18 and 19.

***Rack 4, 18, 19, and 37 Connecting Conduit*** – This connecting conduit would carry flows from Racks 4, 18, 19, and 37 and would meet the OCI Tunnel at the corner of Market Street and Walnut Street.

***Rack 21 Connecting Conduit*** – This conduit would carry flows from Rack 21 at Howard Street west along North Street to an access chamber near Rack 20.

***Racks 20 and 21 Connecting Conduit*** – This connecting conduit would begin at an access chamber near Rack 20 along North Street. It would transfer flows from Racks 20 and 21 westerly to the OCI Tunnel at the intersection of North Street and Maple Street.

***Rack 24 Connecting Conduit*** – This connecting conduit would begin at Rack 24, just west of Hubbard Street, to the OCI Tunnel at Maple Street.

<b>Alignment Alternative 1B: Tunnel and Conduit Summary</b>		
<b>Description</b>	<b>Diameter (FT)</b>	<b>Length (LF)</b>
<b>OCI Tunnel</b>	<b>21</b>	<b>6020</b>
<b>Rack 16, 17 Connecting Conduit</b>	<b>16</b>	<b>2550</b>
<b>Rack 37 Connecting Conduit</b>	<b>5.5</b>	<b>1000</b>
<b>Rack 4, 37 Connecting Conduit</b>	<b>8.5</b>	<b>950</b>
<b>Rack 4, 18, 19, 37 Connecting Conduit</b>	<b>21</b>	<b>1360</b>
<b>Rack 21 Connecting Conduit</b>	<b>12.5</b>	<b>600</b>
<b>Rack 20, 21 Connecting Conduit</b>	<b>14</b>	<b>880</b>
<b>Rack 24 Connecting Conduit</b>	<b>8</b>	<b>440</b>

















































































































































































































































































































































































































































































































































## **APPENDIX E**

















## **APPENDIX F**















































