City of St. Joseph, Missouri

Facilities Plan

Technical Memorandum No. TM-CSO-5

Stormwater Separation Conduits

By

BLACK & VEATCH
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Work Order No. 09-001
B&V Project 163509

January 15, 2010

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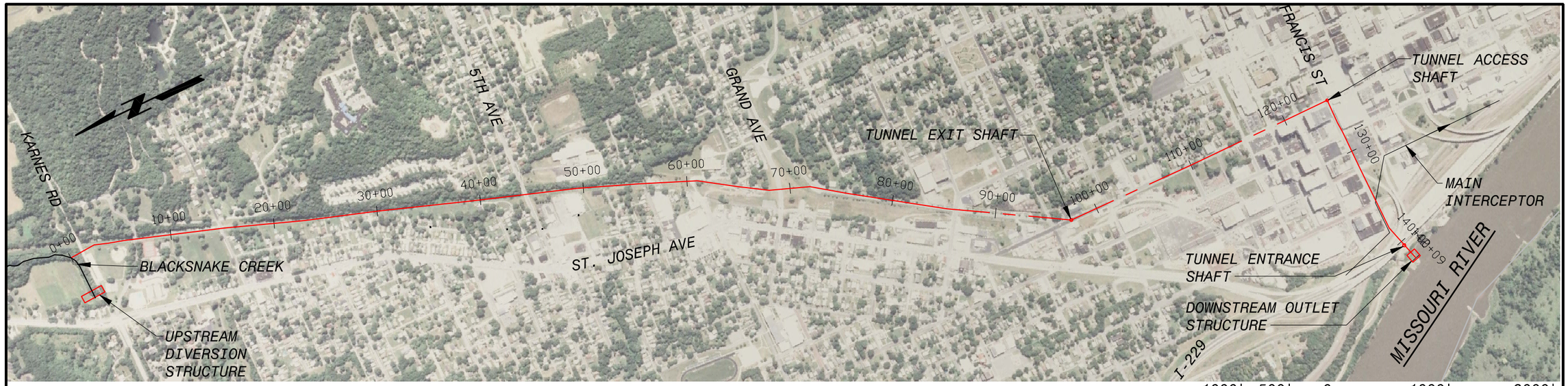
Stormwater Separation Conduits

1.0 Executive Summary

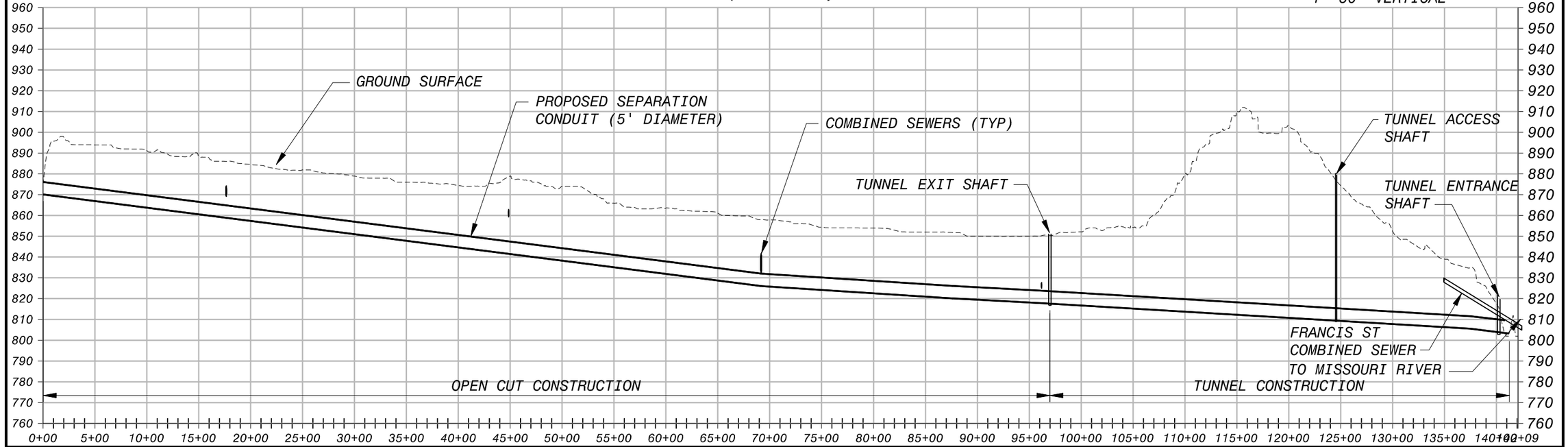
The purpose of this technical memorandum is to evaluate and summarize potential alternatives to separate and remove creek (i.e., stormwater) flows from the City of St. Joseph, Missouri (City) combined sewer system (CSS). Ten stormwater separation alternatives were investigated to remove the Whitehead Creek and Blacksnake Creek flows from the City's CSS. In summary, it appears that gravity flowing stormwater conduits sized without upstream detention and peak flow attenuation are the optimal alternatives to remove creek flows from the CSS in both basins.

There is one recommended alternative in the Blacksnake Basin for removing creek flows from the CSS. Alternative B diverts creek flows through a stormwater separation conduit that is aligned along an existing City owned right-of-way (abandoned railway) east of St. Joseph Avenue. The Blacksnake Alternative B alignment is presented in Figure ES-1. Project costs for the feasible Blacksnake alternatives, including the recommended Alternative B, are summarized in Table ES-1.

Due to its costs savings, Blacksnake Alternative C, as shown in Figure ES-2, was also strongly considered. However, this alternative involves a cross-basin stormwater transfer that could create unacceptable flooding, stream bank erosion, and other problems in the Roy's Branch Basin. Furthermore, the City could be held responsible for any adverse changes this alternative might create in Roy's Branch. The City could be obligated to purchase over a mile worth of stream easements, perform flooding and stream bank stabilization improvement projects, and address other stream issues at the request of downstream property owners. In addition, various state and federal agencies, such as the Federal Emergency Management Agency (FEMA) and the United States Army Corps of Engineers (USACE), could have jurisdiction regarding cross-basin stormwater transfers that could change, limit, or eliminate the alternative in its entirety. Due to liability concerns as well as the potential for complicated regulatory issues, Alterative C is not being recommended herein.



BLACKSNAKE ALTERNATIVE B (PIPE ALONG ABANDONED RAILWAY)
(143+73)



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ALTERNATIVE B

BLACKSNAKE CREEK STORMWATER SEPARATION CONDUIT

FIGURE ES-1

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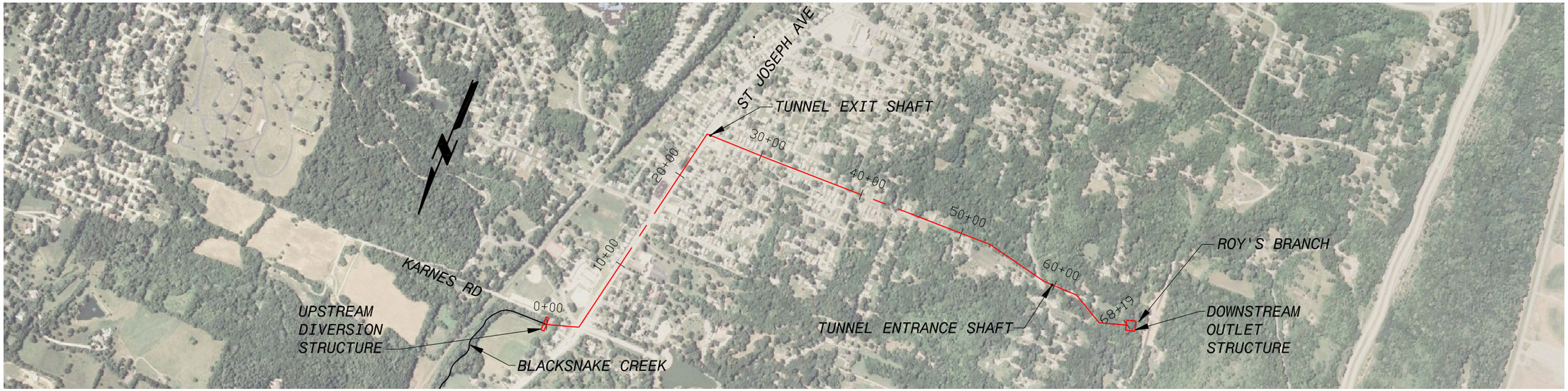


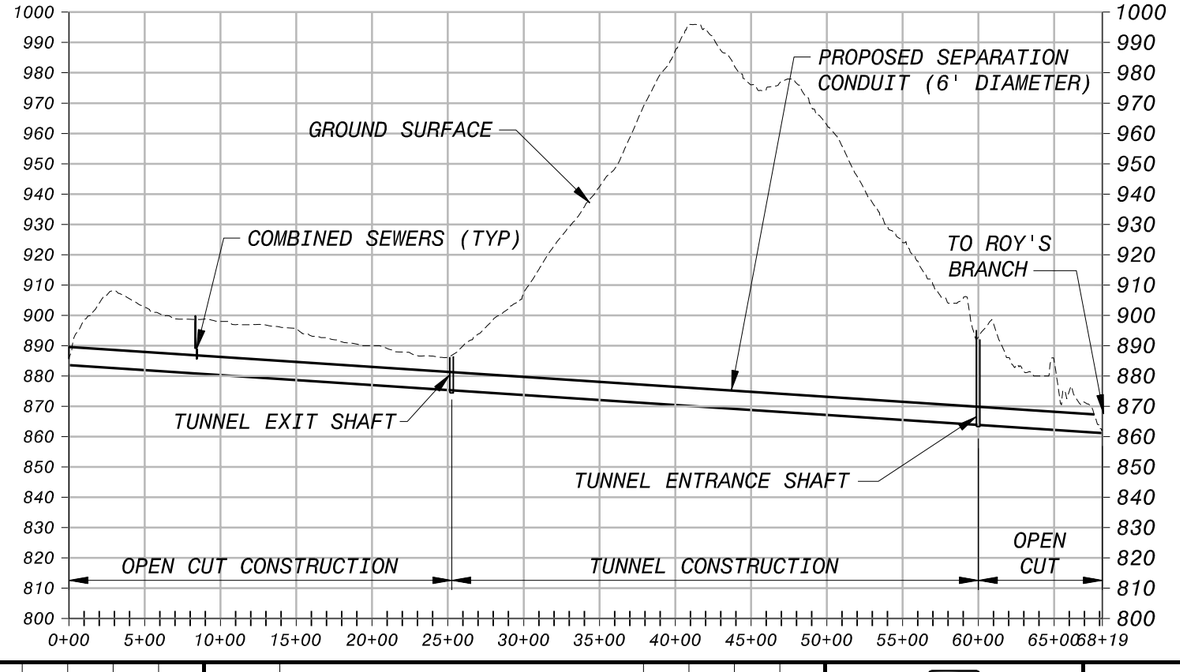
BLACKSNAKE ALTERNATIVE C (PIPE DIVERSION TO ROY'S BRANCH BASIN)
(68+41)

1000' 500' 0 1000' 2000'

1"=1000' HORIZONTAL

50' 25' 0 50' 100'

1"=50' VERTICAL



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ALTERNATIVE C

BLACKSNAKE CREEK STORMWATER SEPARATION CONDUIT

FIGURE ES-2

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Table ES-1
Summary of Opinion of Probable Project Costs for
Blacksnake Stormwater Separation Alternatives

Item	Alternative			
	B, $	C, $	D, $	E, $
Opinion of Total Project Cost	39,707,000	26,574,000	45,018,000	37,362,000

Notes:
1. All costs presented in May 2009 dollars (ENR BCI = 4773).
2. See Table 6 for a more detailed breakdown of the project costs.

There is one recommended stormwater separation conduit alternative for the Whitehead Basin. Whitehead Alternative B redirects creek flow from the Whitehead Basin to the Missouri River. The separation conduit begins near the intersection of 16th and Garfield and parallels, to the south, the existing Whitehead combined trunk sewer. The stormwater conduit daylights in the open channel downstream from the Whitehead Diversion Structure. Figure ES-3 presents the Whitehead Alternative B alignment. The project cost for the feasible Whitehead alternatives is summarized in Table ES-2.

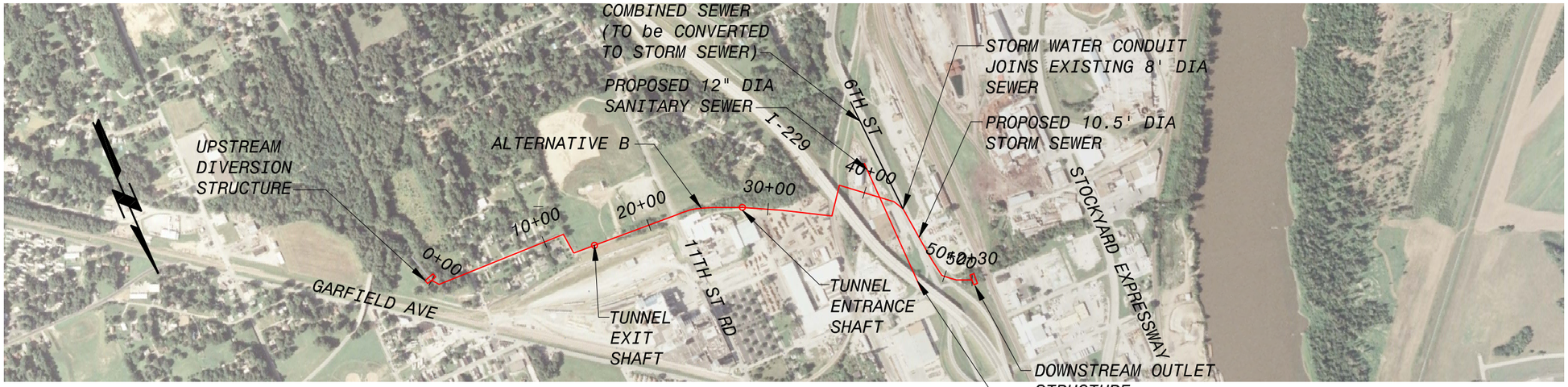
Table ES-2
Summary of Opinion of Probable Project Costs for
Whitehead Stormwater Separation Alternatives

Item	Alternative		
	B,$	C, $	E, $
Opinion of Total Project Cost	21,349,000	23,159,000	34,074,000

Notes:
1. All costs presented in May 2009 dollars (ENR BCI = 4773).
2. See Table 14 for a more detailed breakdown of the project costs.

For all of the recommended alternatives, a detailed alignment study is recommended to finalize the stormwater conduit alignment. The alignment study would allow a detailed review of the alignment corridor and finalize:

1. Selection of the upstream diversion structure location.
2. Location of large trees and other natural resources that could be avoided and preserved by slight adjustments to the alignment.
3. Location of underground and overhead power lines.
4. Location of gas, water, telephone, and cable utilities.



1000' 500' 0 1000' 2000'

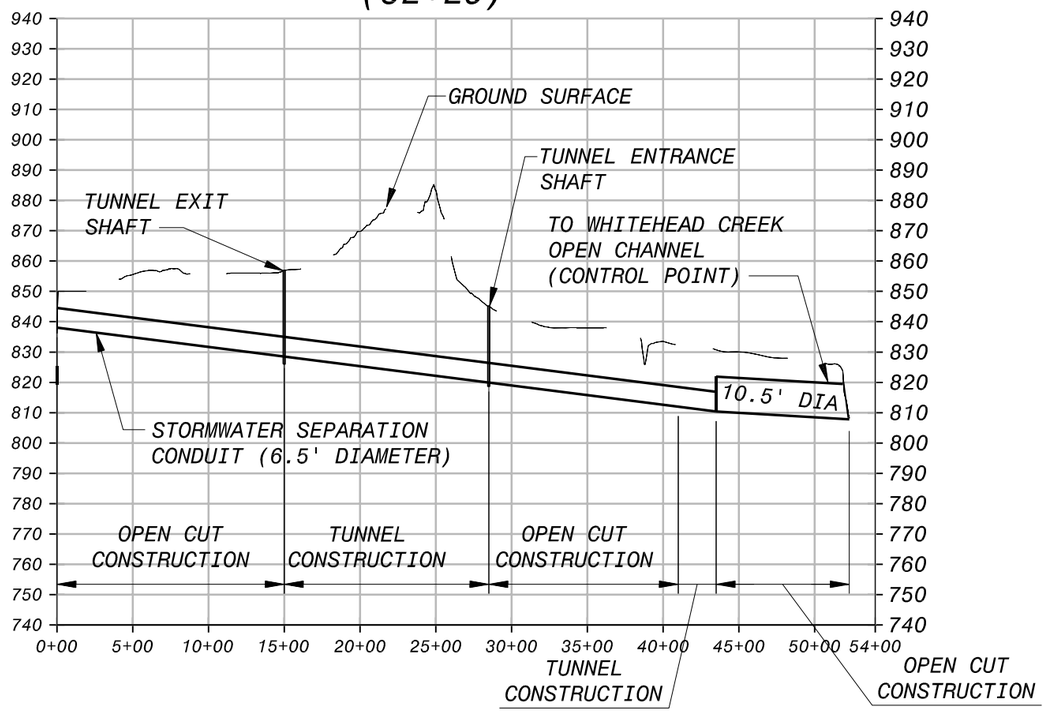
1"=1000' HORIZONTAL

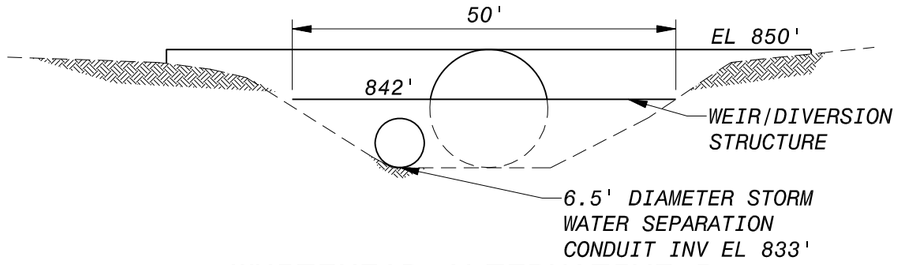
50' 25' 0 50' 100'

1"=50' VERTICAL

ALTERNATIVE B (SOUTHERN ROUTE)

(52+29)





WHITEHEAD ALTERNATIVE B

WEIR STRUCTURE

1" = 20'-0"

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ALTERNATIVE B

WHITEHEAD CREEK STORMWATER SEPARATION CONDUIT

FIGURE ES-3

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5. Selection of tunnel shaft and point of intersection locations.
6. Location of other pertinent obstacles that are relevant to the stormwater conduit placement.

The stormwater separation conduits will significantly reduce the amount of stormwater delivered to the existing CSS and will help the City achieve its Long Term Control Plan Phase IA objectives of 60 percent wet weather capture.

2.0 Purpose of Technical Memorandum

The purpose of this technical memorandum is to evaluate and summarize alternatives to separate and remove creek stormwater flows from the City's combined sewer system. Stormwater separation conduit alignment alternatives are presented herein along with proposed pipeline sizes and opinions of probable project cost. Recommendations are also provided for the most favorable alternative(s) to carry forward into the implementation phase of the combined sewer overflow (CSO) Long Term Control Plan (LTCP) program.

3.0 Introduction and Background

Three stormwater separation conduits were recommended in the 2008 LTCP to direct creek flows away from the CSS and convey the flows to the Missouri River through dedicated stormwater outfalls. These separation conduits were proposed for the Blacksnake, Whitehead, and Brown's Branch Basins and are shown in Figure 1 for reference.

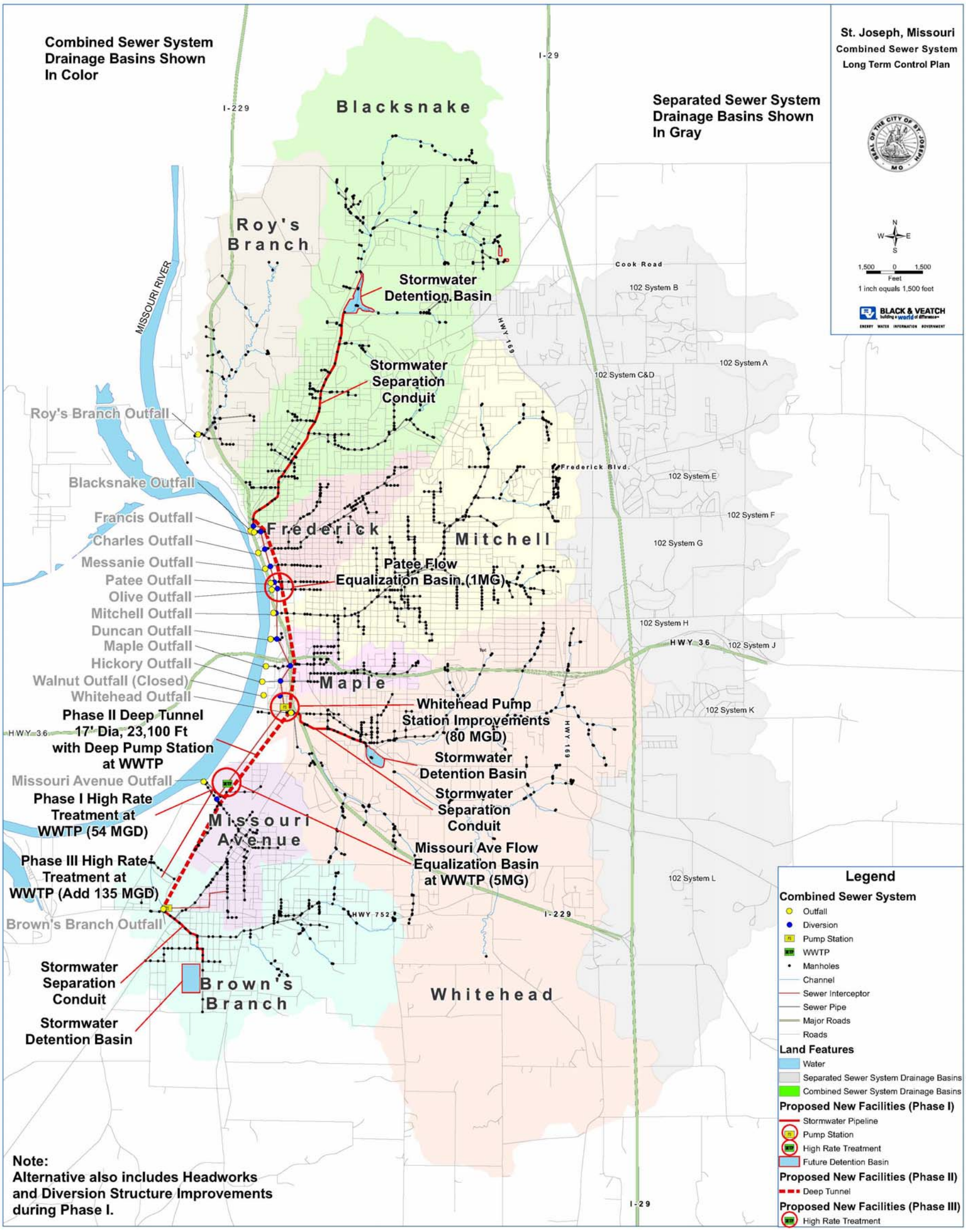


Figure 1 – St. Joseph, Missouri 2008 LTCP Recommendations

Note: Many of the recommendations presented by this figure have been updated and revised as part of the ongoing Facilities Plan.

The basis of design for the stormwater separation conduits is to divert stormwater flows out of the CSS for all wet weather events that are equal to or less than Design Event E, which represents a 20 hour, 1.8 inch rain event that occurs approximately four times a year (i.e., three month storm event). From the United States Environmental Protection Agency (USEPA) CSO policy, water quality objectives in the receiving water body are presumed to meet regulatory requirements if CSOs are limited to four overflows or less per year and/or capture 85 percent of the wet weather combined sewage. The proposed stormwater separation conduits focus on conveying the peak stormwater creek flows for Design Event E out of the CSS entirely which will help the City meet the 85 percent wet weather capture CSO presumption approach goals.

In addition, the Blacksnake and Whitehead Creeks have a continuous dry weather stormwater base flow that enters and passes through the existing CSS to the Water Protection Facility (WPF). The total base inflow to the CSS for these two creeks is approximately 4 million gallons per day (mgd) (2 mgd from Whitehead and 2 mgd from Blacksnake). This stormwater flow does not need to be treated at the WPF, and removing the creek base inflows will provide year round cost savings to the City.

Based on the 2008 LTCP recommendations, each of the three proposed stormwater separation conduits were planned to be connected to proposed detention basins. The proposed detention basins have been under consideration by the City for over the past 20 years. Initially, in 1987, the USACE performed a stormwater flooding reconnaissance study to investigate options to reduce flooding in and around the City. As part of the findings made within the USACE 1987 Detention Basin Reconnaissance Report, flood control detention basins and improvements were suggested within the Blacksnake, Whitehead, and Brown's Branch Basins. Several years later, following completion of the USACE Flood Control Reconnaissance Report, Black & Veatch was selected by the City to perform a comprehensive city-wide stormwater master plan. Recommendations made within the 1998 Comprehensive Stormwater Management Plan indicated detention basins, similar to the ones initially proposed by the USACE, should be implemented. The detention basin concepts recommended by the 1998 Comprehensive Stormwater Management Plan were adopted and incorporated into the

2008 LTCP Update as "Fundamental Projects." These projects have been reviewed in more detail as part of the ongoing Facilities Plan and revisions to the initial LTCP recommendations are made herein.

Concurrent with the Facilities Plan, a more detailed feasibility analysis of the proposed Whitehead Detention Basin is being performed. Flow monitoring, a siting study, flood reduction analysis, and conceptual layouts of this facility will be presented in the Whitehead Stormwater Detention Basin Facilities Assessment. An overview of the Whitehead Detention Basin's interrelationship with the proposed Whitehead stormwater separation conduit is presented in this technical memorandum.

The Blacksnake Detention Basin concept is currently under review by the USACE. At this time, the final USACE recommendation for the Blacksnake Detention Basin is unknown. However, a basic overview of the Blacksnake Detention Basin's interrelationship with the proposed Blacksnake stormwater separation conduit is also included in this technical memorandum.

The Brown's Branch Detention Basin concept and stormwater separation conduit were also reviewed. The findings of this analysis are also presented herein.

4.0 Brown's Branch Detention Basin and Stormwater Separation Conduit

The proposed Brown's Branch Detention Basin and stormwater separation conduit, recommended in the 2008 LTCP, is being removed from consideration. Due to financial limitations of implementing the entire LTCP, in March 2009 the City was asked by the Missouri Department of Natural Resources (MDNR) and USEPA to focus on CSO improvements from the 2008 LTCP that provide the most cost effective solutions for increasing the volumetric capture and treatment of combined sewage over a 20 year period. It was determined that the Brown's Branch Detention Basin and stormwater separation conduit did not fit these criteria.

Table 1 presents the cost per storage volume for the proposed Blacksnake, Whitehead, and Brown's Branch Detention Basins. As shown in Table 1, the Brown's Branch Detention Basin has a far greater (more than four times greater) cost per volume of storage than the other two proposed detention basins. The Brown's Branch Detention

Basin is not cost effective compared to the other proposed basins for the benefits it provides.

Table 1
Cost Effectiveness of 2008 LTCP Proposed Detention Basins

Detention Basin	2008 LTCP Project Cost	Detention Basin Storage Volume	Cost per Acre-Ft of Storage
Blacksnake	$9.0 Million	351 acre-ft	$25,640/acre-ft
Whitehead	$7.3 Million	675 acre-ft	$10,810/acre-ft
Brown's Branch	$9.5 Million	97 acre-ft	$97,940/acre-ft

Furthermore, the conveyance system in the area adjacent to the previously proposed Brown's Branch Detention Basin is currently a combined sewer system and would need to be sewer separated to allow only stormwater to enter the detention basin. As indicated in the 2008 LTCP, with the exception of specific targeted areas, sewer separation is typically not cost effective over a larger area in controlling CSOs.

In addition, the stormwater separation conduit proposed in the LTCP for the Brown's Branch Detention Basin was a 3 foot pipe estimated to cost $3.1 million. The Brown's Branch separation conduit will not, however, convey dry weather base flows because the separated area that it would serve will have no upstream base flow. Therefore, unlike the Blacksnake and Whitehead separation conduits where 4 mgd of base flow will be removed from the WPF year round, the Brown's Branch separation conduit would only convey flows during wet weather from an area that would require sewer separation. This is a significant drawback for the Brown's Branch sewer separation conduit because it lacks a dry weather benefit for the City.

Based on the aforementioned reasons, the Brown's Branch Detention Basin and stormwater separation conduit (both of which would require sewer separation) are not being recommended by the Facilities Plan. From a flood control perspective, the proposed detention basin has a poorer cost to benefit ratio as documented herein and within past studies. From a CSO perspective, since the stormwater separation conduit is only useful if sewer separation is performed, the cost for this solution is also not as effective in comparison with other CSO solutions. This does not imply, however, that

CSOs from the Brown's Branch Basin are being ignored. Technical memorandum TM-CSO-3c – Future Phases of CSO Long Term Control Plan provides a recommendation that address CSOs from the Brown's Branch Basin in a more cost effective manner.

5.0 Blacksnake Detention Basin and Stormwater Separation Conduit

The Blacksnake stormwater separation conduit is proposed to intercept and convey Blacksnake Creek flows that are directed to the combined sewer system. Flows entering the proposed Blacksnake stormwater separation conduit will be directed to a dedicated stormwater outfall. Depending upon the selected stormwater separation conduit alignment, the dedicated outfall directs flow to either the Missouri River or to Roy's Branch Creek located in the Roy's Branch Basin.

Five alternative alignments were investigated for the Blacksnake stormwater separation conduit. The benefits, drawbacks, and opinion of probable cost for each alignment are presented in the following sections. An overview of the Blacksnake Basin is shown in Figure 2.

The Blacksnake separation conduit must be able to convey the peak flow from the Design Event E wet weather event (1.8 inch, 20 hour rain event) for the upstream drainage area of 3,430 acres. The Design Event E peak flow was derived from the calibrated hydrologic and hydraulic computer model developed for the 2008 LTCP and updated as part of the ongoing Facilities Plan. The model refinements accounted for updated flowmeter data collected in 2008 for the Facilities Plan. The Blacksnake Creek Design Event E peak flow is estimated to be approximately 175 cubic feet per second (cfs). This peak flow is based on having no upstream detention and no peak flow attenuation. Four stormwater separation conduit alternatives (A, B, C, and D) are sized to covey this flow.

A fifth alternative, Alternative E, assumes that a detention basin has been constructed directly upstream from the proposed stormwater separation conduit and CSS. The upstream detention basin would attenuate peak stormwater flows resulting in a smaller downstream peak flow and a smaller stormwater separation conduit. This

alternative investigates whether the combination of a detention basin and stormwater separation conduit is more cost effective than the other four alternatives which assume no detention basin and no peak flow attenuation.

For the past several years, the USACE has been investigating a flood control detention basin to be located on Blacksnake Creek north of Karnes Road (directly upstream from the start of the CSS) as shown in Figure 2. A final recommendation from the USACE is not available at this time. Therefore, to get a general sense of what a smaller detention basin, sized to contain runoff from Design Event E, might cost and how it would affect the size of the proposed stormwater conduit, a reasonable size for a Blacksnake detention facility was selected.

A detention basin appears to be the most feasible near the location identified in Figure 2. This is also the same location being investigated by the USACE for construction of a flood control facility. It was assumed that a detention basin would require some aesthetic improvements besides being a dry bottomed "low spot" along the stream corridor. Therefore, the theoretical Blacksnake Detention Basin was conceived to be a wet detention basin sized to have a 5 acre permanent pool with an average depth of approximately 3 feet for a total of 15 acre-feet of dead storage (dead storage is storage unavailable for stormwater attenuation since it is the storage associated with the permanent pool). The total flood storage volume assumed to capture and detain Design Event E runoff would be approximately 135 acre-feet. The dam for the theoretical facility was sized to capture the existing conditions for Event E runoff. The dam would be required to have a height of 12 feet above the bottom of the creek bed and be approximately 450 feet wide. The dam was assumed to be roller compacted concrete which allows it to be overtopped during flood events larger than Design Event E.

Since the existing creek is incised with no room for a permanent pool and has minimal channel storage, the upstream area would need to be significantly re-graded and excavated. By cutting approximately 291,000 cubic yards of soil to make room for the wet pool and necessary detention volume, the detention basin would be approximately 450 feet wide. Modeling demonstrated that a facility having these characteristics reduced the Blacksnake Creek Event E peak flow from 175 cfs to 20 cfs as it enters the existing

CSS near the intersection of Karnes Road and St. Joseph Avenue. Since the peak flow from Design Event E would be reduced due to attenuation, the resulting stormwater conduit could be downsized. Construction of a smaller diameter stormwater conduit would be less expensive than the other stormwater conduit alternatives, but the cost savings from the conduit must be compared to the expense of constructing the detention basin. This cost analysis is presented in Section 5.6.

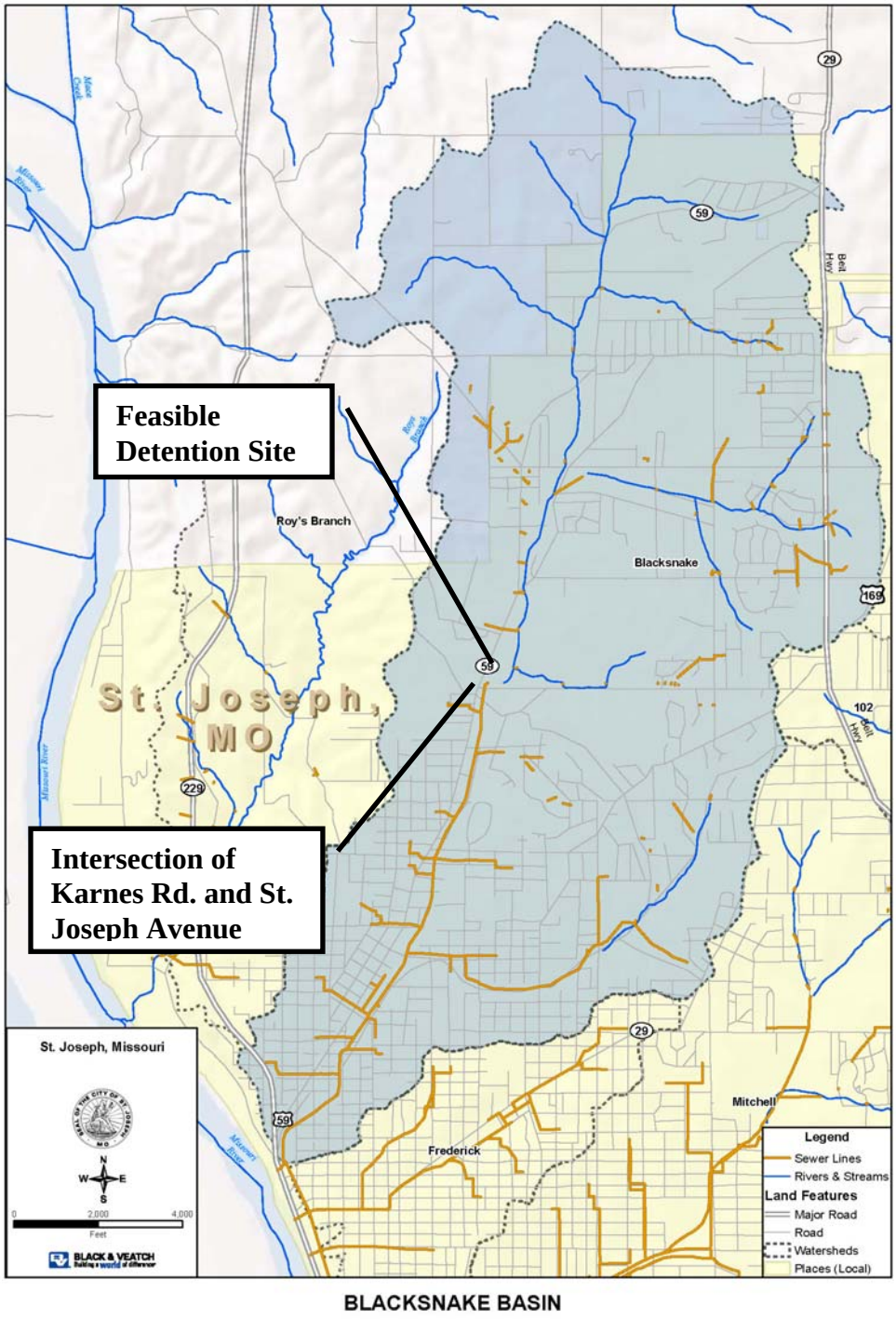


Figure 2 – Blacksnake Basin Overview

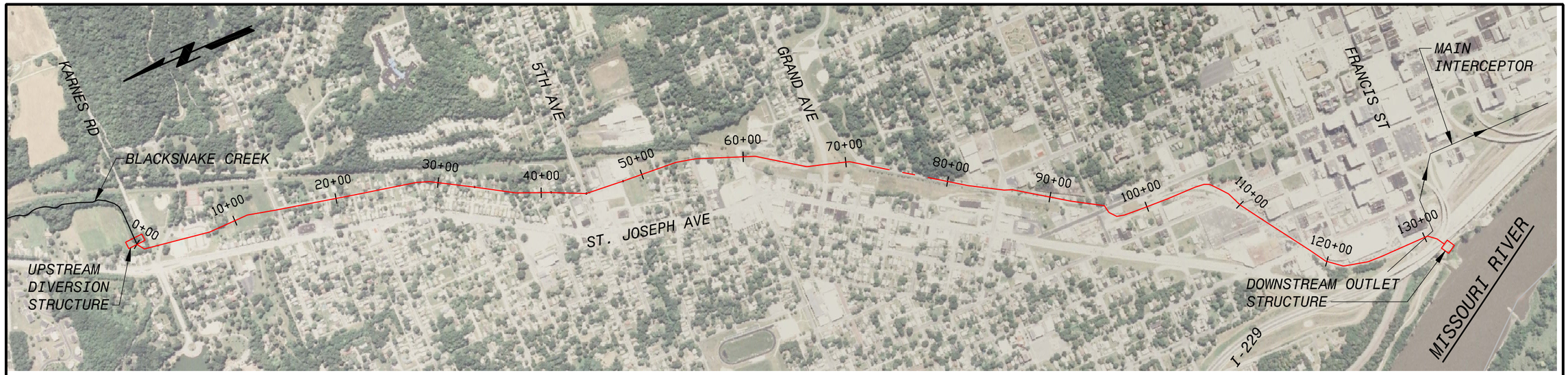
All of the Blacksnake stormwater separation alternatives have two basic structures in common, an upstream stormwater diversion structure/weir and a downstream outlet structure. The upstream diversion structure would be required to divert low flows into the separation conduit while allowing high flows (i.e., creek flows from events larger than Design Event E) to pass, via weir flow, back to the existing CSS. The diversion structure would be configured with the stormwater separation conduit located at the bottom of the structure and a high flow overflow weir to pass flows greater than the Design Event E peak flow back into the CSS.

The design of the upstream diversion structure must ensure that during high flows (i.e., flood flows), the structure itself does not cause any local flooding problems to worsen. This concern can be mitigated by selecting an appropriate weir crest height and weir length. For each of the four Blacksnake stormwater separation conduit alternatives (Alternatives A through D), an evaluation of an appropriate weir height and weir length was conducted to ensure that this potential problem was avoided. Alternative E does not require the upstream diversion structure because a proposed detention basin embankment and outlet works will serve in its place.

The stormwater separation conduits are not sized to provide flood control. Significantly larger pipes would need to be installed to allow the 25-year storm to pass through the sewer system without the occurrence of flooding. The 1998 Comprehensive Stormwater Management Plan details the needed improvements to convey the 25-year event. The stormwater separation conduits recommended herein are sized to eliminate all base creek flows and the peak flows up to Design Event E (i.e., approximately a three month storm) in an effort to achieve CSO control objectives as required by the USEPA and MDNR. Larger, more expensive separation conduits could be installed to provide both CSO and flood control, but this “buy-up” option is a decision that will need to be made by the City during preliminary design.

5.1 Alternative A – Pipe in Pipe

Blacksnake Alternative A, as shown in Figure 3, proposes to place the stormwater separation conduit inside the existing large diameter combined sewer. Alternative A,



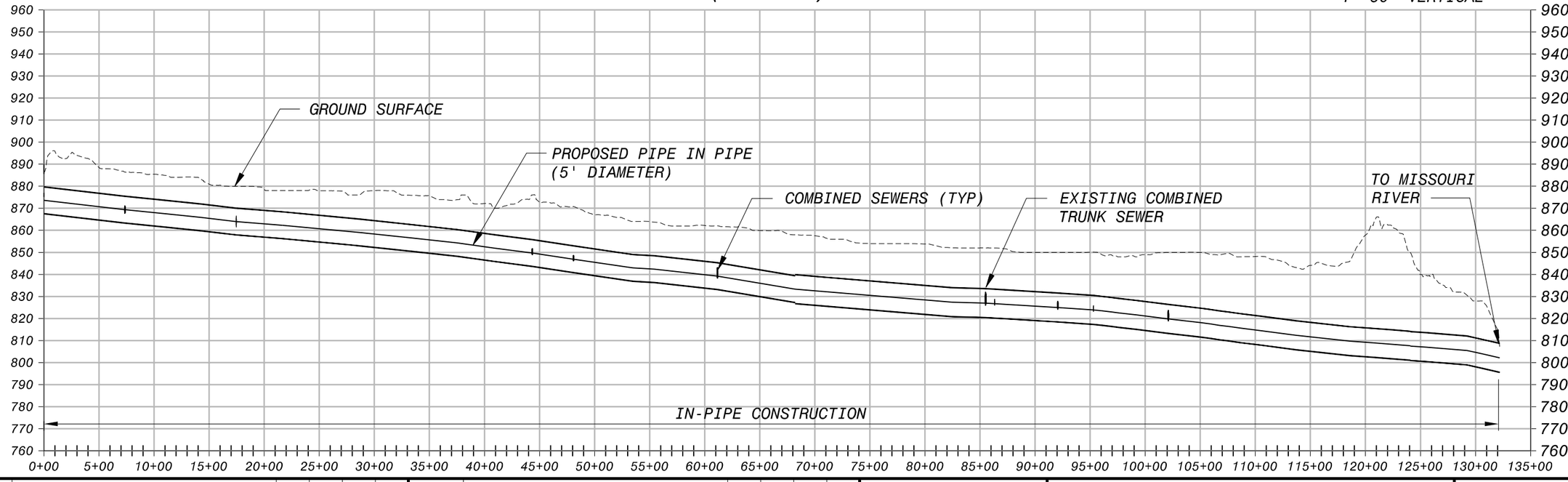
1000' 500' 0 1000' 2000'

1"=1000' HORIZONTAL

50' 25' 0 50' 100'

1"=50' VERTICAL

BLACKSNAKE ALTERNATIVE A (PIPE IN PIPE)
(132+08)



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ST. JOSEPH, MO

ALTERNATIVE A

BLACKSNAKE CREEK STORMWATER SEPARATION CONDUIT

FIGURE 3

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also known as the pipe-in-pipe alternative, allows the existing large diameter combined sewer to serve as the encasement for the smaller stormwater separation conduit. This alternative would limit the amount of earthwork and excavation since the proposed pipe would be placed inside the existing combined sewer. In addition, at the downstream end of the Blacksnake sewer, the existing diversion structure would need to be modified to allow the stormwater pipe to pass through or around it and to the Missouri River.

This alternative, however, has some significant drawbacks. By placing the separation conduit inside the existing combined sewer, the following concerns and issues arise:

1. During construction, the large diameter sewer would be conveying both dry weather sanitary flow and wet weather flow. Dry weather flows would need to be detained and diverted around the construction site. Most likely, construction within the existing CSS would use temporary diversion structures and pumping to pass dry weather flows around the construction zone. This type of construction would be complex and costly.
2. Construction within the active CSS would make the construction area a confined space entry. Workers would likely be required to wear full protective gear, including self contained breathing apparatus which could slow construction, increasing the overall project cost.
3. In late 1998, Black & Veatch completed a comprehensive stormwater management plan to identify sewer improvements necessary to reduce flooding in the City. As part of the recommendation from the stormwater study, the Blacksnake sewer was recommended to be expanded to pass the 25-year design storm. The existing Blacksnake CSS is significantly undersized to convey high flood flows. By placing another conduit inside the existing CSS, the overall conveyance capacity of the Blacksnake sewer would be reduced which is a significant drawback to this alternative.

4. There is a maintenance concern with this alternative. By placing a smaller pipe inside the larger CSS, debris and sediment fallout could occur around the separation conduit. The smaller pipe would cause complex hydraulic conditions such as vortexes and dead spots within the larger CSS that would allow suspended solids to settle out. It is anticipated that maintenance needs would be higher and repair work more complicated with this proposed alternative due to the complexity of the final installation.
5. The stormwater separation conduit would need to be anchored down within the existing CSS. A series of anchor bolts and straps would need to be used to anchor the pipe in place. Approximately halfway down the existing Blacksnake CSS, the Blacksnake sewer transitions from cast-in-place concrete to brick. Anchoring the stormwater separation conduit within the brick sections could be problematic as the structural integrity of the brick sewer may not support the anchors.
6. The stormwater separation conduit must be installed so that it does not allow sanitary flows to leak into the separated stormwater. Leakage of sanitary flows into the separated stormwater would defeat the purpose of the separation conduit by allowing bacteria to enter the stormwater and pass untreated to the Missouri River. A seamless conduit for the pipe-in-pipe option is the optimal pipe design to prevent leakage.
7. If lighter material, such as high density polyethylene, is used for the stormwater conduit, the speed of construction within the existing CSS would be increased. Increasing the installation speed should decrease the overall project cost. Therefore, a seamless high density polyethylene pipe may be the most appropriate material for the pipe-in-pipe conduit.

Upon review of this alternative, the potential problems and drawbacks appear to be numerous and significant. Therefore, the Alternative A pipe-in-pipe option is being removed from further consideration. Unless future work performed as part of the

Facilities Plan necessitates the need to revisit this option, this alternative is screened out and the associated opinion of probable cost is not presented.

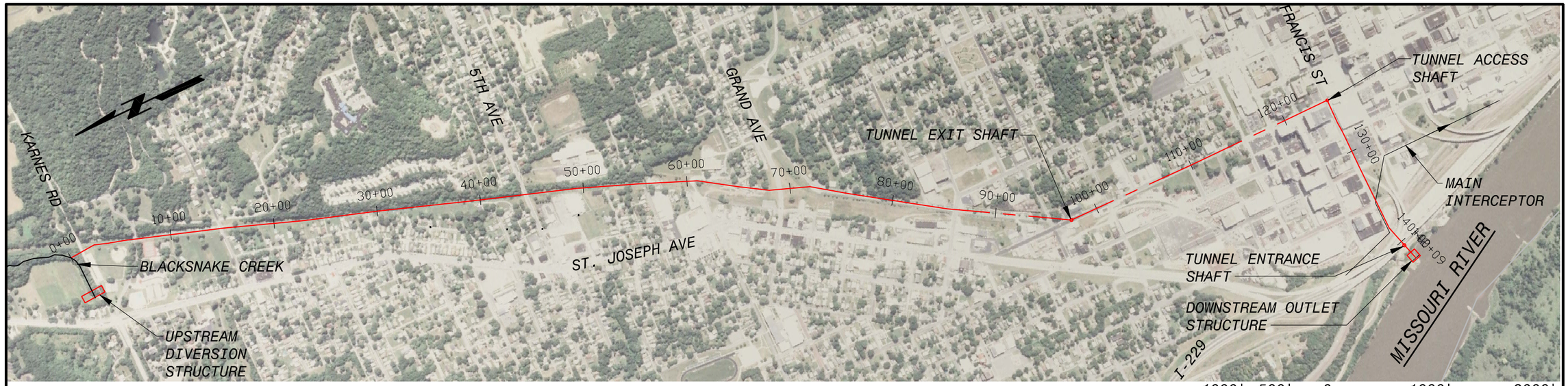
5.2 Alternative B – Pipe along Abandoned Railway

Blacksnake Alternative B, as shown in Figure 4, proposes to place the stormwater separation conduit along an existing City owned right-of-way within an abandoned railway corridor. A number of existing combined sewers would need to be crossed if the proposed alternative is constructed. Therefore, the locations and dimensions of the existing sewers have been shown in profile to demonstrate how the proposed stormwater separation conduit would be oriented to avoid conflicting with the existing combined sewers. This alternative would likely require both open cut and tunneling construction methods. The upstream diversion structure required to divert creek flows into this proposed stormwater conduit is shown in concept form in Figure 5.

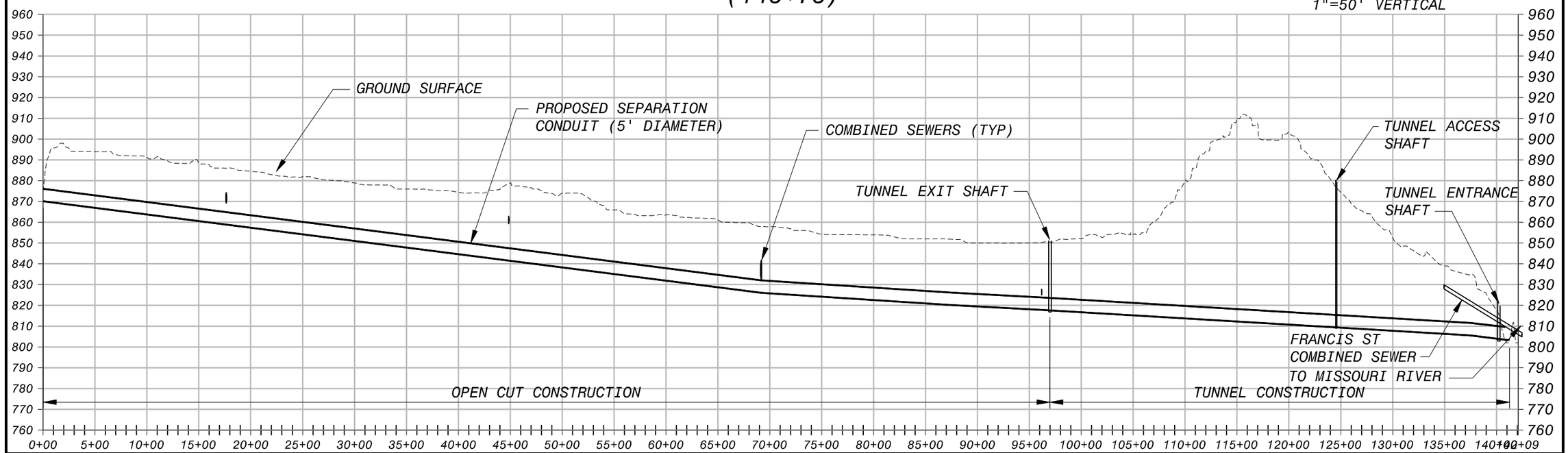
The stormwater conveyance conduit alternative must pass all the creek flows up to the Design Event E peak flow. If gravity flow conditions are to be maintained, this requires the stormwater conveyance conduit to be located at the bottom invert of the creek channel. With the stormwater separation conduit located at the invert of the creek channel, the depth of the stormwater separation conduit is fixed at the upstream end at the invert elevation of the creek channel. The anticipated conceptual profile of Alternative B is shown in Figure 4.

Alternative B would likely include a section of open cut pipe and a section of tunneled pipe. These segments are shown in Figure 4. For costing purposes, the following assumptions were used for the tunneled portion of all of the stormwater separation conduit alternatives:

1. A tunnel boring machine (TBM) would be used for tunnel construction.
2. A standard TBM would be utilized. It is assumed a specialized earth pressure balance or slurry TBM would not be required.
3. The TBM would pass through soft ground. It is assumed mixed face and/or hard rock subsurface conditions would not be encountered during tunneling.



BLACKSNAKE ALTERNATIVE B (PIPE ALONG ABANDONED RAILWAY)
(143+73)



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ST. JOSEPH, MO

ALTERNATIVE B

BLACKSNAKE CREEK STORMWATER SEPARATION CONDUIT

FIGURE 4

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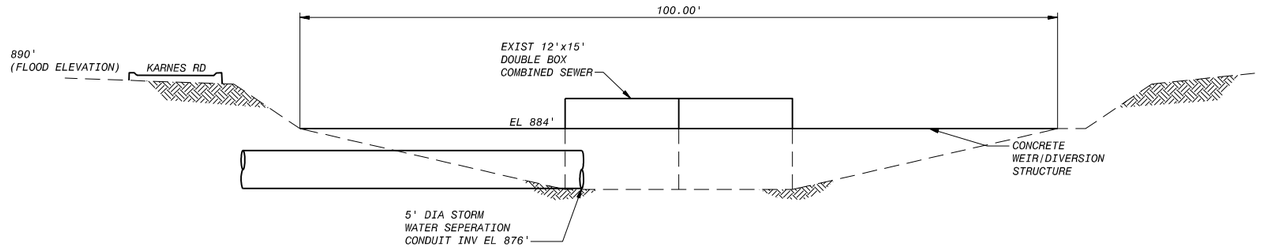
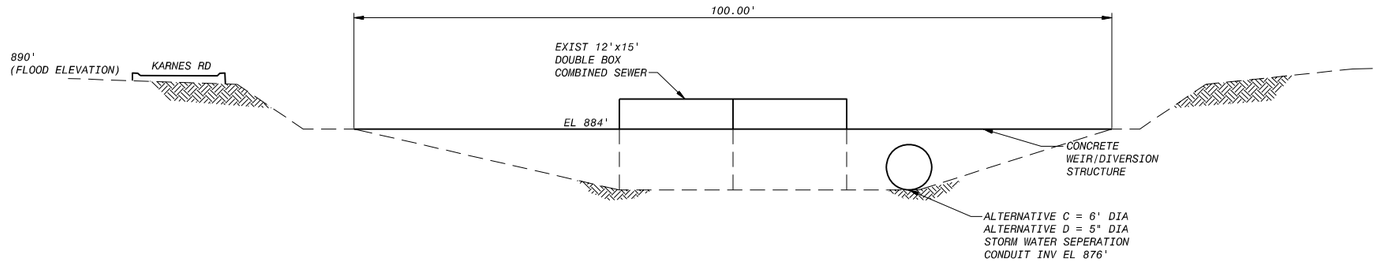


BLACKSNAKE ALIGNMENT B
WEIR/DIVERSION STRUCTURE
1" = 10'-0"



BLACKSNAKE ALIGNMENT C & D
WEIR/DIVERSION STRUCTURE
1" = 10'-0"

20' 0 20' 40'

1"=20'

NOTE:
ALTERNATIVE A AND E DETENTION BASIN CROSS-SECTIONS NOT SHOWN

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BLACK & VEATCH Corporation

PROJECT
163509

ST. JOSEPH, MISSOURI
BLACKSNAKE ALTERNATIVES

UPSTREAM DIVERSION
STRUCTURE CROSS SECTIONS

FIGURE 5

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Additional geotechnical investigations would be required to ensure that the assumptions stated above are valid; however, a review of limited existing geotechnical data (Geotechnical Engineering Report of Wastewater Treatment Facilities, 1974) corroborates these assumptions.

Table 2 presents the dimensions and characteristics of the Alternative B proposed separation conduit.

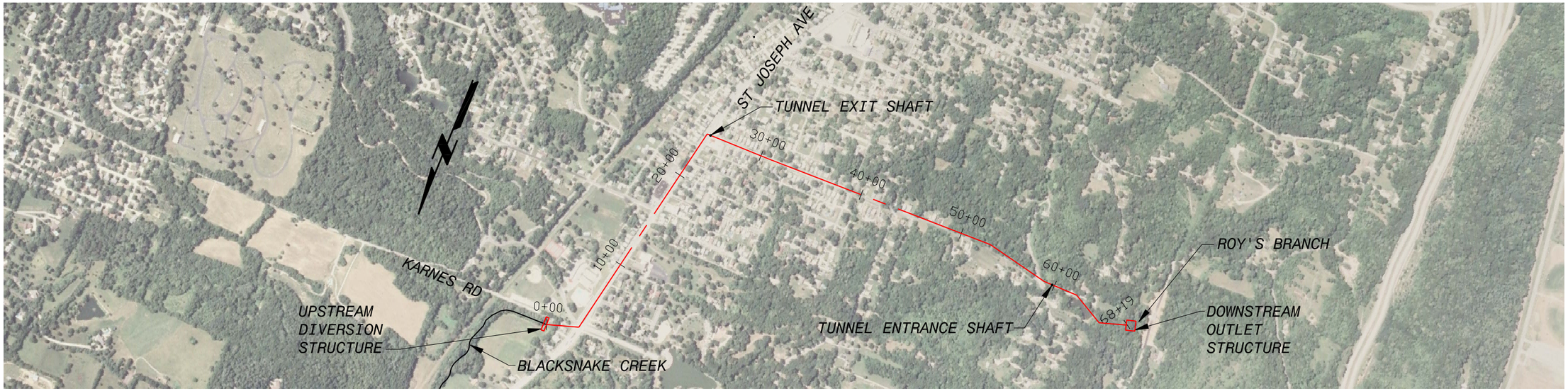
Table 2
Blacksnake Alternative B
Stormwater Separation Conduit Characteristics

Conduit Total Length	14,370 feet
Tunneled Length	4,670 feet
Open Cut Length	9,700 feet
Conduit Diameter	5 feet
Conduit Material	Concrete

5.3 Alternative C – Pipe to Roy's Branch Basin

Blacksnake Alternative C, as shown in Figure 6, represents a stormwater separation conduit alignment that allows the creek flow to be diverted out of the Blacksnake Basin and into the Roy's Branch Basin (i.e., into the Roy's Branch open channel which leads to the Missouri River). An advantage of this alternative is that the overall length of conduit would be shorter than the other Blacksnake alternatives which would reduce the cost.

This alternative involves a cross-basin stormwater transfer that could create unacceptable flooding, stream bank erosion, and other problems in the Roy's Branch Basin. Cross-basin stormwater transfers are typically avoided by stormwater design protocols and standard engineering practices because they can increase the peak stream flows causing any existing flooding problems to be exacerbated. Furthermore, the City could be held responsible for any adverse changes this alternative might create in the Roy's Branch Basin. The City could be obligated to purchase over a mile worth of stream easements, perform flooding and stream bank stabilization improvement projects, and address other stream issues at the request of downstream property owners.

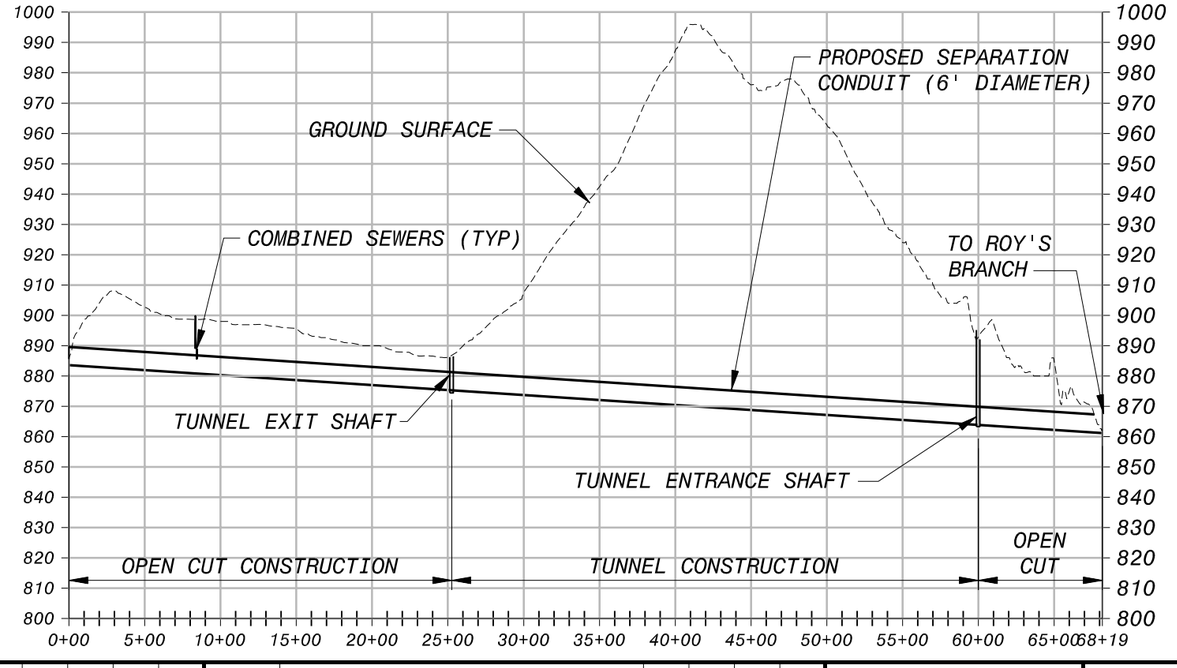


1000' 500' 0 1000' 2000'

1"=1000' HORIZONTAL

BLACKSNAKE ALTERNATIVE C (PIPE DIVERSION TO ROY'S BRANCH BASIN)

(68+41)



50' 25' 0 50' 100'

1"=50' VERTICAL

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BLACK & VEATCH Corporation

PROJECT 163509

ST. JOSEPH, MO

ALTERNATIVE C

BLACKSNAKE CREEK STORMWATER SEPARATION CONDUIT

FIGURE 6

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In addition, various state and federal agencies, such as FEMA and the USACE, could have jurisdiction regarding cross-basin stormwater transfers that could change, limit, or eliminate the alternative in its entirety. For example, if the floodplain is raised as a result of the cross-basin transfer, property owners along the entire extent of the Roy's Branch Basin may have to be notified. Following the property owner notification, a public review process of the plan may be required. It is possible that Alternative C may not be allowed by the permitting agencies or the public.

Alternative C would likely include a section of open cut pipe and a section of tunneled pipe. The open cut and tunneled portions are shown in Figure 6. For costing purposes, the same tunneling assumptions used for Alternative B were used for Alternative C. There are some indications though from a visual inspection of the bluffs in this area that a tunnel at the elevations shown on Figure 6 could encounter rock. A change in the geotechnical assumptions for this alternative could significantly affect the estimated project cost. Additional geotechnical investigations would be required to verify the geotechnical assumptions and corresponding project costs.

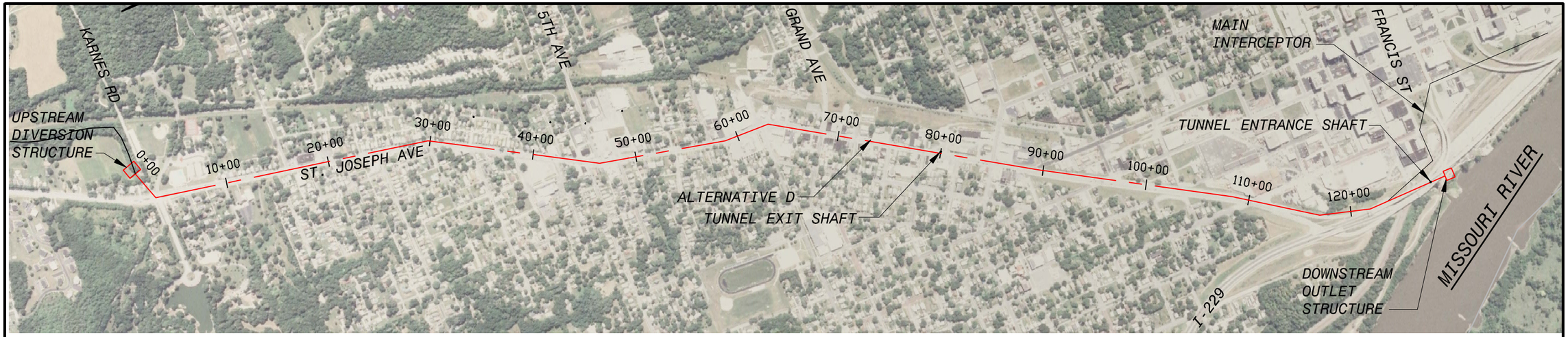
Table 3 presents the dimensions and characteristics of the Alternative C proposed separation conduit. This alternative has a larger pipe diameter than the other Blacksnake alternatives because it has a shallower slope and less driving head than the other alternatives. This is due to the conduit being configured to direct flow into the Roy's Branch Creek rather than directly to the Missouri River.

Table 3
Blacksnake Alternative C
Stormwater Separation Conduit Characteristics

Conduit Total Length	6,870 feet
Tunneled Length	3,500 feet
Open Cut Length	3,370 feet
Conduit Diameter	6 feet
Conduit Material	Concrete

5.4 Alternative D – Pipe along St. Joseph Avenue

Similar to Alternatives A and B, Blacksnake Alternative D, as shown in Figure 7, represents a stormwater separation conduit alignment that allows the creek flow to be



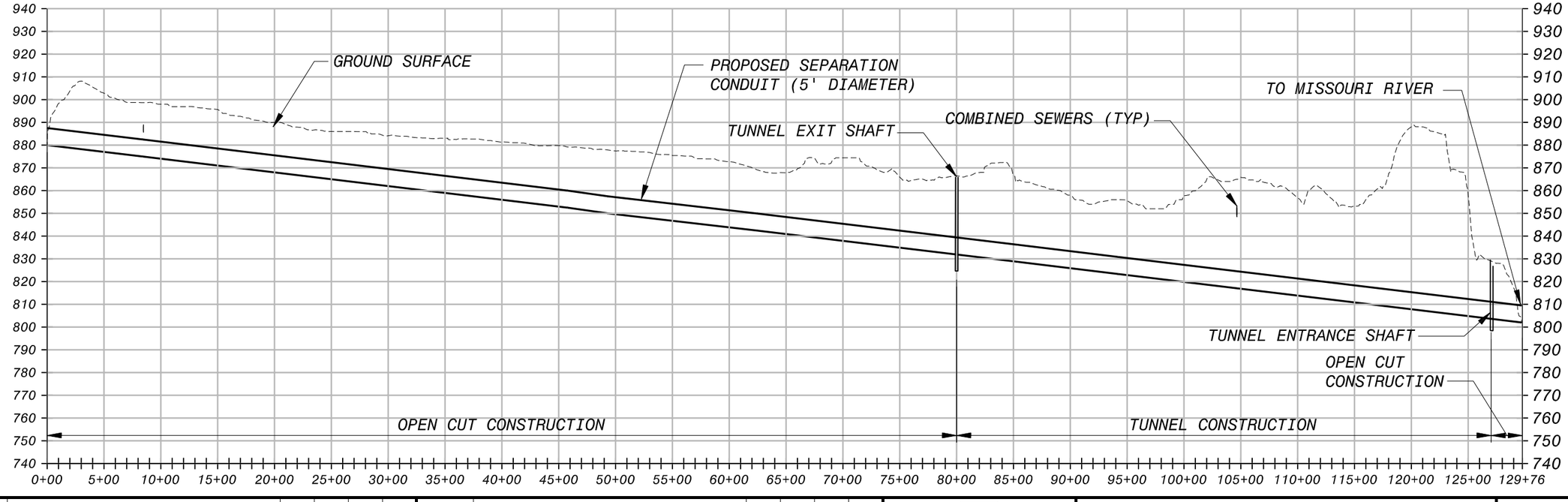
1000' 500' 0 1000'

1"=1000' HORIZONTAL

50' 30' 20' 0 50'

1"=50' VERTICAL

BLACKSNAKE ALTERNATIVE D (PIPE ALONG ST. JOSEPH AVE)
(129+76)



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ST. JOSEPH, MO

ALTERNATIVE D

BLACKSNAKE CREEK STORMWATER SEPARATION CONDUIT

FIGURE 7

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diverted directly to the Missouri River. Alternative D is very similar to Alternative B, however, rather than following the existing City owned right-of-way on the east side of the Blacksnake trunk sewer, Alternative D extends along St. Joseph Avenue on the west side of the existing Blacksnake combined trunk sewer. This alignment helps to minimize the amount of construction performed in and around the downtown buildings at the downstream end of the conduit. However, one major drawback of this alternative is that most of the construction would take place along an active and busy street. Construction of this alternative would therefore require significantly more street pavement replacement and traffic control than the other alternatives. Furthermore, it would likely cause more community and business disruption than the other alternatives.

Alternative D would likely include a section of open cut pipe and a section of tunneled pipe. The open cut and tunneled portions are shown in Figure 7. For costing purposes, the same tunneling assumptions used for Alternative B were used for Alternative D. Additional geotechnical investigations would be required to ensure that the assumptions are valid.

Table 4 presents the dimensions and characteristics of the Alternative D proposed separation conduit.

Table 4
Blacksnake Alternative D
Stormwater Separation Conduit Characteristics

Conduit Total Length	12,980 feet
Tunneled Length	2,980 feet
Open Cut Length	10,000 feet
Conduit Diameter	5 feet
Conduit Material	Concrete

5.5 Alternative E – Pipe along Abandoned Railway with Upstream Detention Basin

Alternative E follows almost the same alignment as Alternative B (except for the downstream portion through the downtown area); however, it is fundamentally different from the other four alternatives as it assumes that a 150 acre-feet detention basin (15 acre-feet permanent pool, 135 acre-feet flood pool) has been constructed near the

location shown on Figure 2, directly upstream of the existing CSS. A small detention basin of this size was estimated to attenuate the peak flow from Design Event E from 175 cfs to 20 cfs downstream from the detention basin. The detention basin flow reduction would significantly reduce the diameter of the stormwater conduits (i.e., diameters would be less than 2 feet for Alternatives A through D).

Alternative E was configured to be a near surface open channel and pipe alternative to convey creek flows to the Missouri River. This allows the open channel and near surface stormwater separation conduit to be downsized and the economic benefits of the upstream detention basin to be compared more fairly with the other alternatives. Alternative E assumes construction of the following project elements:

- A 9,100 foot long, 5 foot by 5 foot concrete open channel along the City owned right-of-way (see Figure 8).
- Six 36 inch diameter culvert street crossings along the open channel section.
- A 5,000 foot, 36 inch diameter buried, near surface (open cut) concrete pipe to convey flows from the open channel to the Missouri River through the downtown area.
- A 20 cfs pump station to lift water into the proposed open channel.

A pump station was assumed to be required to pump creek flows into the proposed open channel. Raising the permanent pool of a detention basin high enough to allow creek flows to pass to the open channel via gravity is not viewed as feasible. Downstream flooding is a problem in the Blacksnake Basin and having a permanent pool high enough to divert flows, via gravity, into an open channel eliminates any potential flood benefit and flow attenuation potential from a detention basin at this site.

The optimal wet weather configuration for this site is to divert creek flows out of the CSS while preserving the site's ability to detain and attenuate flood flows from large, flood events. For this reason, a small 20 cfs pump station was assumed to lift creek flows from the detention basin into the open channel. This allows storage at this site to be preserved for flood attenuation while removing creek flows from the CSS during dry and

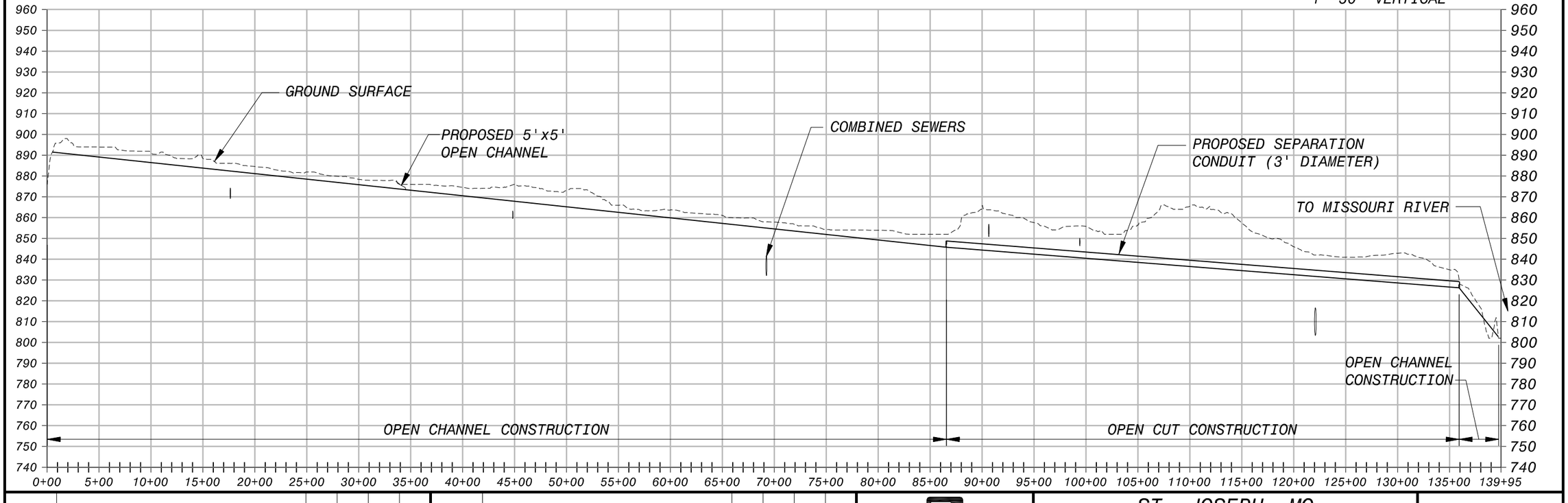
1000' 500' 0 1000' 2000'

1"=1000' HORIZONTAL

50' 25' 0 50' 100'

1"=50' VERTICAL

BLACKSNAKE ALTERNATIVE E (OPEN CHANNEL OPTION)
(140+85)



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ST. JOSEPH, MO
ALTERNATIVE E

BLACKSNAKE CREEK STORMWATER SEPARATION CONDUIT

FIGURE 8

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FB50000

wet weather conditions.

Table 5 presents the dimensions and characteristics of the Alternative E proposed separation conduit.

Table 5
Blacksnake Alternative E
Stormwater Separation Conduit Characteristics

Conduit Total Length	14,100 feet
Tunneled Length	0 feet
Open Cut Length	5,000 feet
Open Channel Length	9,100 feet
Conduit Diameter	3 feet
Open Channel Dimensions	5 foot x 5 foot
Conduit Material	Concrete

5.6 Blacksnake Costs and Recommendations

Multiple alternatives and costs were developed to remove the Blacksnake Creek flows from the CSS via a stormwater separation conduit. Table 6 presents the opinion of probable project costs for Blacksnake Alternatives B, C, D, and E stormwater separation conduits and the detention basin for Alternative E. Alternative A, the pipe-in-pipe option, was previously screened out from consideration and is not presented within the table. Table 7 presents the detailed project cost breakdown for the detention basin required for the Alternative E stormwater separation conduit. Appendix A presents additional details of the development of the conceptual project costs.

Table 6
Summary of Opinion of Probable Project Costs for Blacksnake Stormwater Separation Conduits [1]

Item	Alternative B, $	Alternative C, $	Alternative D, $	Alternative E, $
Stormwater Separation Conduit				
Open Cut Portion with Manholes	8,730,000	3,640,000	9,000,000	2,700,000
Tunneled Portion	8,406,000	7,560,000	5,364,000	0
Open Channel Portion	0	0	0	6,825,000
Tunnel Shafts	1,950,000	750,000	900,000	0
20 cfs Pump Station	0	0	0	3,000,000
Upstream Diversion/Energy Dissipation Structure	500,000	500,000	500,000	500,000
Downstream Outlet Structure and Flap Gate	300,000	300,000	300,000	300,000
Concrete Replacement (street)	1,600,000	1,630,000	8,296,000	306,000
Flood Protection/Fill (placeholder) [2]	0	0	0	0
Site Remediation (placeholder) [2]	0	0	0	0
Subtotal	*21,486,000*	*14,380,000*	*24,360,000*	*13,631,000*
Electrical, I&C, Sitework, Contractor General Requirements [3]	4,985,000	3,336,000	5,652,000	4,086,000
Subtotal	*26,471,000*	*17,716,000*	*30,012,000*	*17,717,000*
Contingency [4]	6,618,000	4,429,000	7,503,000	4,429,000
Land Acquisition (placeholder) [2, 5]	0	0	0	0
Opinion of Probable Construction Cost	**33,089,000**	**22,145,000**	**37,515,000**	**22,146,000**
Engineering, Legal, and Administration [6]	6,618,000	4,429,000	7,503,000	4,429,000
Opinion of Project Cost	**39,707,000**	**26,574,000**	**45,018,000**	**26,575,000**
Detention Basin Opinion of Project Cost (Design Event E, see Table 7 for basin cost details)	**0**	**0**	**0**	**10,787,000**
Opinion of Total Project Cost	**39,707,000**	**26,574,000**	**45,018,000**	**37,362,000**

Table 6
Summary of Opinion of Probable Project Costs for Blacksnake Stormwater Separation Conduits [1]

Item	Alternative B, $	Alternative C, $	Alternative D, $	Alternative E, $

1. All costs presented in May 2009 dollars (ENR BCI = 4773).
2. Site related costs are placeholders and must be revised following final siting of the facilities. It is assumed that these values are zero for the stormwater separation conduits.
3. Electrical and instrumentation and controls (I&C) projected at 25% of the total of all equipment and structure costs. Only Alternative E includes costs for electrical and I&C. Sitework projected at 10% of the total of equipment, structures, electrical, and I&C costs. Contractor general requirements projected at 12% of the total of equipment, structures, electrical, I&C, and sitework costs.
4. Project contingency is projected at 25% of the total of all equipment, structures, electrical, I&C, sitework, contractor general requirements, flood protection/fill, and site remediation costs.
5. Land acquisition is not anticipated for the stormwater separation conduits. The cost for easements is covered by engineering, legal, and administration (ELA).
6. ELA costs are projected at 20% of the total of all equipment, structures, electrical, I&C, sitework, contractor general requirements, flood protection/fill, site remediation costs, contingency, and land acquisition.