RETURN WITHIN 2 WEEKS TO:
CITY OF COLORADO SPRINGS
STORM WATER & SUBDIVISION
101 W. COSTILLA, SUITE 113
COLORADO SPRINGS, CO 80903
(719) 385-5979

MASTER DEVELOPMENT DRAINAGE PLAN for CREEKSIDE CENTER AND FUTURE APARTMENT COMPLEX

MASTER DEVELOPMENT
DRAINAGE PLAN
for
CREEKSIDE CENTER
AND FUTURE APARTMENT COMPLEX

July, 2000

Revised August, 2000
Revised September, 2000
Revised November, 2000

Project No. 00019

Prepared for:

BISHOP POWERS LTD

716 College View Drive

Riverton, Wyoming 82501
(307) 856-3800

Obering Wurth & Associates
Consulting Civil Engineers
Registered Land Surveyors
1015 Elkton Drive
Colorado Springs, Colorado 80907
Phone (719) 531-6200

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APPENDIX

MAP POCKET

Obering, Wurth & Associates
Consulting Civil Engineers
Professional Land Surveyors

1015 Elkton Drive • Colorado Springs, Colorado 80907 • Phone (719) 531-6200 • Fax (719) 531-6266

September, 2000

City of Colorado Springs
Department of Planning,
Development and Finance
Stormwater and Subdivision
101 W. Costilla, Suite 113
Colorado Springs, Colorado 80903

Re: Master Development Drainage Plan
Creekside Center and Future Apartment Complex

Gentlemen:

Transmitted herewith is the Master Development Drainage Plan (MDDP) for Creekside Center and Future Apartment Complex located at the northwest corner of Powers Boulevard and Galley Road. The report was prepared in accordance with the most current City of Colorado Springs and El Paso County Drainage Criteria Manual.

If there are any comments or questions regarding any part of this drainage analysis, please contact the undersigned.

Very truly yours,
OBERING WURTH & ASSOCIATES

Steven G Baggs
Steven G. Baggs, P. E.

Roland G. Obering.
Reviewed by:
Roland G. Obering, P.E. & P.L.S.

Obering, Wurth & Associates
Consulting Civil Engineers
Professional Land Surveyors

1015 Elkton Drive • Colorado Springs, Colorado 80907 • Phone (719) 531-6200 • Fax (719) 531-6266

Master Development Drainage Plan
Creekside Center & Future
Apartment Complex
Corner of Powers Blvd. & Galley Road
Project No. 00019

ENGINEER'S STATEMENT

The attached drainage plan and report were prepared under my direction and supervision and are correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the City for drainage reports and said report is in conformity with the master plan of the drainage basin. I accept responsibility for any liability caused by any negligent acts, errors, or omissions on my part in preparing this report.

Roland G. Obering
Roland G. Obering, P.E. & P.L.S., Colorado 13226

13226
11/21/00

DEVELOPER'S STATEMENT

I, the Developer, have read and will comply with all the requirements specified in this drainage report and plan.

Bishop Powers LTD
Business Name
James E Spittle
By
its Agent
Title
716 College View Dr, Riverton, WY 82501
Address

Wood Avenue Investment Co.
Business Name
Gary Winegar
By
Its Agent
Title
102 N. Cascade, 5th FL.
Address Colorado Spgs, CO 80903

CITY OF COLORADO SPRINGS

Filed in accordance with Section 15-3-906 of the Code of the City of Colorado Springs. 1980, as amended.

City Engineer

11/21/00
Date

Obering, Wurth & Associates
Consulting Civil Engineers
Professional Land Surveyors

1015 Elkton Drive • Colorado Springs, Colorado 80907 • Phone (719) 531-6200 • Fax (719) 531-6266

Master Development Drainage Plan
Creekside Center & Future
Apartment Complex
Project No. 00019

FLOODPLAIN STATEMENT

To the best of my knowledge and belief, the proposed Creekside Center and Apartment Complex site is not located within a designated floodplain as designated by the Flood Insurance Rate Map Panel No. 751 of 1300, dated March 17, 1997. The designated floodplain is contained within the Sand Creek channel according to the FIRM panel.

Roland G Obering

Roland G. Obering, P.E. & P.L.S., Colorado No. 13226

GENERAL

A. PROJECT LOCATION

Creekside Center and the apartment complex parcel is located in Eastern Colorado Springs in the northeast quadrant of Section 12, Township 14 South, Range 66 West of the Sixth Principal Meridian. The site is bounded on the North by Hitters Haven Subdivision Filing No. 1, on the East by Powers Boulevard, on the South by Galley Road, and on the West by Sand Creek. A Vicinity Map is included in the Appendix of the report.

B. PROJECT DESCRIPTION

The Creekside Center/apartment complex development consists of approximately 32.9 acres of which 4.574 acres on the south end has already been platted into 4 lots as Creekside Center Filing No. 1. Access is planned off Galley Road with the extension of Space Center Drive along the west side of the development along Sand Creek. Space Center Drive is proposed to be a public street. The extension of Space Center Drive will also serve as access for maintenance of Sand Creek. It is anticipated that Space Center Drive will eventually be extended north to Palmer Park Boulevard.

The site generally slopes from the Northeast to the Southwest with an average cross slope of approximately 2.0%. The vegetation consists of mostly native grasses and weeds with a few trees. According to the El Paso County Soil Survey published by the Soil Conservation Service, the onsite soils are Blendon Sandy Loam (#10) and Ellicott Loamy Coarse Sand (#28) which are included in the hydrological soil groups B and A, respectively. The Blendon soil is a well-drained soil with moderate erosion hazard. The Ellicott soil is a somewhat excessively drained soil with high erosion hazard. A copy of a portion of the soil survey map is included in the Appendix.

According to the current FEMA's Flood Insurance Rate Maps, the Creekside Center/apartment complex development does not lie within a designated floodplain. The floodplain is contained within the Sand Creek channel adjacent to the site. A copy of a portion of the appropriate Floodplain Map is included in the Appendix.

C. LAND USE

The Creekside Center development is zoned Planned Business Center (PBC). The 4.574 acres on the southern end is currently platted as "Creekside Center Filing No. 1" and is referred to as Phase I in this report. This area will consist of 4 commercial/retail lots. The northern 18.2 acres of this development is preliminarily designed for multi-family. The remaining 10.1 acres in the middle portion of the site is anticipated to be developed as commercial/retail.

Preliminary site plans have been utilized in the preparation of this study. This preliminary development information is reflected on the Drainage Plan and is subject to change as better information becomes available.

D. PROJECT PHASING

The initial phase of the development consists of the 4.574 acre Creekside Center Filing No. 1. It is currently planned to be developed into 4 commercial/retail lots. The exact timing and phasing of development of the remainder of the site is unknown at this time. It is anticipated that the 18.2-acre apartment complex parcel will be developed in a single phase. The remaining 10.1 acres of Creekside Center will be developed for commercial/retail purposes in one or two phases at a future date.

II. DRAINAGE BASIN OVERVIEW

A. DRAINAGE BASIN PLANNING STUDY

Creekside Center is located within the Sand Creek Drainage Basin as defined by the Sand Creek Drainage Basin Planning Study (SCDBPS) prepared by Kiowa Engineering Corporation in January 1993 and revised in March 1996. Pertinent information from the SCDBPS is included in the Appendix. The site lies within subbasin numbers 30 and 32 and within the reach designated as Sand Creek 3 (SC-3). No regional detention basins have been recommended for this reach. A 100-year channel concept for Sand Creek is recommended.

Runoff from the Creekside Center/apartment complex development will be directed into the Sand Creek channel in conformance with the SCDBPS. Improvements to the Sand Creek channel are recommended in the SCDBPS. According to the report, the channel along the northern end of the site is to be riprap lined along its bank for the 10-year storm up to 3' to 5' high. The middle portion of the channel is to be riprap lined 5' high for the 100-year storm. The southern end has already been improved with grouted riprap and 2 drop structures. In addition to these improvements, the SCDBPS recommends 7 ditch checks to be put in place every 400' upstream from these drop structures.

B. OFFSITE/ONSITE FINAL DRAINAGE REPORTS

The Final Drainage Report for Hitters Haven Subdivision Filing No. 1 was prepared by Berge-Brewer & Associates, Inc. in September, 1993 and revised in November, 1993. Hitters Haven is the site directly north of the apartment complex parcel. According to that report, surface runoff from Powers Boulevard and Omaha Boulevard as well as from the Hitters Haven site flows into Sand Creek via a 48" CSP and 36" RCP. A berm is also located on the southern edge of the property allowing some runoff to directly flow into Sand

Creek. No offsite runoff is anticipated to enter the apartment complex parcel from the north.

An unimproved drainage ditch is located along the east side of the site. Runoff from the west half of Powers Boulevard is collected in this ditch and is carried to the northwest corner of Galley Road and Powers Boulevard. At this point an existing 60" CSP culvert discharges additional water from the east side of Powers. Another unimproved ditch along the southern side of the property carries both of these flows westerly alongside Galley Road into an existing 36" CSP culvert. The flows outfall into Sand Creek at the southwest corner of the site. The approved Creekside Center Filing No. 1 Drainage Report recommended replacing the 2 culverts and ditch along the south side with a 60" RCP.

III. HYDROLOGY

A. CRITERIA

The hydrologic criteria used for this analysis was based on criteria set forth in the current City of Colorado Springs Drainage Criteria Manual (DCM) for a Master Development Drainage Plan (MDDP). Preliminary and Final Drainage Reports will be prepared as various phases are developed.

B. RUNOFF

The Rational Method was used to evaluate storm runoff amounts generated by the subject property since the contributing drainage subbasins are less than 100 acres in size. Since all runoff will be allowed to flow directly into Sand Creek and not detained, only developed flows were determined for each subbasin. These design flows were used to size the storm sewer facilities that discharge into Sand Creek.

C. RUNOFF COEFFICIENTS

Runoff coefficients for the Rational Method were obtained from charts found in the DCM.

D. TIME OF CONCENTRATION

Times of concentration were determined by combining travel times for overland flow, channel flow, and curb and gutter flow where applicable. Specific charts and formulas, as presented in the DCM, were used to determine the appropriate travel time for each of the above components.

E. RAINFALL

Rainfall intensities for specific times of concentration for both the 5-year and 100-year storm events for the Rational Method were obtained from the charts included in the DCM.

IV. HYDROLOGICAL ANALYSIS

A. OFFSITE

The approved Final Drainage Report for Creekside Center Filing No. 1 documents the developed 100-year offsite flows at the southeast corner of the site. A portion of this flow comes from a roadside ditch along the east side of the subject property. The remainder comes from the east side of Powers Boulevard at Galley Road and outfalls through a culvert at the southeast corner of Creekside Center. The total flow of 213 cfs is currently transported along the south side of the property through an unimproved ditch and outfalls into Sand Creek through a culvert. There are plans to replace this ditch and culverts with a 60" RCP. A Type C inlet was also proposed to collect Powers Boulevard road ditch runoff. These flows will not affect the rest of the site.

B. ONSITE

The Rational Method was used to estimate stormwater runoff from onsite sources. Only developed conditions were analyzed for each subbasin located within the Creekside Center/apartment complex development.

The southern part of the site is to be developed as commercial and the north end is to be developed as multi-family. Runoff coefficients used were C_5=0.90 and C_{100}=0.90 for commercial, C_5=0.90 and C_{100}=0.95 for pavement, and C_5=0.70 and C_{100}=0.80 for multi-family.

Summaries of these developed flows along with the times of concentration, intensities, and runoff coefficients can be found in the table below.

Subbasin	Size (acres)	T_{c5} (min.)	T_{c100} (min.)	I_5 (in/hr)	I_{100} (in/hr)	C_5	C_{100}	Q_5 (cfs)	Q_{100} (cfs)
A	7.7	7.0	6.9	4.6	7.9	0.90	0.90	31.9	55.0
B	3.7	7.1	7.0	4.6	7.9	0.90	0.90	15.3	26.3
C	0.8	6.9	6.9	4.7	8.0	0.90	0.90	3.4	5.7
D	1.5	5.0	5.0	5.2	9.0	0.90	0.95	7.0	12.8
E	10.5	12.4	9.6	3.7	7.1	0.70	0.80	27.3	59.7
F	7.7	13.0	9.9	3.6	7.0	0.70	0.80	19.4	43.1

C. SAND CREEK

The main channel of Sand Creek is adjacent to this site and was hydrologically modeled in the SCDBPS. The SCDBPS has developed estimated 100-year flows in Sand Creek. The flows for this reach of Sand Creek are 4,320 cfs at the upper end of the site and 4,690 cfs at the lower end of the site. These flows were utilized in the preparation of this MDDP in order to provide a more site-specific analysis of Sand Creek. Analysis of the channel is included in the Hydraulic Analysis section.

V. HYDRAULIC ANALYSIS

A. ONSITE

The curb inlets and storm sewer laterals were sized for the 5-year storm event. It is anticipated that the 100-year overflow will be able to flow directly over the banks of Sand Creek at designated points into the channel. If, however, this is not possible, the pipes and inlets should be sized for the 100-year storm event accordingly.

The storm sewer laterals were sized for the 5-year storm event using Manning's equation. The storm sewers were determined to range in size from 15" RCP to 30" RCP with varying minimum slopes. Curb inlets were sized for the 5-year storm event using the criteria in the DCM. Curb inlets were determined to be as large as 10' in size.

Below is a summary of the storm sewer laterals.

Summary Pt.	Q_{des} (cfs)	Pipe Diam. (in)	Min. Slope (%)	Capacity (cfs)
1	3.4	15	0.5	4.6
2	22.3	24	1.0	22.6
3,4,5	10.6	21	0.5	11.2
6	27.3	30	0.5	29.0
7	19.4	30	0.5	29.0

The storm sewer facilities will be a combination of public and private facilities. Any facilities required in Space Center Drive will be public and all drainage facilities within the individual lots will be private.

A. SAND CREEK

Sand Creek was analyzed using the 100-year flows from the SCDBPS and the HEC-RAS computer model. The model was based primarily on improvements occurring only on the east side of Sand Creek at this time. The flows were determined to be a mixture of subcritical and supercritical flows throughout the length of the channel alongside the site. The channel bottom has slopes varying between 1.0% and 2.4%. The 100-year profile indicates water depths of 4 to 5 feet for the majority of the channel reach adjacent to the site. There are two portions of the channel where the water profile appears to be inconsistent with the remainder of the channel. The profile inconsistencies corresponded with the areas of transition between supercritical and subcritical flow.

The channel between cross sections 5 and 7 shows a water depth of up to 7 feet at this location. This is due to a flow increase in the channel at this location according to the SCDBPS and a slight contraction of the channel at what will be the transition between existing and new channel improvements. A one-foot channel drop also occurs within this section of channel.

The other area where an inconsistency in the water profile occurs is between cross sections 8 and 12. The initial modeling of this reach of the channel, which includes a significant bend, indicated a water depth of up to 9 feet. This is a result of the narrowing of the channel caused by improving only the East side of the channel. Review of the topography of the West side of the channel at this bend indicates that it could be improved (regraded and riprap lined) to create a wider channel bottom. The HEC-RAS model was rerun in this bend to include channel improvements on both sides. The resulting water profile indicates the 100-year water depth rises to a reasonable depth of approximately 6 feet through the bend with improvements.

According to the requirements in the SCDBPS, the banks of Sand Creek are required to be lined with riprap. Part is recommended to be lined for the 10-year storm and another portion for the 100-year storm. The computer model of Sand Creek determined some areas of the channel to have velocities in excess of the 9 fps anticipated in the SCDBPS. Water depths were as high as 7 feet. A riprap size of d_{50} = 24" at 48" thick is recommended to be utilized for the channel lining where indicated on the Drainage Plan. Since the channel has already been improved along the southerly portion of the site, Sand Creek only needs to be improved north of this area.

This report has assumed that on the north half of the site where the channel is still unimproved, the East bank would be reshaped at a 2.5:1 slope with the top of bank starting at approximately 5' off the property line. The HEC-RAS model determined that the 100-year storm did not overtop the bank. It is recommended that the East channel bank be lined for the 100-year storm along the entire stretch of the unimproved portion of the channel adjacent to the site. The West channel bank will require riprap protection that extends from the end of the existing improvements between cross section 5 and 6 to Section 12 to the North. West bank lining will be installed by the Creekside/Apartment complex developer and Colorado Springs Utilities (CSU). The Responsibilities for the channel improvements are as follows:

Improvements	Responsible Party
East Bank – Section 6 to North Property Line	Developer
West Bank – Section 6 to 8	Colorado Springs Utilities Water Resources Dept.
West Bank – Section 8 to 12	Developer

A letter acknowledging CSU's responsibility to install West bank improvements is included in the Appendix. The relatively straight West bank reach upstream from the bend appears to be stable in its current configuration and has ample separation from existing structures to the West. No improvements to the West bank north of Section 12 are recommended at this time. Providing riprap protection for the East bank along the proposed developing property to the East should not create an adverse impact on the flow condition at the West bank. Also, bedrock outcroppings provide additional stability along some portions of the West bank.

The riprap protection is recommended to be placed to the height of the 100-year high water line plus an additional foot of freeboard. Also the riprap needs to be keyed into bedrock at those locations when bedrock is four feet or less below channel bottom. Rock riprap should extend a minimum of six feet below channel bottom in those areas where bedrock is more than four feet below.

The SCDBPS also recommends 2-drop structures and a total of seven (7) ditch checks for the portion of Sand Creek adjacent to this development. The drop structures are already in place. In order to better evaluate the need for the recommended ditch check structures in this reach of Sand Creek, the report titled "Sand Creek Stability – Galley Road to Powers Boulevard" prepared by R. L. Thaemert, P.E., Ph.D. in June, 1998 was reviewed for pertinent information and recommendations. A copy of the report has been included in the appendix of this MDDP. The report included borings along the East bank of Sand Creek at the approximate locations shown on the Drainage Plan. The borings indicate that the depth of bedrock below channel bed through this reach varies from exposed to 2.3 feet.

Below is a table summarizing the channel bed and bedrock elevations for each boring.

Boring #	Bedrock Elev. (feet)	Channel Bed Elev. (feet)
8	6274.0	6274.5
9	6269.0	6268.5
10	6263.0	6265.3
11	6247.5	6247.4
12	6244.0	6244.9
13	6234.0	6235.6

According to the referenced "Sand Creek Stability Report", major storm flow conditions result in movement of the bed material to depths of up to four (4) feet. It also states that "where shallow bedrock depths cause a discontinuity in antidune formation, resistance to flow locally decreases, resulting in localized velocity increases and excess sediment transport energy being directed against the banks." Erosion of the bank can also occur where conditions exist that "direct hydraulic force vectors into the bankline." It is believed that the introduction of ditch checks into this reach of Sand Creek would compound the shallow bedrock situation and would create those very conditions that direct hydraulic forces into the bank (lateral erosion). The installation of ditch checks every 400 feet would further reduce the movement of bed material, which has been determined to be an important aspect of the fluvial stability of Sand Creek. The ditch checks would create and direct unnecessary hydraulic forces into the banks since they will be essentially an obstruction to the flow. The reaches upstream and downstream of the bend are fairly straight so flow momentum together with the recommended riprap bank protection should maintain the channel alignment adequately without the addition of ditch checks. In addition, shallow bedrock depths will essentially limit the vertical degradation of the channel.

The referenced stability report was prepared primarily to support a new interceptor sanitary sewer design in the East bank. The information presented has been considered as it relates to channel flow and has resulted in the channel conclusions contained in this MDDP. Those conclusions include the recommendation that ditch checks are not hydraulically appropriate for this reach of Sand Creek based on the more extensive hydrologic and hydraulic data included in the referenced study.

VI. COST ANALYSIS

The drainage facilities recommended in this study consist of Sand Creek improvements which are public reimbursable drainage facilities and onsite storm sewer facilities which are private. The Sand Creek improvements recommended in this study are well defined and will be mostly unchanged by final design considerations. The private drainage facilities are more schematic at this MDDP level of detail are subject to more significant changes as development plans and finalized grading plans become available for the unplatted parcels. The private drainage facilities shown on the Drainage Plan are intended to only illustrate the locations and magnitude of the proposed outfalls as they relate to the major channel flows. These private systems will be more defined and accompanied by a cost estimate at the time of Preliminary and Final Drainage Report preparation for the individual parcels. Therefore, an Opinion of Probable Cost has been prepared only for the Sand Creek public facility improvements.

The Opinion of Probable Cost for the Sand Creek improvements is as follows:

Sand Creek Improvements – Public (Reimbursable)

Item	Quantity	Unit Cost	Estimate
Rock Riprap Channel Lining (includes D_{50} = 24" rock at 48" thick, granular bedding, topsoil and revegetation)	2990 LF*	$122.00/LF**	$364,780
	Subtotal		$364,780
15% Engineering and Contingencies			$ 54,717
TOTAL ESTIMATE			$419,497

*The footage includes 2050 LF on the East and 940 LF on the West side through this reach as shown on the Drainage Plan.
**The unit cost for channel improvements is provided based on similar improvements previously completed along Sand Creek. A more detailed breakdown of cost can be provided at time of final design if required.

Basin Fee Impact - As previously discussed, a portion of the West bank will not be riprap lined and the seven ditch check structures within this reach are recommended to not be built as a result of the development of the Creekside Center and apartment complex. The SCDBPS developed a unit cost of $268/LF for this reach of Sand Creek which included lining both sides and installing ditch checks. The lineal foot cost of this reach (approximately 2,050 LF) based on the improvements recommended in the MDDP is $178/LF plus Engineering and Contingencies. This represents a $90/LF reduction of the SCDBPS unit cost and results in a cost reduction to the basin as follows:

2,050 LF x $90/LF = $184,500*

15% Engineering & Contingencies	$ 27,675
Total Reduction	$212,175

*This amount is approximately 0.24% of the total eligible Basin improvements estimate of $78M in the DBPS.

It is recommended that this basin cost reduction be considered during the City of Colorado Springs' yearly review and adjustment of the basin fees and the Sand Creek fees adjusted if appropriate. The current fees for the Sand Creek Basin are as follows:

Drainage:	$6,394.00/ac
Bridge:	$ 381.00/ac
Pond-Land:	$ 414.00/ac
Pond-Facilities:	$1,426.00/ac

The fees will be determined for each parcel at the time of Final Drainage Report preparation.

VII. SUMMARY

The Creekside Center/apartment complex development is located within the Sand Creek Drainage Basin. According to the Sand Creek Drainage Basin Planning Study (SCDBPS), no regional detention basins have been recommended within the site's reach. The recommended improvements to Sand Creek adjacent to the site include riprap lining the banks, 2-drop structures, and 7 ditch checks. The 2-drop structures are already in place as well as riprap in the southerly portion of the channel adjacent to the site.

Onsite runoff adjacent in the study area will flow directly to Sand Creek via curb inlets and storm sewer facilities. The inlets and sewers were sized for the 5-year storm with the 100-year overflow flowing directly over the banks of Sand Creek at designated points into the channel. Any overflow points identified during final design will be appropriately landscaped/hardscaped as required to convey overflow to the channel without detrimental effects to channel improvements. If this is not possible, the pipes and inlets should be sized for the 100-year storm event. For the 5-year flows, the inlets varied in size from 5' to 10' and the storm sewers varied in size from 15" RCP to 30" RCP.

It is recommended to riprap the East bank adjacent to the site north of the existing channel improvements. The West bank should be regraded and riprap lined between cross sections 6 and 12. No other West bank improvements are recommended for this reach of Sand Creek as a result of this development as the existing bank will not be adversely affected by this development.

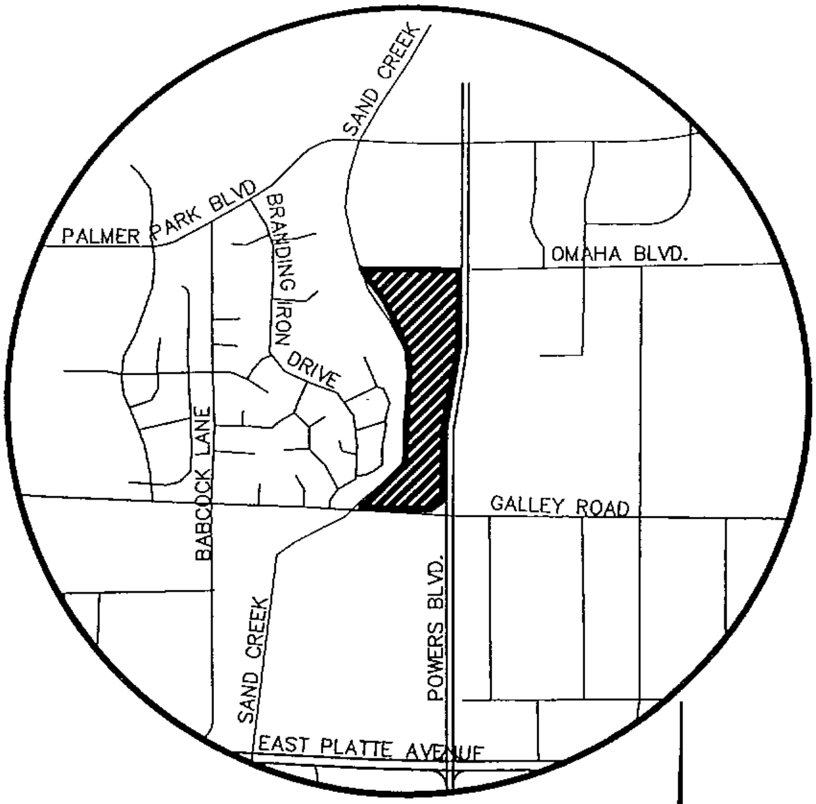
Regrading will minimize the depth of the 100-year flow to about 6 feet through the curve and keep the flow within Sand Creek's banks with at least 1' of freeboard. Due to higher velocities in the channel, a riprap size of D_{50} = 24" at 48" thick is recommended for the channel lining.

The ditch checks recommended in the SCDBPS are not proposed to be installed in this reach of Sand Creek. The Sand Creek Stability Report by R. L. Thaemert provides more detailed and site specific information for this reach of the Sand Creek channel than did the DBPS. This information supports the recommendations for the exclusion of ditch checks in this portion of Sand Creek. Fluvial stability would not be improved by the ditch checks and could very well be diminished.

This drainage analysis has been prepared in accordance with the Colorado Springs Drainage Criteria Manual. Supporting information is included in the Appendix. It is believed all pertinent information has been considered in the preparation of the Master Development Drainage Plan. The recommendations contained herein are subject to the conditions set forth.

APPENDIX

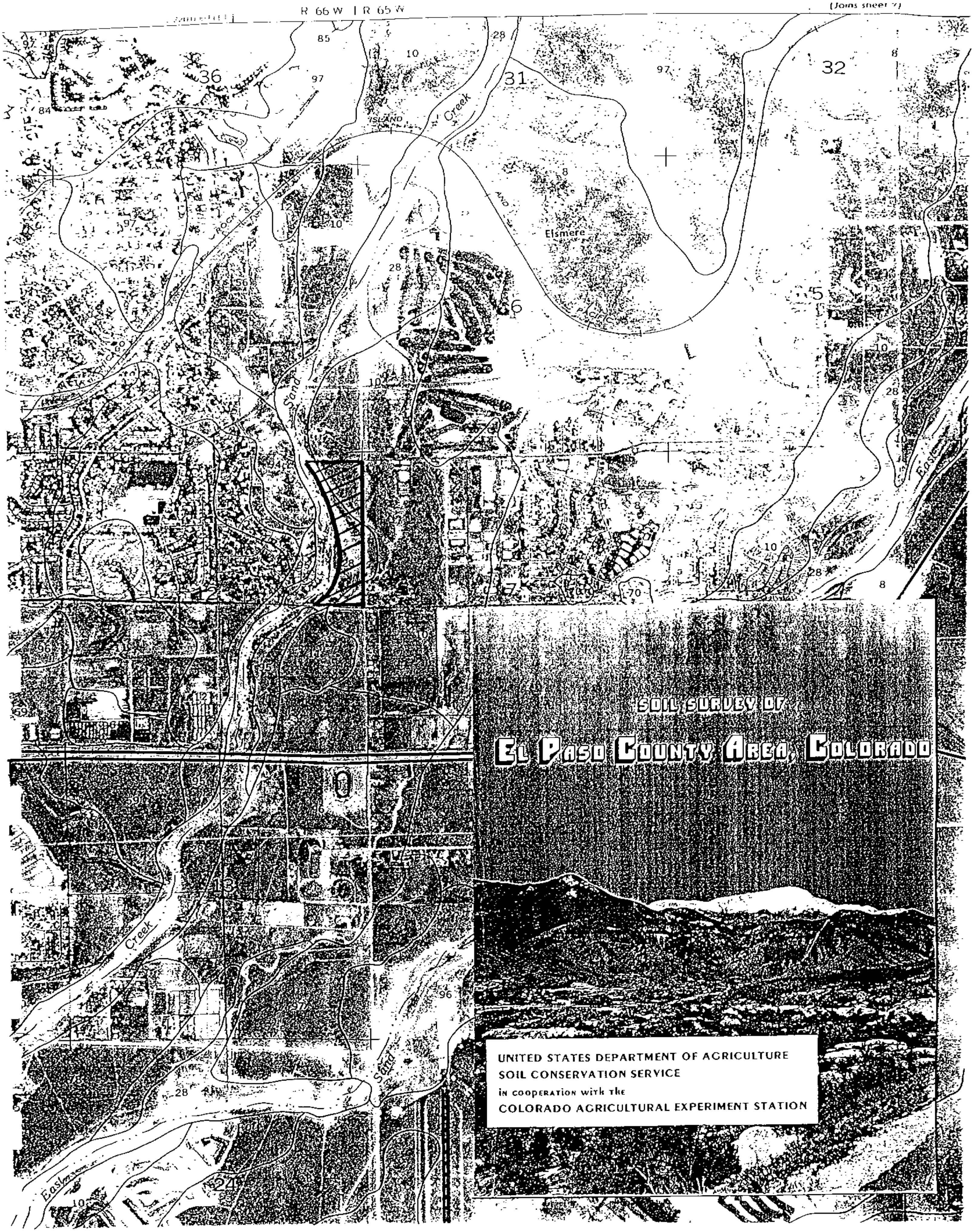
VICINITY MAP



VICINITY MAP

SCALE 1" = 2000'±

SCS SOILS MAP



SOIL SURVEY OF

EL PASO COUNTY AREA, COLORADO

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
in cooperation with the
COLORADO AGRICULTURAL EXPERIMENT STATION

FLOODPLAIN
MAP

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

EL PASO COUNTY,
COLORADO AND
INCORPORATED AREAS

PANEL 751 OF 1300
(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
COLORADO SPRINGS, CITY OF	080060	0751	F
EL PASO COUNTY, UNINCORPORATED AREAS	080059	0751	F

MAP NUMBER
08041C0751 F

EFFECTIVE DATE:
MARCH 17, 1997

Federal Emergency Management Agency

LEGEND

▨ SPECIAL FLOOD HAZARD AREAS INUNDATED BY 100-YEAR FLOOD

ZONE A	No base flood elevations determined
ZONE AE	Base flood elevations determined
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding): base flood elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE A99	To be protected from 100-year flood by Federal flood protection system under construction; no base elevations determined.
ZONE V	Coastal flood with velocity hazard (wave action); no base flood elevations determined.
ZONE VE	Coastal flood with velocity hazard (wave action): base flood elevations determined.

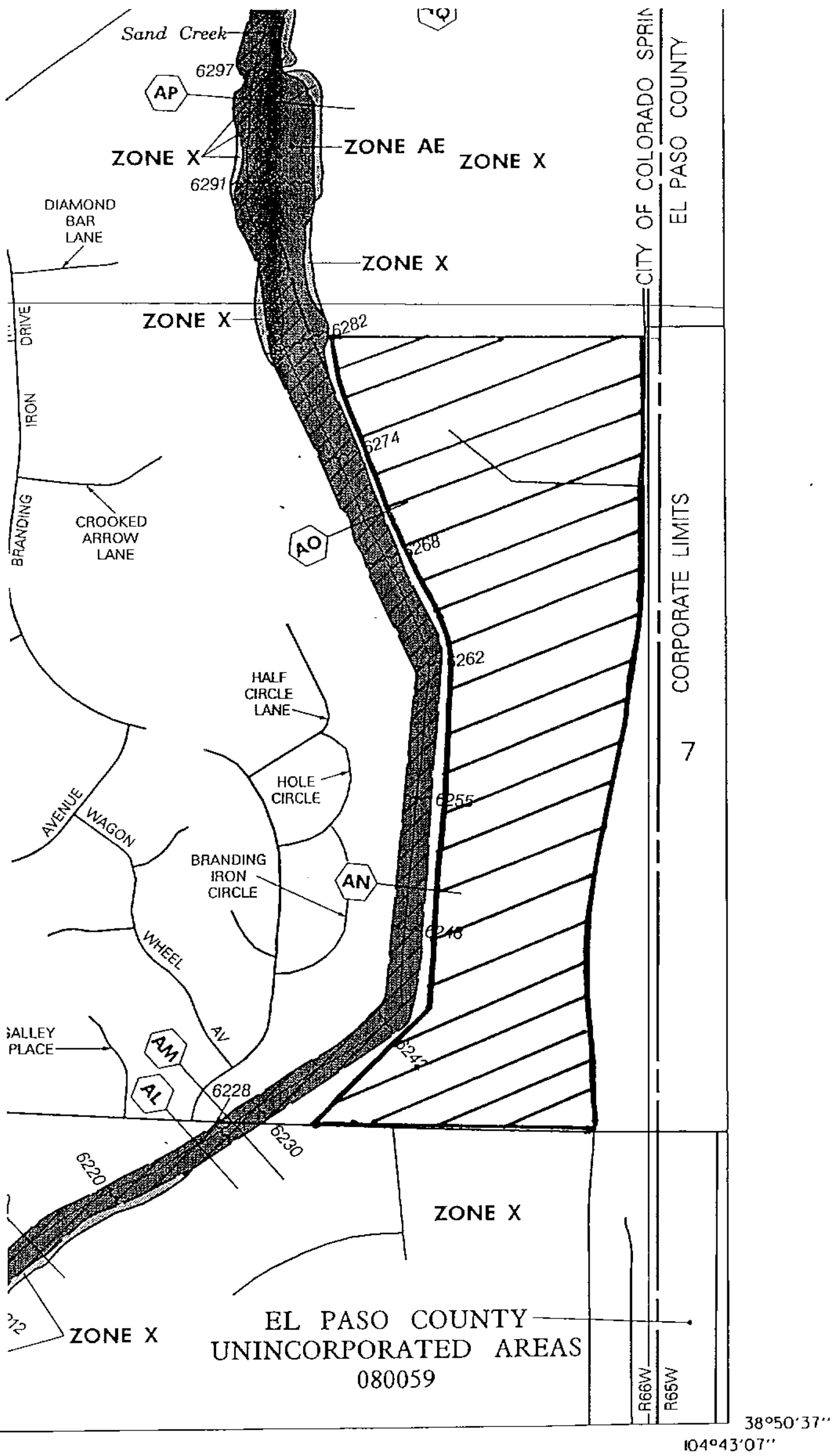
▨ FLOODWAY AREAS IN ZONE AE

▨ OTHER FLOOD AREAS

ZONE X	Areas of 500-year flood; areas of 100-year flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 100-year flood.

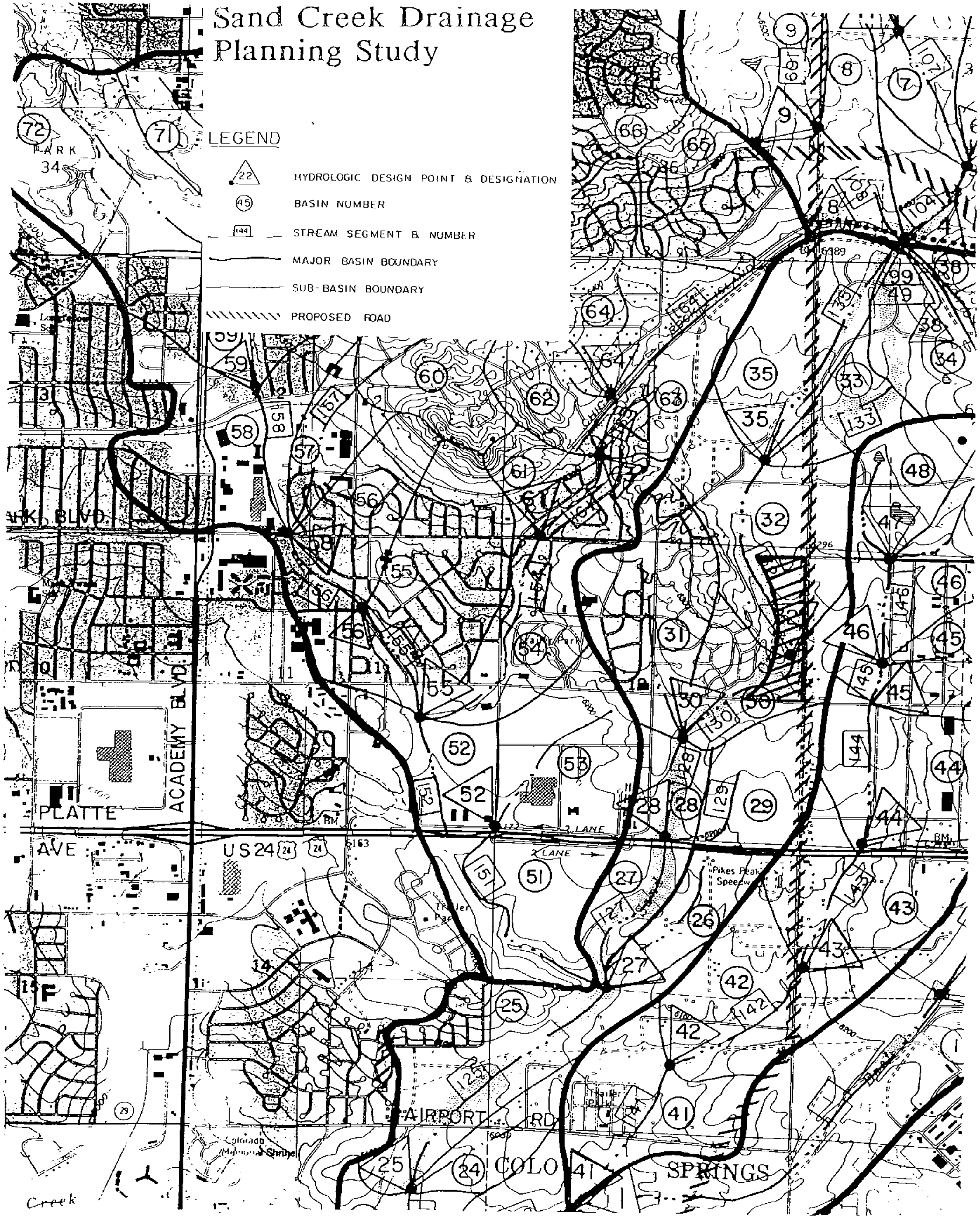
☐ OTHER AREAS

ZONE X	Areas determined to be outside 500-year floodplain.
ZONE D	Areas in which flood hazards are undetermined.



DBPS EXHIBITS

Sand Creek Drainage Planning Study



HYDROLOGIC CALCULATIONS

Obering, Wurth & Associates
Consulting Civil Engineers
Professional Land Surveyors

1015 Elkton Drive
Colorado Springs, Colorado 80907
(719) 531-6200 FAX (719) 531-6266

JOB #00019 Creekside MDDP
SHEET NO. 1 OF
CALCULATED BY JGD DATE 07/00
CHECKED BY DATE
SCALE

Runoff Calculations using Rational Method &
(For Developed) Drainage Criteria Manual (DCM)

C values (DCM Table 5-1) (Hyd. Soil groups A & B)

Subbasin	Area (acres)	Usage	Developed	
			C_5	C_{100}
A	7.7	commercial	0.90	0.90
B	3.7	"	0.90	0.90
C	0.8	"	0.90	0.90
D	1.5	paved road	0.90	0.95
E	10.5	multi-family	0.70	0.80
F	7.7	"	0.70	0.80

Time of Concentration, T_c

for overland flow : $T_c = 1.87(1.1-C)L^{0.5}S^{-0.33}$

Subbasin A overland flow 300' @ 1.1%
Curb & gutter 240' @ 1.0%

overland $T_{c_{5\,\&\,100}} = 1.87(1.1-0.90)300^{0.5}(1.1)^{-.33} = 6.28$ min.

Curb & gutter $V_5 = 5.53$ fps $V_{100} = 6.14$ fps

$T_c = \frac{L}{60V}$ $T_{c_5} = \frac{240}{60(5.53)} = 0.72$ min.

$T_{c_{100}} = \frac{240}{60(6.14)} = 0.65$ min.

JOB #00017 Creekside
SHEET NO. 2 OF
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total $T_{c_5} = 6.28 + 0.72 = \underline{7.00 \text{ min}}$

$T_{c_{100}} = 6.28 + 0.45 = \underline{6.93 \text{ min.}}$

Subbasin B

overland flow 240' @ 0.8%
curb & gutter 185' @ 0.5%

overland $T_{c_{5\&100}} = 1.87(1.1-0.9)240^{0.5}(0.8)^{-0.33} = 6.24 \text{min.}$

c&g $V_5 = 3.54$ $V_{100} = 3.93$

$T_{c_5} = \frac{185}{60(3.54)} = 0.87$ $T_{c_{100}} = \frac{185}{60(3.93)} = 0.78$

total $T_{c_5} = 6.24 + 0.87 = \underline{7.11 \text{ min.}}$

$T_{c_{100}} = 6.24 + 0.78 = \underline{7.02 \text{ min.}}$

Subbasin C

overland flow only 240' 0.6%

$T_{c_{5\&100}} = 1.87(1.1-0.9)240^{0.5}(0.6)^{-.33} = \underline{6.86 \text{ min.}}$

Subbasin D

curb & gutter only 1100' Δ16' 1.4%

$V_5 = 4.37$ $V_{100} = 4.81$

$T_{c_5} = \frac{1100}{60(4.37)} = \underline{4.20 \text{ min}}$ ⇒ use minimum $T_{c_5} = \underline{5.0 \text{min}}$

$T_{c_{100}} = \frac{1100}{60(4.81)} = \underline{3.81 \text{ min.}}$ ⇒ use minimum $T_{c_{100}} = \underline{5.0 \text{min.}}$

JOB #00019 Creekside

SHEET NO. 3 OF

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SCALE

Subbasin E overland flow 300′ Δ7′ 2,33%
c&g flow 700′ Δ5′ 0,71%

overland $T_{c_5} = 1.87 (1.1-0.7) 300^{0.5} (2,33)^{-0.33} = 9,80$ min.

$T_{c_{100}} = 1,87 (1.1-0,8) 300^{0.5} (2,33)^{-0.33} = 7,35$ min.

C&g $V_5 = 4.45$ $V_{100} = 5.22$ fps

$T_{c_5} = \frac{700}{60(4.45)} = 2,62$ min.

$T_{c_{100}} = \frac{700}{60(5.22)} = 2,23$ min

total $T_{c_5} = 9.80 + 2,62 = \underline{12.42 \text{ min.}}$

$T_{c_{100}} = 7,35 + 2,23 = \underline{9.58 \text{ min}}$

Subbasin F overland flow 450′ Δ13′ 2,89%
c&g flow 650′ Δ12′ 1,85%

overland $T_{c_5} = 1,87 (1.1-0.7) 450^{0.5} (2.89)^{-0.33} = 11,18$ min
$T_{c_{100}} = 1,87 (1.1-0,8) 450^{0.5} (2.89)^{-0.33} = 8.38$ min.

C&g $V_5 = 5.90$ $V_{100} = 4.93$ fps

$T_{c_5} = \frac{650}{60(5.90)} = 1.84$ $T_{c_{100}} = \frac{650}{60(4.93)} = 1.56$ min.

total $T_{c_5} = 11.18 + 1,84 = \underline{13.02 \text{ min}}$

$T_{c_{100}} = 8.38 + 1,56 = \underline{9.94 \text{ min.}}$

JOB #00019 Creekside
SHEET NO. 4 OF
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Rainfall Intensity, i

subbasin	Intensity	
	5-yr	100-yr
A	4.6	7.94
B	4.6	7.90
C	4.7	7.98
D	5.2	9.00
E	3.72	7.11
F	3.6	7.0

Developed Flows, Q

Eqn 5-1 in DCM $Q = ciA$

Subbasin	Storm Event	c	*	i (in/hr)	*	A (acres)	=	Q (cfs)
A	5-yr	0.90		4.6		7.7		31.9
	100-yr			7.94				55.0
B	5-yr	0.90		4.6		3.7		15.3
	100-yr			7.90				26.3
C	5-yr	0.90		4.7		0.8		3.4
	100-yr			7.98				5.7
D	5-yr	0.90		5.2		1.5		7.0
	100-yr	0.95		9.00				12.8
E	5-yr	0.70		3.72		10.5		27.3
	100-yr	0.80		7.11				59.7
F	5-yr	0.70		3.6		7.7		19.4
	100-yr	0.80		7.0				43.1

HYDRAULIC CALCULATIONS

Obering, Wurth & Associates
Consulting Civil Engineers
Professional Land Surveyors

1015 Elkton Drive
Colorado Springs, Colorado 80907
(719) 531-6200 FAX (719) 531-6266

JOB 00019 Creekside
SHEET NO. 5 OF
CALCULATED BY JGD DATE 07/00
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SCALE

Sizing Curb Inlets (10-yr storm)

use D-10-R curb inlets @ sag locations

Table 7-1 in DCM → clogging factor = 1.25

Eqn 7-4 $Q = 3.0 L d^{1.5}$

$$Q = 0.67 A [2g(d - h/2)]^{0.5}$$

where L = length of opening
d = depth of water above lip
A = are of opening = hL
h = height of opening

Subbasin E (Sum. Point 6)

$Q_5 = 27.3$ cfs

$h = 8'' = 0.67'$
max $d = 1'$

$Q = 3.0 L d^{1.5} = 3.0 L (1)^{1.5} = 21.5$ cfs

$L = 27.3/3 = 9.1 * \underset{\text{clogging factor}}{1.25} = 11.4$ ⇒ use 12' long inlet

Subbasin F (Sum. Point 7)

$Q_5 = 19.4$ cfs

$Q = 3.0 L (1)^{1.5} = 15.5$

$L = 19.4/3 = 6.47' * 1.25 = 8.1'$ ⇒ use 8' long inlet

JOB 00019 Creekside
SHEET NO. 4 OF
CALCULATED BY JGD DATE 07/00
CHECKED BY DATE
SCALE

CURB INLETS

Sum. Point 1

$Q_5 = 3.4$ cfs

$Q = 3.0L = 3.4$ cfs

$L = 3.4/3 = 1.13 * 1.25 = 1.42' \Rightarrow$ 5' inlet

Sum. Point 2

$Q_5 = 22.3$ cfs

$Q = 3.0L = 22.3$

$L = 22.3/3 = 7.43 \times 1.25 = 9.29' \Rightarrow$ 10' inlet

Sum. points 3,4,5

$Q_5 = 10.6$ cfs (for each point)

$Q = 3.0L = 10.6$

$L = 10.6/3 = 3.53 \times 1.25 = 4.42' \Rightarrow$ 5' inlet

00019 Creekside

Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	Circular Channel
Flow Element	Circular Channel
Method	Manning's Formu
Solve For	Full Flow Slope

Input Data		
Mannings Coeffic	).013	
Diameter	15	in
Discharge	3.40	cfs

Results		
Slope	002771	ft/ft
Depth	1.25	ft
Flow Area	1.2	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	0.74	ft
Percent Full	100.0	%
Critical Slope	006298	ft/ft
Velocity	2.77	ft/s
Velocity Head	0.12	ft
Specific Energ	1.37	ft
Froude Numbe	0.00	
Maximum Disc	3.66	cfs
Discharge Full	3.40	cfs
Slope Full	002771	ft/ft
Flow Type	N/A	

Summary Part 1

(Subbasin C)

$Q_5 = 3.4$ cfs

15" Lateral

0.5% min slope

00011 Creekside

Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	Circular Channel
Flow Element	Circular Channel
Method	Manning's Formu
Solve For	Full Flow Slope

Input Data		
Mannings Coeffic	0.013	
Diameter	24	in
Discharge	22.30	cfs

Results		
Slope	009718	ft/ft
Depth	2.00	ft
Flow Area	3.1	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	1.68	ft
Percent Full	100.0	%
Critical Slope	009279	ft/ft
Velocity	7.10	ft/s
Velocity Head	0.78	ft
Specific Energ	2.78	ft
Froude Numbe	0.00	
Maximum Disc	23.99	cfs
Discharge Full	22.30	cfs
Slope Full	009718	ft/ft
Flow Type	N/A	

Summary Point 2

(Subbasins B & D)

$Q_5 = 15.3 + 7 = 22.3$ cfs

24" Lateral

min slope 1%

00014 Creekside

Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	Circular Channel
Flow Element	Circular Channel
Method	Manning's Formu
Solve For	Full Flow Slope

Input Data		
Mannings Coeffic	).013	
Diameter	21	in
Discharge	10.63	cfs

Results		
Slope	004501	ft/ft
Depth	1.75	ft
Flow Area	2.4	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	1.21	ft
Percent Full	100.0	%
Critical Slope	006562	ft/ft
Velocity	4.42	ft/s
Velocity Head	0.30	ft
Specific Energ:	2.05	ft
Froude Numbe	0.00	
Maximum Disc	11.43	cfs
Discharge Full	10.63	cfs
Slope Full	004501	ft/ft
Flow Type	N/A	

Sum. Points 3,4,5
(Subbasin A)
Q_5 = 10.6 cfs
3-21" Laterals
min slope 0.5%

D0019 Creekside

Worksheet
Worksheet for Circular Channel

Sum Pt 6

Subbasin E

Q_5 = 27.3 cfs

30" Lateral

min slope 0.5%

Project Description	
Worksheet	Circular Channel
Flow Element	Circular Channel
Method	Manning's Formu
Solve For	Full Flow Slope

Input Data		
Mannings Coeffic	0.013	
Diameter	30	in
Discharge	27.30	cfs

Results		
Slope	004430	ft/ft
Depth	2.50	ft
Flow Area	4.9	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	1.78	ft
Percent Full	100.0	%
Critical Slope	006033	ft/ft
Velocity	5.56	ft/s
Velocity Head	0.48	ft
Specific Energ	2.98	ft
Froude Numbe	0.00	
Maximum Disc	29.37	cfs
Discharge Full	27.30	cfs
Slope Full	004430	ft/ft
Flow Type	N/A	

00019 Creekside

Worksheet
Worksheet for Circular Channel

Sam Pt. 7
Subbasin F

$Q_5 = 19.4$ cfs

30" Lateral

min slope 0.5%

Project Description

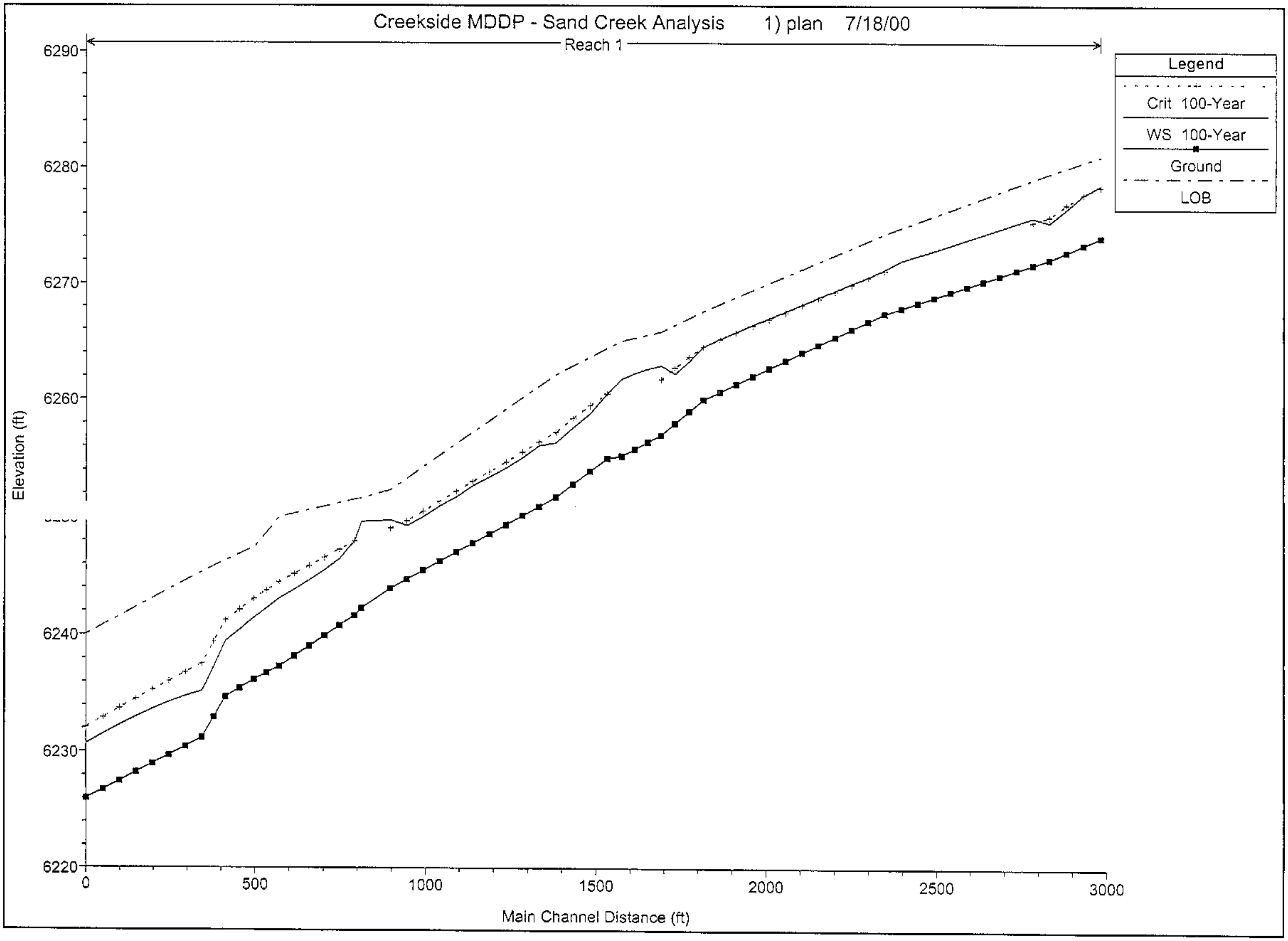
Worksheet	Circular Channel
Flow Element	Circular Channel
Method	Manning's Formu
Solve For	Full Flow Slope

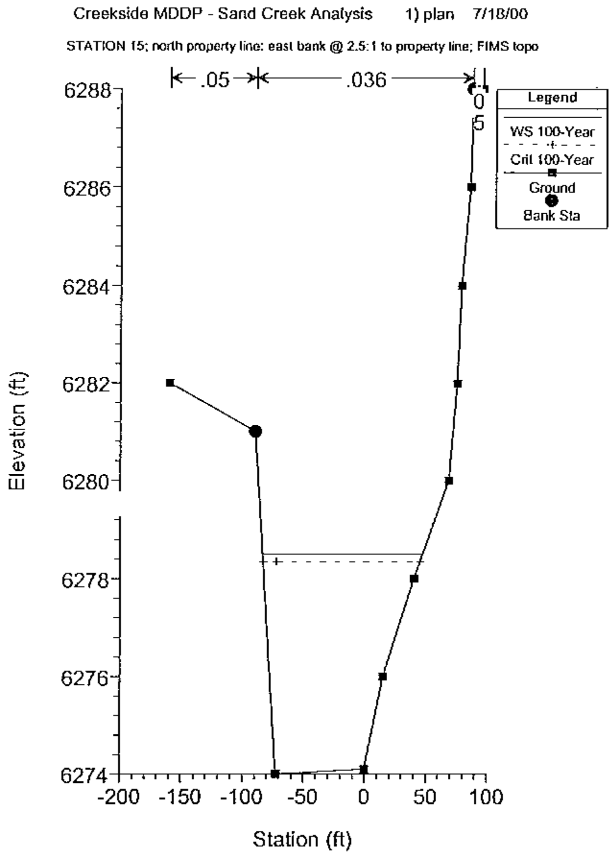
Input Data

Mannings Coeffic	).013	
Diameter	30	in
Discharge	19.40	cfs

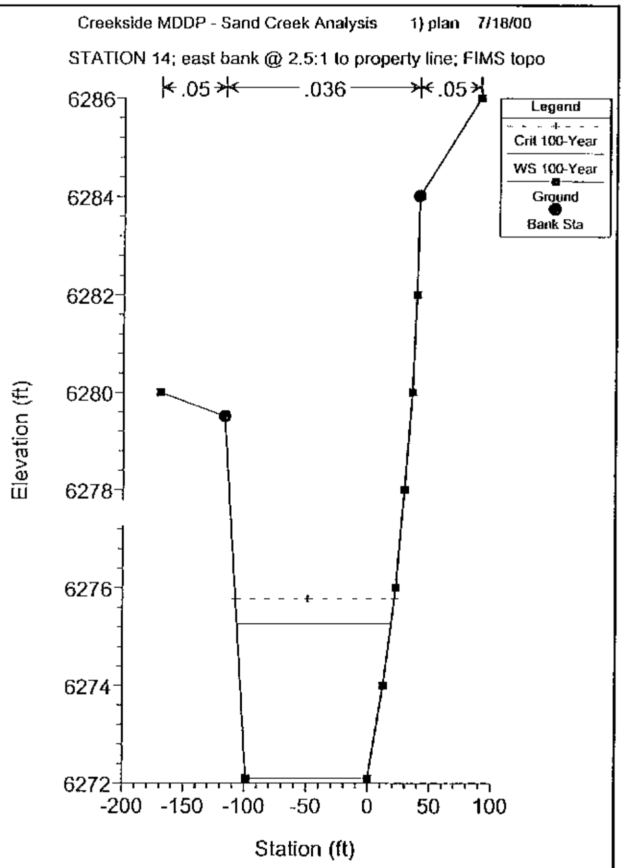
Results

Slope	002237	ft/ft
Depth	2.50	ft
Flow Area	4.9	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	1.49	ft
Percent Full	100.0	%
Critical Slope	005018	ft/ft
Velocity	3.95	ft/s
Velocity Head	0.24	ft
Specific Energ:	2.74	ft
Froude Numbe	0.00	
Maximum Disc	20.87	cfs
Discharge Full	19.40	cfs
Slope Full	002237	ft/ft
Flow Type	N/A	

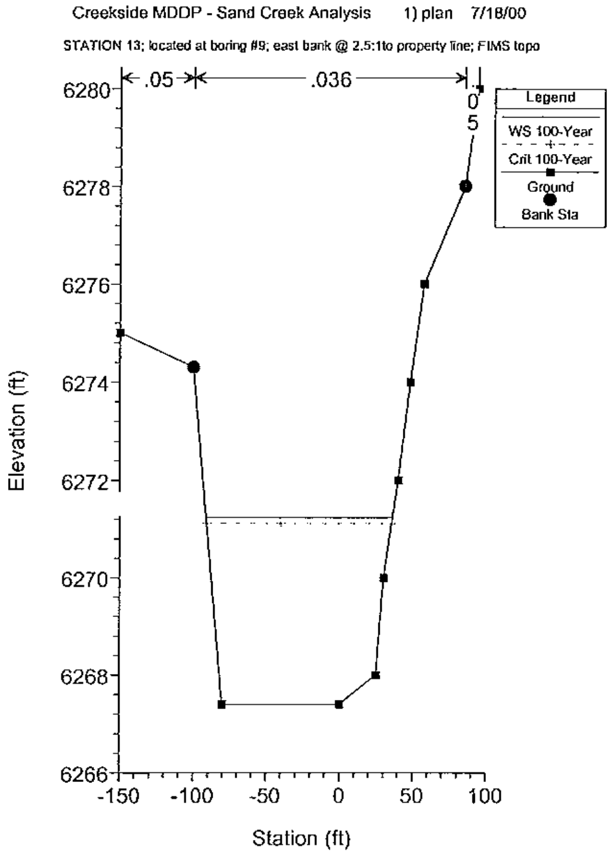

Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00
Reach 1
Legend
Crit 100-Year
WS 100-Year
Ground
LOB
Elevation (ft)
6290
6280
6270
6260
6240
6230
6220
0
500
1000
1500
2000
2500
3000
Main Channel Distance (ft)


Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

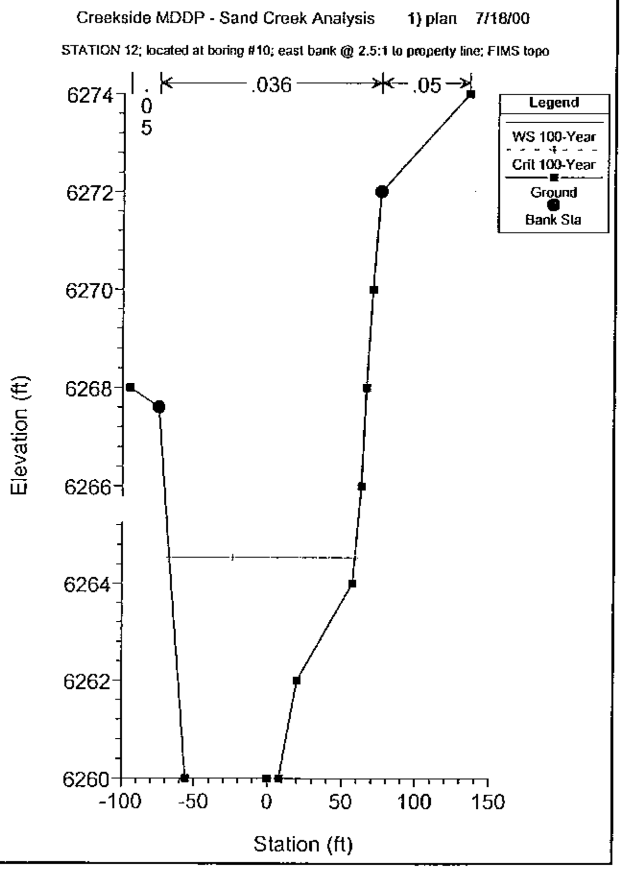
STATION 15; north property line; east bank @ 2.5:1 to property line; FIMS topo


Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 14; east bank @ 2.5:1 to property line; FIMS topo


Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

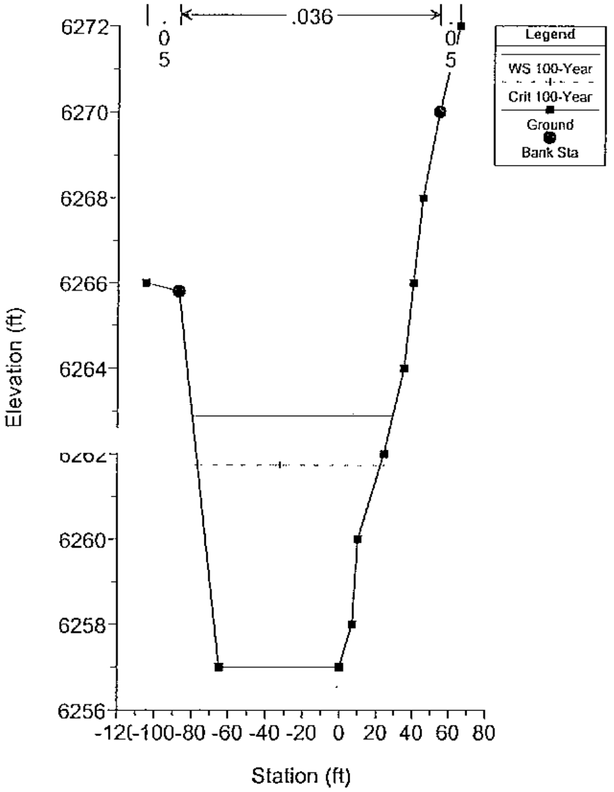
STATION 13; located at boring #9; east bank @ 2.5:1to property line; FIMS topo


Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 12; located at boring #10; east bank @ 2.5:1 to property line; FIMS topo

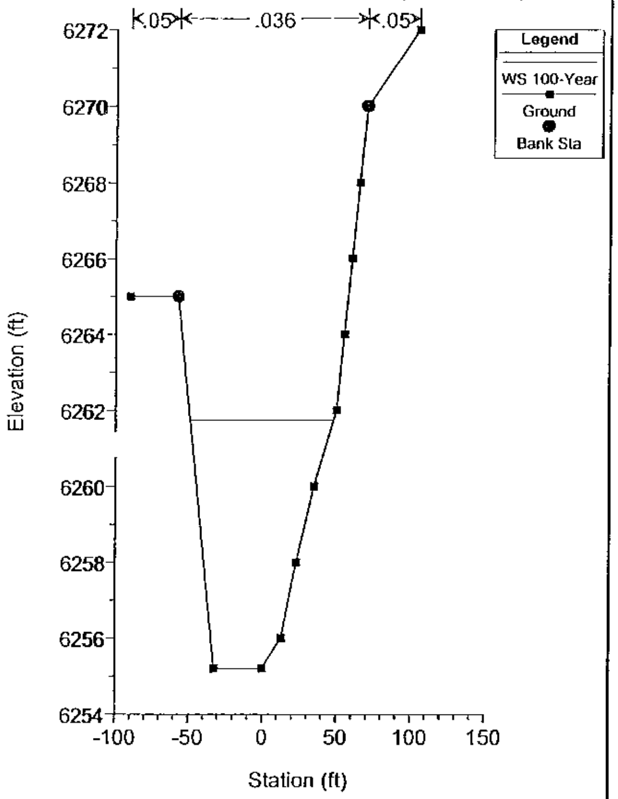
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 11; east bank @ 2.5:1 to property line; FIMS topo



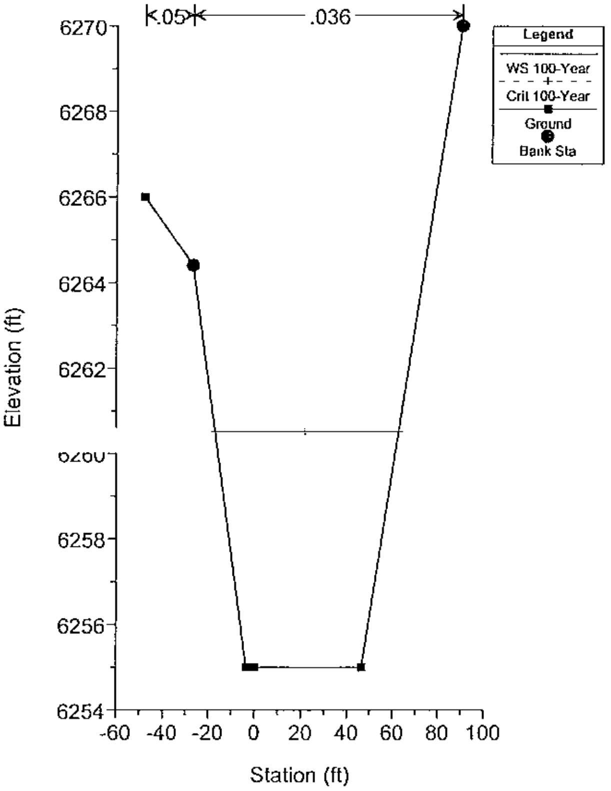
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 10; east bank@2.5:1 to property line; FIMS topo



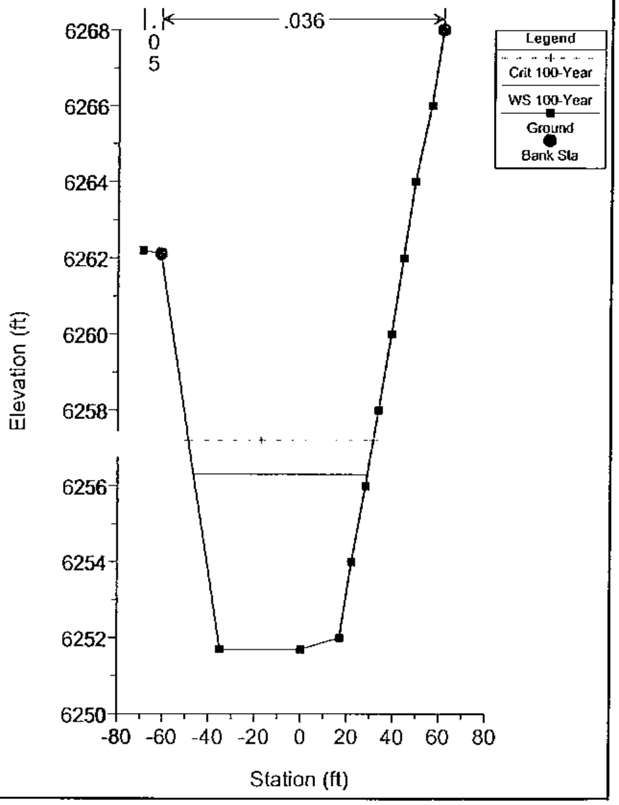
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 9; east bank @ 2.5:1 to property line; near south end property line of apts.; existing topo



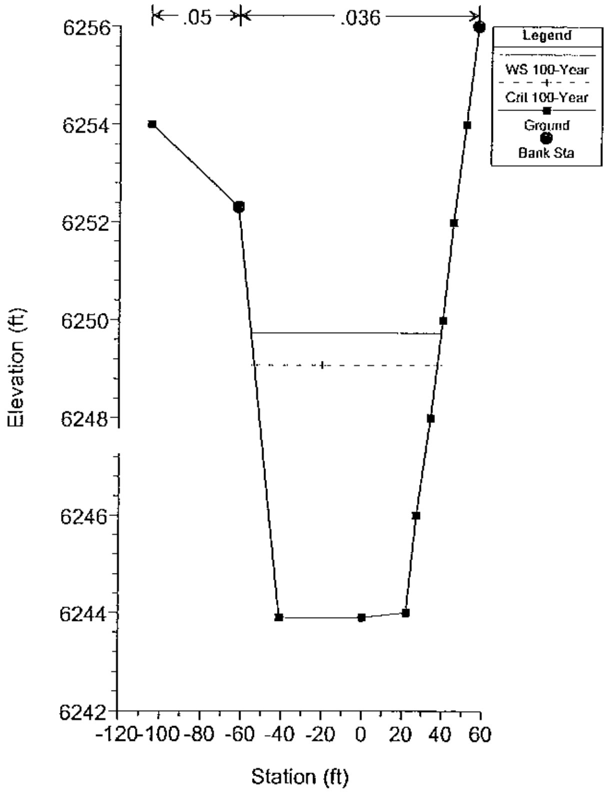
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 8; boring #11; east bank @ 2.5:1 to property line; existing topo



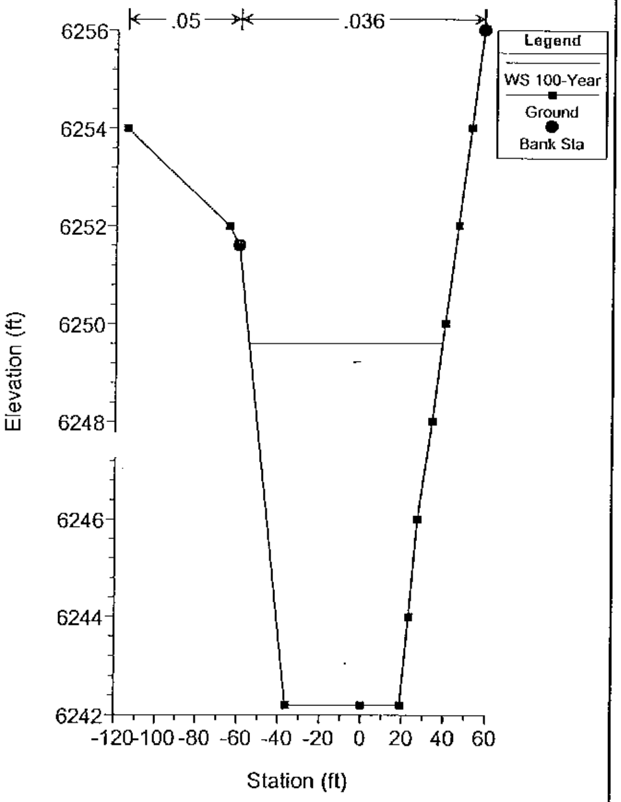
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 7; boring #12; east bank @ 2.5:1to property line; existing topo



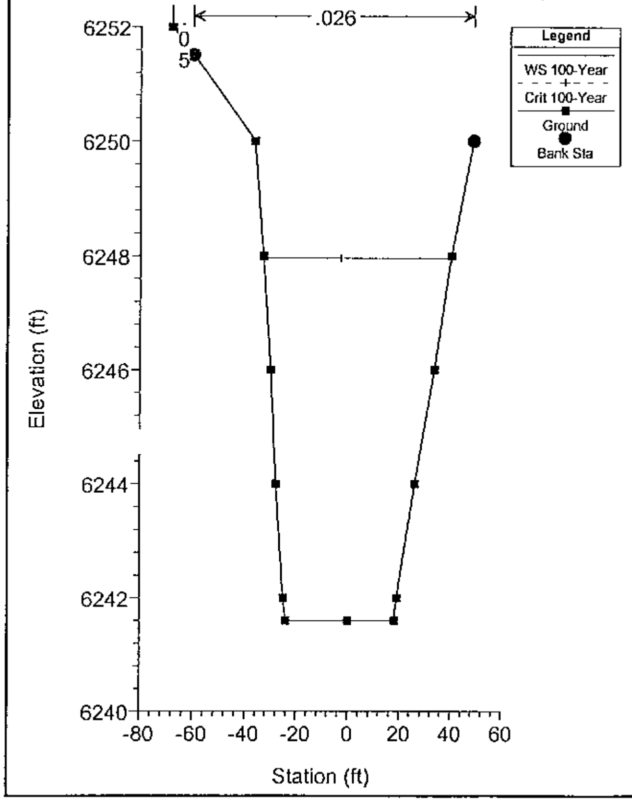
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 6; south end unimproved channel; east bank @ 2.5:1 to property line; existing topo



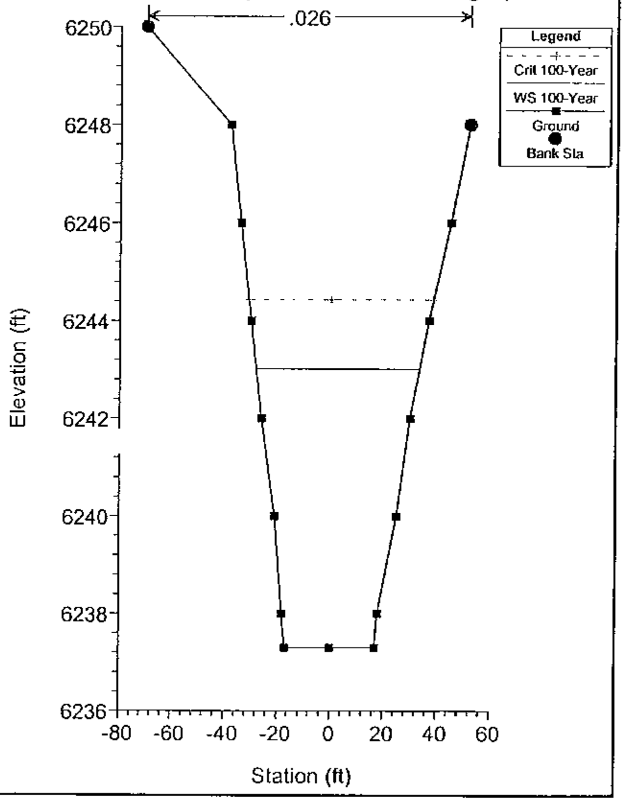
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 5; north end improved channel; existing topo



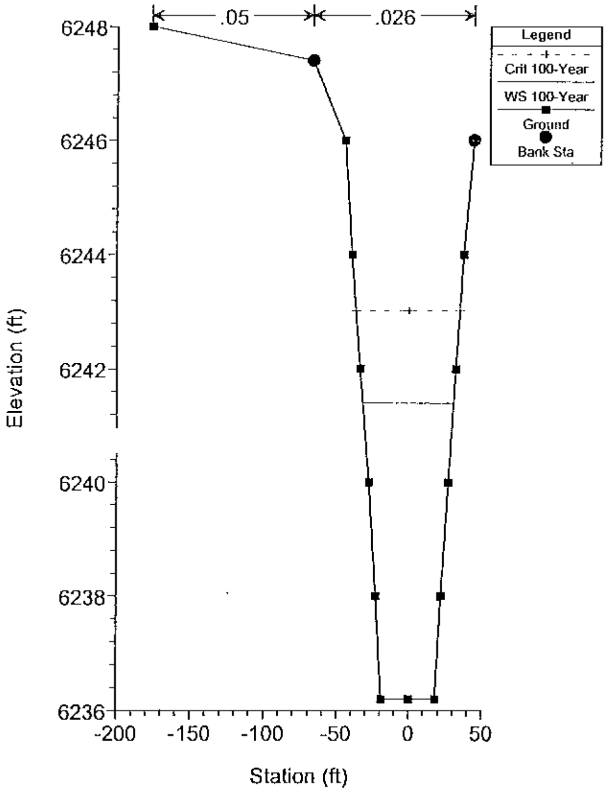
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 4.1; improved channel; existing topo



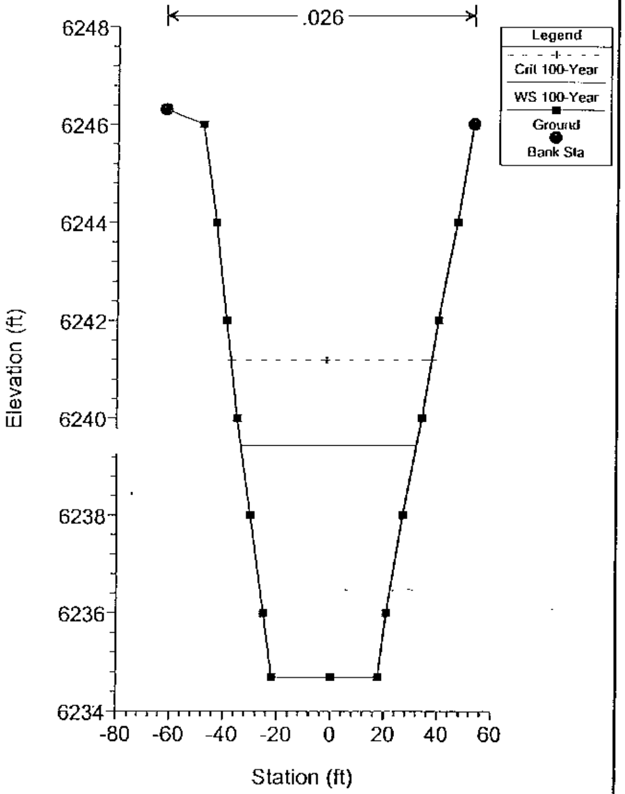
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 4; improved channel; existing topo



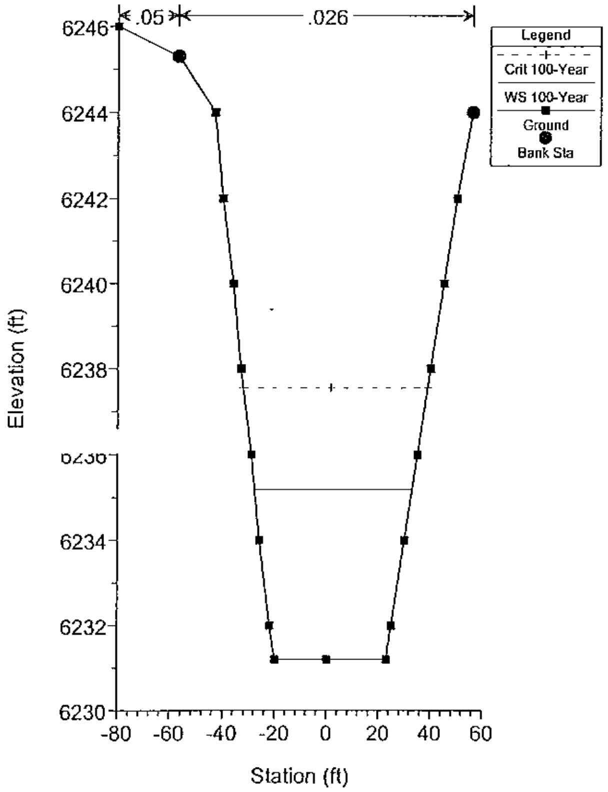
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 3; boring #13; improved channel; existing topo



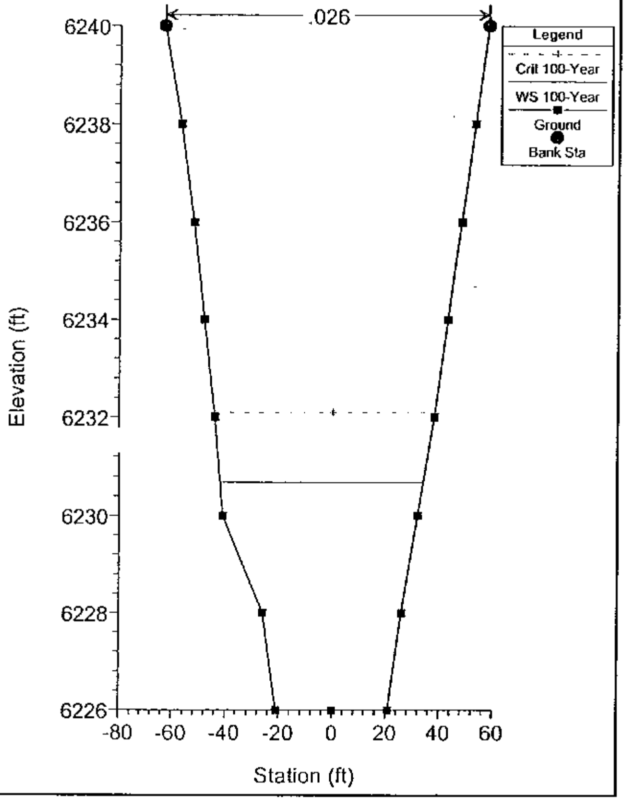
Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 2; improved channel; existing topo



Creekside MDDP - Sand Creek Analysis 1) plan 7/18/00

STATION 1; improved channel; existing topo; south end of channel



Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 15 Profile: 100-Year

W.S. Elev (ft)	6278.50	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.50	Wt. n-Val.		0.036	
E.G. Elev (ft)	6280.00	Reach Len. (ft)	37.67	50.00	59.67
Crit W.S. (ft)	6278.35	Flow Area (sq ft)		439.51	
E.G. Slope (ft/ft)	0.011395	Area (sq ft)		439.51	
Q Total (cfs)	4320.00	Flow (cfs)		4320.00	
Top Width (ft)	130.82	Top Width (ft)		130.82	
Vel Total (ft/s)	9.83	Avg. Vel. (ft/s)		9.83	
Max Chl Dpth (ft)	4.50	Hydr. Depth (ft)		3.36	
Conv. Total (cfs)	40469.1	Conv. (cfs)		40469.1	
Length Wtd. (ft)	50.00	Wetted Per. (ft)		131.91	
Min Ch El (ft)	6274.00	Shear (lb/sq ft)		2.37	
Alpha	1.00	Stream Power (lb/ft s)		23.30	
Frctn Loss (ft)	0.61	Cum Volume (acre-ft)		25.07	
C & E Loss (ft)	0.02	Cum SA (acres)		6.66	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 14 Profile: 100-Year

W.S. Elev (ft)	6275.27	Element	Left OB	Channel	Right OB
Vel Head (ft)	2.30	Wt. n-Val.		0.036	
E.G. Elev (ft)	6277.57	Reach Len. (ft)	44.60	48.60	51.20
Crit W.S. (ft)	6275.78	Flow Area (sq ft)		355.04	
E.G. Slope (ft/ft)	0.021750	Area (sq ft)		355.04	
Q Total (cfs)	4320.00	Flow (cfs)		4320.00	
Top Width (ft)	124.75	Top Width (ft)		124.75	
Vel Total (ft/s)	12.17	Avg. Vel. (ft/s)		12.17	
Max Chl Dpth (ft)	3.17	Hydr. Depth (ft)		2.85	
Conv. Total (cfs)	29292.5	Conv. (cfs)		29292.5	
Length Wtd. (ft)	48.60	Wetted Per. (ft)		125.63	
Min Ch El (ft)	6272.10	Shear (lb/sq ft)		3.84	
Alpha	1.00	Stream Power (lb/ft s)		46.69	
Frctn Loss (ft)	1.00	Cum Volume (acre-ft)		23.71	
C & E Loss (ft)	0.02	Cum SA (acres)		6.23	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 13 Profile: 100-Year

W.S. Elev (ft)	6271.24	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.55	Wt. n-Val.		0.036	
E.G. Elev (ft)	6272.79	Reach Len. (ft)	48.46	48.36	48.09
Crit W.S. (ft)	6271.12	Flow Area (sq ft)		431.72	
E.G. Slope (ft/ft)	0.011676	Area (sq ft)		431.72	
Q Total (cfs)	4320.00	Flow (cfs)		4320.00	
Top Width (ft)	127.31	Top Width (ft)		127.31	
Vel Total (ft/s)	10.01	Avg. Vel. (ft/s)		10.01	
Max Chl Dpth (ft)	3.84	Hydr. Depth (ft)		3.39	
Conv. Total (cfs)	39979.9	Conv. (cfs)		39979.9	
Length Wtd. (ft)	48.36	Wetted Per. (ft)		128.46	
Min Ch El (ft)	6267.40	Shear (lb/sq ft)		2.45	
Alpha	1.00	Stream Power (lb/ft s)		24.51	
Frctn Loss (ft)	0.58	Cum Volume (acre-ft)		18.60	
C & E Loss (ft)	0.01	Cum SA (acres)		4.79	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 12 Profile: 100-Year

W.S. Elev (ft)	6264.54	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.68	Wt. n-Val.		0.036	
E.G. Elev (ft)	6266.21	Reach Len. (ft)	50.00	41.67	36.67
Crit W.S. (ft)	6264.54	Flow Area (sq ft)		415.86	
E.G. Slope (ft/ft)	0.013045	Area (sq ft)		415.86	
Q Total (cfs)	4320.00	Flow (cfs)		4320.00	
Top Width (ft)	125.95	Top Width (ft)		125.95	
Vel Total (ft/s)	10.39	Avg. Vel. (ft/s)		10.39	
Max Chl Dpth (ft)	4.54	Hydr. Depth (ft)		3.30	
Conv. Total (cfs)	37823.2	Conv. (cfs)		37823.2	
Length Wtd. (ft)	41.67	Wetted Per. (ft)		127.13	
Min Ch El (ft)	6260.00	Shear (lb/sq ft)		2.66	
Alpha	1.00	Stream Power (lb/ft s)		27.67	
Frctn Loss (ft)	0.54	Cum Volume (acre-ft)		13.46	
C & E Loss (ft)	0.01	Cum SA (acres)		3.28	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 11 Profile: 100-Year

W.S. Elev (ft)	6262.90	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.14	Wt. n-Val.		0.036	
E.G. Elev (ft)	6264.03	Reach Len. (ft)	40.00	38.33	35.67
Crit W.S. (ft)	6261.74	Flow Area (sq ft)		504.85	
E.G. Slope (ft/ft)	0.005683	Area (sq ft)		504.85	
Q Total (cfs)	4320.00	Flow (cfs)		4320.00	
Top Width (ft)	108.66	Top Width (ft)		108.66	
Vel Total (ft/s)	8.56	Avg. Vel. (ft/s)		8.56	
Max Chl Dpth (ft)	5.90	Hydr. Depth (ft)		4.65	
Conv. Total (cfs)	57306.5	Conv. (cfs)		57306.5	
Length Wtd. (ft)	38.33	Wetted Per. (ft)		110.70	
Min Ch El (ft)	6257.00	Shear (lb/sq ft)		1.62	
Alpha	1.00	Stream Power (lb/ft s)		13.84	
Frctn Loss (ft)	0.22	Cum Volume (acre-ft)		12.35	
C & E Loss (ft)	0.01	Cum SA (acres)		2.96	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 10 Profile: 100-Year

W.S. Elev (ft)	6261.75	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.51	Wt. n-Val.		0.036	
E.G. Elev (ft)	6263.26	Reach Len. (ft)	45.00	43.00	39.00
Crit W.S. (ft)		Flow Area (sq ft)		438.33	
E.G. Slope (ft/ft)	0.007816	Area (sq ft)		438.33	
Q Total (cfs)	4320.00	Flow (cfs)		4320.00	
Top Width (ft)	96.99	Top Width (ft)		96.99	
Vel Total (ft/s)	9.86	Avg. Vel. (ft/s)		9.86	
Max Chl Dpth (ft)	6.55	Hydr. Depth (ft)		4.52	
Conv. Total (cfs)	48864.4	Conv. (cfs)		48864.4	
Length Wtd. (ft)	43.00	Wetted Per. (ft)		98.76	
Min Ch El (ft)	6255.20	Shear (lb/sq ft)		2.17	
Alpha	1.00	Stream Power (lb/ft s)		21.35	
Frctn Loss (ft)	0.41	Cum Volume (acre-ft)		11.09	
C & E Loss (ft)	0.07	Cum SA (acres)		2.69	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 9 Profile: 100-Year

W.S. Elev (ft)	6260.52	Element	Left OB	Channel	Right OB
Vel Head (ft)	2.26	Wt. n-Val.		0.036	
E.G. Elev (ft)	6262.78	Reach Len. (ft)	50.00	50.00	50.00
Crit W.S. (ft)	6260.52	Flow Area (sq ft)		358.04	
E.G. Slope (ft/ft)	0.011931	Area (sq ft)		358.04	
Q Total (cfs)	4320.00	Flow (cfs)		4320.00	
Top Width (ft)	79.79	Top Width (ft)		79.79	
Vel Total (ft/s)	12.07	Avg. Vel. (ft/s)		12.07	
Max Chl Dpth (ft)	5.52	Hydr. Depth (ft)		4.49	
Conv. Total (cfs)	39549.9	Conv. (cfs)		39549.9	
Length Wtd. (ft)	50.00	Wetted Per. (ft)		81.78	
Min Ch El (ft)	6255.00	Shear (lb/sq ft)		3.26	
Alpha	1.00	Stream Power (lb/ft s)		39.35	
Frctn Loss (ft)	0.60	Cum Volume (acre-ft)		10.69	
C & E Loss (ft)	0.00	Cum SA (acres)		2.60	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 8 Profile: 100-Year

W.S. Elev (ft)	6256.31	Element	Left OB	Channel	Right OB
Vel Head (ft)	3.49	Wt. n-Val.		0.036	
E.G. Elev (ft)	6259.80	Reach Len. (ft)	48.60	48.60	48.60
Crit W.S. (ft)	6257.21	Flow Area (sq ft)		288.34	
E.G. Slope (ft/ft)	0.022671	Area (sq ft)		288.34	
Q Total (cfs)	4320.00	Flow (cfs)		4320.00	
Top Width (ft)	75.38	Top Width (ft)		75.38	
Vel Total (ft/s)	14.98	Avg. Vel. (ft/s)		14.98	
Max Chl Dpth (ft)	4.61	Hydr. Depth (ft)		3.83	
Conv. Total (cfs)	28690.9	Conv. (cfs)		28690.9	
Length Wtd. (ft)	48.60	Wetted Per. (ft)		77.04	
Min Ch El (ft)	6251.70	Shear (lb/sq ft)		5.30	
Alpha	1.00	Stream Power (lb/ft s)		79.37	
Frctn Loss (ft)	1.09	Cum Volume (acre-ft)		9.63	
C & E Loss (ft)	0.02	Cum SA (acres)		2.34	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 7 Profile: 100-Year

W.S. Elev (ft)	6249.74	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.64	Wt. n-Val.		0.036	
E.G. Elev (ft)	6251.38	Reach Len. (ft)	85.00	85.00	85.00
Crit W.S. (ft)	6249.08	Flow Area (sq ft)		456.49	
E.G. Slope (ft/ft)	0.007842	Area (sq ft)		456.49	
Q Total (cfs)	4690.00	Flow (cfs)		4690.00	
Top Width (ft)	94.80	Top Width (ft)		94.80	
Vel Total (ft/s)	10.27	Avg. Vel. (ft/s)		10.27	
Max Chl Dpth (ft)	5.84	Hydr. Depth (ft)		4.82	
Conv. Total (cfs)	52960.2	Conv. (cfs)		52960.2	
Length Wtd. (ft)	85.00	Wetted Per. (ft)		96.87	
Min Ch El (ft)	6243.90	Shear (lb/sq ft)		2.31	
Alpha	1.00	Stream Power (lb/ft s)		23.70	
Frctn Loss (ft)	0.48	Cum Volume (acre-ft)		5.92	
C & E Loss (ft)	0.15	Cum SA (acres)		1.42	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 6 Profile: 100-Year

W.S. Elev (ft)	6249.60	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.15	Wt. n-Val.		0.036	
E.G. Elev (ft)	6250.75	Reach Len. (ft)	20.00	20.00	20.00
Crit W.S. (ft)		Flow Area (sq ft)		545.54	
E.G. Slope (ft/ft)	0.004315	Area (sq ft)		545.54	
Q Total (cfs)	4690.00	Flow (cfs)		4690.00	
Top Width (ft)	93.80	Top Width (ft)		93.80	
Vel Total (ft/s)	8.60	Avg. Vel. (ft/s)		8.60	
Max Chl Dpth (ft)	7.40	Hydr. Depth (ft)		5.82	
Conv. Total (cfs)	71398.6	Conv. (cfs)		71398.6	
Length Wtd. (ft)	20.00	Wetted Per. (ft)		96.62	
Min Ch El (ft)	6242.20	Shear (lb/sq ft)		1.52	
Alpha	1.00	Stream Power (lb/ft s)		13.08	
Frctn Loss (ft)	0.10	Cum Volume (acre-ft)		4.94	
C & E Loss (ft)	0.14	Cum SA (acres)		1.23	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 5 Profile: 100-Year

W.S. Elev (ft)	6247.96	Element	Left OB	Channel	Right OB
Vel Head (ft)	2.54	Wt. n-Val.		0.026	
E.G. Elev (ft)	6250.51	Reach Len. (ft)	44.00	44.00	44.00
Crit W.S. (ft)	6247.96	Flow Area (sq ft)		366.53	
E.G. Slope (ft/ft)	0.006136	Area (sq ft)		366.53	
Q Total (cfs)	4690.00	Flow (cfs)		4690.00	
Top Width (ft)	72.83	Top Width (ft)		72.83	
Vel Total (ft/s)	12.80	Avg. Vel. (ft/s)		12.80	
Max Chl Dpth (ft)	6.36	Hydr. Depth (ft)		5.03	
Conv. Total (cfs)	59874.4	Conv. (cfs)		59874.4	
Length Wtd. (ft)	44.00	Wetted Per. (ft)		75.85	
Min Ch El (ft)	6241.60	Shear (lb/sq ft)		1.85	
Alpha	1.00	Stream Power (lb/ft s)		23.69	
Frctn Loss (ft)	0.27	Cum Volume (acre-ft)		4.74	
C & E Loss (ft)	0.00	Cum SA (acres)		1.19	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 4.1 Profile: 100-Year

W.S. Elev (ft)	6243.01	Element	Left OB	Channel	Right OB
Vel Head (ft)	4.75	Wt. n-Val.		0.026	
E.G. Elev (ft)	6247.77	Reach Len. (ft)	50.00	37.00	25.00
Crit W.S. (ft)	6244.43	Flow Area (sq ft)		268.10	
E.G. Slope (ft/ft)	0.013890	Area (sq ft)		268.10	
Q Total (cfs)	4690.00	Flow (cfs)		4690.00	
Top Width (ft)	61.58	Top Width (ft)		61.58	
Vel Total (ft/s)	17.49	Avg. Vel. (ft/s)		17.49	
Max Chl Dpth (ft)	5.71	Hydr. Depth (ft)		4.35	
Conv. Total (cfs)	39793.7	Conv. (cfs)		39793.7	
Length Wtd. (ft)	37.00	Wetted Per. (ft)		64.05	
Min Ch El (ft)	6237.30	Shear (lb/sq ft)		3.63	
Alpha	1.00	Stream Power (lb/ft s)		63.49	
Frctn Loss (ft)	0.60	Cum Volume (acre-ft)		3.25	
C & E Loss (ft)	0.01	Cum SA (acres)		0.86	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 4 Profile: 100-Year

W.S. Elev (ft)	6241.40	Element	Left OB	Channel	Right OB
Vel Head (ft)	5.20	Wt. n-Val.		0.026	
E.G. Elev (ft)	6246.60	Reach Len. (ft)	55.00	41.50	32.50
Crit W.S. (ft)	6243.03	Flow Area (sq ft)		256.39	
E.G. Slope (ft/ft)	0.016357	Area (sq ft)		256.39	
Q Total (cfs)	4690.00	Flow (cfs)		4690.00	
Top Width (ft)	62.72	Top Width (ft)		62.72	
Vel Total (ft/s)	18.29	Avg. Vel. (ft/s)		18.29	
Max Chl Dpth (ft)	5.20	Hydr. Depth (ft)		4.09	
Conv. Total (cfs)	36671.1	Conv. (cfs)		36671.1	
Length Wtd. (ft)	41.50	Wetted Per. (ft)		64.76	
Min Ch El (ft)	6236.20	Shear (lb/sq ft)		4.04	
Alpha	1.00	Stream Power (lb/ft s)		73.95	
Frctn Loss (ft)	0.58	Cum Volume (acre-ft)		2.81	
C & E Loss (ft)	0.02	Cum SA (acres)		0.76	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 3 Profile: 100-Year

W.S. Elev (ft)	6239.44	Element	Left OB	Channel	Right OB
Vel Head (ft)	5.61	Wt. n-Val.		0.026	
E.G. Elev (ft)	6245.05	Reach Len. (ft)	35.00	35.00	35.00
Crit W.S. (ft)	6241.19	Flow Area (sq ft)		246.64	
E.G. Slope (ft/ft)	0.019597	Area (sq ft)		246.64	
Q Total (cfs)	4690.00	Flow (cfs)		4690.00	
Top Width (ft)	65.61	Top Width (ft)		65.61	
Vel Total (ft/s)	19.02	Avg. Vel. (ft/s)		19.02	
Max Chl Dpth (ft)	4.74	Hydr. Depth (ft)		3.76	
Conv. Total (cfs)	33502.9	Conv. (cfs)		33502.9	
Length Wtd. (ft)	35.00	Wetted Per. (ft)		67.31	
Min Ch El (ft)	6234.70	Shear (lb/sq ft)		4.48	
Alpha	1.00	Stream Power (lb/ft s)		85.25	
Frctn Loss (ft)	0.79	Cum Volume (acre-ft)		2.33	
C & E Loss (ft)	0.01	Cum SA (acres)		0.64	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 2 Profile: 100-Year

W.S. Elev (ft)	6235.19	Element	Left OB	Channel	Right OB
Vel Head (ft)	7.86	Wt. n-Val.		0.026	
E.G. Elev (ft)	6243.05	Reach Len. (ft)	49.43	48.86	48.29
Crit W.S. (ft)	6237.55	Flow Area (sq ft)		208.46	
E.G. Slope (ft/ft)	0.031108	Area (sq ft)		208.46	
Q Total (cfs)	4690.00	Flow (cfs)		4690.00	
Top Width (ft)	60.76	Top Width (ft)		60.76	
Vel Total (ft/s)	22.50	Avg. Vel. (ft/s)		22.50	
Max Chl Dpth (ft)	3.99	Hydr. Depth (ft)		3.43	
Conv. Total (cfs)	26591.2	Conv. (cfs)		26591.2	
Length Wtd. (ft)	48.86	Wetted Per. (ft)		62.51	
Min Ch El (ft)	6231.20	Shear (lb/sq ft)		6.48	
Alpha	1.00	Stream Power (lb/ft s)		145.70	
Frctn Loss (ft)	0.99	Cum Volume (acre-ft)		1.97	
C & E Loss (ft)	0.10	Cum SA (acres)		0.53	

Plan: plan River: Sand Creek Reach:Reach 1 Riv Sta: 1 Profile: 100-Year

W.S. Elev (ft)	6230.68	Element	Left OB	Channel	Right OB
Vel Head (ft)	4.70	Wt. n-Val.		0.026	
E.G. Elev (ft)	6235.38	Reach Len. (ft)			
Crit W.S. (ft)	6232.10	Flow Area (sq ft)		269.47	
E.G. Slope (ft/ft)	0.017633	Area (sq ft)		269.47	
Q Total (cfs)	4690.00	Flow (cfs)		4690.00	
Top Width (ft)	76.05	Top Width (ft)		76.05	
Vel Total (ft/s)	17.40	Avg. Vel. (ft/s)		17.40	
Max Chl Dpth (ft)	4.68	Hydr. Depth (ft)		3.54	
Conv. Total (cfs)	35318.6	Conv. (cfs)		35318.6	
Length Wtd. (ft)		Wetted Per. (ft)		77.59	
Min Ch El (ft)	6226.00	Shear (lb/sq ft)		3.82	
Alpha	1.00	Stream Power (lb/ft s)		66.54	
Frctn Loss (ft)	0.85	Cum Volume (acre-ft)			
C & E Loss (ft)	0.02	Cum SA (acres)			

REFERENCE REPORTS

SAND CREEK STABILITY – GALLEY ROAD TO POWERS BOULEVARD

Prepared for:

The Sear-Brown Group

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SAND CREEK STABILITY – GALLEY ROAD TO POWERS BOULEVARD

SAND CREEK STABILITY – GALLEY ROAD TO POWERS BOULEVARD

This report is an evaluation of the fluvial stability of a short reach of the upper part of the main stem of Sand Creek, a tributary to Fountain Creek, in El Paso County, Colorado. The report has been prepared in support of design for increased capacity of the sanitary sewer which is located on the margins of Sand Creek between Galley Road and Powers Boulevard, on the east side of Colorado Springs, Colorado. The objective is to provide design information for sewer line protection measures in the near-stream environment. The existing sewer line is located such that segments of it could be destroyed by migration of Sand Creek. (Such destruction has in fact happened on at least one previous occasion, immediately to the north of Galley Road.) This report consists of two parts. The first part briefly covers the geologic setting of the stream, and the natural forces which act to determine the form of the stream – both of which may be grouped as *fluvial geomorphologic determinants* of stream form, which could impact the sewer line. The second part provides recommendations for protection of the sewer line from flood-induced changes to stream geometry.

1. BACKGROUND

1.1 Geomorphic Setting. The geologic environment of Sand Creek is determined by the local bedrock formations and by the soil, most of which has been derived from that bedrock.

Bedrock. Information from the boring logs shows the underlying bedrock to be comprised of at least three formations of sandstone, siltstone or claystone. Some of the formations outcrop in the area, most notably on the right (west) bank of the Creek south of Palmer Park Drive, and in at least two locations in the bed of the Creek, each within about one-half mile upstream and downstream from Galley Road. The right bank outcrop to the south of Palmer Park Drive provides a hard channel boundary for a distance of around 2300 feet. The depth to bedrock under the channel (as indicated by the borelogs) varies between 0 to 12.2 feet, except in the upper one-fourth of the study reach, where bedrock depth was indicated to be greater than 15 feet. There was one small anomaly in bedrock depth determination near stream station 336+00 (test hole 9); where bedrock elevation was indicated to be around 0.5 foot higher than the adjacent stream bed level. Bedrock superelevation could be a possibility if the stream channel were located at a notch in the bedrock. Such a possibility would also be consistent with the stream form in that location. It appears from available data that the stream channel in the lower 2000 feet of the study reach (between stations 316+10 and 336+00) is essentially vertically constrained by bedrock.

Soil Mantle. Soil which overlies the bedrock is primarily a non-cohesive silty sand which is largely derived from the local bedrock. It is readily subject to hydraulic transport, especially when saturated. The effect of such loose boundary material is that the left-side (east) stream margins are largely indeterminate over time: possibly limited locally by a bedrock notch (around Sta 336+00), and limited to a lesser extent by vegetal root integrity at various locations along the bankline.

1.2 Stream Morphology. The stream boundaries are determined by hydraulic forces, which are locally constrained by infrastructure features, bedrock, or well-established vegetation. The channel is a steep sandbed channel which flows under a wide range of regimes, depending on discharge.

Low Flow. Sand creek is an ephemeral stream which, for the greatest proportion of time, has essentially a dry bed. Flow rates which do not exceed a discharge on the order of the mean annual flood are easily accommodated in the channel and generally result temporarily in a braided channel -- where sediment supply is well in excess of transport capacity. However, such low flows could threaten the integrity of the adjacent sewer line if a meander bend were allowed to continually work against the bank over an extended series of smaller discharges. Some stream changes owing to meandering and related bank caving are currently in process at the location of two storm sewer outfalls near stream station 341+00 (Photo 5.)

Bankfull Flow. The channel slope is hydraulically steep. That is, bankfull flow would be in the upper regime (supercritical) if the channel were a rigid-boundary channel. What actually happens during passage of larger-magnitude floods (generally greater than 10-year recurrence interval) is that flows tend to modify the entire channel geometry as the flow regime seeks to establish conditions for minimum specific energy (critical flow). In fully-developed loose boundary upper regime flow, it appears that bed material is in motion to a depth of at least 4 feet below the level of the dry stream bed; and the bed forms are antidunes. Where shallow bedrock depths cause a discontinuity in antidune formation, resistance to flow locally decreases, resulting in localized velocity increases and excess sediment transport energy being directed against the banks. In such cases, stream transport power can not be absorbed by vertical scour, fluidizing of bed material, and bed material transport; so excess energy is available to erode streambanks. Bank erosion will occur where conditions exist to direct hydraulic force vectors into the bankline. Bank erosion therefore happens most readily on outsides of bends, but it can also result when current is deflected into the bank by a rock outcrop, a stabilized sandbar (Photo 7.), or a large displaced object such as a tree or a joint of large-diameter concrete pipe. Where the channel alignment is essentially straight, it tends to maintain that alignment as a result of flow momentum. Therefore, areas most likely to experience instability are at left bank locations where the channel bends to the right. When such bends are located over shallow bedrock, the rate of bend migration under flood flows can be quite dramatic -- as has been previously experienced upstream of Galley Road.

2. ANALYSIS

This stability analysis considers boundary- normal hydraulic force vectors and boundary shear forces associated with the 100-year return period flood, along the length of the study reach.

2.1 Hydraulic Forces. Force vectors of concern are those which act against the bank, setting up (spiral) secondary currents which -- in combination with shear forces -- result in lateral movement of the bankline. Those normal forces are *qualitatively* considered by noting locations at which they are most likely to result in attack of bank material. Shear forces are *quantitatively* analyzed by direct computation of boundary shear as the product of specific weight of water, hydraulic radius, and energy slope, or:

$$\tau = \gamma RS,$$

where: τ is boundary shear force in pounds per square foot; γ is specific weight of water in pounds per cubic foot; R is hydraulic radius of the water cross-section in feet; and S is slope of the energy grade line in feet per foot. Boundary shear computations have been done for each stream cross-section at a test hole location; and are summarized in Table 1.

Table 1. Bedrock Locations and Boundary Shear Force Elements in the Study Reach

(1) Test Hole	(2) Stream Station	(3) Hole Elev.	(4) Bedrock Depth	(5) Bedrock Elev.	(6) Bed Elev.	(7) Flow Depth	(8) Energy Slope	(9) Boundary Shear
1	369+14	6331.5	>15.5	<6316.0	6322.1	2.0	0.017	2.12
2	365+00	6325.0	>15.5	<6309.5	6316.2	2.0	0.017	2.12
3	359+67	6314.0	>15.5	<6298.5	6307.3	2.5	0.017	2.65
4*	**	6305.0	-16.5	6288.5	**	**	**	**
5	352+45	6296.0	-13.0	6283.0	6295.2	4.2	0.00825	2.16
6	348+32	6293.5	-13.0	6280.5	6287.8	4.6	0.017	4.88
7	345+00	6288.0	-13.5	6274.5	6282.3	4.9	0.017	5.20
8	340+17	6281.0	- 7.0	6274.0	6274.5	4.9	0.017	5.20
9	336+00	6276.0	- 7.0	6269.0	6268.5	5.4	0.017	5.73
10	334+06	6267.0	- 4.0	6263.0	6265.3	5.3	0.017	5.62
11	322+46	6256.5	- 9.0	6247.5	6247.4	5.9	0.0196	7.32
12	320+95	6253.0	- 9.0	6244.0	6244.9	5.6	0.0196	6.85
13	316+10	6247.0	-13.0	6234.0	6235.6	4.9	0.02318	7.09

(1) Test hole number from geotech. boring of 5-15-98. (* - Location not available for T.H. 4; ** - information to be determined based on location information for T.H. 4)
(2) Approximate stream stationing from SCS/CWCB <u>Flood Hazard Analysis</u> (FHA) July 1973
(3) Ground elevation (ft., MSL) at test hole location (per D.Silar note 11 June 98)
(4) Depth to bedrock (ft.) from surface (per geotech. borelogs of 5-15-98)
(5) Bedrock elevation (ft., MSL) [column (3) plus column (4)]
(6) Stream bed elevation estimated from contour mapping of June 1998
(7) Depth of stream flow estimated from SCS/CWCB <u>FHA</u>, July 1973
(8) Slope of water surface estimated from SCS/CWCB FHA, July 1973
(9) Boundary shear force computed by $\tau = \gamma RS$

In the absence of specific hydraulic cross-section data for computation of area and wetted perimenter, R has been approximated by flow depth (which results in a conservative estimate for R in regard to computation of boundary shear). Flow depths have been estimated from the profile plots in the SCS/CWCB Flood Hazard Analysis, along with S, the slope of the energy grade line - approximated by the slope of the water surface profile. (Although Flood Hazard Analysis dates from 1973, it is the available data source which provides computed flow depths and water surface slopes based on field measurements of stream geometry. The stream stationing from that report was also used, so that flow depths and water surface slopes could be related as closely as possible to physical locations of the test holes.)

2.2 Stream Form. Several conclusions about possible stream morphology can be drawn from an examination of Table 1. By comparing bedrock elevation(column 5) to streambed elevation (column 6), shallow bedrock between stream stations 316+10 and 340+17 is indicated. Shallow bedrock can provide conditions for rapid lateral migration of streambanks in response to normal forces. Also in regard to bedrock proximity, it appears that the present sewer crossing location, near station 351+50, is not into bedrock; nor would a possible alternative location upstream of Palmer Park Bridge be into bedrock. Therefore a buried pipeline crossing would require scour protection at either location. The depth of required scour protection cannot be readily discerned from the grain size analyses (included in the Appendix), as no grain sizes sufficiently large to constitute bed armoring are present in any of the grain size determinations. (Design of scour protection measures is covered in the section which follows.) The boundary shear values in column 9 generally increase in a downstream direction from the Powers Boulevard crossing. Since boundary shear is related directly to grain size for stable riprap installations, the effective size of riprap required for stream stabilization measures increases with distance downstream from Powers. Stable riprap size for angular rock at a sideslope of 1:2.5 is related to boundary shear by the expression:

$$D = 0.47\tau,$$

where D is the effective riprap grain size, which is most commonly the D65, or the mean rock dimension for which 65 percent of the sample size is smaller. Based on that size relationship, the required effective riprap size would vary along the reach from 1.01 feet to 3.44 feet.

3. RECOMMENDATIONS

These recommendations cover design aspects based upon past experience with the existing sewer line, making allowance for stream morphologic processes which have been covered in preceding sections, and stream environment pipeline protection measures implemented on the Trans-Alaska Pipeline System.

3.1 Past Experience. Past experience with design of the existing sewer line can be valuable in addressing questions about alignment and scour protection. The location of the existing sewer line appears to have been generally safe from the effects of stream migration -- with four exceptions. The one location where line failure has occurred, plus three others where failure seems certain to occur in the near future, are near stream stations 356+50, 351+50, 334+75, and 316+10. At station 351+55, the manhole is currently located directly on the edge of the active stream bed; it does not appear that the sewer line has been damaged by the stream so far – most likely due to scour protection associated with the stream crossing and a manhole location on the *inside* of a bend. A manhole and line location further east of the active channel would seem prudent. If no failures of the existing stream crossing have happened in the past, it may also be enlightening to review the original design of scour protection measures at that crossing. At stations 356+50 and 334+75, bank caving associated with unstabilized inflow points for overland flows could remove support from the nearby manholes. It is not clear why the line and manhole near station 356+50 have not been damaged so far. Around station 334+75, the straight reach of channel and proximity of bedrock may be preventing more active erosion. Near station 316+10, the sewer line was previously damaged when inadequately-installed bank stabilization measures failed, allowing the bend to laterally migrate a distance greater than 50 feet during the passage of a single flood event.

3.2 **Stream Morphology.** The attention given to protective measures should vary with location on the stream. This section indicates specific locations on the stream where stability measures will be required, either as part of the current sewer work or as a part of future stream stabilization measures. Relative stability of the existing stream geometry tends to decrease in a downstream direction from Powers Boulevard. The sub-reach between Powers to immediately downstream of Palmer Park has sufficient sediment depth below the dry-channel streambed elevation to allow for full development of an antidune flow regime during flood passage. The stream boundaries are therefore able to provide for a balance between stream power and resistance to flow during flood passage, which results in a minimal tendency for the stream to meander during flood flows. However, possible vertical scour still may be an issue in the upper sub-reach. With the sewer line stream crossing located in this reach, specific scour protection measures around the pipeline will be required. The possibilities for stream meandering increase downstream of Palmer Park, but are constrained on the right bank by bedrock outcrop to ← around station 343+00. A possible tendency for low-flow meandering exists between stations 350+00 and 348+00. The left bank is presently unstable between stations 342+00 and 340+00 due to unstabilized inflow points and point bar formation along the right bank. A similar possible future problem exists near station 335+00, but it is not currently exacerbated by unstabilized storm sewer outfalls or point bar formation on the opposite bank. A straight channel alignment at that location also tends to minimize meander tendencies as well. Significant lateral meander tendencies should be ← anticipated between stations 332+00 to 327+00. A bendway situated over shallow bedrock is fairly certain to result in lateral stream migration tendencies. Willow growths have locally tended to check stream migration; but there is currently active left bank erosion near station 328+00, where the toe of the existing streambank is within 15 feet of the indicated sewer line location. A straight channel which transitions into existing stabilized sections runs between stations 326+00 to 317+00. High velocities, and related excess stream power, can be expected along this straight reach; but meander tendencies do not currently exist. Some possible future problems may be experienced with some of the existing riprap around station 320+00, which appears to be unstable as placed and grouted. The existing stream bed appears to be lower than the extent of in-place bank protection at some locations – which could set up future conditions for undermining and failure of that bank protection. Bank protection is critical at that location, as conditions favorable to flanking of the two downstream drop structures exist in the event of bank protection failure.

3.3 **Pipeline Protection Measures.** Protection measures are appropriate when the potential for pipeline damage due to vertical or lateral scour exists.

Channel Crossing. The pipeline crossing location may be hazarded as a result of vertical scour. The recommended approach for design of scour protection is to concrete encase the sewer line crossing from 20 feet back of the bank toes, then provide riprap scour protection (over the entire length of encasement) which, when moved (launched) by design flow rates, will result in a riprap covering over the encasement with a minimum depth of two feet and a downstream slope of 4h:1v. A graded riprap with a specific gravity of 2.65 and a D65 of 1.25 feet (D50 = 0.90'; D100 = 1.80') would be appropriate for that application. A total depth of scour of 8 feet should be considered in design (4' for antidune formation and 4' for local scour due to vertical velocity components formed by the pipeline crossing works).

Channel Banks. Bankline protection against lateral scour is recommended at four locations (Stations 350+00--348+00; 342+00--340+00; 335+00; and 332+00--327+00). Design criteria should include side slopes not steeper than 2.5:1; extension of riprap blankets to bedrock when it lies within 4 feet of the channel bottom; and when bedrock is more than 4 feet below channel bottom, lower termination of riprap blankets in a toe trench with sufficient volume to armor to a depth of 6 feet below the elevation of the dry channel bottom.

In/Along H. Hays Haven, by So. end of existing crossing on So. side of bridge.

Low-flow meander protection is advisable from station 350+00 to 348+00 (riprap with D65 > 2.30').

Culvert area along So. Side of H. Hays Haven

The existing bank instability between stations 342+00 and 340+00 should be addressed by a combination of stabilized rundowns to accommodate inflows, plus bank protection transitioning into and away from stabilized rundowns (riprap with D65 > 2.45').

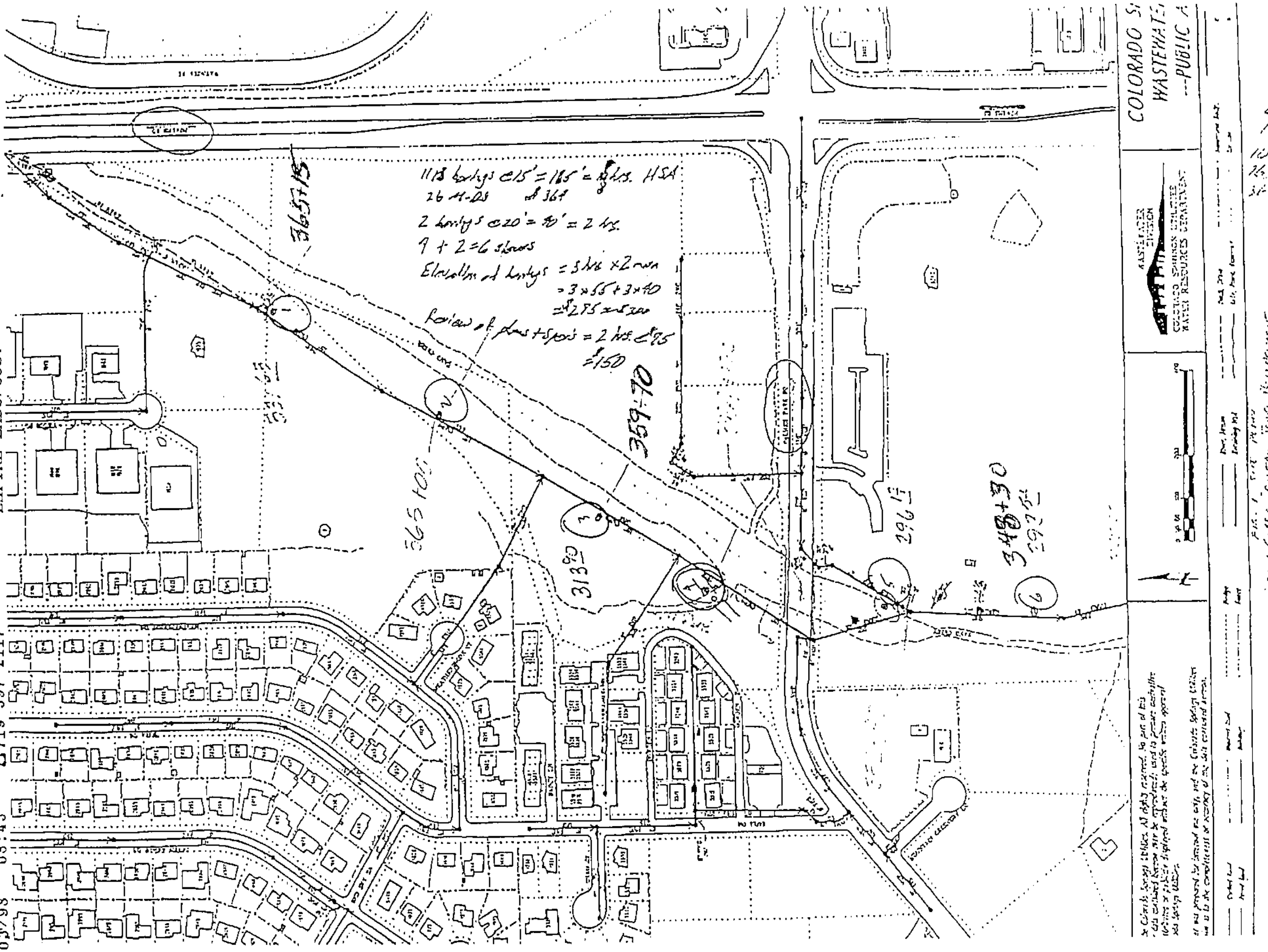
Similar measures to those immediately upstream would be appropriate for the surface runoff inflow point near station 335+00 (riprap with D65 > 2.70'). side drainage from Rustic Hills Subdivison

The currently-active bend erosion between stations 332+00 and 327+00 should be addressed by a combination of bankline fairing to re-establish a smooth bend geometry, followed by riprap bank protection (D65 > 2.90).

For near-future consideration, it would also be advisable to stabilize the left bankline of the straight sub-reach between stations 326+00 to 320+00 with continuous willow plantings above a riprap toe trench which should extend to bedrock. appears to be covered 12+40 to 17+40

Some of these recommendations extend beyond the immediate scope of sewer line protection; but the project owner should be aware of pipeline protection issues not covered by the scope of the present work. Protection of the proposed sewer line crossing is within the scope of the contract; while necessary bank protection measures are not.

The remainder of this report includes photographs of selected locations and an Appendix of sub-surface exploration results.



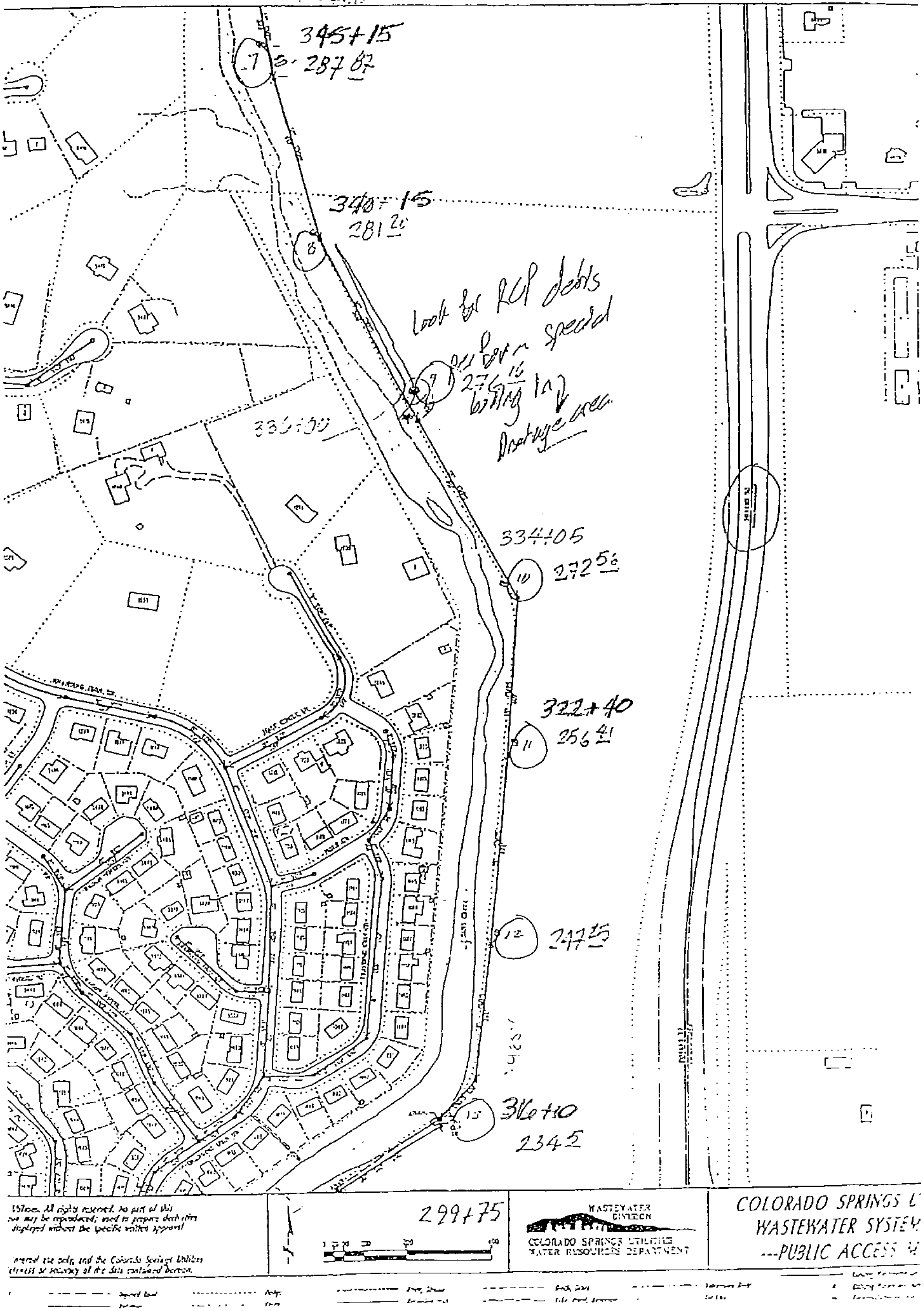
11 borings @15' = 165' = 4 hrs. HSA
26 H-DS @ 364

2 borings @20' = 40' = 2 hrs.

4 + 2 = 6 hours

Elevations of borings = 3 hrs × 2 men
= 3×55 + 3×40
= $295 use $300

Review of plans + specs = 2 hrs. @$75
= $150



SAND CREEK SEWER

345+15
287 87

340+15
281 20

look for RCP debris on berm spread
276 16
bedding in
Drainage area

333+00

334+05
272 56

322+40
256 41

247 25

316+10
234 5

299+75

WASTEWATER DIVISION
COLORADO SPRINGS UTILITIES
WATER RESOURCES DEPARTMENT

COLORADO SPRINGS U
WASTEWATER SYSTEM
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COLORADO SPRINGS UTILITIES LETTER

Colorado Springs Utilities
It's how we're all connected

Water Resources
Infrastructure Services

September 12, 2000

Mr. David Lethbridge
City of Colorado Springs
Department of Planning,
Development and Finance
Stormwater and Subdivision
101 West Costilla Street
Colorado Springs, CO 80903

RE: Sand Creek Sanitary Sewer Trunk Line

Dear Dave:

Colorado Springs Utilities, Water Resources Department has been corresponding with Chris Smith of Tigre Development Services, Inc. concerning stream channel lining/erosion control requirements for the proposed Creekside Center and "Future Apartment Complex" located along Sand Creek, north of Galley Road.

As per your March 14, 2000 letter, WRD will be responsible for the lining/erosion control improvements on the west side of Sand Creek through the above captioned development area. The west bank improvements on the north side of the existing drop structure located near Sanitary Sewer Trunk Line station 5+00 will be constructed this fall by the developer.

The remaining west bank improvements will be constructed by WRD during the first quarter of 2001, as part of the sewer line replacement project. Other bank protection improvements, as generally described in previous WRD submittals will also be completed.

As WRD now has definite plans from the developer, we will complete our final submittals for protection improvements by mid-October. Final QRD plans will be compatible with the developer plans where necessary.

If you have any questions or comments, please give me a call.

Thank you.

Sincerely,

Orig. Signed RSD 9/12/2000

Richard S. Dressel
Project Manager

c. Jane Fredman

East Las Vegas Street
rado Springs, CO 80903-4348

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