

**PRELIMINARY BRIDGE DESIGN REPORT**

**LAKWOOD GULCH**

Denver, Colorado

Prepared for:

City and County of Denver  
Wastewater Management Division  
2000 West Third Avenue  
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Urban Drainage and Flood Control District  
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## L PROJECT SCOPE

The intent of this report is to summarize the preliminary bridge design analysis results associated with the Lakewood Gulch Preliminary Design Project located in Denver, Colorado. The Lakewood Gulch drainageway subject to the preliminary design begins at West 10th Avenue and ends at Sheridan Boulevard. This project was authorized by the City and County of Denver and the Urban Drainage and Flood Control District.

Lakewood Gulch is an urban drainageway, subject to high flow mainly the result of summertime thunderstorms. There is a base flow in the drainageway year round. Within the preliminary design reach, the Gulch crosses under 10th Avenue, Perry Street, Tennyson Street, Wolff Street, and Sheridan Boulevard. The Gulch also passes through a box culvert under a parking lot just east of Sheridan. The existing structures are all single or multiple-bay box culverts. None of the existing structures are capable of conveying the 100-year flood discharge without causing the roadway to be overtopped.

The scope of the preliminary bridge design study included the following tasks:

1. Collect and review pertinent information related to the replacement of the Lakewood Gulch bridges. Conduct a field review of the existing bridge and drainageway conditions.
2. Review geotechnical report.
3. Review existing utilities at each site.
4. Review existing hydrologic analysis for Lakewood Gulch.
5. Review existing hydraulic information for Lakewood Gulch.
6. Assess impact of replacement structure(s) upon the 100-year water surface profile for the segment(s) of Lakewood Gulch adjacent to and upstream of each bridge.
7. Assess impact on traffic, constructability, maintenance, schedule and cost various bridge and/or culvert types at each site.
8. Provide recommendations for optimizing the hydraulic capacity for the replacement structures.
9. Prepare written report summarizing findings and recommendations.

### SUMMARY OF INFORMATION REVIEWED

The following documents were collected and reviewed during the course of conduction the preliminary design analysis:

1. *City of Denver Flood Insurance Study*, prepared by the Federal Emergency Management Agency, dated April 1977, with most current revisions through April, 1993.

2. Lakewood Gulch Major Drainageway Planning, Phase B Report, prepared by Sellards and Grigg, Inc.
3. Subsurface Exploration Report, Proposed Lakewood Gulch Improvement, Denver, Colorado, prepared by Earth Engineering Consultants, Inc., April, 1995.
4. Federal Highway Administration, HEC-18, Scour at Bridges, 1989.

Topographic mapping was prepared for the project at a scale of 1-inch to 50 feet horizontal and a contour interval of one foot. This mapping was used to lay out the location of proposed bridge and drainageway improvements associated with the bridge replacements, and for the determination of channel cross-sections for the hydraulic analysis.

### **PROJECT DESCRIPTION**

The Lakewood Gulch bridge replacements will involve the demolition of existing concrete or masonry box culverts at 10th Avenue, Perry Street, Tennyson Street and Wolff Streets. At this time, it is not anticipated that the structure under Sheridan Boulevard will be modified as part of the Lakewood Gulch project. A culvert with increased capacity under the parking lot east of Sheridan Boulevard has been analyzed for replacement. The 100-year flow overtops each of the roadways crossed, as shown in the City and County of Denver Flood Insurance Rate Map. The location of each of the replacement sites is presented on Figure 1. A brief description of each site follows.

**West 10th Avenue:** 10th Avenue is an east-west collector roadway, with one lane in each direction, and a flowline-to-flowline dimension of 40-feet. The posted speed limit is 35 miles per hour. The existing structure is a 13-foot high by 14.5-foot wide single-bay box culvert. An existing 8-inch waterline crosses through the culvert opening. A duct with electric lines parallels the box culvert on the east. The channel is deep and incised into bedrock. Private property abuts the roadway at the southeast corner of the bridge. Public ownership (parkland) abuts the roadway along the north and at the southwest corner of the bridge.

**Perry Street:** Perry Street is a north-south collector roadway, with one lane in each direction, and a flowline-to-flowline dimension of 30-feet. The posted speed limit is 35 miles per hour. The existing structure is a 7-foot high by 6-foot wide single-bay box culvert. Utilities at this site include 8-inch and 24-inch waterlines, an 8-inch sanitary sewer over the existing box, and a 2-inch gas line. All of these lines will have to be relocated as part of the replacement of the existing crossing. The channel is deep and incised into bedrock. Private property abuts the roadway, east and west. The 100-

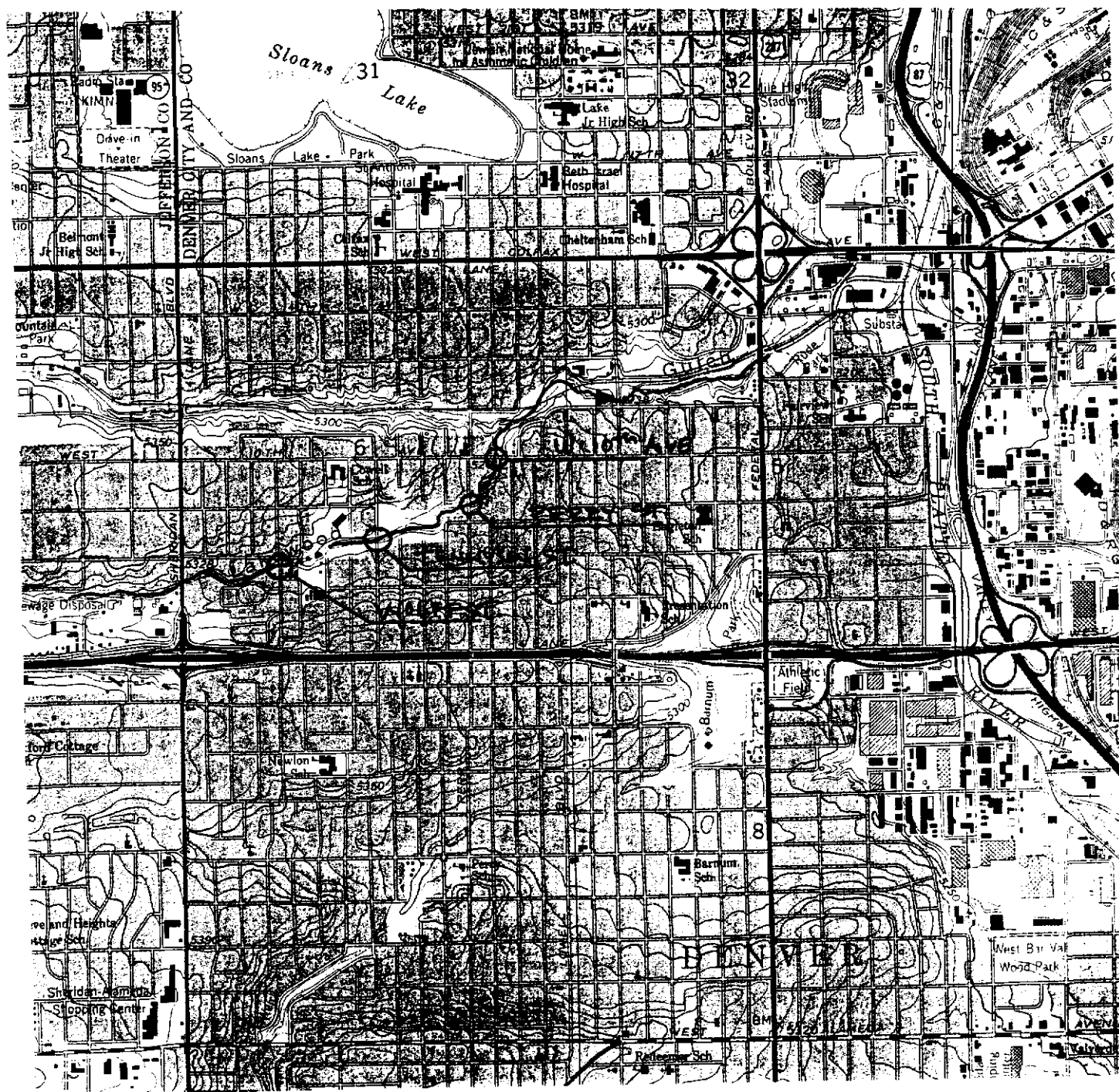


FIGURE 1:

BRIDGE REPLACEMENT SITES

year discharge overtops the existing structure and shallow flooding is forced north along Perry Street. There is very little opportunity to raise the roadway at this site because of existing driveways along Perry in the vicinity of the existing bridge.

**Tennyson Street:** Tennyson Street is a north-south local roadway, with one lane in each direction, and a flowline-to-flowline dimension of 36-feet. The posted speed limit is 30 miles per hour. The existing structure is a 7-foot high by 6-foot wide single-bay box culvert. A 6-inch waterline crosses over the existing structure. This line will have to be relocated as part of the replacement of the existing crossing. Private property abuts the roadway to the west, and public property (parkland), abuts the roadway along the east. The 100-year discharge overtops the existing structure which creates a shallow flooding area in the vicinity of the northwest corner of the bridge. There is very little opportunity to raise the roadway at this site because of existing driveways along Tennyson in the vicinity of the existing bridge.

**Wolff Street:** Wolff Street is also a north-south local roadway, with one lane in each direction, and a flowline-to-flowline dimension of 40-feet. The posted speed limit is 30 miles per hour. The existing structure is a 8-foot high by 5-foot wide single-bay box culvert. A 4-inch gas line crosses over the existing structure. This line will have to be relocated as part of the replacement of the existing crossing. Private property abuts the roadway both east and west. The 100-year discharge overtops the existing structure which creates a shallow flooding area south of the bridge. As with the other sites, there is very little opportunity to raise the roadway at this site because of existing driveways along Wolff in the vicinity of the existing bridge.

## II. PRELIMINARY HYDRAULIC ANALYSIS

The hydraulic analysis included the review of existing hydrology for the project site, review of existing planning studies, and the hydraulic analysis of existing and proposed structures.

### HYDROLOGY

Hydrology for the Lakewood Gulch drainageway was obtained from the Lakewood Gulch Major Drainageway Planning Study, Phase B report. These flows were used in the preparation of the flood insurance study for Lakewood Gulch. Presented in Table 1 below are the peak discharges for the study area subject to the preliminary design analysis.

**Table 1: Summary of Peak Discharges (1)**

Location	10-year cfs	100-year cfs
Perry Street	5,100	8,000
Sheridan Blvd.	5,000	7,800

(1) From Figure III-3, Lakewood Gulch Major Drainageway Planning, Phase B Report

### HYDRAULIC ANALYSIS

The hydraulic analysis for the four bridge sites was conducted in two steps. First, the hydraulic grade lines for the existing site conditions and current topography were evaluated and compared to the results shown in the FIS and the Major Drainageway Planning Study. The second step was to evaluate the drainageway hydraulics with replacement structures in place. The hydraulic analysis was developed for the existing and proposed conditions using a combination of the U.S. Army Corps of Engineers HEC-2 Water Surface profile program and the Federal Highway Administration HYDRAIN computer model. HEC-2 was used to model water surface profile beginning at West 10th Avenue. The HYDRAIN model was used to estimate the hydraulic grade line at the inlet to the existing culverts for only the existing condition case. The hydraulic grade line obtained using HYDRAIN was then input to the HEC-2 model for the existing

drainageway condition. Cross-sectional data for the HEC-2 program was obtained from the topographic mapping prepared for this project. The locations of the cross-sections used in the HEC-2 model were chosen to coincide with the locations of the cross-sections presented in the master drainageway planning study wherever possible.

In general, a reasonable comparison in the water surface profile was achieved between this analysis and the Major Drainageway Planning Study. As a result of this analysis it was found that the existing structures have less than a five year capacity, with the exception of the Sheridan Boulevard box culvert, which has approximately 10-year flow capacity. The backwater from the West 10th Avenue, Perry, Tennyson, and Wolff Street box culverts causes several areas of split flow and shallow overbank flooding for the 100-year flood. This flooding could effect existing single-family residences, however there is no known record of this occurring.

#### ALTERNATIVE EVALUATION

The alternative hydraulic evaluation focused upon trying to optimize the flow capacity at each site, while recognizing the physical constraints at each site. Various bridge openings and structure depths were modeled using the HEC-2 program. Spans ranging from 30-feet to 70-feet were analyzed for the various sites. Presented on Table 2 is a summary of the water surface elevations at each of the bridge sites for the existing structures and for the alternative bridge openings.

The results of the hydraulic analysis show that it will probably be impractical to construct a bridge which will pass the 100-year discharge beneath the low chord of the bridge for any of the sites unless the channel capacity upstream and/or downstream of each site is expanded. The exception to this situation is at West 10th Avenue where a structure of reasonable span could be built and pass the 100-year discharge beneath the low chord of the bridge. At Perry Street and at Wolff Street, spans over 60-feet do not appreciably lower the water surface profile to eliminate the flow splits and overbank flooding which typify the existing conditions. At Perry and at Wolff, low berms at the approaches to the bridge openings may have to be incorporated into the design to fully develop the capacity of a particular bridge opening. It appears that the maximum practical bridge span is limited to 60-feet at each of the bridge sites. This is mainly because of physical constraints with the existing roadway and channel which limit the span of the bridge or the possibility of raising the roadway to create more headroom under the bridge.

The 10-year and 100-year frequencies were analyzed at each site. It was found that spans in the range of 30-feet were capable of conveying the 10-year flow beneath the

**TABLE 2  
 COMPARISON OF WATER SURFACE ELEVATIONS  
 ALTERNATIVE BRIDGE HYDRAULICS  
 LAKEWOOD GULCH PRELIMINARY DESIGN PROJECT**

LOCATION	100-YEAR WATER SURFACE ELEVATIONS (1)					
	PHASE B WSE	30-FOOT SPAN	40-FOOT SPAN	50-FOOT SPAN	60-FOOT SPAN	70-FOOT SPAN
WEST 10TH AVENUE	261.5	261.4	253.5			
PERRY STREET	266.5	266.5		263.7	264.3	264.6
TENNYSON STREET	282.0	282.0		279.6		
WOLFF STREET	296.8	295.6			293.8	

**ALL ELEVATIONS TAKEN AT UPSTREAM FACE OF BRIDGE**

low chord of the bridge at each site, with the exception of Wolff Street where a longer span would be required. The 10-year frequency may be a reasonable alternative to pursue, especially if the expansion of the downstream channel capacity to meet the 100-year flow capacity is impractical.

### **SCOUR POTENTIAL**

Two soil borings were taken at each of the replacement sites. With the exception of Wolff Street, the borings indicate the presence of moderately hard bedrock at the present invert of the drainageway or within two to three feet of the invert. This situation can be seen in the field. For the West 10th Avenue, Perry Street and Tennyson Street, the foundations of the bridges will be placed upon bedrock, and therefore deep scour protection will not be needed. At Wolff Street, the bedrock elevation is approximately 10-feet beneath the invert. At this location, riprap linings along the invert and possibly a grade control structure immediately downstream of the bridge opening will be needed to prevent scouring through the bridge opening and immediately downstream of the bridge.

### **TRAIL CONSIDERATIONS**

Based upon the results of community meetings held in connection with the design project, it was found that below grade trail crossings were desired. This is physically possible at West 10th Avenue, Perry Street and at Tennyson Street. There is not enough headroom at Wolff Street to accommodate a trail crossing through the structure. Hydraulically, the trail will reduce the capacity of all the bridge openings, and may cause additional blockage during a high flow event because of railing which may be needed along the trail. The trail grade was assumed to be a minimum of two feet above the invert in the hydraulic modeling. The introduction of the trail within the bridge opening has a negligible impact upon the water surface in a 10-year and greater event. Bridge superstructure depths ranging from 32- to 42-inches were assumed in determining the clearance over the trail.

### **DISCUSSION**

The various alternative culvert and bridge openings analyzed need to be considered in light of the overall project costs, constructability and site constraints. When considering the use of a clear span bridge versus a box culvert, the following advantages and disadvantages were identified:

1. A multiple-bay box culvert will be less conducive to the construction of a trail under the roadway compared to a clear span structure. Trail user safety issues are more of a concern with a multiple-bay box culvert than a clear opening.
2. A clear span structure may have less problems associated with construction dewatering than a box culvert. The floor slab for a multiple bay box culvert will have to be formed all at once compared to working with a bridge footing which can be installed one side at a time.
3. A clear span will be more efficient hydraulically and less subject to debris accumulation than a multiple-bay box culvert since the piers are eliminated.
4. A low flow channel should be provided through a clear opening structure. The low flow channel will protect the toe of the existing banks and will allow for the transition of the low flow into the existing channel downstream of each bridge site.
5. Since a trail under the roadway at Wolff is not feasible, a cast-in-place box culvert may have a greater feasibility at this site than at the other locations.
6. A structure with ten year capacity can be constructed using cast-in-place box culverts or precast box culverts or box bridges. Bridges are needed to pass flows greater than the 10-year.

### **III. ALTERNATIVE BRIDGE DESIGN ANALYSIS**

The alternative bridge design analysis included the review of various structure types for the range of spans identified in the hydraulic analysis for the site. As part of the alternative development, representatives from the City of Denver design engineering and the traffic engineering sections were contacted in order to gain input on the type of structures which would be most feasible at each location.

#### **STRUCTURE TYPE**

As a result of discussions with the City of Denver concerning the type of structures most commonly used in this type of crossing, steel and concrete superstructures are both currently in use throughout the City. Moreover, concrete superstructures are preferred over metal structures, primarily because of the long-term maintenance aspects associated with steel substructures. Because of this preference, concrete structures were the focus of this alternative evaluation, and steel structures were eliminated from further consideration.

#### **TRAFFIC CONTROL DURING CONSTRUCTION**

A field meeting was held with a representative from the City of Denver Department of Public Works Traffic Engineering section. Each site was visited, and the concerns from the standpoint of traffic control were discussed. At issue was whether or not each bridge site could be closed to through traffic while the replacement structure was being constructed, or whether the roadway must be kept open to one or both lanes of traffic. The following traffic constraints were identified for each site.

**West 10th Avenue:** Because of the lack of an alternative detour route, Traffic Engineering desires that at least one lane of traffic be kept open throughout the construction process. Signalization to control two-way traffic will be needed. Phasing of the construction to allow for the one-lane to be kept open over the existing structure needs to be considered.

**Perry Street:** Similar to West 10th Avenue, there does not appear to be a reasonable detour route to accommodate traffic on Perry Street. Traffic Engineering suggested that one lane remain open on Perry throughout the construction process. It was further recommended that southbound traffic be closed, and one lane be kept open for northbound traffic only throughout the construction.

**Tennyson Street:** Closure of Tennyson Street to through traffic is feasible at this location. Pedestrian access through or around the construction site must be maintained.

This appears to be possible by aligning a temporary asphalt walkway east of the existing roadway, within Martinez Park.

**Wolff Street:** Traffic Engineering indicated that one-lane must be kept open at Wolff Street throughout the construction process, primarily because of a lack of reasonable detour routes for northbound traffic. Of all the locations, this will be the most difficult crossing in which to phase the construction because of the condition of the existing structure, the condition of the drainageway both upstream and downstream of the roadway, and limitations associated with the road right-of-way and abutting privately owned property.

The following general traffic design criteria was established for all of the sites:

1. Temporary roadway and pedestrian wearing surfaces shall be asphalt.
2. Pedestrian traffic shall be maintained through or around all of the sites.
3. All sidewalks shall be five foot in width.
4. Traffic railing and handrailing shall be required over the bridge and at the wingwalls, however approach guardrailing may not be required.

In general, phasing construction at any of the sites will lengthen the construction schedule and increase the costs of the replacement structure compared to a full roadway closure scenario. The costs for keeping one-lane of traffic open at all times is probably justifiable at West 10th Avenue and at Perry Street, however this justification is questionable at Wolff Street. Further analysis of traffic counts and possible detour routes for northbound traffic on Wolff Street is recommended prior to proceeding with a phased construction scenario.

#### **ALTERNATIVE EVALUATION CRITERIA**

The alternative evaluation was carried out keeping in mind the social, environmental and economic impacts at each site. Specifically, the following design considerations were used to evaluate the positive and negative impacts of each structure type relative to another structure type:

**Aesthetics:** The bridge aesthetics for the replacement structures will be governed by compatibility of the structure with the adjacent drainageway, park setting and local neighborhood. Review from the City of Denver Urban Design section is anticipated prior to finalizing the design of the replacement structures. Opportunities for bridge color finishes, handrailings and street lighting need to be addressed for each alternative structure. Because of the proximity of each site relative to the other sites, a consistent aesthetic approach may be reasonable.

**Hydraulics:** The hydraulic performance of each type of structure is a key design consideration since there are currently habitable structures within the 100-year floodplain adjacent to each site. The possibility of lowering the 100-year water surface from current conditions needs to be considered in combination with channel improvements.

**Maintenance:** Long-term maintenance of the selected structural system needs to be evaluated. Different deck materials will have different periodic maintenance requirements. This aspect should be considered basic to the selection process.

**Construction Phasing:** Because of the traffic constraints presented above, the impact of phasing upon the construction schedule needs to be considered as a basic selection criteria. Different types of sub- and superstructures will require different construction techniques. For example, a composite system which combines the deck construction with the precast/prestressed superstructure, compared to a cast-in-place deck, will have a considerably shorter construction schedule.

**Cost:** The initial cost of a structure will vary depending upon the span, construction phasing, product availability and hydraulic requirements discussed previously, for each site.

**Trail Access:** The ability to pass a trail beneath the roadway will depend upon the structure depth (i.e., thickness from the roadway to the low chord of the bridge), and clear span. Box culverts with bays less than twelve feet wide tend to restrict the entry of maintenance vehicles and tend to make the structure less inviting to enter from the trail users standpoint, compared to a clear span structure.

## **BRIDGE FOUNDATION ALTERNATIVES**

The geotechnical report prepared as part of this preliminary design development has indicated that bedrock is within a few feet of the surface at all the replacement sites except at Wolff Street. The proximity of bedrock to the invert of the drainageway make the use of pilings and caissons unnecessary. Bridge abutment footings can bear directly upon the bedrock surface at West 10th, Perry and at Tennyson. The use of steel pilings is recommended in the geotechnical report wherever bedrock is below the invert as it is at Wolff Street. Construction dewatering will be a key component of the construction of spread footings for the bridge abutments. Presented in Table 3 is a summary of the approximate bedrock elevations at each of the crossing sites.

## **BRIDGE TYPES**

As a result of the hydraulic analysis, box culverts, either precast or cast-in-place are feasible to pass the 10-year flow. Above this flow level, bridges, using a prestressed

**TABLE 3  
LAKEWOOD GULCH PRELIMINARY BRIDGE DESIGN  
FOUNDATION DATA AND RECOMMENDATIONS**

LOCATION	EST. AVG. BEDROCK ELEVATION	INVERT ELEVATION	DIFFERENCE (FT)
WEST 10TH AVENUE	39.0	41.0	-2.0
PERRY STREET	46.0	47.0	-1.0
TENNYSON STREET	61.0	65.2	-5.2
WOLFF STREET	71.0	81.0	-10.0

**FOUNDATION ALTERNATIVES**

LOCATION	SPREAD FOOTING	H-PILES	CAISSONS
WEST 10TH AVENUE	xx		
PERRY STREET	xx		
TENNYSON STREET	xx	x	
WOLFF STREET		xx	x

xx- PREFERRED

x- ACCEPTABLE

or cast-in-place superstructure are required. Spans greater than 60-feet have not been considered further since there is little hydraulic benefit afforded to spans greater than 60-feet, and the sites do not lend themselves to spans greater than 60-feet because of downstream or upstream channel cross-sections. Channel alternatives which have been developed separately from this preliminary bridge report have shown that increasing the flow capacity of the existing approach channels is really only feasible in the reach of Lakewood Gulch above Wolff Street.

Using the above criteria the types of structures to be advanced to further design analysis were:

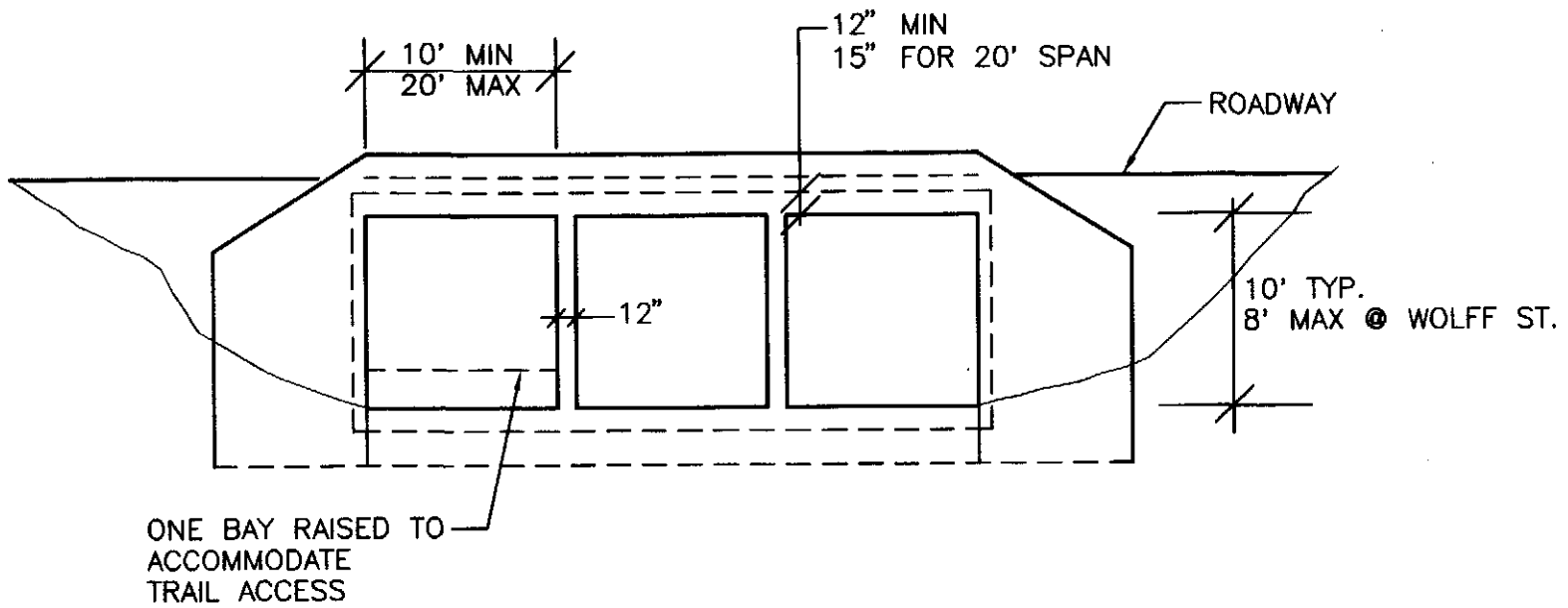
1. Multiple-bay box culvert, cast-in-place, 10-year capacity
2. Precast box bridge, 10-year capacity
3. Precast box girder bridge, 40- to 60-foot spans
4. Precast prestressed double tees, 40- to 60-foot spans

Each of the above structures can be designed to meet the loading and traffic requirements discussed above. Cast-in-place bridges were not considered because of their increased time of construction required compared to precast box girders or double-tee bridges, which is less desirable considering the road closure aspects for each site. Multiple-bay box culverts have individual spans ranging from 10-feet (considered to be a minimum), to twenty feet. Presented on Figures 2 through 5, are typical sections for each of the above structure types.

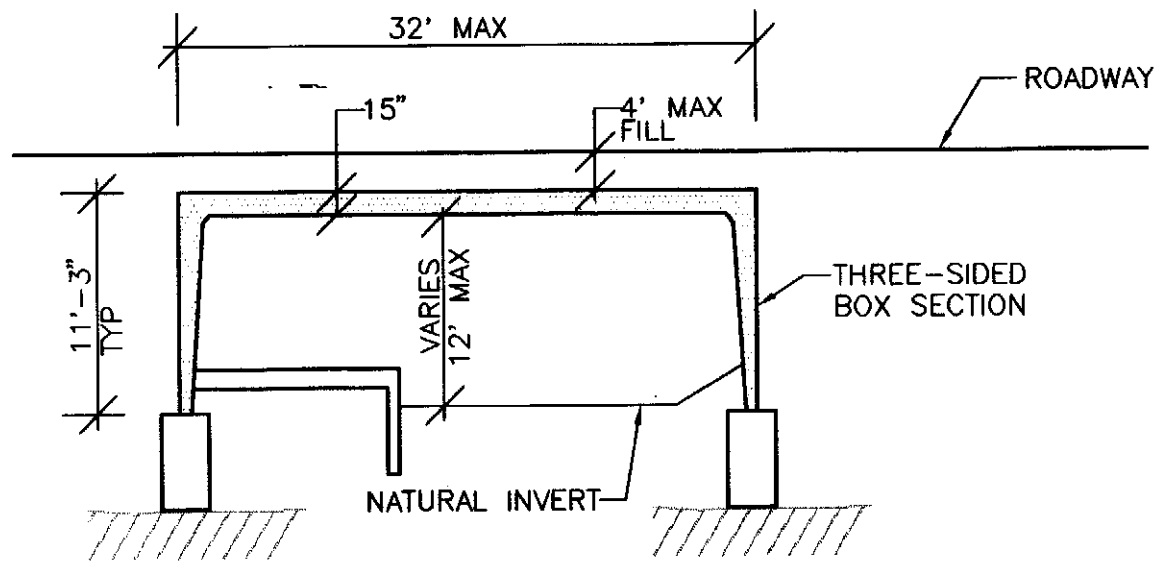
Presented on Tables 4 through 7 are qualitative and quantitative comparisons for each bridge type analyzed. These comparisons exclude considerations for utility replacement, traffic control, stream approach work and landscaping, which would be considered to be common for all of the replacement sites. Cost estimates for the recommended bridge type at each site can be found in tables 8 through 11.

## DISCUSSION

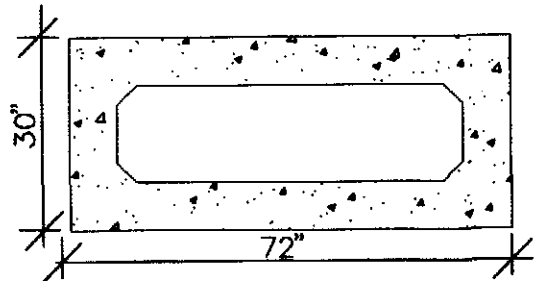
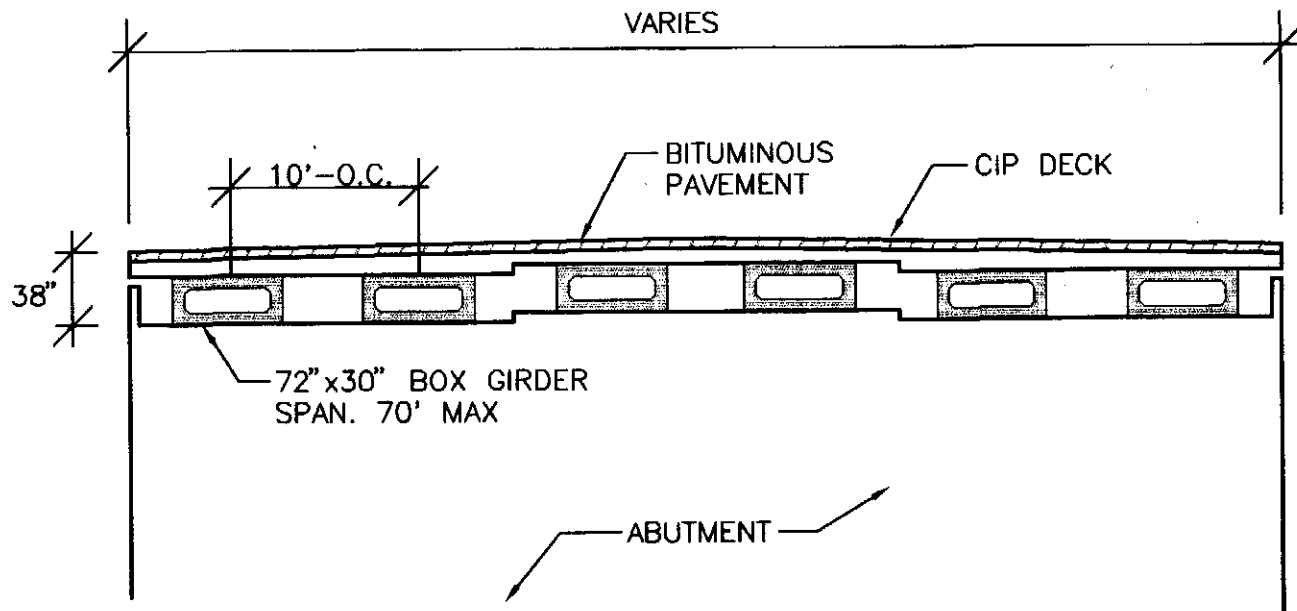
West 10th Avenue: The key design considerations at this site are the construction phasing, traffic control, and trail design. The phasing of the construction would have to take into consideration constructing at least one-half to two-thirds of the replacement structure while maintaining two way traffic across a portion of the existing structure. Costs for traffic control will be directly related to the length of the construction. In this regard, a prestressed/precast superstructure would be quicker to construct than a cast-in-place structure. Also, a composite deck will shorten the construction schedule and present a somewhat easier phasing compared to a cast-in-place deck. A trail beneath the



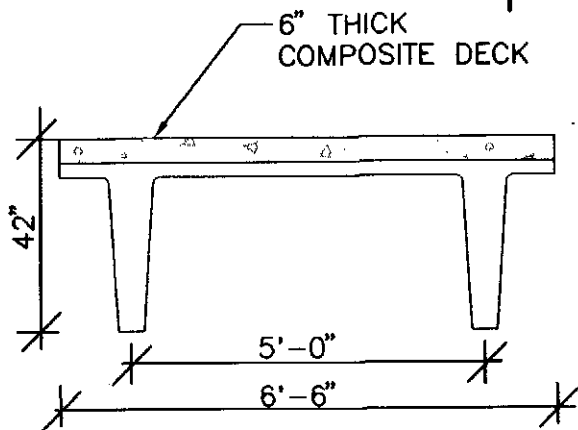
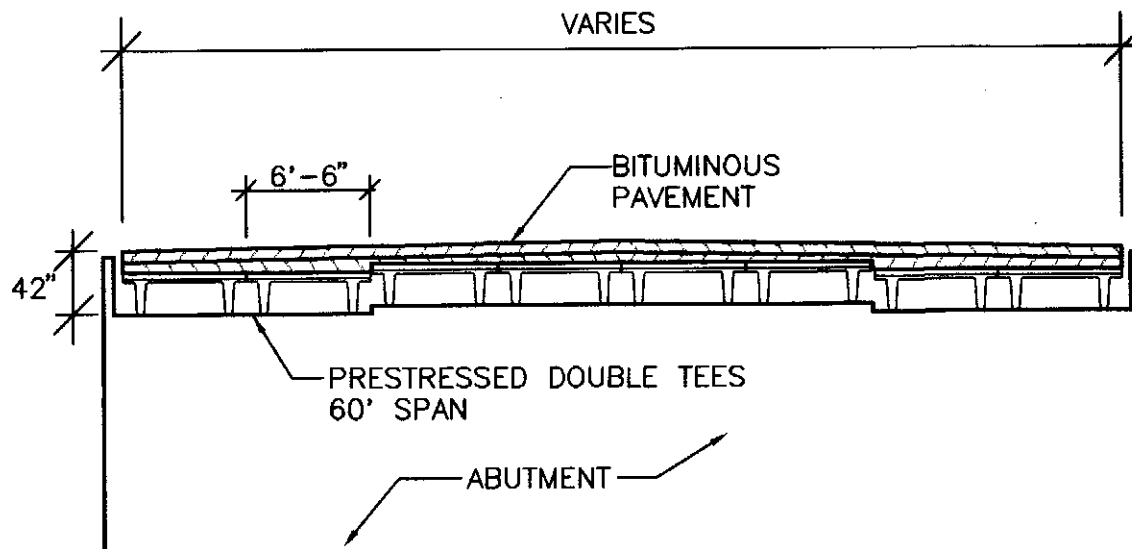
MULTIPLE BAY BOX CULVERT  
FIGURE 2



PRECAST BOX BRIDGE  
(THREE-SIDED BOX)  
FIGURE 3



BOX GIRDER WITH CIP DECK  
FIGURE 4



PRESTRESSED DOUBLE TEE  
w/COMPOSITE DECK

FIGURE 5

**TABLE 4  
COMPARISON OF BRIDGE ALTERNATIVES**

**LOCATION: WEST 10TH AVENUE**

STRUCTURE TYPE	DESIGN CONSIDERATION						COMMENTS
	LONG-TERM MAINTENANCE	HYDRAULICS	CONSTRUCTION PHASING	AESTHETICS	TRAIL ACCESS	COST	
CAST-IN PLACE BOX CULVERT 10-YEAR	3	4	2	4	4	1	COMPATIBILITY WITH ADJACENT PARK USE A KEY URBAN DESIGN ISSUE. VISUAL ACCESS TO TRAIL BENEATH CROSSING IS POOR FOR THIS STRUCTURE TYPE.
PRECAST BOX BRIDGE 10-YEAR CAPACITY	2	3	1	2	2	2	PHASING OF DETOUR ENHANCED BY A SHORTER OVERALL CONSTRUCTION SCHEDULE FOR THIS STRUCTURE TYPE
PRECAST BOX GIRDER > 10-YEAR CAPACITY CAST-IN-PLACE DECK	1	1	4	1	1	4	LARGER CLEAR SPANS ENHANCE MAINTENANCE AND TRAIL ACCESS OPPORTUNITIES. HIGHEST COST, LONGEST SCHEDULE RELATIVE TO OTHER BRIDGE TYPES. 100-YEAR FLOW BENEATH ROAD FOR FORTY FOOT SPANS AND GREATER.
PRESTRESSED DOUBLE TEES > 10-YEAR CAPACITY COMPOSITE DECK	2	1	3	1	1	3	SHORTER CONSTRUCTION PERIOD COMPARED TO BOX GIRDER. COMPOSITE DECK WOULD ALLOW FOR EASIER CONSTRUCTION PHASING. SLIGHTLY GREATER STRUCTURE DEPTH COMPARED TO BOX GIRDER BRIDGE.

1 = POSITIVE RELATIVE IMPACT ON DESIGN CONSIDERATION  
 5 = NEGATIVE RELATIVE IMPACT ON DESIGN CONSIDERATION  
 N = NEUTRAL, NO POSITIVE OR NEGATIVE IMPACTS

**TABLE 5  
COMPARISON OF BRIDGE ALTERNATIVES**

**LOCATION: PERRY STREET**

STRUCTURE TYPE	DESIGN CONSIDERATION						COMMENTS
	LONG-TERM MAINTENANCE	HYDRAULICS	CONSTRUCTION PHASING	AESTHETICS	TRAIL ACCESS	COST	
CAST-IN PLACE BOX CULVERT 10-YEAR	3	4	2	3	4	1	COMPATIBILITY WITH ADJACENT PARK USE A KEY URBAN DESIGN ISSUE. VISUAL ACCESS TO TRAIL BENEATH CROSSING IS POOR FOR THIS TYPE. 24-INCH WATERLINE WOULD HAVE TO BE RELOCATED UNDER OR AROUND THIS TYPE OF STRUCTURE.
PRECAST BOX BRIDGE 10-YEAR CAPACITY	2	3	1	2	2	2	PHASING OF DETOUR ENHANCED BY A SHORTER OVERALL CONSTRUCTION SCHEDULE FOR THIS STRUCTURE TYPE. 24-INCH WATERLINE WOULD HAVE TO BE RELOCATED UNDER OR AROUND THIS TYPE OF STRUCTURE.
PRECAST BOX GIRDER > 10-YEAR CAPACITY CAST-IN-PLACE DECK	1	2	4	1	1	4	LARGER CLEAR SPANS ENHANCE MAINTENANCE AND TRAIL ACCESS OPPORTUNITIES. HIGHEST COST, LONGEST SCHEDULE RELATIVE TO OTHER BRIDGE TYPES. 100-YEAR FLOW CANNOT BE PASSED BENEATH THE ROADWAY ELEVATION.
PRESTRESSED DOUBLE TEES > 10-YEAR CAPACITY COMPOSITE DECK	2	1	3	1	1	3	SHORTER CONSTRUCTION PERIOD COMPARED TO BOX GIRDER. COMPOSITE DECK WOULD ALLOW FOR EASIER CONSTRUCTION PHASING. RELOCATION OF 24-INCH WATERLINE MAY BE EASIEST WITH DOUBLE TEE CONSTRUCTION.

1 = POSITIVE RELATIVE IMPACT ON DESIGN CONSIDERATION  
 5 = NEGATIVE RELATIVE IMPACT ON DESIGN CONSIDERATION  
 N = NEUTRAL, NO POSITIVE OR NEGATIVE IMPACTS

**TABLE 6  
COMPARISON OF BRIDGE ALTERNATIVES**

**LOCATION: TENNYSON STREET**

STRUCTURE TYPE	DESIGN CONSIDERATION						COMMENTS
	LONG-TERM MAINTENANCE	HYDRAULICS	CONSTRUCTION PHASING	AESTHETICS	TRAIL ACCESS	COST	
CAST-IN PLACE BOX CULVERT 10-YEAR	3	4	N	3	4	1	COMPATIBILITY WITH ADJACENT PARK USE A KEY URBAN DESIGN ISSUE. VISUAL ACCESS TO TRAIL BENEATH CROSSING IS POOR FOR THIS TYPE.
PRECAST BOX BRIDGE 10-YEAR CAPACITY	2	3	N	2	2	2	CLEAR SPAN ENHANCES TRAIL USAGE AND PROVIDES FOR SAFER CROSSING.
PRECAST BOX GIRDER > 10-YEAR CAPACITY CAST-IN-PLACE DECK	1	3	N	1	1	4	SPANS GREATER THAN 50-FEET NOT COMPATIBLE WITH ADJACENT DRAINAGEWAY. 100-YEAR FLOW CANNOT BE PASSED BENEATH THE ROADWAY ELEVATION FOR THIS STRUCTURE TYPE.
PRESTRESSED DOUBLE TEES > 10-YEAR CAPACITY COMPOSITE DECK	2	3	N	1	1	3	SPANS GREATER THAN 50-FEET NOT COMPATIBLE WITH ADJACENT DRAINAGEWAY. 100-YEAR FLOW CANNOT BE PASSED BENEATH THE ROADWAY ELEVATION FOR THIS STRUCTURE TYPE.

1 = POSITIVE RELATIVE IMPACT ON DESIGN CONSIDERATION  
 5 = NEGATIVE RELATIVE IMPACT ON DESIGN CONSIDERATION  
 N = NEUTRAL, NO POSITIVE OR NEGATIVE IMPACTS

**TABLE 7  
COMPARISON OF BRIDGE ALTERNATIVES**

**LOCATION: WOLFF STREET**

STRUCTURE TYPE	DESIGN CONSIDERATION						COMMENTS
	LONG-TERM MAINTENANCE	HYDRAULICS	CONSTRUCTION PHASING	AESTHETICS	TRAIL ACCESS	COST	
CAST-IN PLACE BOX CULVERT 10-YEAR	4	4	2	3	N	1	TRAIL ACCESS NOT REQUIRED. 10-YEAR FLOW WOULD OVERTOP ROADWAY FOR 30-FOOT SPAN.
PRECAST BOX BRIDGE 10-YEAR CAPACITY	2	4	1	3	N	2	TRAIL ACCESS NOT REQUIRED. 10-YEAR FLOW WOULD OVERTOP ROADWAY FOR 30-FOOT SPAN.
PRECAST BOX GIRDER > 10-YEAR CAPACITY CAST-IN-PLACE DECK	1	2	4	3	N	4	LARGER CLEAR SPANS, GREATER THAN 30-FEET, WOULD BE MORE EFFICIENT HYDRAULICALLY.
PRESTRESSED DOUBLE TEES > 10-YEAR CAPACITY COMPOSITE DECK	2	1	3	3	N	3	LARGER CLEAR SPANS WOULD BE MORE EFFICIENT HYDRAULICALLY.

1 = POSITIVE RELATIVE IMPACT ON DESIGN CONSIDERATION  
 5 = NEGATIVE RELATIVE IMPACT ON DESIGN CONSIDERATION  
 N = NEUTRAL, NO POSITIVE OR NEGATIVE IMPACTS

TABLE 8

Lakewood Gulch  
Preliminary Design

## TENTH AVENUE BRIDGE

Item	Unit	Unit Price	Quantity	Price
Clearing and Grubbing	acre	\$5,000	1	\$5,000
Bridge/Culvert/Road Demolition	each	\$25,000	1	\$25,000
Excavation and Backfill	C.Y.	\$4	900	\$3,600
Structure Excavation and Backfill	C.Y.	\$10	700	\$7,000
Utility Relocation	each	varies		\$10,000
Asphalt Path, 6" x 10' (c.i.p.)	L.F.	\$20	0	\$0
Concrete Path, 5" x 10' (c.i.p.)	L.F.	\$27	90	\$2,430
Concrete Wall, 6' exposed	L.F.	\$150	0	\$0
Concrete Wall, 8' exposed	L.F.	\$200	0	\$0
Concrete Wall, 9' exposed	L.F.	\$225	140	\$31,500
Local Drainage Structures	L.S.	\$6,000	1	\$6,000
Bridge Structures (substructure, superstructure)	S.F.	\$50	2600	\$130,000
Curb, Gutter & Sidewalk	L.F.	\$20	240	\$4,800
Asphalt Paving	S.Y.	\$14	600	\$8,400
Riprap and Bedding	C.Y.	\$45	750	\$33,750
Fencing (42" min.)	L.F.	\$15	140	\$2,100
Traffic Control	L.S.	\$20,000	1	\$20,000
Landscaping	L.S.	5% of total		\$13,479
Mobilization	L.S.	20% of total		\$60,612
Engineering and Contingency	L.S.	20% of total		\$90,918
Estimated Cost				\$454,589

TABLE 9

Lakewood Gulch  
Preliminary Design

## PERRY STREET BRIDGE

Item	Unit	Unit Price	Quantity	Price
Clearing and Grubbing	acre	\$5,000	1	\$5,000
Bridge/Culvert/Road Demolition	each	\$15,000	1	\$15,000
Excavation and Backfill	C.Y.	\$4	1300	\$5,200
Structure Excavation and Backfill	C.Y.	\$10	500	\$5,000
Utility Relocation	each	varies		\$50,000
Asphalt Path, 6" x 10' (c.i.p.)	L.F.	\$20	0	\$0
Concrete Path, 5" x 10' (c.i.p.)	L.F.	\$27	90	\$2,430
Concrete Wall, 6' exposed	L.F.	\$150	0	\$0
Concrete Wall, 8' exposed	L.F.	\$200	120	\$24,000
Concrete Wall, 9' exposed	L.F.	\$225	0	\$0
Local Drainage Structures	L.S.	\$4,000	1	\$4,000
Bridge Structures (substructure, superstructure)	S.F.	\$50	2600	\$130,000
Curb, Gutter & Sidewalk	L.F.	\$20	240	\$4,800
Asphalt Paving	S.Y.	\$14	600	\$8,400
Riprap and Bedding	C.Y.	\$45	700	\$31,500
Fencing (42" min.)	L.F.	\$15	120	\$1,800
Traffic Control	L.S.	\$10,000	1	\$10,000
Landscaping	L.S.	5% of total		\$14,357
Mobilization	L.S.	20% of total		\$62,297
Engineering and Contingency	L.S.	20% of total		\$93,446
Estimated Cost				\$467,230

TABLE 10

Lakewood Gulch  
Preliminary Design

## TENNISON STREET BRIDGE

Item	Unit	Unit Price	Quantity	Price
Clearing and Grubbing	acre	\$5,000	1	\$5,000
Bridge/Culvert/Road Demolition	each	\$15,000	1	\$15,000
Excavation and Backfill	C.Y.	\$4	1300	\$5,200
Structure Excavation and Backfill	C.Y.	\$10	500	\$5,000
Utility Relocation	each	varies		\$10,000
Asphalt Path, 6" x 10' (c.i.p.)	L.F.	\$20	0	\$0
Concrete Path, 5" x 10' (c.i.p.)	L.F.	\$27	90	\$2,430
Concrete Wall, 6' exposed	L.F.	\$150	0	\$0
Concrete Wall, 8' exposed	L.F.	\$200	120	\$24,000
Concrete Wall, 9' exposed	L.F.	\$225	0	\$0
Local Drainage Structures	L.S.	\$4,000	1	\$4,000
Bridge Structures (substructure, superstructure)	S.F.	\$55	1760	\$96,800
Curb, Gutter & Sidewalk	L.F.	\$20	240	\$4,800
Asphalt Paving	S.Y.	\$14	600	\$8,400
Riprap and Bedding	C.Y.	\$45	700	\$31,500
Fencing (42" min.)	L.F.	\$15	120	\$1,800
Traffic Control	L.S.	\$2,000	1	\$2,000
Landscaping	L.S.	5% of total		\$10,697
Mobilization	L.S.	20% of total		\$45,325
Engineering and Contingency	L.S.	20% of total		\$67,988

Estimated Cost

\$339,940

TABLE 11

Lakewood Gulch  
Preliminary Design

## WOLFF STREET Box Culvert

Item	Unit	Unit Price	Quantity	Price
Clearing and Grubbing	acre	\$5,000	1	\$5,000
Bridge/Culvert/Road Demolition	each	\$15,000	1	\$15,000
Excavation and Backfill	C.Y.	\$4	1000	\$4,000
Structure Excavation and Backfill	C.Y.	\$10	900	\$9,000
Utility Relocation	each	varies		\$10,000
Asphalt Path, 6" x 10' (c.i.p.)	L.F.	\$20	0	\$0
Concrete Path, 5" x 10' (c.i.p.)	L.F.	\$27	90	\$2,430
Concrete Wall, 6' exposed	L.F.	\$150	100	\$15,000
Concrete Wall, 8' exposed	L.F.	\$200	0	\$0
Concrete Wall, 9' exposed	L.F.	\$225	0	\$0
Local Drainage Structures	L.S.	\$4,000	1	\$4,000
Concrete Box Culvert. 8' x 60'	C.Y.	\$350	300	\$105,000
Curb, Gutter & Sidewalk	L.F.	\$20	160	\$3,200
Asphalt Paving	S.Y.	\$14	320	\$4,480
Riprap and Bedding	C.Y.	\$45	600	\$27,000
Fencing (42" min.)	L.F.	\$15	100	\$1,500
Traffic Control	L.S.	\$10,000	1	\$10,000
Landscaping	L.S.	5% of total		\$10,281
Mobilization	L.S.	20% of total		\$45,178
Engineering and Contingency	L.S.	20% of total		\$67,767

Estimated Cost

\$338,836

bridge is feasible and should be considered at this site. A clear span structure is desirable with regard to accommodating the trail beneath the replacement structure.

Perry Street: The key considerations at this site are construction phasing, traffic control, hydraulics and the trail crossing. Similar to West 10th Avenue, traffic must be maintained for at least the northbound traffic. As such, a precast/prestressed superstructure will be easier to phase and shorten the overall construction schedule compared to a cast-in-place structure. Since numerous houses are in the 100-year floodplain at this site, a 100-year capacity crossing is favored over a 10-year crossing which would do little to remove the structures from the 100-year floodplain. The trail beneath the bridge is desirable at this location, and can be accommodated with either a prestressed double-tee or precast box girder bridge.

Tennyson Street: The key considerations at this site are hydraulics, cost and trail design. There are currently no habitable structures within the 100-year floodplain at this site, therefore either a ten-year or a 100-year culvert is sufficient. Either a 10-year or 100-year structure improves the situation hydraulically over the existing condition. The cost of a ten-year capacity structure is less than a 100-year structure. There are no plans to greatly modify the channel cross-section downstream of Tennyson Street within Martinez Park, which further detracts from the feasibility of constructing a 100-year crossing at this site. The trail beneath the roadway is desirable and can be accommodated with a clear span, 10-year capacity culvert.

Wolff Street: The key considerations at this crossing are traffic control, hydraulics and cost. Should one lane be required to remain open northbound over the existing structure, phasing the structure will be required which is difficult at this site as previously mentioned. Because of the hydraulics of this site, right-of-way limitations along the drainageway, and the approach and outlet channel characteristics, it is not feasible to construct a crossing which can pass the 100-year flow beneath the roadway. There is not enough headroom to accommodate a trail beneath the crossing, so therefore there is no advantage to constructing a clear-span structure. The cost of the replacement structures could be increased by as much as fifty percent if phasing is introduced in order to maintain one lane of northbound traffic across the site.

#### IV. RECOMMENDATIONS

Based upon the alternative design analyses conducted to date, recommendations have been developed for each of the bridge sites. The preliminary design hydraulics and plans will be based upon these recommendations. The channel improvements will be identified in the preliminary design report for the Lakewood Gulch drainageway. Each of the recommendations are subject to project sponsor review and comment and subsequent final design analyses.

**West 10th Avenue:** The recommended structure(s) for this site is a fifty-foot clear span bridge. The bridge superstructure can be either a precast box girder or a prestressed double tee. A double tee with a composite deck should be considered in order to address cost and phasing issues. A ten-foot wide trail is recommended to pass beneath the bridge. The minimum headroom at this site is 8.5 feet over the trail grade at the upstream face of the bridge. The foundation will mostly likely be a spread footing with abutment walls. One lane of traffic should be maintained at all times. Temporary signalization will be needed to control traffic across the site.

**Perry Street:** The recommended structure(s) for this site is a fifty-foot clear span bridge. The bridge superstructure can be either a precast box girder or a prestressed double tee. A double tee is somewhat more desirable than a box girder when considering the relocation of the existing 24-inch waterline across the bridge. A double tee with a composite deck should be considered in order to address cost and phasing issues. A ten-foot wide trail is recommended to pass beneath the bridge. The minimum headroom at this site is 8.5 feet over the trail grade at the upstream face of the bridge. The foundation will mostly likely be a spread footing with abutment walls. One northbound lane of traffic should be maintained across the site, and a detour route for southbound traffic.

**Tennyson Street:** The recommended structure(s) for this site is a thirty-foot clear span bridge capable of passing the 10-year flow. The recommended bridge superstructure is a precast box bridge (i.e., a three-sided box culvert), or a similar cast-in-place culvert. A ten-foot wide trail is recommended to pass beneath the bridge. The minimum headroom at this site is 8.0 feet over the trail grade at the upstream face of the bridge. The foundation will mostly likely be a spread footing with abutment walls. Traffic can be closed across the site. Pedestrian traffic should be provided around the construction site.

**Wolff Street:** The recommended structure(s) for this site is a sixty-foot multiple box culvert, matching the recommended upstream channel width. Either a precast multiple box culvert, or a cast-in-place twin or triple box culvert. The trail is not

recommended to pass beneath the bridge at this site. It has been requested by the City of Denver traffic engineering section that one lane of northbound traffic be maintained across the site. It is Kiowa's recommendation that further study of this request be conducted in later design stages, possibly supplemented by traffic count information at this site. The cost of maintaining traffic at this location is substantial and may effect the type of crossing to be recommended for final design.