FINAL
HYDROLOGY & HYDRAULICS REPORT
FOR STATE HIGHWAY NO. 21
POWERS BLVD CORRIDOR IMPROVEMENTS
SOUTH CAREFREE CIRCLE TO
DUBLIN BLVD. PROJECT
COLORADO SPRINGS, COLORADO

A Part of Sections 7, 18, 19, 30, and 31 Township 13 South, Range 65 and
Sections 12, 13, 24, 25, and 36 Township 13 South, Range 66 West of the 6th P.M.,
City Colorado Springs and County of El Paso, Colorado

Submittal: June 25, 2014

Prepared for:
Colorado Department of Transportation
1480 Quail Lake Loop, Suite A
Colorado Springs, CO 80906

Prepared by:
Felsburg Holt & Ullevig
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FHU Reference No. 12-266-09
CDOT Project SHE 0212-006, Sub Account No. 19500

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 area. I accept responsibility for any liability caused by any negligent acts, errors, or omissions on my part in preparing this report.

COLORADO REGISTERED KEVAN P. KUHNEL 42726 PROFESSIONAL ENGINEER 10-29-2014

Kevan P. Kuhnel, Colorado P.E. # 42726 Date
For and On Behalf of Felsburg, Holt, and Ullevig

CDOT STATEMENT:

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

Owner: Colorado Department of Transportation

By: Andrew Stecklein

Title: CDOT Region 2 – North Program Hydraulics Engineer

Address: 1480 Quail Lake Loop
Colorado Springs, CO 80906

Phone Number: 719/227-3264

CITY OF COLORADO SPRINGS ONLY:

Filed in accordance with Section 7.7.906 of the Code of the City of Colorado Springs, 2001, as amended.

Lydia A. Marsing 11/5/14
For the City Engineer Date

Conditions:

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1. GENERAL LOCATION AND DRAINAGE OVERVIEW

1.1 Location of Improvements

This report presents the hydrologic and hydraulic analysis for the State Highway 21 improvements. The project consists of adding acceleration and deceleration lanes along the Powers Blvd (SH 21) corridor between South Carefree Circle and Dublin Blvd. The scope will consist of constructing 12 foot auxiliary lanes and 4 foot shoulders on the outside. Drainage will be conveyed by a combination of proposed roadside ditches and curb and gutter to the existing storm sewer infrastructure. The areas adjacent to the project are a mix of commercial, residential, and undeveloped rangeland uses. The project is located in a part of Sections 7, 18, 19, 30, and 31, Township 13 South, Range 65 and Sections 12, 13, 24, 25, and 36 Township 13 South, Range 66 West of the 6th P.M.., City Colorado Springs and County of El Paso, Colorado. **Figure 1** indentifies the overall project limits and **Figure 2** contains the soils map.

1.2 Discussion of Existing and Proposed Drainage Conditions

The project area generally drains from north to south and west to east into Sand Creek. There is a small portion of the north most project area draining west to Cottonwood Creek. No portion of the project area is within the 100 year floodplain, see **Appendix A** for FEMA Floodplain Maps. Generally, the corridor can be broken into eleven segments from intersection to intersection. See **Appendix D** for Proposed Basin Maps. Erosion and flooding have been ongoing problems for the corridor do to the lack of existing roadside drainage facilities. Currently, the water follows the path of least resistance and finds its way downstream to the nearest culvert or inlet. The only existing storm sewer infrastructure is typically located near the intersecting streets conveying runoff east to Sand Creek or west to Cottonwood Creek. A component of this project is to improve, as much as economically possible, the stormwater conveyance along the roadway and improve routing to the existing storm sewer system. See **Appendix B** for Hydrologic calculations and **Appendix C** for Hydraulic calculations. A number of options were explored such as inlets with storm sewer, riprap lined roadside ditches, curb and gutter, and concrete lined ditches. Ultimately, the project is driven by a tight construction budget, so it was determined a combination of permanent turf reinforcement mats (TRMs), rock check dams, and riprap in the proposed roadside ditches would be the most economical solution. Also, there are a few areas where proposed curb and gutter were necessary due to existing utility and grading constraints. These fixes are not all optimum long-term solutions and in some cases will not fully comply with CDOT's standards. Ultimately, considering the numerous project constraints, the fixes will vastly improve the current drainage conveyance issues until the Powers corridor is upgraded to a grade separated freeway.

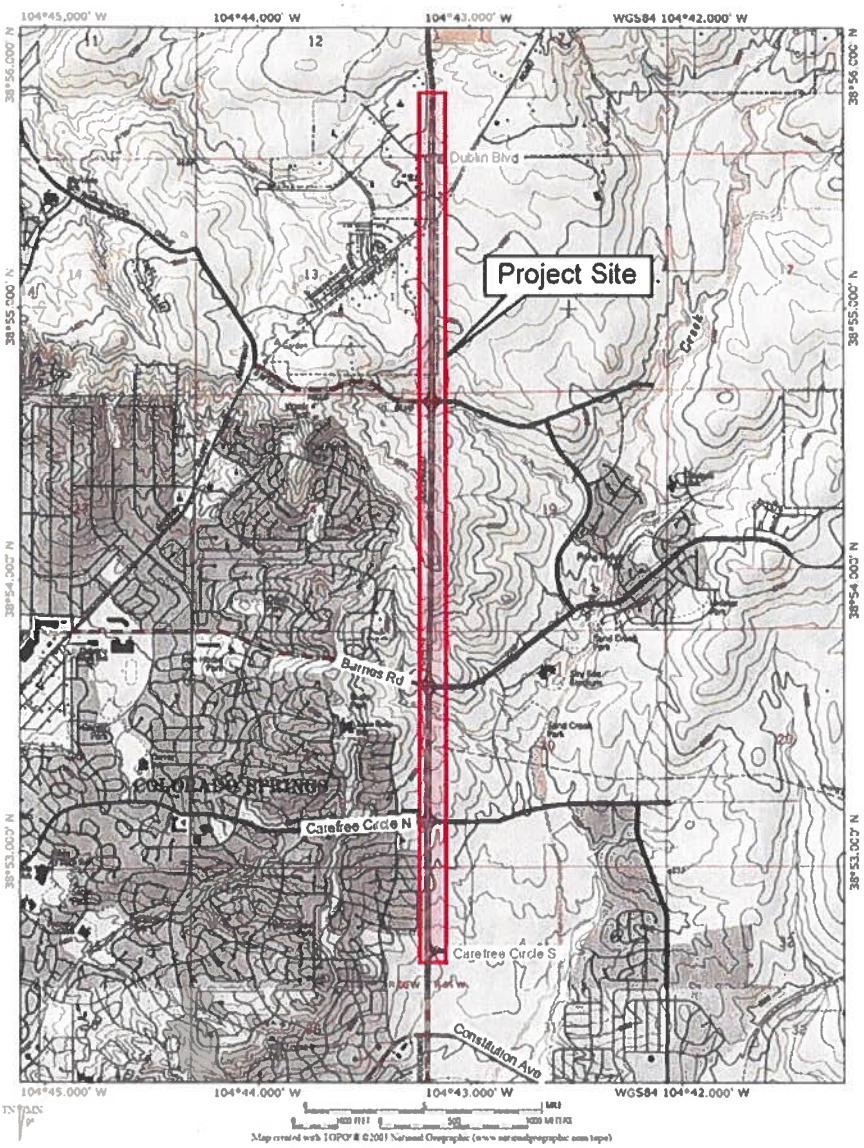


Figure 1. Vicinity Map

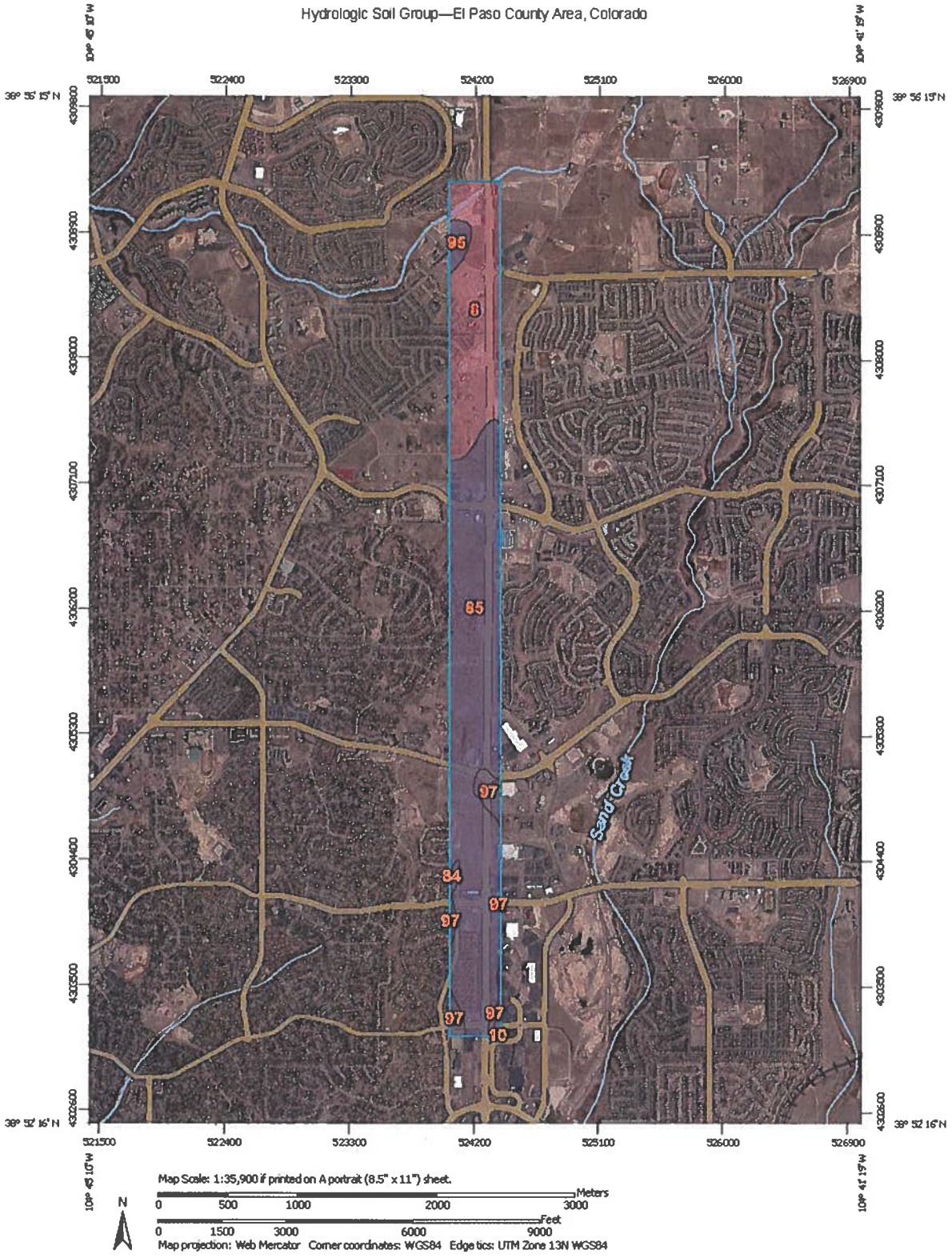


Figure 2. Soils Map

Hydrologic Soil Group— Summary by Map Unit — El Paso County Area, Colorado (CO625)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
8	Blakeland loamy sand, 1 to 9 percent slopes	A	162.4	28.4%
10	Blendon sandy loam, 0 to 3 percent slopes	B	1.7	0.3%
84	Stapleton sandy loam, 8 to 15 percent slopes	B	2.9	0.5%
85	Stapleton-Bernal sandy loams, 3 to 20 percent slopes	B	368.0	64.2%
95	Truckton loamy sand, 1 to 9 percent slopes	B	11.6	2.0%
97	Truckton sandy loam, 3 to 9 percent slopes	B	26.2	4.6%
Totals for Area of Interest			572.9	100.0%

Figure 2. Soils Map Legend

2. DRAINAGE BASINS

Per the direction of the CDOT Project Manager, the scope of this Hydrology and Hydraulics Report was limited to the proposed improvement areas and corresponding basins. Hydrology and hydraulics for the existing conditions was not performed on the basins, roadside ditches, or conveyance facilities. Additionally, the hydraulic analysis of the roadside ditches was limited to the 100-yr storm wherever both the 10-yr and 100-yr storm were contained within the ditch cross section. Both the 10-yr and 100-yr storms were analyzed when either the ditch capacity was exceeded or the design included curb and gutter spread calculations. The hydraulic calculations can be found in **Appendix C**.

Proposed Drainage Basins

- Basin A1 is 2.59 acres in size and includes the eastern half of Powers Blvd from South Carefree Circle north 1400'. The western edge of the basin follows the center line of the median and the eastern edge generally follows the ROW line. The basin slopes from north to south at 2-6% and flows south into an existing 36" RCP Flared End Section located at Design Point 1. Runoff is conveyed to Design Point 1 via a proposed TRM lined trapezoidal roadside ditch.
- Basin A2 is 2.59 acres in size, due north of Basin A1, and is similarly shaped. The basin slopes from north to south at 2-5% and flows south into Basin A1 via a proposed TRM lined trapezoidal roadside ditch.

- Basin B1 is 2.40 acres in size and includes the eastern half of Powers Blvd from the highpoint in Powers Blvd between North Carefree Circle and Barnes Rd, south roughly 1400' to an existing 36" RCP Flared End Section. The western edge of the basin follows the center line of the median and the eastern edge generally follows the ROW line. The basin slopes from north to south at 0.5-4% and runoff will be conveyed through a combination of proposed curb and gutter and TRM lined trapezoidal roadside ditch. The curb and gutter will be installed in the northernmost 200' of the basin. Due to the limited size of the basin contributing to the curb and gutter and similar characteristics of this basin to Basin B2, spread width was determined to be similar, if not less, to that found in Basin B2.

- Basin B2 is 0.73 acres in size and immediately north of Basin B1. This basin lies on the north side of the highpoint in Powers Blvd., between North Carefree Circle and Barnes Rd, and extends north roughly 390'. Runoff is conveyed north via a combination of proposed curb and gutter, then a proposed TRM lined trapezoidal roadside ditch at 0.5%, and ultimately into an existing riprap rundown. The riprap rundown routes the flows east through an existing grass and rock lined drainage swale similar to historic conditions. The curb and gutter spread for the 10-year storm is 10.40' and 100-year storm is 13.14'. Both storms will encroach into the auxiliary lane. Basin B2 does not meet CDOT's standards for spread width, but was deemed appropriate by CDOT based on the same reasoning as described in Basin C1.

- Basin C1 is 11.25 acres in size and includes the western half of Powers Blvd from the highpoint in Powers Blvd between North Carefree Circle and Barnes Rd, south to the existing grate inlets at the northwest corner of the intersection of North Carefree Circle and Powers Blvd. In the north half of the basin, the western edge of the basin extends to Rio Vista Dr. and the eastern edge is bound by the median island. The basin tapers in the southern half and is loosely bound by the ROW line and median island. The basin slopes from west to east and north to south. Proposed curb and gutter will route the flows from north to south at slopes ranging from 1-4%. The curb and gutter will outfall a portion of the runoff into a proposed Type 5 embankment protector. The embankment protector ties into an existing drainage swale that routes flows another 100' south to two existing Type C inlets. The remaining bypass flows will continue south, similar to historic conditions, to an existing combination inlet located in the sump of the right turn lane. Basin C1 was originally designed to convey flows to the existing Type C inlets per the METEX Powers Boulevard Phase 2 Construction Plans, by KKBNA Incorporated Consulting Engineers, dated 9-15-1987. The capacity of the existing combination inlet was not analyzed as it was beyond the scope of this Report, though it is likely undersized. Accounting for the original design intent and potentially undersized inlet were the drivers behind installing the proposed Type 5 embankment protector to relieve flows to the existing combination inlet. The spread for the 10-year storm is 14.26' and will encroach 10.26' into the auxiliary lane. To limit the spread to the shoulder only, it would have required an additional 10.26' of shoulder, additional utility relocations, and likely a retaining wall. The spread for the 100-year storm will encroach 4.17' into the travel lane. Currently there is little to no shoulder, so the outside travel lane is frequently inundated. The proposed project improvements will result in improved drainage conveyance. Due to the limited project budget and fact that Powers Blvd will be upgraded to a grade separated freeway in the future, the design was deemed appropriate by CDOT.

- Basin D1 is 2.75 acres in size, immediately north of Basin C1, and includes the western half of Powers Blvd from the highpoint in Powers Blvd between North Carefree Circle and Barnes Rd, north roughly 300' to an existing low point in Powers Blvd. The basin extends west to near Rio Vista Dr. incorporating a large undeveloped offsite area. The eastern basin edge is bound by the median island. Runoff sheet flows from west to east into the proposed curb and gutter. The curb and gutter conveys the flows north to Design Point 6 at a slope of roughly 0.7%. Design Point 6 is located at the low point in Powers Blvd where a proposed Type 5 Embankment Protector will be installed to convey runoff from the roadway into a roadside ditch. Design Point 6 combines runoff from Basins D1, D3, and D5 bypass. Along the curb and gutter, spread for both the 10-year=10.82' and 100-year=16.08' storms will encroach into the auxiliary lane. The 100-yr storm will also encroach 0.08' into the travel lane. Basin D1 does not meet CDOT's standards for spread width, but was deemed appropriate by CDOT based on the same reasoning as described in Basin C1.

- Basin D2 is 8.72 acres and includes a large undeveloped offsite basin adjacent to the west side of Powers Blvd and directly north of Basin D1. This basin is largely undeveloped rangeland sloping from west to east at 10-20%. The eastern edge of the basin is a proposed TRM lined trapezoidal roadside ditch that conveys the combined runoff from Design Point 6 and Basin D2. The roadside ditch starts at the Type 5 Embankment Protector described in Basin D1, slopes from south to north at 0.5%, and outfalls into an existing grate inlet located at Design Point 7. The capacity of the south end of the roadside ditch, at the outfall to Design Point 6, will be exceeded by 0.05' in the 100-year storm and could result in some ponding on the shoulder and auxiliary lane. This condition is caused by the limited fall from the existing low point in Powers Blvd to the existing grate inlet at Design Point 7. The roadside ditch quickly increases in depth moving from south to north and therefore minimizes the area exceeding design capacity. Design Point 7 combines runoff from Basins D1, D2, D3, D4 and D5.
- Basin D3 is 1.48 acres and includes the west half of Powers Blvd from north of Basin D1, extending north to the intersection of Barnes Rd and Powers Blvd. Runoff will be conveyed south via proposed curb and gutter to the Type 5 Embankment Protector located at Design Point 6 and previously described in Basin D1. Additional runoff from Basin D5 bypass flows (Q_{10}=3.65 cfs, Q_{100}=8.22 cfs) will also enter the north end of this basin. The spread for the 10-year storm is 15.41' and will encroach into the auxiliary lane. Also, the 100-year storm spread is 19.75' and will encroach 3.75' into the travel lane. With the installation of the Type 5 Embankment Projector at the northern limits to this basin, the runoff will be reduced from existing conditions. Basin D3 does not meet CDOT's standards for spread width, but was deemed appropriate by CDOT based on the same reasoning as described in Basin C1.
- Basin D4 is 0.53 acres and includes a small sliver behind the curb line on the west side of Powers Blvd. The western edge of the basin starts roughly 200' west of the intersection of Barnes Rd and Powers Blvd and extends south to the existing grate inlet located at Design Point 7. Runoff for this basin is conveyed from north to south via a proposed TRM lined trapezoidal swale sloped at 1-6%. Additional runoff from Basin D5 (Q_{10}=2.15 cfs, Q_{100}=2.98 cfs), captured by the Type 5 Embankment Protector and later described in Basin D5, will enter into the north end of this basin.
- Basin D5 is 3.71 acres and includes the south half of Barnes Rd from the intersection of Barnes Rd and Powers Blvd west to the highpoint in Barnes Rd near Solar Ridge Dr. The roadway slopes from west to east at slopes ranging from 1.5-10%. Runoff is conveyed via curb and gutter to the proposed Type 5 Embankment Protector located at the southwest corner of Barnes Rd and Powers Blvd. The Embankment Protector has a captured flow of (Q_{10}=2.15 cfs, Q_{100}=2.98 cfs) that is conveyed south to Basin D4. The bypass flow (Q_{10}=3.65 cfs, Q_{100}=8.22 cfs) continues east into Basin D3.

- Basin E1 is 2.43 acres in size and includes the eastern half of Powers Blvd from Barnes Rd north 1100'. The western edge of the basin follows the center line of the median and the eastern edge generally follows the ROW line. The basin slopes from north to south at 3-7% and flows south into an existing Type C Grate Inlet located at Design Point 2. Runoff is conveyed via a proposed TRM lined trapezoidal roadside ditch on the north end of the basin into an existing riprap lined v-swale.
- Basin E2 is 5.55 acres in size, due north of Basin E1, is similarly shaped, and extends north to the highpoint in Powers Blvd. The basin slopes from north to south at 1.5-7% and flows south into Basin E1. Starting on the north end of the basin, runoff is conveyed south via an existing grass lined v-swale, existing riprap lined v-swale, proposed curb and gutter, and then a proposed TRM lined trapezoidal roadside ditch. The spread in the curb and gutter section for the 10-year storm is 11.82' and the 100-year storm is 15.43'. Both storms will encroach into the acceleration lane. Basin E2 does not meet CDOT's standards for spread width, but was deemed appropriate by CDOT based on the same reasoning as described in Basin C1.

- Basin F1 is 9.72 acres in size and includes a portion of the western half of Powers Blvd from the highpoint between Barnes Rd and Stetson Hills Blvd, north 800'. The western portion of the basin includes a portion of the High Chaparral Open Space and the eastern boundary follows the median island in Powers Blvd. The basin slopes from west to east at roughly 10% until reaching a roadside ditch along the west edge of Powers Blvd. The roadside ditch conveys drainage from south to north at a slope of 0.7-3%. The southern half of the ditch is an existing grass lined v-swale that will convey runoff north into a proposed TRM lined trapezoidal ditch. Drainage will continue north into Basin F2.
- Basin F2 is 6.16 acres in size and north of Basin F1. The basin slopes from west to east at 10% until reaching a roadside ditch along the west edge of Powers Blvd. Basin F1 flows combine with Basin F2 runoff and are conveyed north via a proposed TRM lined trapezoidal roadside ditch at 2-3%. The runoff routes to a few existing Type C grate inlets located at Design Point 3.

- Basin G1 is 5.93 acres in size and mostly includes a large undeveloped area west of Powers Blvd and north of Stetson Hills Blvd. This area is comprised of mostly rangeland with a small portion of a parking lot and a single family home. The basin slopes from northwest to southeast are roughly 10%. Runoff travels overland via sheet flow and shallow swales until reaching an existing riprap lined swale near the southern basin limits. At this swale, the basin combines with flows from Basin G2 and routes south into a 58"x36" CMP arch pipe located at Design Point 4.
- Basin G2 is 8.07 acres in size, immediately north of Basin G1, and extends north to the highpoint in Powers Blvd. The basin is bound on the west by two large lot residential home sites and on the east by the median in Powers Blvd. Topography slopes from west to east at 20% into a proposed TRM lined trapezoidal roadside ditch along the west edge of Powers Blvd. The roadside ditch conveys runoff from north to south into Basin G1 at slopes of 0.6-5%.

- Basin H1 is 2.18 acres in size and includes the eastern half of Powers Blvd from Stetson Hills Blvd north 900'. The western edge of the basin follows the center line of the median and the eastern edge generally follows the ROW line. The basin slopes from north to south at 3-6% and flows south into an existing Type C grate inlet located at Design Point 5. The runoff is conveyed via a combination of proposed TRM lined v-swale at the northern extents and a TRM lined trapezoidal roadside ditch for the remaining southern portion.
- Basin H2 is 1.88 acres, due north of Basin H1, is similarly shaped, and extends north to the highpoint in Powers Blvd. The basin slopes from north to south at 1-4% and flows south into Basin H1 via a proposed TRM lined v-swale roadside ditch.

3. DRAINAGE DESIGN CRITERIA

The Rational Method was used to estimate storm water runoff anticipated from design storms with 10-year and 100-year recurrence intervals. The design storms were calculated using a mix of the City of Colorado Springs\El Paso County Drainage Criteria Manual and Urban Drainage and Flood Control District's Urban Storm Drainage Criteria Manual. Hydraulic calculations were performed on the proposed roadside ditches, Type 5 Embankment Protectors, and curb and gutter sections using Bentley FlowMaster. Turf Reinforcement Mats were analyzed for shear stress using ErosionWorks by American Excelsior Company. ErosionWorks output for the worst case, highest flow with steepest slope, TRM application has been included in **Appendix C**

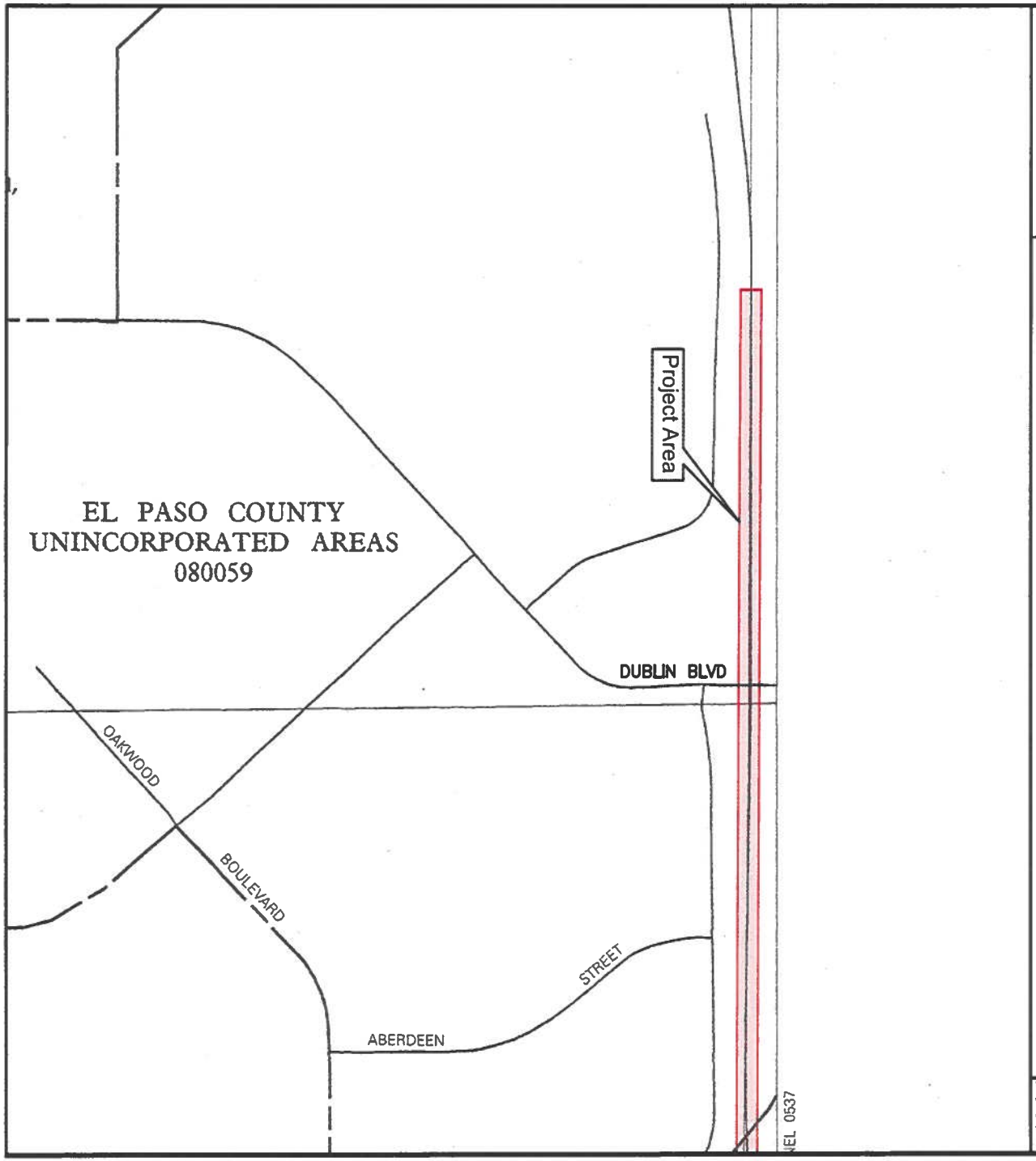
4. PERMANENT BEST MANAGEMENT PRACTICES

See the Final Water Quality Letter for State Highway No. 21, prepared by Felsburg Holt & Ullevig, dated June 25, 2014 for information on permanent BMPs, water quality maps, and forms.

5. REFERENCES

1. Felsburg Holt & Ullevig, progress and field meetings with staff from CDOT, various dates.
2. Urban Drainage and Flood Control District, Urban Storm Drainage Criteria Manual (USDCM), Volumes I, II, and III.
3. Colorado Department of Transportation, Drainage Design Manual, 2004.
4. City of Colorado Springs and El Paso County Drainage Criteria Manual revised 1994.
5. "Hazard Classification Report, Sand Creek Detention Basin No. 1," dated July 15, 1996, prepared by Kiowa Engineering Corporation.
6. Metropolitan Expressway District (METEX) Powers Boulevard Phase 2 Construction Plans, by KKBNA Incorporated Consulting Engineers, dated 9-15-1987

APPENDIX A FEMA FLOODPLAIN MAPS



APPROXIMATE SCALE IN FEET

500 0 500

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

EL PASO COUNTY, COLORADO AND INCORPORATED AREAS

PANEL 536 OF 1300

(SEE MAP INDEX FOR PANELS NOT PRINTED)

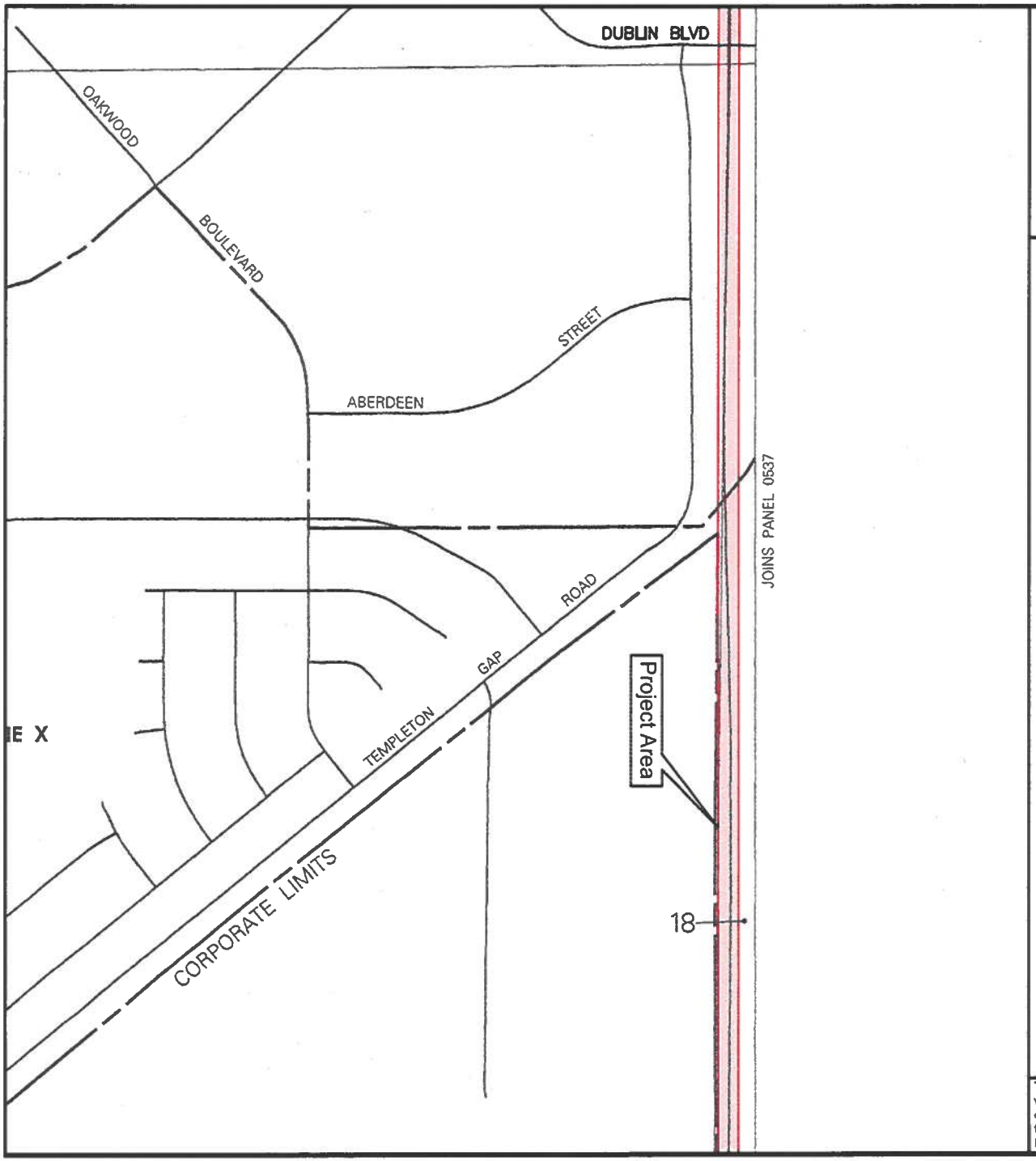
CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
COLORADO SPRINGS, CITY OF	080060	0536	F
EL PASO COUNTY, UNINCORPORATED AREAS	080059	0536	F

MAP NUMBER
08041C0536 F

EFFECTIVE DATE:
MARCH 17, 1997

Federal Emergency Management Agency



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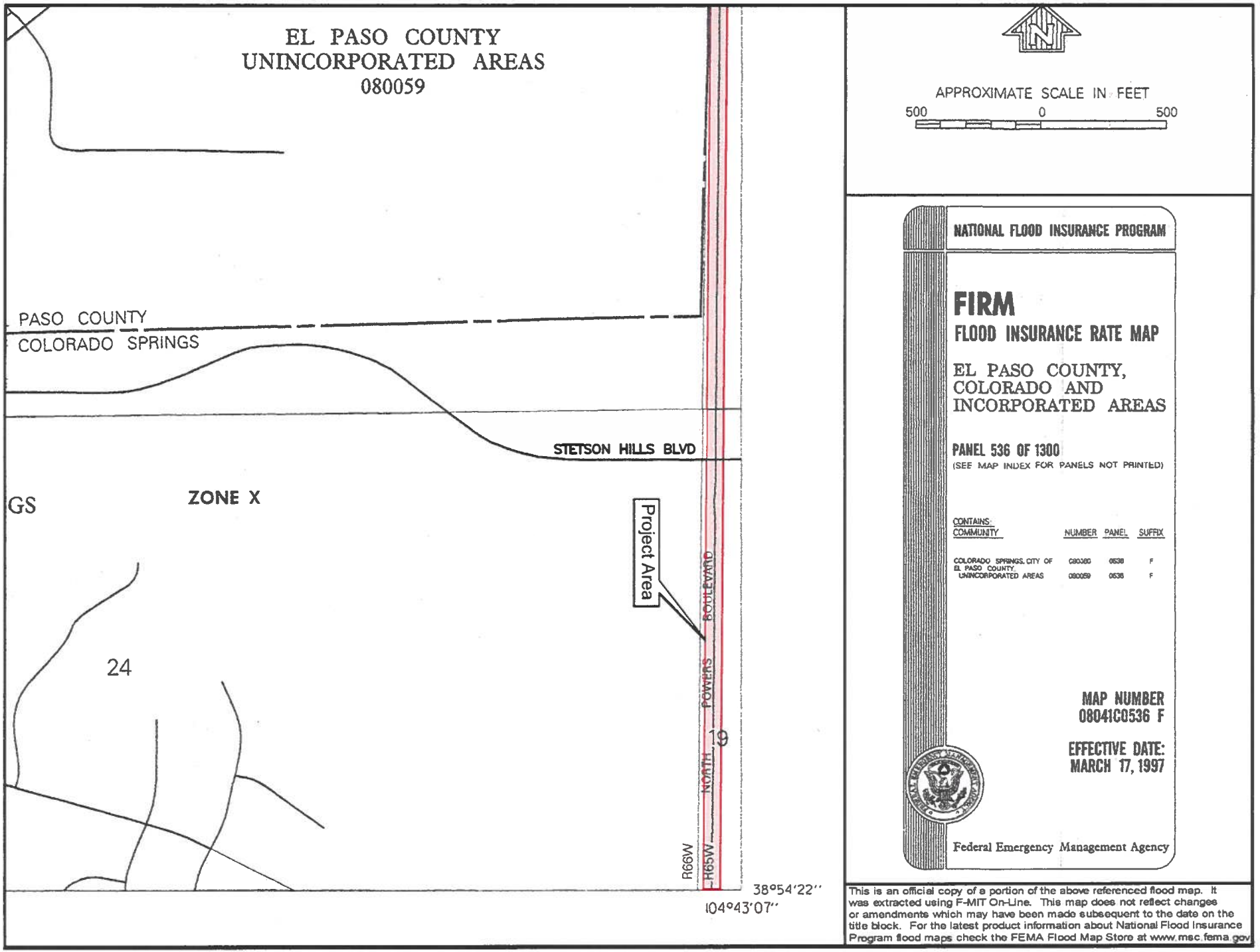

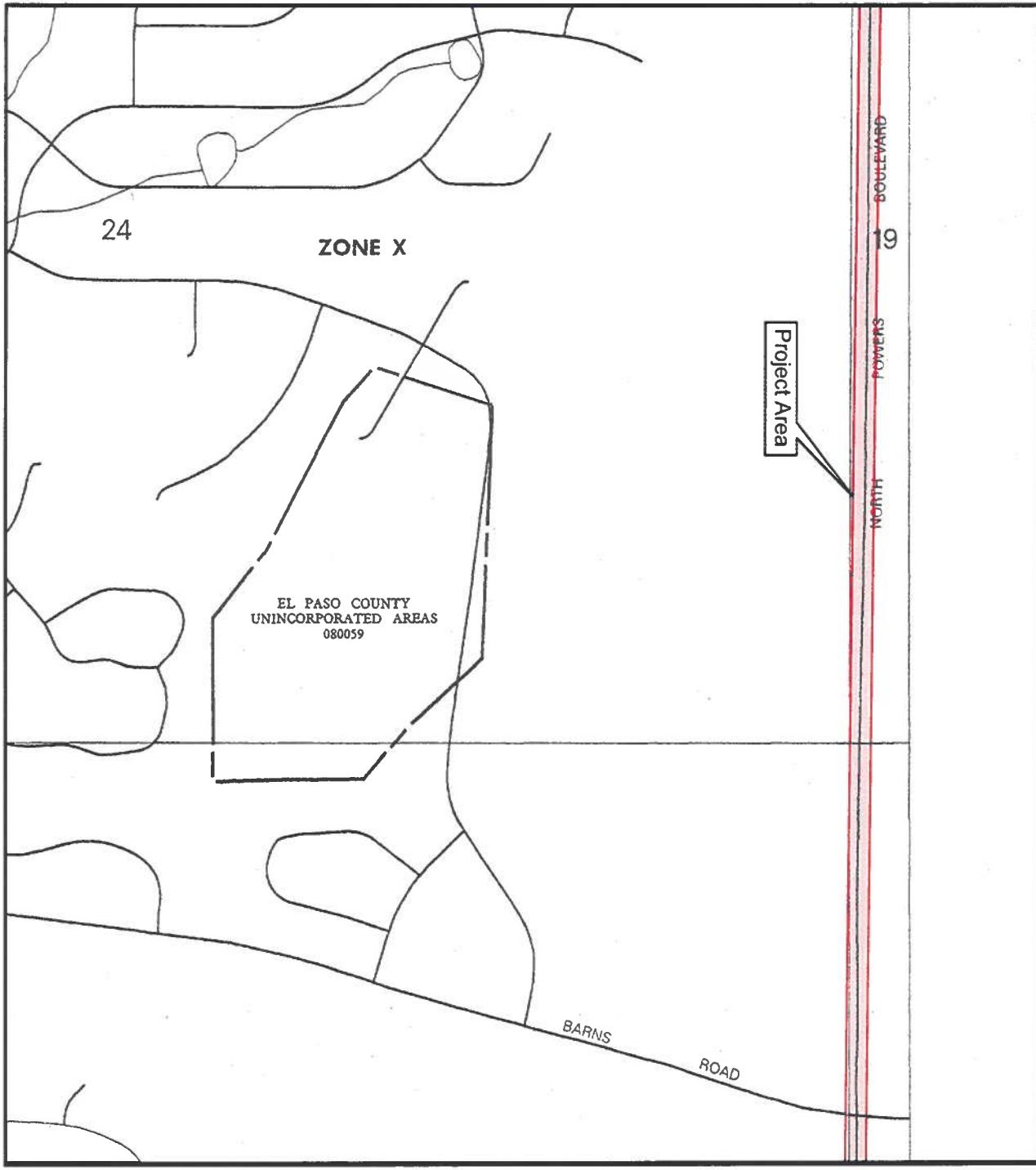

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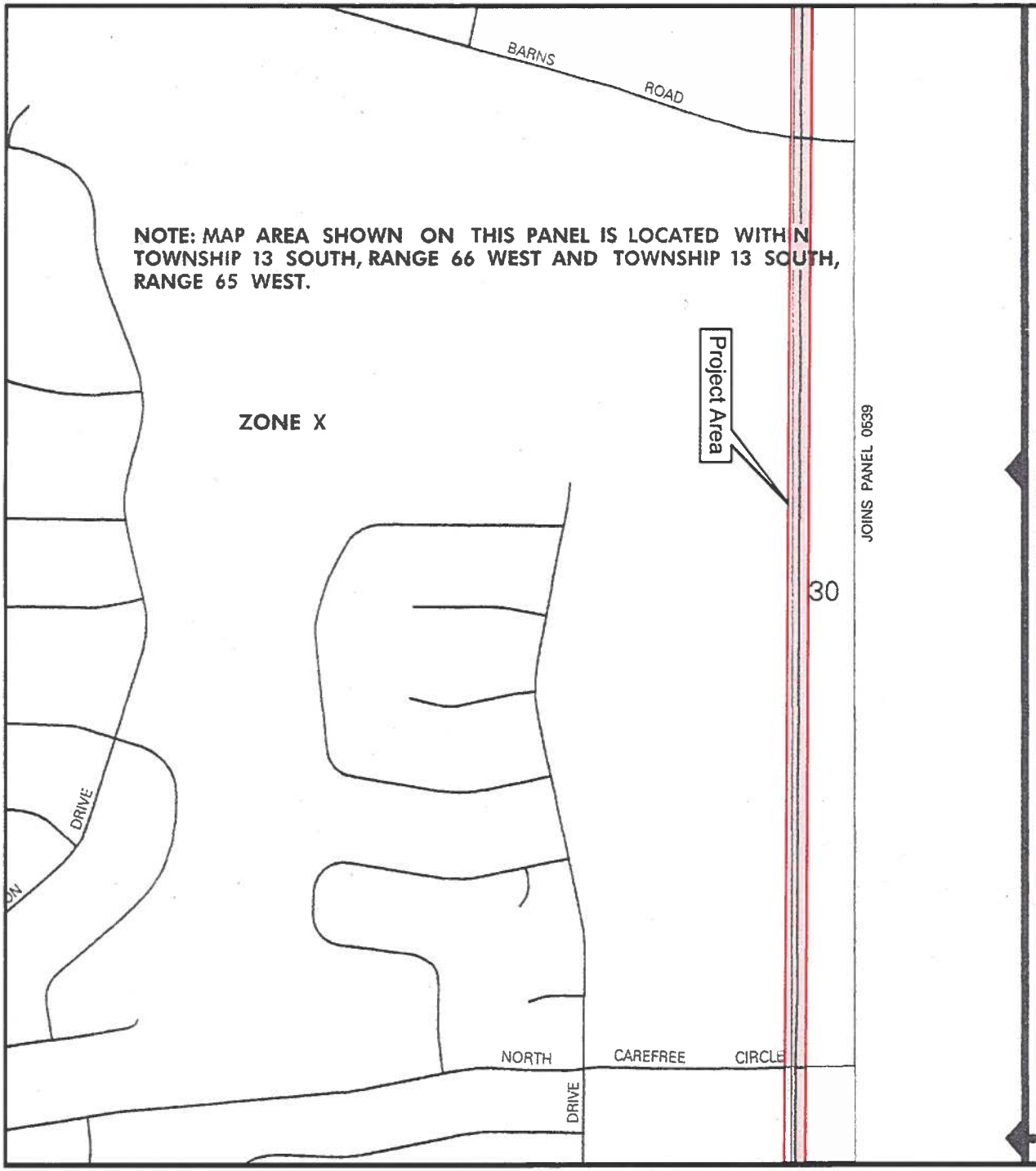

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NATIONAL FLOOD INSURANCE PROGRAM

FIRM

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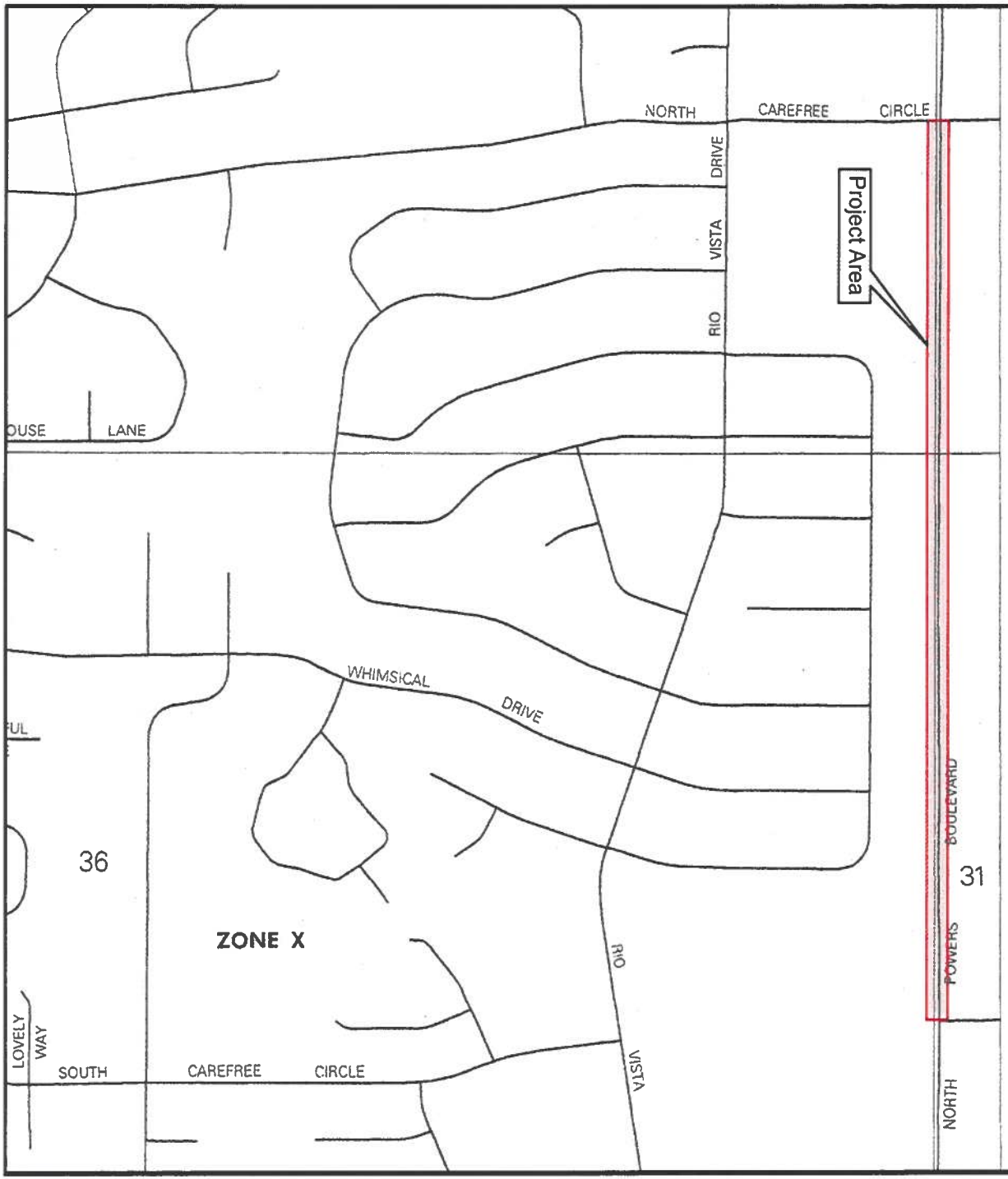

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Federal Emergency Management Agency

APPENDIX B HYDROLOGIC COMPUTATIONS

COEFFICIENTS OF DEVELOPMENT

Project: Powers Blvd
Project #: S:\12266-09\19500\Hydraulics\Calculations
Date: 25-Jun-14
File: Powers Hydrology-Final.xls

BASIN	AREA ACRES	IMPERVIOUSNESS			SOIL TYPE			RUNOFF COEFF.		
		Open % Imp. 5 Acres	Paved % Imp. 100 Acres	Comp. % Imp.	A Percent of Total Area	B Percent of Total Area	C/D Percent of Total Area	5 YEAR	10 YEAR	100 YEAR
A1	2.59	0.93	1.66	65.89		100.0		0.46	0.50	0.59
A2	2.59	0.58	2.01	78.73		100.0		0.58	0.61	0.69
B1	2.40	0.77	1.63	69.52		100.0		0.49	0.53	0.62
B2	0.73	0.19	0.54	75.27		100.0		0.54	0.58	0.66
C1	11.25	8.97	2.28	24.25		100.0		0.22	0.29	0.45
D1	2.75	2.38	0.37	17.78		100.0		0.18	0.26	0.43
D2	8.72	8.72	0.00	5.00		100.0		0.10	0.19	0.38
D3	1.48	0	1.48	100.00		100.0		0.90	0.92	0.96
D4	0.53	0.53	0.00	5.00		100.0		0.10	0.19	0.38
D5	3.71	1.87	1.84	52.12		100.0		0.36	0.42	0.53
E1	2.43	1.2	1.23	53.09		100.0		0.37	0.42	0.54
E2	5.55	2.45	3.10	58.06		100.0		0.40	0.45	0.56
F1	9.72	8.93	0.79	12.72		100.0		0.15	0.24	0.41
F2	6.16	4.56	1.60	29.68		100.0		0.25	0.32	0.47

COEFFICIENTS OF DEVELOPMENT

Project: Powers Blvd
Project #: S:\12266-09\19500\Hydraulics\Calculations
Date: 25-Jun-14
File: Powers Hydrology-Final.xls

BASIN	AREA ACRES	IMPERVIOUSNESS			SOIL TYPE			RUNOFF COEFF.		
		Open % Imp. 5 Acres	Paved % Imp. 100 Acres	Comp. % Imp.	A Percent of Total Area	B Percent of Total Area	C/D Percent of Total Area	5 YEAR	10 YEAR	100 YEAR
G1	5.93	5.09	0.84	18.46		100.0		0.19	0.27	0.44
G2	8.07	6.13	1.94	27.84		100.0		0.24	0.31	0.46
H1	2.18	1.08	1.10	52.94		100.0		0.37	0.42	0.53
H2	1.88	0.74	1.14	62.61		100.0		0.43	0.48	0.58

TIME OF CONCENTRATION

Project: Powers Blvd
Project #: S:\12266-09\19500\Hydraulics\Calculations
Date: 25-Jun-14
File: Powers Hydrology-Final.xls

Equation:
$t_t=0.395(1.1-C_5)L^{0.5}/S^{0.33}$
$V=C_V S_W^{0.5}$
$t_t=L_W/(60V)$

SUB-BASIN DATA			INITIAL/OVERLAND TIME (t_i)				TRAVEL TIME (t_t)					T_c	T_c Check (urban)**		FINAL
DESIG.	C5	Surface C5	AREA (AC)	LENGTH, L (FT)	SLOPE, S (%)	t_i (MIN)	LENGTH, L_W (FT)	SLOPE, S_W (%)	SURF. TYPE	VEL. (F/S)	t_t (MIN)	t_i+t_t (MIN)	$L_T=L+L_W$ (FT)	$L_T/180+10$ (MIN)	T_c (MIN)
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
A1	0.46	0.90	2.59	75	5.3	1.8	1346	4.1	F	4.0	5.5	7.3	1421	17.9	7.3
A2	0.58	0.90	2.59	110	3.6	2.5	1110	3.0	F	3.5	5.3	7.8	1220	16.8	7.8
B1	0.49	0.90	2.40	51	2.0	2.1	1392	3.0	F	3.5	6.7	8.7	1443	18.0	8.7
B2	0.54	0.90	0.73	52	2.0	2.1	364	0.5	F	1.4	4.3	6.4	416	12.3	6.4
C1	0.22	0.35	11.25	300	13.0	10.1	1915	4.0	F	4.0	8.0	18.0	2215	22.3	18.0
D1	0.18	0.35	2.75	300	11.0	10.6	548	4.9	F	4.4	2.1	12.7	848	14.7	12.7
D2	0.10	0.35	8.72	300	15.7	9.5	665	4.3	F	4.1	2.7	12.1	965	15.4	12.1
D3	0.90	0.90	1.48	90	2.2	2.6	922	1.8	F	2.7	5.7	8.4	1012	15.6	8.4
D4	0.10	0.35	0.53	30	3.3	5.0	643	3.0	F	3.5	3.1	8.1	673	13.7	8.1
D5	0.36	0.35	3.71	247	9.7	10.1	2070	5.1	F	4.5	7.6	17.7	2317	22.9	17.7
E1	0.37	0.90	2.43	58	2.0	2.2	1094	5.5	F	4.7	3.9	6.1	1152	16.4	6.1
E2	0.40	0.90	5.55	55	2.0	2.1	2584	4.7	F	4.3	9.9	12.1	2639	24.7	12.1
F1	0.15	0.35	9.72	124	10.5	6.9	1160	5.3	F	4.6	4.2	11.1	1284	17.1	11.1
F2	0.25	0.35	6.16	300	9.7	11.1	1481	5.4	F	4.6	5.3	16.4	1781	19.9	16.4

SURFACE TYPES

A=Forest with ground litter & meadow
B=Fallow or minimum tillage cultivation
C= Short grass pasture & lawns
D=Nearly bare ground
E=Grassed waterway
F=Paved area (sheet flow) & shallow gutter flow

TIME OF CONCENTRATION

Project: Powers Blvd
Project #: S:\12266-09\19500\Hydraulics\Calculations
Date: 25-Jun-14
File: Powers Hydrology-Final.xls

Equation:
$t_i = 0.395(1.1 - C_5)L^{0.5}/S^{0.33}$
$V = C_V S_W^{0.5}$
$t_t = L_W/(60V)$

SUB-BASIN DATA			INITIAL/OVERLAND TIME (t_i)				TRAVEL TIME (t_t)					T_c	T_c Check (urban)**		FINAL
DESIG.	C5	Surface C5	AREA (AC)	LENGTH (FT)	SLOPE (%)	t_i (MIN)	LENGTH (FT)	SLOPE (%)	SURF. TYPE	VEL. (F/S)	t_t (MIN)	t_i+t_t (MIN)	TOTAL (FT)	L/180+10 (MIN)	T_c (MIN)
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
G1	0.19	0.35	5.93	209	10.0	9.2	854	6.1	F	4.9	2.9	12.0	1063	15.9	12.0
G2	0.24	0.90	8.07	50	2.0	2.0	1672	3.0	F	3.5	8.0	10.1	1722	19.6	10.1
H1	0.37	0.90	2.18	77	5.2	1.8	866	4.3	F	4.1	3.5	5.3	943	15.2	5.3
H2	0.43	0.90	1.88	42	2.0	1.9	1005	2.1	F	2.9	5.8	7.6	1047	15.8	7.6
D2 Ditch Only							405	0.5	F	1.4	4.8				
F2 Ditch Only							1267	3.5	F	3.7	5.6				
G1 Ditch Only							291	4.8	F	4.4	1.1				

SURFACE TYPES
A=Forest with ground litter & meadow
B=Fallow or minimum tillage cultivation
C= Short grass pasture & lawns
D=Nearly bare ground
E=Grassed waterway
F=Paved area (sheet flow) & shallow gutter flow

STORM DRAINAGE SYSTEM DESIGN
(RATIONAL METHOD PROCEDURE)
10-YEAR STORM

Project: Powers Blvd
Project : S:\12266-09\19500\Hydraulics\Calculations
Date: 25-Jun-14
File: Powers Hydrology-Final.xls

Q=C*I*A

1-Hour Intensities
10-Year
1.75

$I=(26.65\ P_1)/(10+T_C)^{0.76}$

ROUTING	DES. PT.	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			REMARKS
		AREA DESIG.	AREA (AC.)	COEF.	tc (MIN)	C*A (AC)	I (IN/HR)	Q (CFS)	tc (MIN)	C*A (AC)	I (IN/HR)	Q (CFS)	SLOPE (%)	Q	DESIGN (CFS)	SLOPE (%)	PIPE SIZE	LENGTH (FT.)	VEL. (FPS)	tt (MIN)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
		A1	2.59	0.50	7.3	1.30	5.33	6.9													
		A2	2.59	0.61	7.8	1.59	5.22	8.3													
	1	A1&A2							13.4	2.89	4.25	12.3									TC=7.8+5.6=13.4
		B1	2.40	0.53	8.7	1.27	5.03	6.4													
		B2	0.73	0.58	6.4	0.42	5.57	2.4													
		C1	11.25	0.29	18.0	3.29	3.70	12.2													
		D1	2.75	0.26	12.7	0.72	4.35	3.1													
D2+DP-6		D2	8.72	0.19	12.1	1.63	4.43	7.2	28.2	4.69	2.93	13.7									TC=17.7+5.7+4.8=28.2
D3+D5 Bypass		D3	1.48	0.92	8.4	1.35	5.11	6.9	23.4	2.33	3.24	7.6									D5 Bypass=3.65CFS, CA=0.98, TC=17.7+5.7=23.4
D4+D5 Capture		D4	0.53	0.19	8.1	0.10	5.16	0.5	20.8	0.67	3.45	2.3									D5 Capture=2.15CFS, CA=0.57, TC=17.7+3.1=20.8
		D5	3.71	0.42	17.7	1.54	3.74	5.8													
	6	D1,D3,D5 Bypass							23.4	3.06	3.24	9.9									TC=17.7+5.7=23.4
	7	D1,D2,D3,D4,D5							28.2	5.35	2.93	15.7									TC=17.7+5.7+4.8=28.2
		E1	2.43	0.42	6.1	1.02	5.65	5.8													
		E2	5.55	0.45	12.1	2.49	4.44	11.1													
	2	E1&E2							16.0	3.51	3.93	13.8									TC=12.1+3.9=16.0
		F1	9.72	0.24	11.1	2.29	4.59	10.5													
		F2	6.16	0.32	16.4	1.95	3.88	7.5													
	3	F1&F2							16.8	4.23	3.83	16.2									TC=11.1+5.7=16.8

STORM DRAINAGE SYSTEM DESIGN
(RATIONAL METHOD PROCEDURE)
10-YEAR STORM

Project: Powers Blvd
Project : S:\12266-09\19500\Hydraulics\Calculations
Date: 25-Jun-14
File: Powers Hydrology-Final.xls

Q=C*I*A

1-Hour Intensities
10-Year
1.75

$I=(26.65\ P_1)/(10+T_C)^{0.76}$

ROUTING	DES. PT.	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			REMARKS
		AREA DESIG.	AREA (AC.)	COEF.	tc (MIN)	C*A (AC)	I (IN/HR)	Q (CFS)	tc (MIN)	C*A (AC)	I (IN/HR)	Q (CFS)	SLOPE (%)	Q	DESIGN (CFS)	SLOPE (%)	PIPE SIZE	LENGTH (FT.)	VEL. (FPS)	tt (MIN)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
		G1	5.93	0.27	12.0	1.57	4.45	7.0													
		G2	8.07	0.31	10.1	2.49	4.77	11.9													
	4	G1&G2							11.2	4.06	4.58	18.6									TC=10.1+1.1=11.2
		H1	2.18	0.42	5.3	0.91	5.86	5.4													
		H2	1.88	0.48	7.6	0.90	5.26	4.7													
	5	H1&H2							11.1	1.81	4.59	8.3									TC=7.6+3.5=11.1

STORM DRAINAGE SYSTEM DESIGN
(RATIONAL METHOD PROCEDURE)
100-YEAR STORM

Project: Powers Blvd
Project: S:\12266-09\19500\Hydraulics\Calculations
Date: 25-Jun-14
File: Powers Hydrology-Final.xls

Q=C*I*A

1-Hour Intensities
100-Year
2.67

$I=(26.65\ P_1)/(10+T_C)^{0.76}$

ROUTING	DES. PT.	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			REMARKS
		AREA DESIG.	AREA (AC.)	COEF.	tc (MIN)	C*A (AC)	I (IN/HR)	Q (CFS)	tc (MIN)	C*A (AC)	I (IN/HR)	Q (CFS)	SLOPE (%)	Q	DESIGN (CFS)	SLOPE (%)	PIPE SIZE	LENGTH (FT.)	VEL. (FPS)	tt (MIN)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
		A1	2.59	0.59	7.3	1.54	8.14	12.5													
		A2	2.59	0.69	7.8	1.78	7.97	14.2													
	1	A1&A2							13.4	3.32	6.49	21.6									TC=7.8+5.6=13.4
		B1	2.40	0.62	8.7	1.48	7.67	11.4													
		B2	0.73	0.66	6.4	0.48	8.51	4.1													
		C1	11.25	0.45	18.0	5.11	5.65	28.8													
		D1	2.75	0.43	12.7	1.19	6.63	7.9													
D2+DP-6		D2	8.72	0.38	12.1	3.31	6.76	22.4	28.2	7.35	4.47	32.8									TC=17.7+5.7+4.8=28.2
D3+D5 Bypass		D3	1.48	0.96	8.4	1.41	7.79	11.0	23.4	2.85	4.94	14.1									D5 Bypass=8.22CFS, CA=1.44, TC=17.7+5.7=23.4
D4+D5 Capture		D4	0.53	0.38	8.1	0.20	7.88	1.6	20.8	0.72	5.26	3.8									D5 Capture=2.98CFS, CA=0.52, TC=17.7+3.1=20.8
		D5	3.71	0.53	17.7	1.97	5.70	11.2													
	6	D1,D3,D5 Bypass							23.4	4.05	4.94	20.0									TC=17.7+5.7=23.4
	7	D1,D2,D3,D4,D5							28.2	8.09	4.47	36.1									TC=17.7+5.7+4.8=28.2
		E1	2.43	0.54	6.1	1.30	8.62	11.2													
		E2	5.55	0.56	12.1	3.08	6.78	20.9													
	2	E1&E2							16.0	4.38	5.99	26.3									TC=12.1+3.9=16.0
		F1	9.72	0.41	11.1	4.03	7.00	28.2													
		F2	6.16	0.47	16.4	2.89	5.91	17.1													
	3	F1&F2							16.8	6.92	5.85	40.5									TC=11.1+5.7=16.8

STORM DRAINAGE SYSTEM DESIGN
(RATIONAL METHOD PROCEDURE)
100-YEAR STORM

Project: Powers Blvd
Project : S:\12266-09\19500\Hydraulics\Calculations
Date: 25-Jun-14
File: Powers Hydrology-Final.xls

Q=C*I*A

1-Hour Intensities
100-Year
2.67

$I=(26.65\ P_1)/(10+T_C)^{0.76}$

ROUTING	DES. PT.	DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			REMARKS
		AREA DESIG.	AREA (AC.)	COEF.	tc (MIN)	C*A (AC)	I (IN/HR)	Q (CFS)	tc (MIN)	C*A (AC)	I (IN/HR)	Q (CFS)	SLOPE (%)	Q	DESIGN (CFS)	SLOPE (%)	PIPE SIZE	LENGTH (FT.)	VEL. (FPS)	tt (MIN)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
		G1	5.93	0.44	12.0	2.59	6.78	17.5													
		G2	8.07	0.46	10.1	3.74	7.28	27.2													
	4	G1&G2							11.2	6.33	6.99	44.2									TC=10.1+1.1=11.2
		H1	2.18	0.53	5.3	1.17	8.94	10.4													
		H2	1.88	0.58	7.6	1.08	8.03	8.7													
	5	H1&H2							11.1	2.25	7.01	15.8									TC=7.6+3.5=11.1

APPENDIX C HYDRAULIC COMPUTATIONS

Cross Section for DP-1

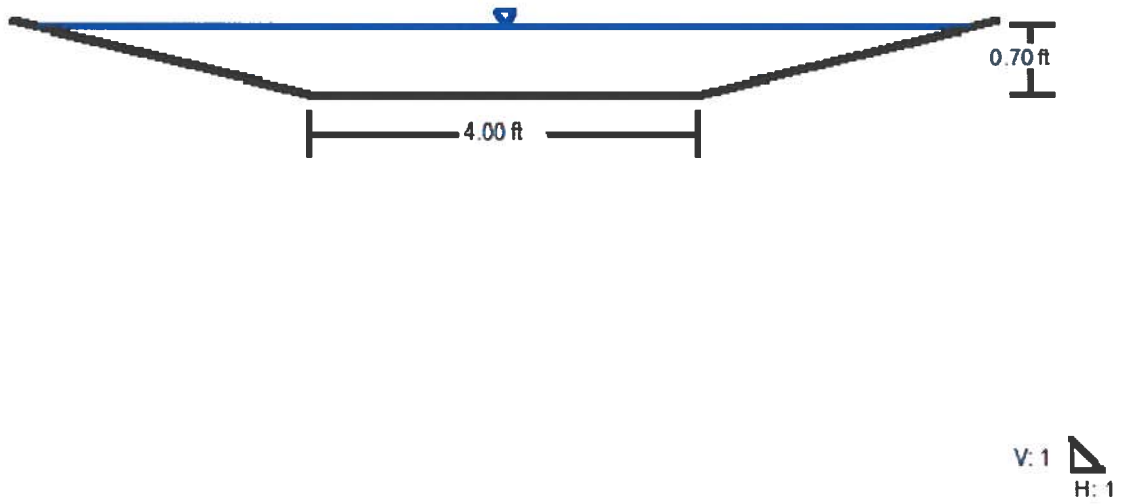
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.03000	ft/ft
Normal Depth	0.70	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	21.60	ft³/s

Cross Section Image



Cross Section for Basin B1-100yr

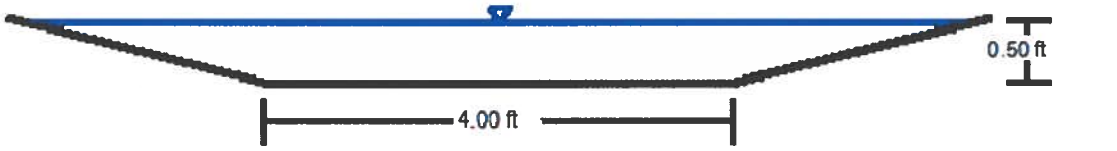
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.03000	ft/ft
Normal Depth	0.50	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	11.40	ft³/s

Cross Section Image



V: 1
H: 1

Spread for Basin B2-10yr

Project Description

Solve For	Spread

Input Data

Channel Slope	0.00500	ft/ft
Discharge	2.40	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	10.40	ft
Roughness Coefficient	0.016	

Cross Section Image

V: 1
H: 1

Spread for Basin B2-100yr

Project Description

Solve For	Spread

Input Data

Channel Slope	0.00500	ft/ft
Discharge	4.10	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	13.14	ft
Roughness Coefficient	0.016	

Cross Section Image

V: 1
H: 1

Cross Section for Basin B2-100yr

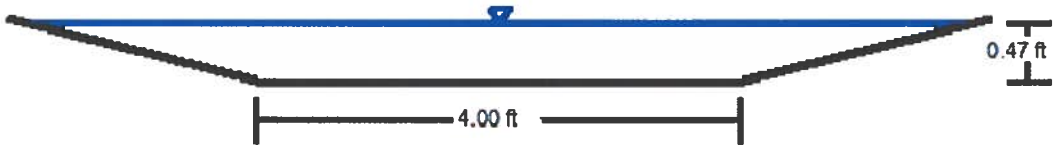
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.00500	ft/ft
Normal Depth	0.47	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	4.10	ft³/s

Cross Section Image



V: 1
H: 1

Cross Section for Basin C1-10yr

Project Description

Solve For	Spread

Input Data

Channel Slope	0.03000	ft/ft
Discharge	12.20	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	14.26	ft
Roughness Coefficient	0.016	

Cross Section Image

V: 1
H: 1

Cross Section for Basin C1-100yr

Project Description

Solve For	Spread

Input Data

Channel Slope	0.03000	ft/ft
Discharge	28.80	ft^3/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	20.17	ft
Roughness Coefficient	0.016	

Cross Section Image

V: 1
H: 1

Spread for Basin D1-10yr

Project Description

Solve For	Spread

Input Data

Channel Slope	0.00700	ft/ft
Discharge	3.10	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	10.82	ft
Roughness Coefficient	0.016	

Cross Section Image

V: 1
H: 1

Spread for Basin D1-100yr

Project Description

Solve For	Spread

Input Data

Channel Slope	0.00700	ft/ft
Discharge	7.90	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	16.08	ft
Roughness Coefficient	0.016	

Cross Section Image

V: 1
H: 1

Type 5 Embankment Protector Capacity @ DP-6

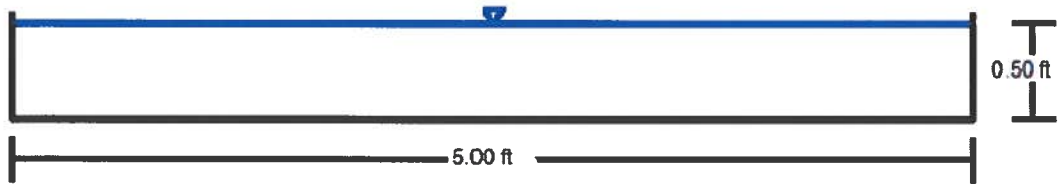
Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Roughness Coefficient	0.016	
Channel Slope	0.10000	ft/ft
Normal Depth	0.50	ft
Bottom Width	5.00	ft
Discharge	40.96	ft³/s

Cross Section Image



V: 1
H: 1

Cross Section for Basin D2 @ Design Point 6-100yr

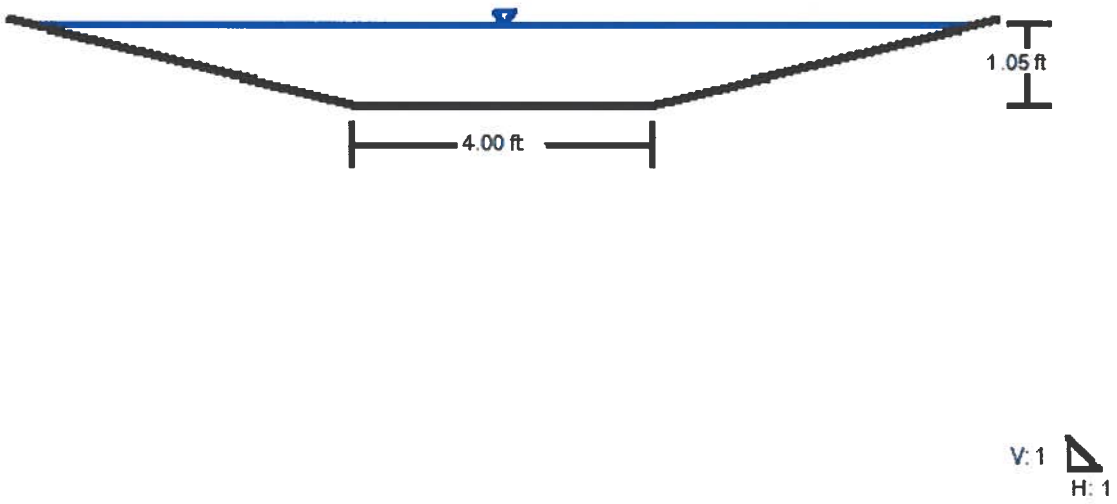
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.00500	ft/ft
Normal Depth	1.05	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	20.00	ft³/s

Cross Section Image



Cross Section for Basin D2 @ Design Point 7-100yr

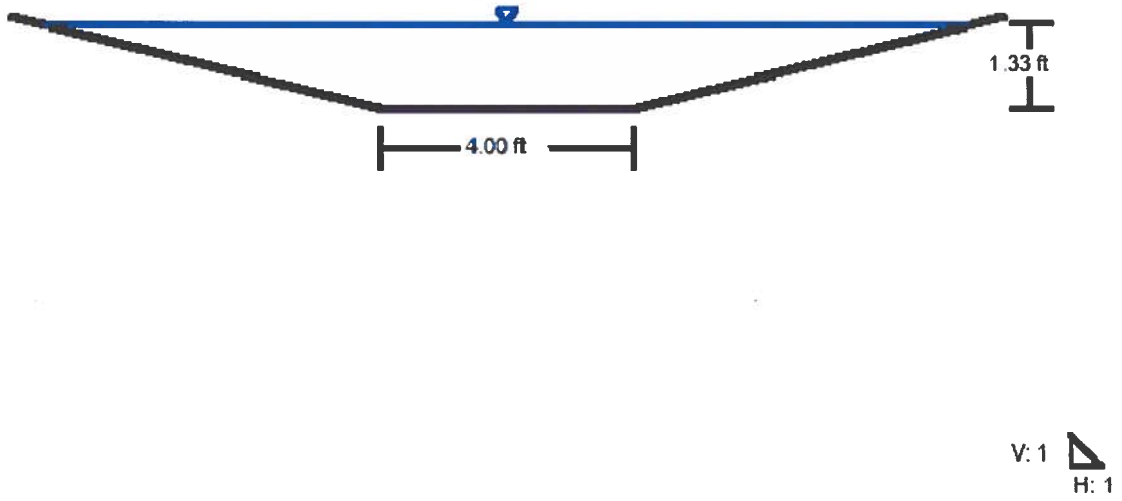
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.00500	ft/ft
Normal Depth	1.33	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	32.80	ft³/s

Cross Section Image



Spread for Basin D3-10yr

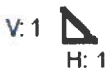
Project Description

Solve For	Spread

Input Data

Channel Slope	0.00800	ft/ft
Discharge	7.60	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	15.41	ft
Roughness Coefficient	0.016	

Cross Section Image



Spread for Basin D3-100yr

Project Description

Solve For	Spread

Input Data

Channel Slope	0.00800	ft/ft
Discharge	14.10	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	19.75	ft
Roughness Coefficient	0.016	

Cross Section Image

Cross Section for Basin D4-100yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.03000	ft/ft
Normal Depth	0.27	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	3.80	ft³/s

Cross Section Image

Embankment Protector for Basin D5-10yr

Project Description

Solve For	Efficiency

Input Data

Discharge	5.80	ft³/s
Slope	0.00800	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Roughness Coefficient	0.016	
Curb Opening Length	5.00	ft
Local Depression	0.00	in
Local Depression Width	2.00	ft

Results

Efficiency	37.08	%
Intercepted Flow	2.15	ft³/s
Bypass Flow	3.65	ft³/s
Spread	13.78	ft
Depth	0.40	ft
Flow Area	2.02	ft²
Gutter Depression	0.13	ft
Total Depression	0.13	ft
Velocity	2.87	ft/s
Equivalent Cross Slope	0.04718	ft/ft
Length Factor	0.23	
Total Interception Length	22.03	ft

Embankment Protector for Basin D5-100yr

Project Description

Solve For	Efficiency

Input Data

Discharge	11.20	ft³/s
Slope	0.00800	ft/ft
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Roughness Coefficient	0.016	
Curb Opening Length	5.00	ft
Local Depression	0.00	in
Local Depression Width	2.00	ft

Results

Efficiency	26.59	%
Intercepted Flow	2.98	ft³/s
Bypass Flow	8.22	ft³/s
Spread	18.02	ft
Depth	0.49	ft
Flow Area	3.37	ft²
Gutter Depression	0.13	ft
Total Depression	0.13	ft
Velocity	3.32	ft/s
Equivalent Cross Slope	0.04079	ft/ft
Length Factor	0.16	
Total Interception Length	31.69	ft

Cross Section for DP-2

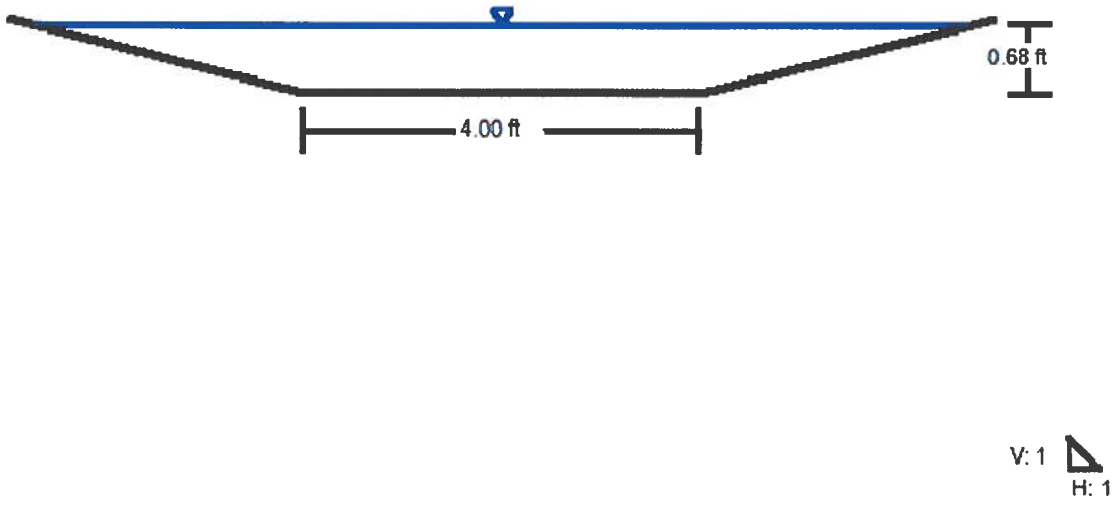
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.05000	ft/ft
Normal Depth	0.68	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	26.30	ft³/s

Cross Section Image



Spread for Basin E2-10yr

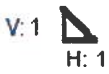
Project Description

Solve For	Spread

Input Data

Channel Slope	0.06000	ft/ft
Discharge	11.10	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	11.82	ft
Roughness Coefficient	0.016	

Cross Section Image



Spread for Basin E2-100yr

Project Description

Solve For	Spread

Input Data

Channel Slope	0.06000	ft/ft
Discharge	20.90	ft³/s
Gutter Width	2.00	ft
Gutter Cross Slope	0.08	ft/ft
Road Cross Slope	0.02	ft/ft
Spread	15.43	ft
Roughness Coefficient	0.016	

Cross Section Image

V: 1
H: 1

Cross Section for DP-3

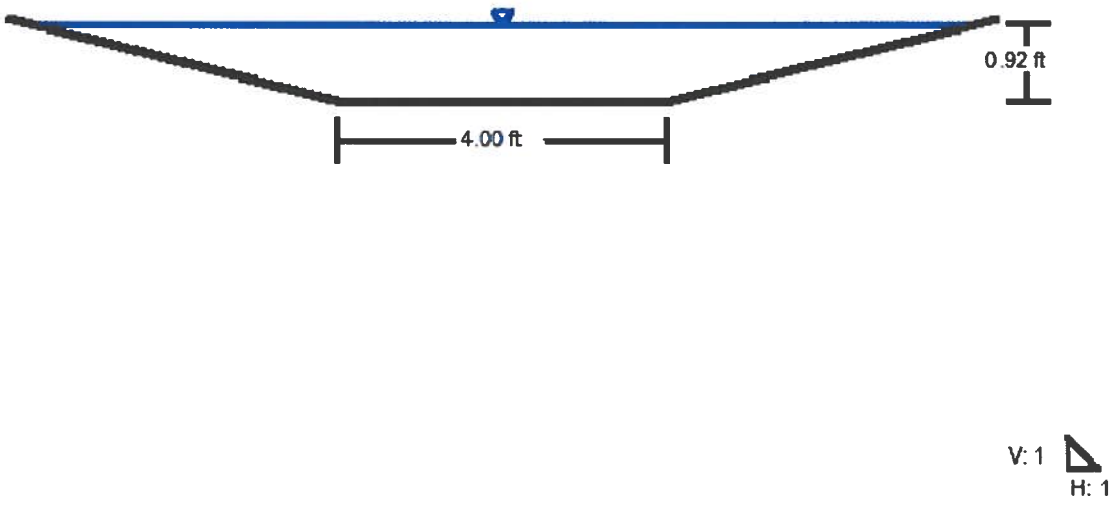
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.03500	ft/ft
Normal Depth	0.92	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	40.50	ft³/s

Cross Section Image



Cross Section for DP-4

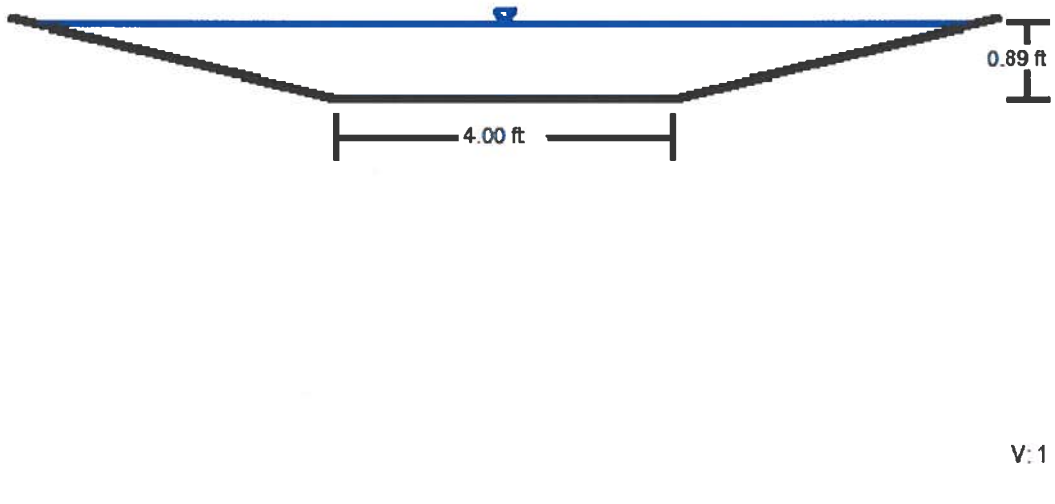
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.04800	ft/ft
Normal Depth	0.89	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	44.20	ft³/s

Cross Section Image



Cross Section for DP-5

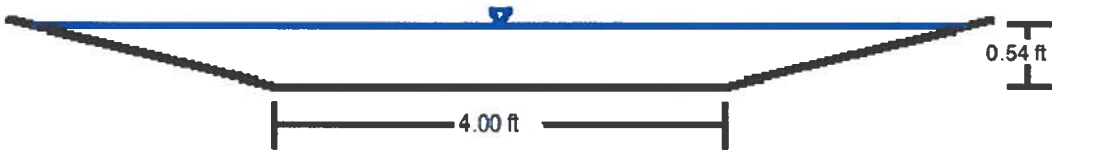
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.04300	ft/ft
Normal Depth	0.54	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	4.00	ft
Discharge	15.80	ft³/s

Cross Section Image



Cross Section for Basin H2-100yr

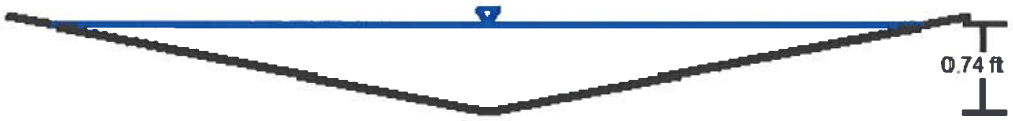
Project Description

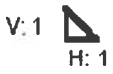
Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.02100	ft/ft
Normal Depth	0.74	ft
Left Side Slope	5.00	ft/ft (H:V)
Right Side Slope	5.00	ft/ft (H:V)
Discharge	8.70	ft³/s

Cross Section Image





Trapezoidal Channel Analysis

Project Info

American Excelsior Company®
Earth Science Division

Units of Measurement:	(•) English units ( ) SI (metric) units	
Channel bed slope:	.05	(ft/ft)
Channel left side slope:	4	(H:1V)
Channel right side slope:	4	(H:1V)
Channel bed Manning's n-Value:	.032	
Channel left Manning's n-Value:	.032	
Channel right Manning's n-Value:	.032	
Channel bottom width:	4	(ft)
Design discharge:	44.2	(ft^3/sec)
Bend coefficient:	1	
100% Biodegradable Products only:	☐	
Desired Product Longevity:	Permanent	

Hydraulic Conditions:

Depth:	0.84 ft
Froude:	1.65
Velocity:	7.13 ft/s
Shear:	2.62 lb/ft^2

Designer's Name:	Kevan Kuhnel
Designer's Title:	Engineer
Designer's Organization:	FHU
Project Name:	Powers
Project Number:	19500
Project Location (City, State)*:	Colorado Springs, Colorado
Project Segment:	DP-6 Worst Case
Application(s):	
Project Description*:	
Project Bid Date*:	
Project Start Date:	

Trapezoidal Channel Analysis

Analysis Results

American Excelsior Company®
Earth Science Division

Good	Better	Best
Recyclex TRM-V (Vegetated)	Curlex Enforcer (Vegetated)	Recyclex TRM (Vegetated)

Stability factors less than one are highlighted **RED** and mean the material is likely to fail if the calculated hydraulic conditions are encountered.

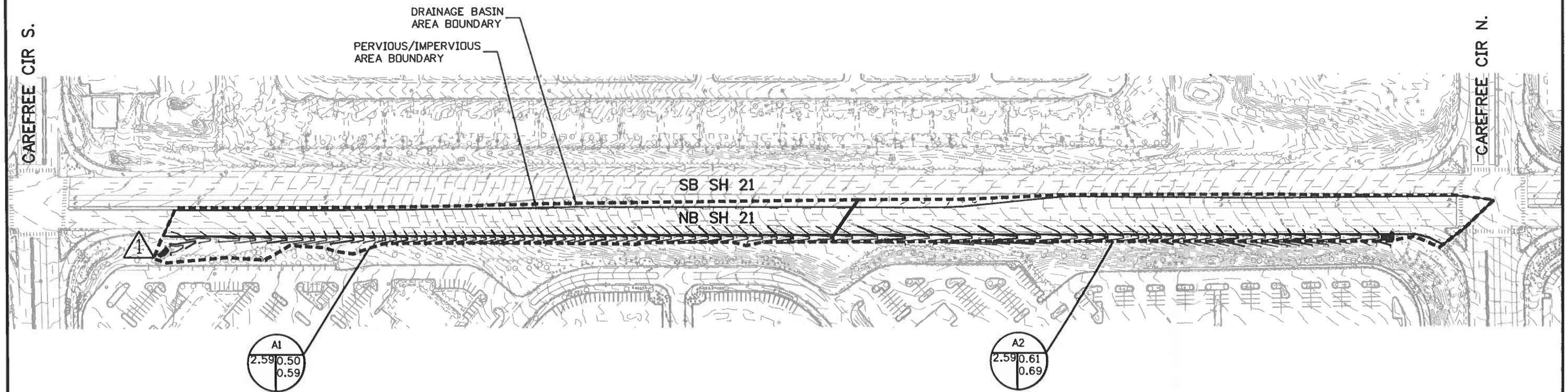
Product	Velocity	Shear Stress	Functional Longevity (months)	DOT Approved (Colorado)
Curlex Enforcer (Unvegetated)	1.45031	1.23815	Permanent	Yes
Recyclex TRM (Vegetated)	2.78683	4.57163	Permanent	Yes
Curlex Enforcer (Vegetated)	2.54402	3.80969	Permanent	Yes
Recyclex TRM-V (Vegetated)	2.27544	3.04775	Permanent	N/A

APPENDIX D PROPOSED BASIN MAPS

Know what's below. Call before you dig.

N

0' 100' 200' 400'



LEGEND

A - BASIN DESIGNATION
B - AREA IN ACRES
C - 10 YEAR RUNOFF COEFFICIENT
D - 100 YEAR RUNOFF COEFFICIENT

SUMMARY RUNOFF TABLE

Contributing Basins	Peak Runoff (cfs)	
	10-Year	100-Year
Basin A1	6.9	12.5
Basin A2	8.3	14.2

Print Date: 7/3/2014
File Name: 19500BASINS_Plan01.dgn
Horiz. Scale: 1:200 Vert. Scale: As Noted
Unit Information Unit Leader Initials

FELSBURG HOLT & ULLEVIG
508 South Tejon Street
Colorado Springs, CO 80903
(719) 314-1800

Sheet Revisions		
Date:	Comments	Init.

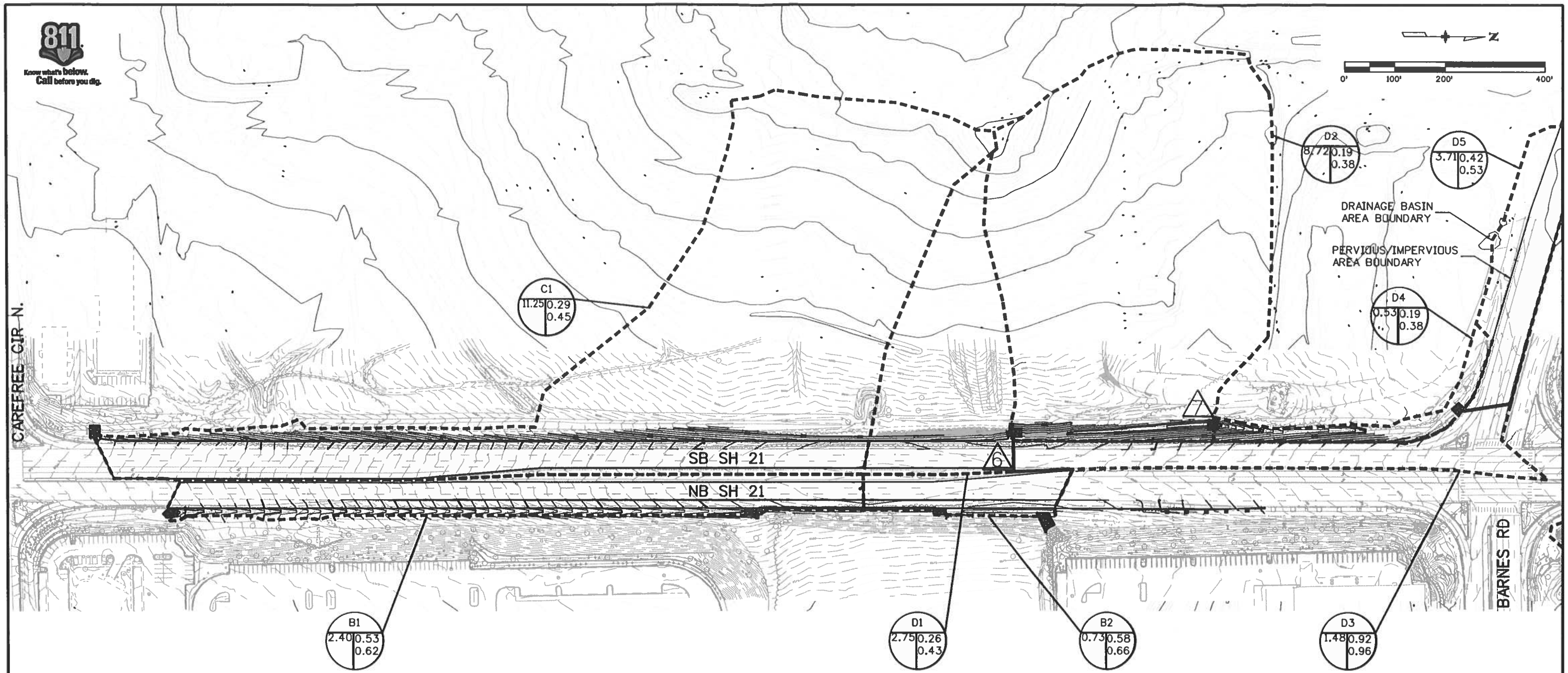
Colorado Department of Transportation
1480 Quail Lake Loop, Suite A
Colorado Springs, CO 80906
Phone: 719-634-2323 FAX: 719-227-3298
Region 2 MSA

As Constructed
No Revisions:
Revised:
Void:

STATE HIGHWAY NO. 21
POWERS BLVD CORRIDOR
IMPROVEMENTS BASIN MAP

Designer: KPK
Detailer: CJL
Sheet Subset: BASINS
Structure Numbers:
Subset Sheets: BM-1 OF 6

Project No./Code
SHE-0212-006
19500R
Sheet Number



LEGEND

A - BASIN DESIGNATION
B - AREA IN ACRES
C - 10 YEAR RUNOFF COEFFICIENT
D - 100 YEAR RUNOFF COEFFICIENT

SUMMARY RUNOFF TABLE

Contributing Basins	Peak Runoff (cfs)	
	10-Year	100-Year
Basin B1	6.4	11.4
Basin B2	2.4	4.1
Basin C1	12.2	28.8
Basin D1	3.1	7.9
Basin D2	7.2	22.4
Basin D3	6.9	11.0
Basin D4	0.5	1.6
Basin D5	5.8	11.2

Print Date: 7/3/2014
File Name: 19500BASINS_Plan02.dgn
Horiz. Scale: 1:200 Vert. Scale: As Noted
Unit Information Unit Leader Initials

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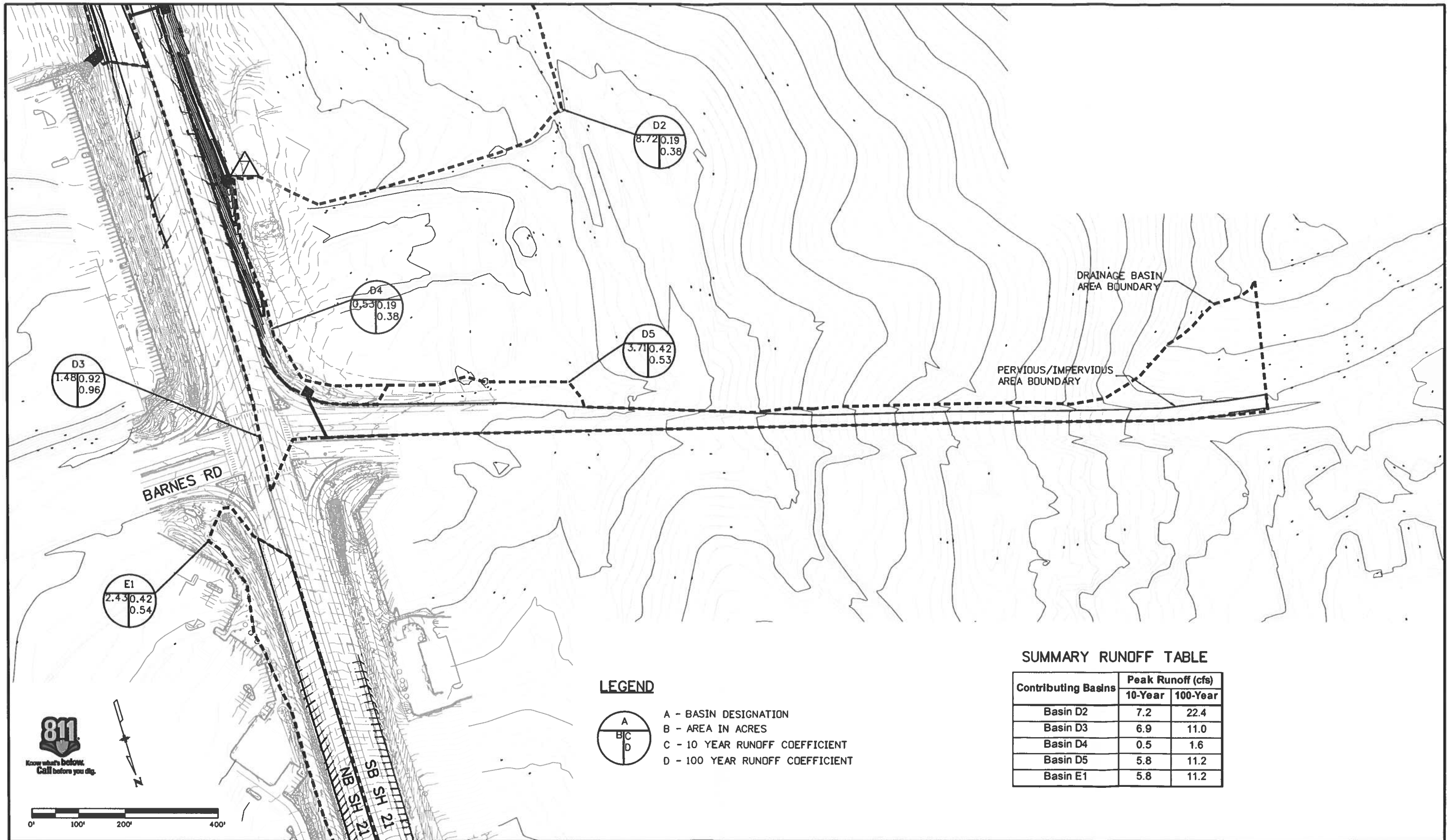
Phone: 719-634-2323 FAX: 719-227-3298
Region 2 MSA

As Constructed
No Revisions:
Revised:
Void:

STATE HIGHWAY NO. 21
POWERS BLVD CORRIDOR
IMPROVEMENTS BASIN MAP

Designer: KPK
Detailer: CJL
Sheet Subset: BASINS
Structure Numbers:
Subset Sheets: BM-2 OF 6

Project No./Code
SHE-0212-006
19500R
Sheet Number



LEGEND

A - BASIN DESIGNATION
B - AREA IN ACRES
C - 10 YEAR RUNOFF COEFFICIENT
D - 100 YEAR RUNOFF COEFFICIENT

SUMMARY RUNOFF TABLE

Contributing Basins	Peak Runoff (cfs)	
	10-Year	100-Year
Basin D2	7.2	22.4
Basin D3	6.9	11.0
Basin D4	0.5	1.6
Basin D5	5.8	11.2
Basin E1	5.8	11.2

Print Date: 7/3/2014
File Name: 19500BASINS_Plan03.dgn
Horiz. Scale: 1:200 Vert. Scale: As Noted
Unit Information Unit Leader Initials

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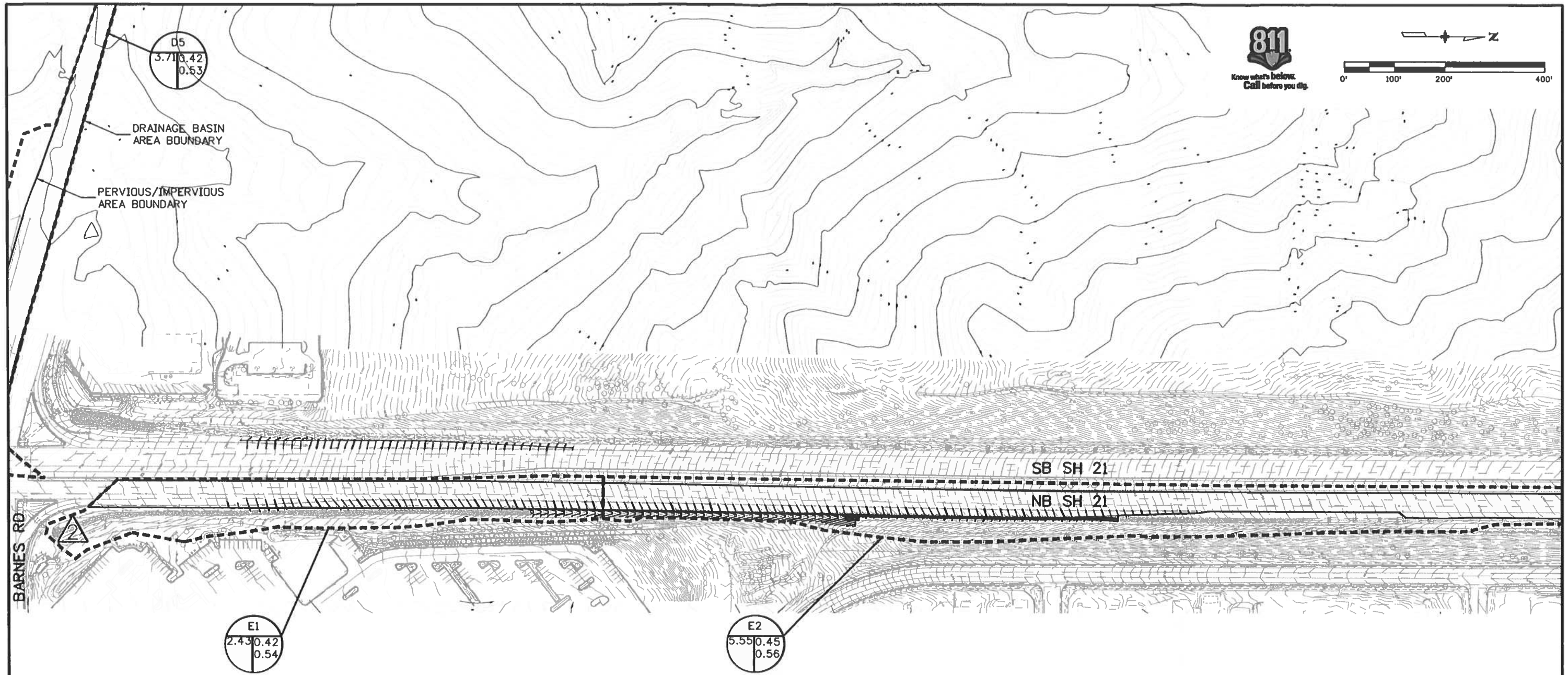
No Revisions:
Revised:
Void:

STATE HIGHWAY NO. 21
POWERS BLVD CORRIDOR
IMPROVEMENTS BASIN MAP

Designer: KPK
Detailer: CJL
Sheet Subset: BASINS
Structure Numbers:
Subset Sheets: BM-3 OF 6

Project No./Code
SHE-0212-006
19500R
Sheet Number



LEGEND

A - BASIN DESIGNATION
B - AREA IN ACRES
C - 10 YEAR RUNOFF COEFFICIENT
D - 100 YEAR RUNOFF COEFFICIENT

SUMMARY RUNOFF TABLE

Contributing Basins	Peak Runoff (cfs)	
	10-Year	100-Year
Basin D5	5.8	11.2
Basin E1	5.8	11.2
Basin E2	11.1	20.9

Print Date: 7/3/2014
File Name: 19500BASINS_Plan04.dgn
Horiz. Scale: 1:200 Vert. Scale: As Noted
Unit Information Unit Leader Initials

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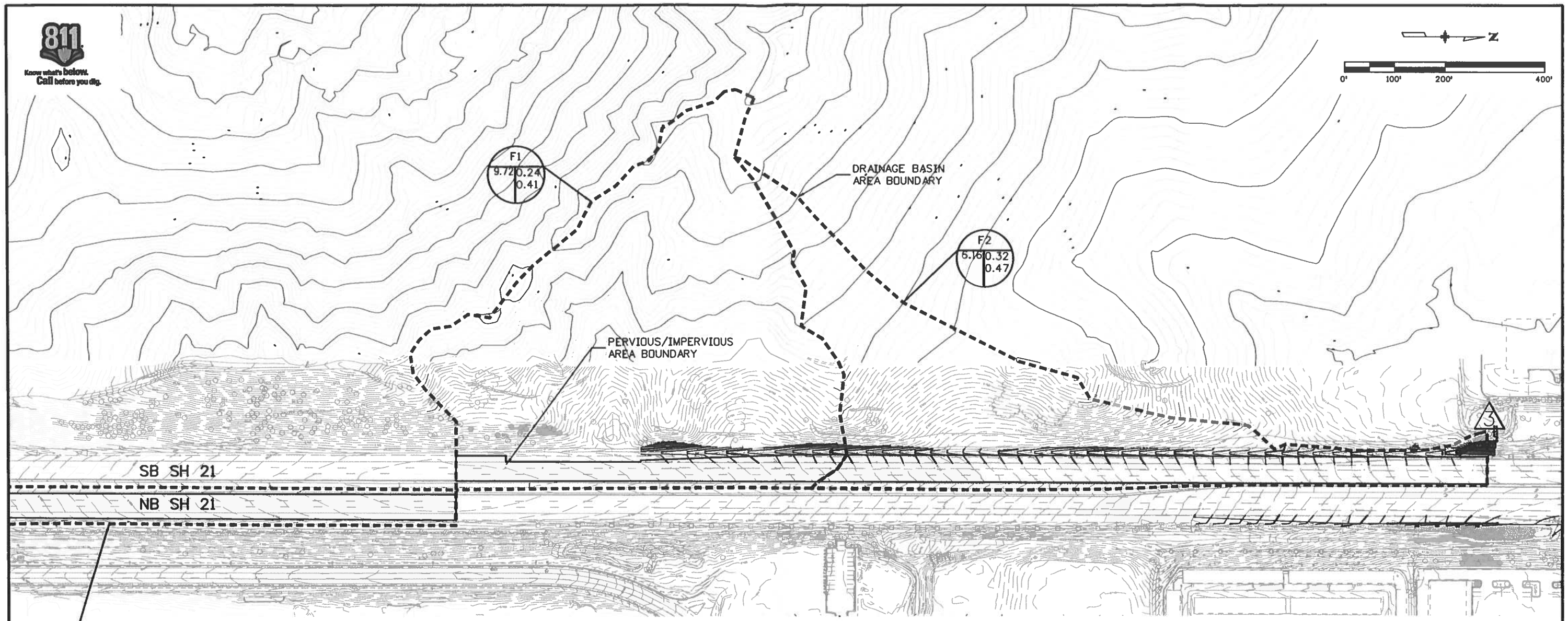
Revised:
Void:

STATE HIGHWAY NO. 21
POWERS BLVD CORRIDOR
IMPROVEMENTS BASIN MAP

Designer: KPK
Detailer: CJL
Sheet Subset: BASINS
Structure Numbers:
Subset Sheets: BM-4 OF 6

Project No./Code
SHE-0212-006
19500R
Sheet Number



LEGEND

A - BASIN DESIGNATION
B - AREA IN ACRES
C - 10 YEAR RUNOFF COEFFICIENT
D - 100 YEAR RUNOFF COEFFICIENT

SUMMARY RUNOFF TABLE

Contributing Basins	Peak Runoff (cfs)	
	10-Year	100-Year
Basin E2	11.1	20.9
Basin F1	10.5	28.2
Basin F2	7.5	17.1

Print Date: 7/3/2014
File Name: 19500BASINS_Plan05.dgn
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Region 2 MSA

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No Revisions:
Revised:
Void:

STATE HIGHWAY NO. 21
POWERS BLVD CORRIDOR
IMPROVEMENTS BASIN MAP

Designer: KPK
Detailer: CJL
Sheet Subset: BASINS
Structure Numbers:
Subset Sheets: BM-5 OF 6

Project No./Code
SHE-0212-006
19500R
Sheet Number

Know what's below. Call before you dig.

N

0' 100' 200' 400'

G1
5.93 | 0.27
0.44

DRAINAGE BASIN AREA BOUNDARY

PERVIOUS/IMPERVIOUS AREA BOUNDARY

STETSON HILLS BLVD.

G2
8.07 | 0.31
0.46

SB SH 21

NB SH 21

H1
2.18 | 0.42
0.53

H2
1.88 | 0.48
0.58

LEGEND

A - BASIN DESIGNATION
B - AREA IN ACRES
C - 10 YEAR RUNOFF COEFFICIENT
D - 100 YEAR RUNOFF COEFFICIENT

SUMMARY RUNOFF TABLE

Contributing Basins	Peak Runoff (cfs)	
	10-Year	100-Year
Basin G1	7.0	17.5
Basin G2	11.9	27.2
Basin H1	5.4	10.4
Basin H2	4.7	8.7

Print Date: 7/3/2014
File Name: 19500BASINS_Plan06.dgn
Horiz. Scale: 1:200 Vert. Scale: As Noted
Unit Information Unit Leader Initials

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Region 2 MSA

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No Revisions:
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Void:

STATE HIGHWAY NO. 21
POWERS BLVD CORRIDOR
IMPROVEMENTS BASIN MAP

Designer: KPK
Detailer: CJL
Sheet Subset: BASINS
Structure Numbers:
Subset Sheets: BM-6 OF 6

Project No./Code
SHE-0212-006
19500R
Sheet Number