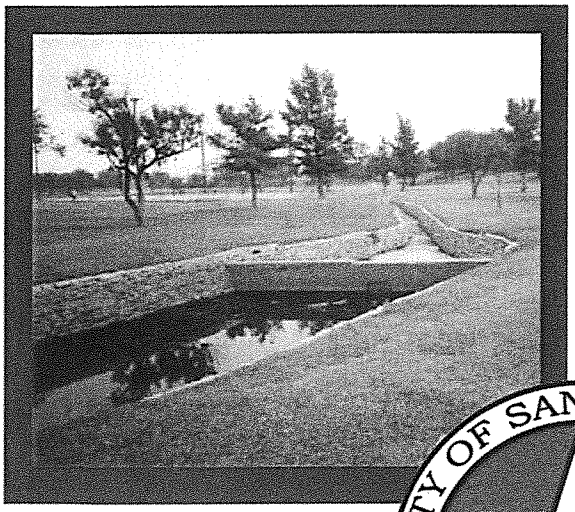
CITY OF SAN ANGELO

MASTER DRAINAGE PLAN AND STORMWATER ORDINANCE



OCTOBER 2000

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CITY OF SAN ANGELO

MASTER DRAINAGE PLAN

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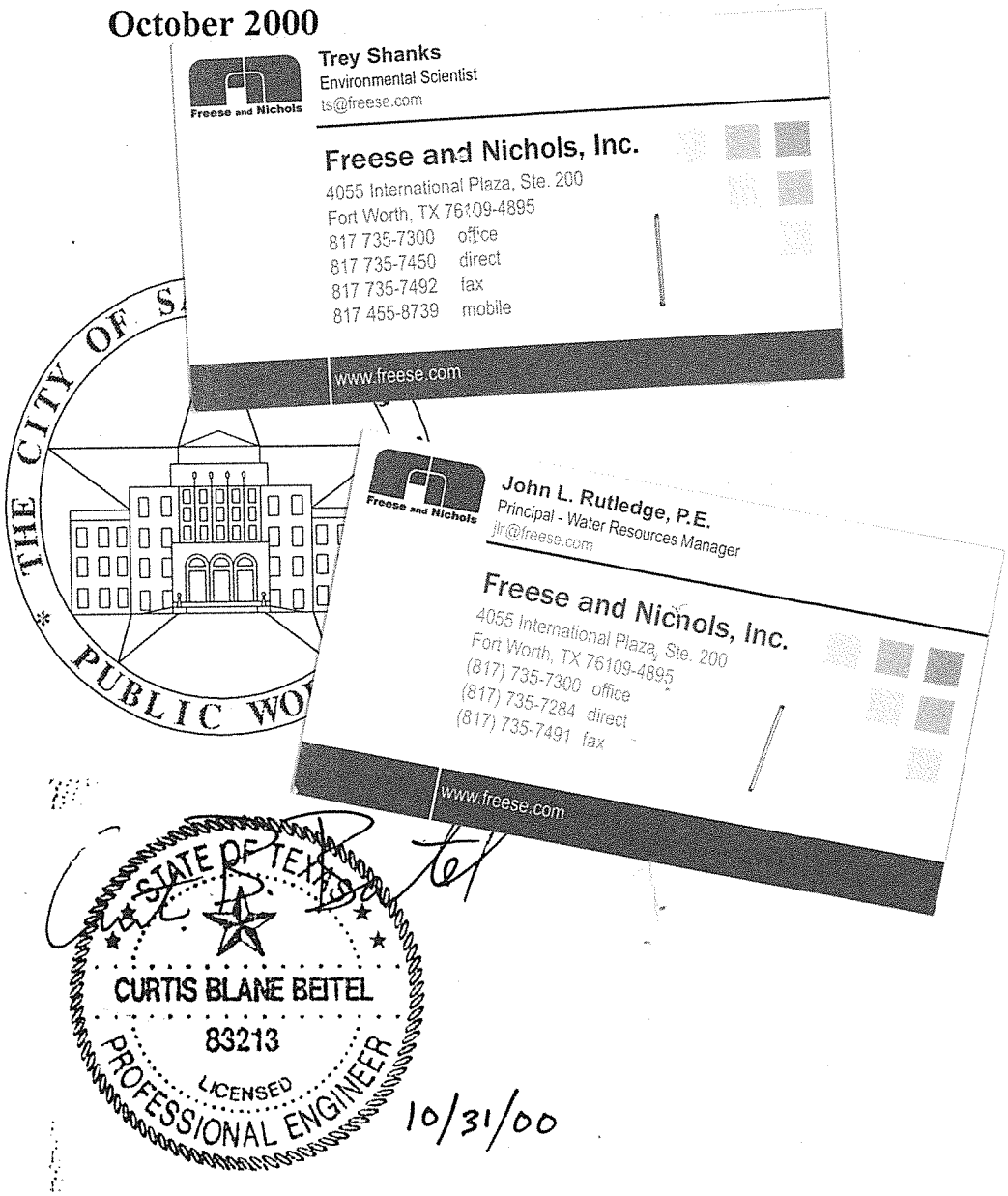

FREESE AND NICHOLS, INC.
CONSULTING ENGINEERS
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City of San Angelo
Master Drainage Plan

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City of San Angelo
Master Drainage Plan

Executive Summary

The City of San Angelo Master Drainage Plan was prepared to assist the City in evaluating the existing conditions of their drainage infrastructure, provide solutions to address the existing drainage problems throughout the city, and to develop the drainage policies and criteria that require adequate drainage infrastructure to be included in future development. Drainage criteria which is appropriate for the City of San Angelo was developed for street flows, bridge and culvert designs, and detention pond designs. A proposed Stormwater Ordinance was developed to put the criteria in place, and a Stormwater Manual was prepared to standardize the design methods which designers will use to satisfy the criteria. In addition, a Stormwater Maintenance Manual was developed to establish drainage maintenance procedures.

Through discussions with City staff and field verification, a list of 57 key study elements was developed which represents most of the known drainage problems which currently exist in San Angelo. Design flow rates were determined at each of the key study element locations as well as the capacity of the existing drainage infrastructure. A ranking procedure was developed to prioritize the key study elements which included a number of factors, such as: the traffic loading and street type, degree of the problem relative to the 10-year and 100-year criteria, velocity of 100-year flow, estimated construction cost, amount of contributing drainage area, City staff opinion, ability to solve adjacent problems, history of flooding, and number of structures in the 100-year floodplain. Based on the numeric scores from the ranking process, the list of 57 key study elements was prioritized. Proposed solutions were developed for the top 25 key study elements, and each of the proposed solutions is described in Section 4 of this report along with an opinion of probable project cost which includes construction, contingency, utilities conflicts, engineering, and surveying expenses. In addition, methods for funding the improvements were investigated, as described in Section 5, and the impact of current and future environmental regulations on the City was reviewed in Section 6, including the upcoming Phase 2 NPDES regulations.

The following table summarizes the conceptual improvements which were recommended for the top 25 key study elements.

Solution (Rank-Element-Option)	Key Study Element Description	Project	Conceptual Project Cost
1-50-2	Bell Street at Koberlin Street	1	$2,087,800
2-34-1	West Avenue P at Bryant Boulevard	2	$1,489,500
3-14-2	Pecan Street at 3rd Street	3	$719,100
4-11-2	Taylor Street at Conchita Street	4	$2,486,200
5-51-2	Preusser Street (Lowrie to Schroeder)	5	$582,000
17-52-2	Coke Street at East Angelo Draw	5	$1,510,600
6-37-2	Sul Ross Street at Sunset Drive	6	$1,231,400
14-38-2	Lindenwood Drive at Vista Del Arroyo	6	$553,300
7-29-2	Southwest Blvd at S. Fork Red Arroyo	7	$3,318,400
8-10-2	Beauregard Ave (Campus to N. Concho)	8	$2,212,100
25-12-2	Madison Street (Avenue J to Algerita)	8	$171,900
9-7-2	Howard Street (North to Webster)	9	$294,300
24-5-2	Howard Street at Brentwood Park	9	$43,800
10-2-2	Glenwood Drive at Howard Street	10	$781,700
23-3-1	Glenwood Drive(Harrison to Greenwood)	10	$747,800
11-54-1	Regent Boulevard at Gordon Boulevard	11	$2,132,700
12-28-1	College Hills Blvd at N. Fork Red Arroyo	12	$3,542,300
15-31-1	College Hills Blvd at S. Fork Red Arroyo	12	$3,486,600
13-43-2	30th Street at Day Elementary	13	$256,000
16-13-2	Monroe Street at Sulphur Draw Park	14	$456,200
18-30-1	Loop 306 Access Road at Eckerd's	15	$2,713,400
19-18-1	Lester Lane at Tres Rios Drive	16	$104,100
20-20-1	Goodfellow Draw at Evelyn Avenue	17	$976,000
21-46-1	24th Street at Blum Street	18	$2,777,200
22-47-2	Bradford Street at 24th Street	19	$509,700
			$35,184,100

Section 1 Introduction

Located in west Texas, the annual rainfall of San Angelo is less than most parts of the state, which has historically resulted in less emphasis on the drainage infrastructure. Much of the stormwater runoff is conveyed in streets, including some streets which have an inverted crown section, and San Angelo has very few underground storm drain systems. In addition, some areas of San Angelo are extremely flat, which reduces the amount of As a result of these factors, the occasional large storms result in widespread flooding of streets.

1.1 Purpose

The purpose of this Master Drainage Plan is twofold: to develop drainage policies and criteria that require adequate drainage infrastructure for future development, and to identify solutions which address the existing drainage problems. The general steps taken to accomplish this goal are discussed below:

1. Identified drainage problem areas throughout the city
2. Prepared updated hydrologic and hydraulic models for each area
3. Established practical drainage criteria for San Angelo
4. Prioritized the problem areas using a ranking system with City staff involvement
5. Developed proposed solutions for the top 25 problem areas, including estimates of probable project costs
6. Evaluated possible funding sources for stormwater management
7. Reviewed environmental regulations, including the impact of NPDES Phase 2 requirements
8. Developed a comprehensive Stormwater Ordinance to put the criteria in place
9. Prepared a Stormwater Design Manual to standardize the design methods to be used to satisfy the criteria
10. Prepared a Stormwater Maintenance Manual to establish maintenance practices and procedures

1.2 Data Collection

Drainage data collected from the City of San Angelo included:

1. Information from City staff concerning known flooding concern areas
2. Existing drainage system "As Built" drawings
3. Current drainage policies, criteria, and ordinances
4. City topographic maps (reproducible and digital)
5. City aerial photos
6. Applicable zoning maps
7. Current FEMA maps, hydrology models, and hydraulic models

1.3 Identification of Key Study Elements

As with most cities, an almost endless list of drainage problems could be generated for San Angelo. To allow our study to focus on the most important drainage issues, Key Study Elements were identified throughout the city which included the major streets and channels with a contributing drainage area greater than 25 acres or flow greater than 100 cubic feet per second (cfs), key roadway crossings, and locations with historic reported flooding. At each of these locations design flow rates were developed and the drainage conditions were assessed as described in Section 2 of this report. Based on discussions with City staff and a review of the collected data, a total of 57 Key Study Elements within the City limits were identified, the locations of which are shown on Plate 1, located in Appendix A of this report. A detailed listing of each Key Study Element location and brief description of the problem at that location is included in Table 1-1.

1.4 Field Reconnaissance and Problem Identification

Field reconnaissance was performed at each Key Study Element to confirm the general condition, location, and size of the significant drainage facilities. The review was limited to those items that could be visibly observed, and a minimal amount of surveys were performed to verify flow line elevations or pipe sizes. In addition to locating storm drain outfalls, bridge openings and culvert sizes were verified.

Table 1-1
Key Study Elements

Element	Location	Problem Description
1	Glenna St. at Childress St	Ponded water flows over and around berm into neighborhood to the southeast.
2	Glenwood Dr. at Howard St.	Excessive street flow
3	Glenwood Dr. between Harrison and Greenwood	Low water crossing
4	Van Buren St. between Westcliff and Glenwood St.	Low water crossing
5	Howard St. at Brentwood Park	Low water crossing and street flooding
6	Monroe St. between Woodlawn Dr. and Forest Park Ave	Low channel capacity in park through Jefferson St.
7	Howard St. between North St. and Webster Ave.	Heavy street flow
8	19th St. at 19th St. ramp	Excessive street flow south along RR to 19th St, then west to North Concho River
9	Culvert under U.S.Hwy 67 west of U.S. Hwy 87	Ponding and overland flow
10	Beauregard Ave. from Campus to Concho River	Excessive street flow along Beauregard to North Concho River
11	Taylor St. at Conchita St.	Waist high street flow from Beauregard
12	Madison St. between Avenue J and Algerita Dr.	Excessive flows along Conchita to Santa Rita Elementary
13	Monroe St. at Sulphur Draw Park	Receives excessive street flow from Lincoln and Conchita
14	Pecan St. at 3rd St.	Reported flooding of buildings at 3rd St. and Main, street flow to Harris Ave.
15	Main St. at Harris Ave.	Undersized culvert from 3rd St., excessive street flow along Main
16	Holcomb St. between 12th/10th St.	West Side 12th/10th and Holcomb St. Excessive street flow
17	Seller St. between Norma St. and La Salle Dr.	Inadequate channel between Norma St. and La Salle Dr.
18	Lester Ln. at Tres Rios Dr.	Excessive street flow and ponding
19	Clovis St. at Kennedy Dr.	Excessive street flow from Riverside Ave. down to Concho River
20	Goodfellow Draw at Evelyn and Era	Reported flow between houses
21	Christoval Rd. at Crestwood Dr.	Low water crossing
22	Between Jackrabbit Tr. And Delwood Dr. west of Christoval Rd.	Excessive flow from area upstream of Christoval Rd.
23	Arden Rd. at Houston Harte Frontage Rd.	Excessive flow in alley
24	Robinhood Tr. At Amistad Rd.	Excessive ponding at intersection
25	Cedar Creek Lane at Clare Dive	High velocity flow in alley, between houses/ Street to River
26	Trinity Dr. at College Hills Blvd.	Street, yard, and house flooding start of College Hills Blvd. street flooding.
27	Cornell Dr. at College Hills Blvd.	Street, yard, and house flooding start of College Hills Blvd. street flooding.
28	College Hills Blvd. at North Fork Red Arroyo	As south street flow from Oxford enters Red Arroyo, 3-4' depth of flow in street (north side)
29	Southwest Blvd. at South Fork Red Arroyo	Low water crossing
30	Behind Eckerds Loop 306 Access Road	Channel from Loop 306 discharges across the parking lot to College Hills
31	College Hills Blvd. at South Fork Red Arroyo	As north street flow from Sunset enters Red Arroyo, 3-4' depth of flow in street (south side)
32	W. Avenue N at Jackson St.	Ponding in Avenue N due to slotted drains.
33	W. Avenue P upstream of Bryant Blvd.	Excessive street flow, reported house flooding, ponding
34	W. Avenue P downstream of Bryant Blvd.	Excessive street flow, channel capacity down to Ave. Q
35	Hill St., between Avenue P and Avenue Q	Excessive alley flow and low water crossing, reported house flooding
36	Austin at Avenue N	Upstream from #33
37	Sul Ross St. at Sunset Dr.	Excessive street flow from drainage area south of Loop 306
38	Lindenwood Dr. at Vista Del Arroyo St.	Excessive street flow, low water crossing
39	Parkview Dr. between Lindenwood and Vista Del Arroyo	Low water crossing
40	Proposed Valleyview Blvd. west of College Hills Blvd.	Proposed low water crossing
41	College Hills Blvd. north of Valleyview Blvd.	Low water crossing
42	Valleyview Blvd. east of College Hills Blvd.	Low water crossing
43	30th St. at east side of Day Elementary	Undersized channel
44	33rd St. and Orchard Dr.	Excessive flow behind homes between 33rd St. and Garden Rd. down to Day Elem.
45	29th St. at Magdalene St.	Excessive alley flow from 33rd St. and Garden Rd. to Lakeview Park
46	24th St. and Blum St.	Excessive alley flow from Blum across street, reported ponding
47	Bradford St. at 24th St.	Low water crossing into Bradford Park
48	Poe St. at Jones St.	Excessive street flow from 20th St. down to Jones and Scout streets
49	Emerson St. at Scout St.	Excessive street flow from Poe and Jones (up to 3' deep) to TX-DOT structure at U.S. 67
50	Bell St. between Koberlin and Spaulding	Low water crossing of East Angelo Draw
51	Preusser St. between Lowrie and Schroeder	Low water crossing of East Angelo Draw
52	Coke St. at East Angelo Draw	Low water crossing of East Angelo Draw
53	Smith Blvd. Between Gordon Blvd. and McGill Blvd.	Low water crossing downstream of proposed pond
54	Regent Blvd. and Gordon Blvd.	Proposed pond west of Sunlake Park
55	Ricks Drive at Pond	
56	River Valley Lane	Low water crossing
57	Wilde Subdivision, Templin Ct. and south of Templin Cir.	Low Water crossing

Section 2 Hydrologic and Hydraulic Analysis

2.1 Development of Land Use Estimates

Using the June 1, 1998 zoning maps, provided by the City of San Angelo, land uses for existing conditions were projected over the drainage basins for each of the 57 Key Study Elements. By combining these land uses along with soil types, provided by the December 1976 "Soil Survey of Tom Green County, Texas," by the Soil Conservation Service, basic stormwater runoff parameters were developed for each basin.

2.2 Development of Existing Flows

In accordance with the proposed Stormwater Manual, peak flows for drainage areas under 200 acres in size were calculated using the Rational Method. Peak flows for areas between 200 and 2,000 acres were calculated using the SCS Method, and for areas greater that 2,000 acres, peak flows were calculated using the Snyder Method. The intensity-duration-frequency relationship used for the design rainfall is also given in Section 4 of the Stormwater Manual. In areas where the official FEMA current effective hydrologic model was available, the peak flow rates were compared and were in general agreement with the FEMA flow rates. The design flow rates at each Key Study Element for the 2-year through 500-year storm events are provided in Table 2-1, which also indicates which method was used to calculate the peak flow rate for each basin.

2.3 Hydraulic Models of Main Conveyance Channels

The major streams which have been studied in the San Angelo area are: the North Concho River, Brentwood Park Arroyo, Sulfur Draw, South Concho River, East Angelo Draw, North Fork Red Arroyo, South Fork Red Arroyo, West Branch South Fork Red Arroyo, and Goodfellow Draw. For Key Study Elements along these streams, the FEMA current effective hydraulic model was used as the basis for the hydraulic analysis. In some instances these models were enhanced with additional cross sections taken from the two foot topographic map provided by the City. For stream and conveyance channels which were not previously studied, short HEC-RAS hydraulic models were developed using cross sections taken from the two foot topographic maps. In both cases, the existing condition models were analyzed in the computer program HEC-RAS. The geometry of these models was then modified to describe the proposed Solutions which are described in Section 4 of this report.

Table 2-1
San Angelo Master Drainage Plan
Key Study Element Design Flows

Element	Method	Rational Method										SCS Method										
		Area (ac)	C	Tc	Q-2	Q-5	Q-10	Q-25	Q-50	Q-100	Q-500	Total A Mi^2	W CN	Tc	Int Loss	Q-2	Q-5	Q-10	Q-25	Q-50	Q-100	Q-500
1	RATIONAL	105.0	0.50	33.53	107	142	164	214	272	312	403	0.16	83.72	0.34	0.39	100	174	222	293	354	406	550
10A	RATIONAL	51.2	0.67	31.38	73	97	112	145	185	212	272	0.08	88.02	0.31	0.27	65	104	128	164	195	221	292
10B	SCS	208.0	0.56	37.63	221	296	342	445	568	654	851	0.33	83.82	0.38	0.39	183	320	410	544	660	761	1038
10C	RATIONAL	130.6	0.73	46.86	154	208	240	313	402	465	613	0.20	89.27	0.47	0.24	138	218	269	342	409	464	623
11	SCS	273.9	0.58	45.98	259	349	404	526	676	781	1029	0.43	84.17	0.46	0.38	217	378	485	644	785	907	1249
12	SCS	543.4	0.55	54.35	432	585	678	885	1140	1321	1758	0.85	83.29	0.54	0.40	367	654	844	1130	1389	1615	2253
13	SCS	496.6	0.55	50.69	419	566	655	854	1099	1272	1686	0.78	83.40	0.51	0.40	347	622	803	1072	1315	1527	2123
14	SCS	650.2	0.61	60.79	530	720	835	1090	1408	1635	2187	1.02	84.84	0.61	0.36	453	786	1003	1322	1616	1868	2593
15	SCS	772.5	0.64	63.51	641	871	1011	1321	1707	1984	2660	1.21	85.85	0.64	0.33	558	948	1198	1560	1900	2189	3029
16	RATIONAL	8.3	0.55	32.23	10	13	15	19	24	28	36	0.01	81.81	0.32	0.44	7	13	17	22	27	32	43
17	RATIONAL	177.9	0.58	29.63	227	303	349	453	575	658	842	0.28	82.36	0.30	0.43	22	39	51	69	83	96	131
18	RATIONAL	76.8	0.51	30.13	85	114	131	170	216	247	317	0.12	80.29	0.30	0.49	60	112	148	204	250	291	401
19	RATIONAL	83.8	0.50	36.44	81	108	125	162	207	238	309	0.13	81.20	0.36	0.46	63	118	154	209	256	298	412
2	SCS	274.6	0.51	41.29	245	330	381	496	635	732	959	0.43	82.61	0.41	0.42	218	390	503	670	818	946	1302
20	SCS	591.4	0.51	45.18	500	674	779	1015	1302	1504	1981	0.92	80.72	0.45	0.48	383	718	947	1293	1596	1867	2614
21	RATIONAL	139.5	0.59	35.76	160	214	248	322	411	472	613	0.22	83.11	0.36	0.41	120	214	276	368	447	516	705
22	RATIONAL	87.5	1.53	40.03	242	324	375	290	340	376	491	0.14	82.10	0.40	0.44	243	434	559	744	908	1049	1444
23	RATIONAL	17.3	0.75	16.32	41	53	61	79	98	111	135	0.03	90.87	0.16	0.20	35	52	63	78	90	100	127
24A	RATIONAL	20.5	0.56	23.10	29	39	45	58	73	83	105	0.03	82.02	0.23	0.44	21	37	48	65	79	90	122
24B	RATIONAL	151.0	0.56	29.83	186	247	285	371	470	538	689	0.24	82.30	0.30	0.43	136	243	316	426	517	598	813
25	RATIONAL	35.2	0.50	22.33	46	61	70	91	114	130	163	0.06	80.83	0.22	0.47	34	63	82	112	135	156	210
26A	RATIONAL	37.1	0.71	20.28	73	96	111	144	180	204	253	0.06	89.59	0.20	0.23	67	101	123	155	180	200	255
26B	RATIONAL	54.4	0.65	21.74	94	124	142	185	232	264	329	0.09	87.10	0.22	0.30	78	126	157	203	239	270	351
27A	RATIONAL	10.2	0.56	23.31	15	19	22	29	36	41	52	0.02	85.13	0.23	0.35	13	21	27	35	42	48	63
27B	RATIONAL	69.1	0.59	23.51	104	138	158	206	259	295	371	0.11	81.17	0.24	0.46	66	120	155	209	253	292	396
28A	RATIONAL	146.6	0.56	26.98	190	252	291	378	477	545	693	0.23	81.35	0.27	0.46	131	242	315	426	518	599	814
28B	RATIONAL	155.5	0.57	28.52	199	265	305	396	502	574	733	0.24	81.83	0.29	0.44	140	255	332	447	542	626	851
29	RATIONAL	156.8	0.55	36.38	166	222	257	334	426	490	636	0.25	81.91	0.36	0.44	125	230	298	402	491	569	782
3	SCS	311.0	0.52	43.69	273	368	425	554	710	819	1077	0.49	82.96	0.44	0.41	236	424	548	732	895	1036	1432
30	RATIONAL	28.8	0.61	26.36	42	55	64	83	104	119	151	0.05	86.13	0.26	0.32	37	60	75	97	115	131	172
31	SCS	238.7	0.62	42.55	255	343	397	516	662	763	1002	0.37	80.48	0.43	0.49	150	289	382	523	647	758	1064
32	RATIONAL	97.3	0.56	34.31	109	146	168	219	279	320	414	0.15	83.32	0.34	0.40	88	155	199	265	321	370	504
33A	RATIONAL	28.2	0.50	24.75	35	46	53	69	87	99	125	0.04	81.23	0.25	0.46	26	48	63	84	102	118	160
33B	RATIONAL	181.8	0.63	35.19	224	300	346	450	573	659	854	0.28	85.65	0.35	0.34	192	321	404	525	630	719	965
34	SCS	467.8	0.60	47.63	451	608	704	917	1178	1362	1799	0.73	83.89	0.48	0.38	362	634	810	1069	1304	1506	2079
35	SCS	537.6	0.60	53.10	476	644	746	972	1253	1451	1928	0.84	83.41	0.53	0.40	366	655	847	1133	1391	1616	2252
35	SCS	553.6	0.60	56.44	469	635	736	961	1239	1437	1915	0.87	83.44	0.56	0.40	365	655	845	1126	1383	1607	2243
36	RATIONAL	160.6	0.55	42.85	152	204	236	307	393	454	596	0.25	82.42	0.43	0.43	117	214	277	373	458	532	737
37	SCS	282.2	0.71	27.04	468	621	715	929	1174	1341	1706	0.44	88.72	0.27	0.25	414	645	790	999	1176	1321	1721
38	SCS	330.9	0.69	28.82	510	679	782	1016	1287	1473	1882	0.52	87.54	0.29	0.28	437	699	865	1106	1310	1479	1945
39	SCS	382.7	0.68	34.73	517	691	798	1037	1322	1518	1967	0.60	86.82	0.35	0.30	432	706	880	1133	1354	1539	2055
4	SCS	322.6	0.52	45.03	277	373	431	562	721	833	1096	0.50	82.98	0.45	0.41	242	433	560	748	916	1062	1468
40A	SCS	209.9	0.56	31.25	250	334	385	500	635	728	935	0.33	75.12	0.31	0.66	108	235	324	463	582	692	988
40B	SCS	216.3	0.56	32.32	252	336	388	504	641	735	948	0.34	75.12	0.32	0.66	109	239	329	472	594	706	1007
41	RATIONAL	102.4	0.50	29.60	113	150	173	225	285	326	418	0.16	78.04	0.30	0.56	69	136	182	255	316	371	518
42	RATIONAL	147.2	0.50	35.22	146	195	225	292	373	428	555	0.23	79.73	0.35	0.51	103	199	263	361	445	520	722
43	RATIONAL	169.6	0.59	79.22	109	149	173	227	294	343	464	0.27	83.59	0.79	0.39	93	166	213	284	350	408	576
44	RATIONAL	89.0	0.60	70.74	64	87	101	132	171	199	268	0.14	84.90	0.71	0.36	56	98	124	164	201	233	325
45	SCS	283.5	0.56	86.79	162	222	259	340	440	515	698	0.44	82.89	0.87	0.41	136	249	323	433	537	629	895
46	RATIONAL	71.7	0.60	43.22	74	99	114	149	191	220	290	0.11	84.07	0.43	0.38	59	104	133	176	214	246	338
47	RATIONAL	176.0	0.54	60.81	127	173	201	262	339	393	526	0.28	82.72	0.61	0.42	107	194	252	339	418	487	683
48	RATIONAL	177.3	0.62	42.18	191	257	297	387	496	572	750	0.28	87.23	0.42	0.29	181	295	369	474	569	649	875
49	RATIONAL	197.8	0.61	43.44	206	277	320	416	534	616	810	0.31	86.95	0.43	0.30	197	324	405	522	627	715	966
5	RATIONAL	171.5	0.52	33.84	180	241	278	361	460	528	682	0.27	82.33	0.34	0.43	145	262	339	455	554	640	877
5B	SCS	558.4	0.52	33.84	587	784	905	1176	1498	1720	2223	0.87	84.05	0.37	0.38	0	0	0	0	0	0	0
50	SNYDERS	15151.4	0.44	253.65	2890	4054	4778	6417	8297	9851	13486	23.67	80.53	2.54	0.48	2704	5300	7079	9921	12486	15043	22151
51	SNYDERS	15457.9	0.45	258.98	2920	4097	4830	6490	8390	9965	13639	24.15	80.59	2.59	0.48	2715	5320	7104	9969	12544	15115	22254
52	SNYDERS	15542.4	0.45	263.26	2898	4068	4796	6448	8335	9901	13550	24.29	80.57	2.63	0.48	2696	5283	7060	9904	12458	15019	22124
53	SNYDERS	2101.1	0.51	172.49	631	878	1030	1371	1778	2100	2877	3.28	81.71	1.72	0.45	550	1053	1390	1912	2395	2856	4162
54	SCS	1793.3	0.49	166.28	535	744	873	1161	1505	1777	2435	2.80	81.41	1.66	0.46	460	889	1181	1634	2054	2454	3589
55	SCS	1833.0	0.49	169.58	540	751	881	1172	1520	1795	2460	2.86	81.43	1.70	0.46	462	894	1185	1640	2062	2466	3610
56	SCS	281.6	0.50	39.49	256	344	397	517	661	762	995	0.44	79.70	0.39	0.51	186	356	470	643	795	933	1306
57	RATIONAL	138.9	0.55	62.45	100	136	158	206	267	310	415	0.22	81.99	0.62	0.44	79	146	190	257	318	373	526
6	SCS	635.9	0.51	43.67	553	744	861	1120	1437	1658	2179	0.99	83.06	0.44	0.41	516	907	1162	1538	1872	2160	2967
7a	SCS	371.8	0.52	36.22	373	500	577	750	957	1100	1429	0.58	84.87	0.36	0.36	362	620	787	1032	1245	1426	1928
7b	SCS	380.2	0.52	36.81	377	506	584	759	969	1114	1449	0.59	84.86	0.37	0.36	363	623	791	1039	1255	1438	1948
8	RATIONAL	53.1	0.70	23.67	94	125	143	186	234	267	336	0.08	85.64	0.24	0.34	69	113	141	182	217	246	325
9	SCS	965.1	0.66	66.84	794	1081	1256	1641	2122	2469	3316	1.51	84.10	0.67	0.38	593	1055	1357	1802	2215	2574	3604

Section 3 Prioritization of Key Study Elements

3.1 Development of Design Criteria

The design criteria which applied at each key study element was dependent on whether it was a street, open channel, bridge, or culvert. Working with City staff, acceptable levels of flow were identified during the 10-year and 100-year storm events for each type of key study element. For streets during the 10-year storm, one lane would remain open in each direction for arterial streets, one lane would remain open for collector streets, and the flow was to be contained within the top of curb for residential streets. In addition, the 100-year street flow was contained within the right-of-way limits. Improved open channels were sized to contain the 100-year ultimate development flow with 1 foot of freeboard to the top of the channel lining. Culvert crossings were sized to pass the 100-year ultimate development flow with 1 foot of freeboard to the lowest elevation of the roadway at the culvert. Bridge crossings were designed to pass the 100-year ultimate development flow with one foot of clearance below the lowest part of the open span of the bridge, often called the low chord. Detention pond outlets were sized such that the resulting pond elevation from the 100-year ultimate development inflow was 1 foot below the lowest point around the perimeter of the pond. These criteria are summarized in Table 3-1.

Table 3-1
Design Criteria

Key Study Element Type	10-year Criteria	100-year Criteria
Arterial Streets	11' lane each way open	within right-of-way
Collector Streets	11' lane open	within right-of-way
Residential Streets	top of curb (6" at crown)	within right-of-way
Alleys	top of curb	within right-of-way
Open channels	none	1 foot freeboard to top of channel
Culvert crossings	none	1 foot freeboard to roadway elevation
Bridge crossings	none	1 foot freeboard to low chord
Detention Ponds	none	1 foot of freeboard to top of slope

3.2 Development of the Ranking Process

The ranking system developed for determining the priority of the key study elements consists of 8 categories, as summarized in Table 3-2.

Table 3-2
Ranking System for Determining Priority of Key Study Elements

1	Traffic/Street Type*	Arterials	Collector	Residential			
	Score	10	7	3			
2	Storm Passing the 10-year Criteria	< 2 year	2 year	5 year	10 year		
	Score	10	7	3	0		
3	Storm Passing the 100-year Criteria	< 10 year	10 year	25 year	50 year	< 100 year	100 year
	Score	10	8	6	4	2	0
4	100-Year Velocity (fps), for depths over one foot in the street	10	8	6	4	2	0
	Score	10	8	6	4	2	0
5	Cost Benefit (summation of a, b, and c)*	25	20	15	10	5	0
	a. Probable construction cost (millions)	less than .5	.5 to 1	1 to 1.5	1.5 to 3	3 to 6	more than 6
	Score	5	4	3	2	1	0
	b. Acres of incorporated drainage area contributing to the element	> 640	640-401	400-251	250-151	150-81	< 80
	Score	10	8	6	4	2	0
	c. City Staff input*	10	8	6	4	2	0
	Score	10	8	6	4	2	0
6	Ability to Improve Other Infrastructure and Drainage Problems	Very High	High	Moderate	Low	None	
	Score	10	8	5	3	0	
7	History of Flooding of Structures (residential and commercial)	Every Storm	Yearly	Occasionally	Never		
	Score	10	7	3	0		
8	Number of Structures with Design Storm Flooding (residential and commercial)	5 or more	4 to 3	2 to 1	0		
	Score	15	10	5	0		

If either 10-year or 100-year criteria do not apply, the score for the criteria which does apply will be doubled
Maximum Total Score = 100
* Indicates City Staff input Required

In the event that two, or more elements receive the same score, the elements will be ranked using the following criteria:

1. Score for item 6. Ability to Improve Other Infrastructure and Drainage Problems
2. Score for item 3. Storm Passing the 100-year Criteria
3. Score for item 8. Number of Structures with Design Storm Flooding (residential and commercial)
4. City Staff Input*

The key study elements were ranked based on the total score of the eight categories, which resulted in a maximum possible score of 100 points. Each of the categories are described below:

1. Traffic/Street Type

   This category reflects the street type and traffic loading at the key element location, with the larger streets receiving more points. Arterial streets were assigned 10 points, collector streets were assigned 7 points, and residential streets were assigned 3 points.

2. Storm Passing the 10-year Criteria

   As discussed in the previous section, each type of key study element has a design criteria for the 10-year storm event. Points were assigned based on a comparison of the 2-year, 5-year, and 10-year design flows with the capacity of the existing drainage infrastructure. Depending on if the 10-year, 5-year, 2-year, or less than 2-year design flow was less than the existing capacity, 0, 3, 7, and 10 points were assigned, respectively. If either the 10-year or 100-year criteria did not apply, the score of the criteria that did apply was doubled. For example, at a culvert there is no 10-year criteria, so the score for the 100-year criteria is doubled.

3. Storm Passing the 100-year Criteria

   Each type of key study element also has a design criteria for the 100-year storm event. Points were assigned based on a comparison of the 10-year, 25-year, and 50-year design flows with the capacity of the existing drainage infrastructure. Depending on whether the 100-year, between the 100-year and 50-year, 50-year, 25-year, 10-year, or less than 10-year design flow was less than the existing capacity, 0, 2, 4, 6, 8, and 10 points were assigned, respectively.

4. Velocity of Flow

   This category accounts for the velocity of the 100-year flow at a key study element. If the 100-year velocity at a key study element was greater than 10 feet per second 10 points were assigned, and points for 100-year velocities less than 10 feet per second were assigned in even multiples between 10 feet per second and zero feet per second.

5. Cost-Benefit

   This category reflects the estimated cost of correcting the problem at the key study element, and includes aspects for probable construction cost, contributing drainage area, and City staff input. A total of 5 points were assigned for the probable construction cost, ranging from 0 points for more than $6 million to 5 points for less than $500,000. A total of 10 points were assigned for the amount of contributing drainage area, ranging from 0 points for less than 80 acres to 10 points for more than

80 acres. A total of 10 points were assigned to reflect City staff input, ranging from 0 points for projects not considered urgent to 10 points for projects that City staff viewed as definitely needing to be constructed.

6. Ability to Improve Other Problem Areas

This category reflects the ability of the solution at this key study element to solve drainage problems in other areas. A key study element with a high ability to reduce the problems in other areas, such as detention, was assigned 10 points, while a key study element that does not impact other elements did not receive any points.

7. History of Flooding of Structures

This category accounts for historical flooding at the key study element. If a structure adjacent to the key study element had a history of frequent flooding, it was assigned 10 points, and if no structure had reported flooding at the key study element, no points were assigned.

8. Number of Flooding Structures

The final category reflects the number of structures in the 100-year floodplain at the key study element. Points were assigned based on a comparison of the 100-year base flood elevation from the FEMA FIS with the ground elevation of adjacent lots. A key study element with 5 or more structures in the 100-year floodplain was assigned 15 points, while a key study element with no adjacent structures flooded received no points.

3.3 Prioritized List of Key Study Elements

Once design flow rates and capacities were determined for each of the key study elements, the ranking system was applied to develop scores for each element. In the event that two or more key study elements received the same score, the element with the highest score in category 6, "Ability to Improve Other Problem Areas" was ranked highest. If the elements received the same score in category 6, the score for category 3 was used to rank them, after which the score for category 8 was used to rank the elements. Table 3-3 is a list of the key study elements, along with the scores they were assigned in each category. The key study elements have been arranged according to their score in descending order.

Table 3-3
Individual Key Study Element Rankings

Element	Location	Problem Description	Score	Rank	Street	10 Year	100 Year	Vel	Cost	Area	City	Others	History	Number
					1	2	3	4	5a	5b	5c	6	7	8
50	Bell St. between Koberlin and Spaulding	Low water crossing of East Angelo Draw	71	1	Collector	< 2 year	< 10 year	6.83	6.40	15151	8	High	0	4
34	W. Avenue P downstream of Bryant Blvd.	Excessive street flow, channel capacity down to Ave. Q	70	2	Residential	< 2 year	< 10 year	15.19	3.93	468	10	Moderate	3	4
14	Pecan St. at 3rd St.	Reported flooding of buildings at 3rd St. and Main, street flow to Harris Ave.	69	3	Collector	< 2 year	< 10 year	33.60	3.81	650	6	Moderate	0	3
11	Taylor St. at Conchita St.	Waist high street flow from Beauregard	66	4	Residential	< 2 year	< 10 year	8.49	4.00	274	8	High	0	4
51	Preusser St. between Lowrie and Schroeder	Low water crossing of East Angelo Draw	63	5	Residential	< 2 year	< 10 year	5.48	3.20	15458	8	Moderate	0	4
37	Sul Ross St. at Sunset Dr.	Excessive street flow from drainage area south of Loop 306	62	6	Collector	< 2 year	< 10 year	17.27	1.13	282	6	Moderate	0	2
29	Southwest Blvd. at South Fork Red Arroyo	Low water crossing	62	7	Arterial	< 2 year	< 10 year	15.50	1.81	1190	10	None	0	0
10A	Beauregard Ave. from Campus to Concho River	Excessive street flow along Beauregard to North Concho River	61	8	Collector	< 2 year	< 100 year	5.71	5.00	208	8	Very High	3	3
7B	Howard St. between North and Webster	Heavy street flow	61	9	Residential	< 2 year	< 10 year	24.93	5.25	380	8	Low	0	4
2	Glenwood Dr. at Howard St.	Excessive street flow	60	10	Collector	< 2 year	< 10 year	18.39	0.98	275	8	Moderate	0	0
54	Regent Blvd. and Gordon Blvd.	Proposed pond west of Sunlake Park	60	11	Residential	< 2 year	< 10 year	4.45	1.64	1793	4	Moderate	0	4
28B	College Hills Blvd. at North Fork Red Arroyo	As street flow from Oxford enters Red Arroyo, 3-4' depth of flow in street (north side)	60	12	Arterial	< 2 year	10 year	9.17	0.24	156	10	Low	0	0
43	30th St. at east side of Day Elementary	Undersized channel	58	13	Residential	< 2 year	< 10 year	3.65	1.05	170	6	High	0	4
38	Lindenwood Dr. at Vista Del Arroyo St.	Excessive street flow, low water crossing	58	14	Residential	< 2 year	< 10 year	5.70	1.13	331	10	Moderate	0	2
31	College Hills Blvd. at South Fork Red Arroyo	As north street flow from Sunset enters Red Arroyo, 3-4' depth of flow in street (south side)	58	15	Arterial	< 2 year	< 10 year	8.01	0.84	239	10	None	0	0
13	Monroe St. at Sulphur Draw Park	Receives excessive street flow from Lincoln and Conchita	57	16	Residential	< 2 year	< 10 year	4.00	2.88	497	8	Moderate	0	2
52	Coke St. at East Angelo Draw	Low water crossing of East Angelo Draw	57	17	Residential	< 2 year	< 10 year	5.24	1.92	15542	8	Low	0	2
30	Behind Eckerds Loop 306 Access Road	Channel from Loop 306 discharges across the parking lot to College Hills	56	18	Collector	< 2 year	25 year	9.00	0.06	29	10	High	0	0
18	Lester Ln. at Tres Rios Dr.	Excessive street flow and ponding	56	19	Collector	< 2 year	< 10 year	7.66	0.03	77	10	None	6	0
20	Goodfellow Draw at Evelyn and Era	Reported flow between houses	56	20	Collector	< 2 year	< 10 year	4.06	0.19	591	10	None	0	0
46	24th St. and Blum St.	Excessive alley flow from Blum across street, reported ponding	55	21	Residential	< 2 year	< 10 year	6.41	1.95	72	4	High	0	4
47	Bradford St. at 24th St.	Low water crossing into Bradford Park	55	22	Residential	< 2 year	< 10 year	10.62	0.95	176	4	Moderate	0	2
3	Glenwood Dr. between Harrison and Greenwood	Low water crossing	55	23	Collector	< 2 year	< 10 year	4.24	0.13	311	8	Low	0	0
5	Howard St. at Brentwood Park	Low water crossing and street flooding	55	24	Collector	< 2 year	< 10 year	5.00	0.11	172	10	Low	0	0
12	Madison St. between Avenue J and Algerita Dr.	Excessive flows along Conchita to Santa Rita Elementary	55	25	Residential	2 year	< 10 year	5.55	0.15	543	10	Low	3	0
15	Main St. at Harris Ave.	Undersized culvert from 3rd St., excessive street flow along Main	54	26	Collector	< 2 year	< 10 year	7.12	2.00	772	2	Moderate	0	0

Table 3-3
Individual Key Study Element Rankings

Element	Location	Problem Description	Score	Rank	Street	10 Year	100 Year	Vel	Cost	Area	City	Others	History	Number
					1	2	3	4	5a	5b	5c	6	7	8
9	Culvert under U.S.Hwy 67 west of U.S. Hwy 87	Ponding and overland flow	54	27	Arterial	-	< 10 year	42.90	0.87	965	0	None	0	0
35B	Avenue R, between Irving and Chadbourne	Excessive alley flow and low water crossing, reported house flooding	53	28	Residential	< 2 year	< 10 year	4.06	0.42	554	8	Low	0	0
10B	Beauregard Ave. from Campus to Concho River		52	29	Collector	< 2 year	< 10 year	9.53	5.00	208	0	Very High	0	0
4	Van Buren St. between Westcliff and Glenwood St.	Low water crossing	51	30	Collector	< 2 year	< 10 year	3.58	0.14	323	6	Low	0	0
7A	Howard St. between North St. and Webster Ave.	Heavy street flow	51	31	Collector	< 2 year	< 10 year	16.85	-	372	0	Low	0	0
10C	Beauregard Ave. from Campus to Concho River		50	32	Collector	< 2 year	< 10 year	8.09	5.00	131	0	Very High	0	0
33B	W. Avenue P upstream of Bryant Blvd.	Excessive street flow, reported house flooding, ponding	50	33	Arterial	< 2 year	< 10 year	3.38	1.18	182	4	Moderate	0	0
48	Poe St. at Jones St.	Excessive street flow from 20th St. down to Jones and Scout streets	50	34	Residential	< 2 year	< 10 year	15.03	0.89	177	4	Moderate	0	0
32	W. Avenue N at Jackson St.	Ponding in Avenue N due to slotted drains.	50	35	Arterial	< 2 year	100 year	8.66	2.18	97	6	Moderate	0	2
36	Austin at Avenue N	Upstream from #33	50	36	Residential	< 2 year	< 10 year	9.76	0.87	161	6	Low	0	0
49	Emerson St. at Scout St.	Excessive street flow from Poe and Jones (up to 3' deep) to TX-DOT structure at U.S. 67	50	37	Residential	< 2 year	< 10 year	15.24	0.80	198	4	None	0	2
45	29th St. at Magdalene St.	Excessive alley flow from 33rd St. and Garden Rd. to Lakeview Park	49	38	Residential	< 2 year	< 10 year	10.15	1.05	284	4	Low	0	0
55	Ricks Drive at Pond		48	39	Residential	< 2 year	< 10 year	3.42	0.76	1833	4	Low	0	0
24B	Robinhood Tr. At Amistad Rd.	Excessive ponding at intersection	48	40	Residential	< 2 year	< 10 year	11.69	0.41	151	6	None	0	0
27B	Cornell Dr. at College Hills Blvd.	Street, yard, and house flooding start of College Hills Blvd. street flooding.	47	41	Collector	< 2 year	25 year	10.24	0.43	69	4	Moderate	0	0
26B	Trinity Dr. at to College Hills Blvd.	Street, yard, and house flooding start of College Hills Blvd. street flooding.	46	42	Collector	< 2 year	< 100 year	11.79	0.49	54	4	High	0	0
35A	Hill St., between Avenue P and Avenue Q	Excessive alley flow and low water crossing, reported house flooding	46	43	Residential	< 2 year	< 10 year	15.68	-	538	0	None	0	0
40A	Proposed Valleyview Blvd. west of College Hills Blvd.	Proposed low water crossing	46	44	Collector	< 2 year	< 10 year	15.12	1.13	216	2	None	0	0
53	Smith Blvd. Between Gordon Blvd. and McGill Blvd.	Low water crossing downstream of proposed pond	45	45	Residential	< 2 year	< 10 year	3.65	0.76	2101	4	None	0	0
57	Wilde Subdivision, Templin Ct. and south of Templin Cir.	Low Water crossing	45	46	Residential	< 2 year	< 10 year	11.48	0.83	139	6	None	0	0
28A	College Hills Blvd. at North Fork Red Arroyo	As south street flow from Oxford enters Red Arroyo, 3-4' depth of flow in street (north side)	45	47	Arterial	< 2 year	10 year	10.33	-	147	0	None	0	0
6	Monroe St. between Woodlawn Dr. and Forest Park Ave	Low channel capacity in park through Jefferson St.	44	48	Residential	< 2 year	< 10 year	3.87	0.14	636	4	None	0	0
39	Parkview Dr. between Lindenwood and Vista Del Arroyo	Low water crossing	44	49	Residential	< 2 year	< 10 year	2.94	0.15	383	6	None	0	0
1	Glenna St. at Childress St	Ponded water flows over and around berm into neighborhood to the southeast.	43	50	Collector	< 2 year	10 year	7.76	1.17	105	2	Low	0	0

Table 3-3
Individual Key Study Element Rankings

Element	Location	Problem Description	Score	Rank	Street	10 Year	100 Year	Vel	Cost	Area	City	Others	History	Number
					1	2	3	4	5a	5b	5c	6	7	8
40B	Proposed Valleyview Blvd. west of College Hills	Proposed low water crossing	42	51	Residential	< 2 year	< 10 year	12.38	-	210	0	None	0	0
22	Between Jackrabbit Tr. And Delwood Dr. west of Christoval Rd.	Excessive flow from area upstream of Christoval Rd.	40	52	Residential	< 2 year	< 10 year	1.29	0.09	87	8	None	0	0
44	33rd St. and Orchard Dr.	Excessive flow behind homes between 33rd St. and Garden Rd. down to Day Elem.	39	53	Residential	< 2 year	< 10 year	2.10	0.58	89	6	None	0	0
23	Arden Rd. at Houston Harte Frontage Rd.	Excessive flow in alley	39	54	Residential	2 year	10 year	10.83	0.25	17	6	None	0	0
16	Holcomb St. between 12th/10th St.	West Side 12th/10th and Holcomb St. Excessive street flow	37	55	Residential	< 2 year	10 year	2.59	0.29	8	2	None	0	2
56	River Valley Lane	Low water crossing	35	56	Residential	2 year	25 year	2.44	0.06	282	4	None	0	0
8	19th St. at 19th St. ramp	Excessive street flow south along RR to 19th St, then west to North Concho River	35	57	Arterial	< 2 year	100 year	11.56	-	53	0	None	0	0
26A	Trinity Dr. at College Hills Blvd.	Street, yard, and house flooding start of College Hills Blvd. street flooding.	34	58	Residential	< 2 year	25 year	9.47	-	37	0	None	0	0
25	Cedar Creek Lane at Clare Dive	High velocity flow in alley, between houses/ Street to River	34	59	Residential	< 2 year	< 100 year	8.28	0.30	35	4	None	0	0
21	Christoval Rd. at Crestwood Dr.	Low water crossing	33	60	Collector	10 year	100 year	8.00	-	140	8	Low	0	0
17	Seller St. between Norma St. and La Salle Dr.	Inadequate channel between Norma St. and La Salle Dr.	33	61	Residential	2 year	25 year	3.51	0.07	178	4	None	0	0
42	Valleyview Blvd. east of College Hills Blvd.	Low water crossing	32	62	Residential	< 2 year	25 year	2.37	0.31	147	2	None	0	0
19	Clovis St. at Kennedy Dr.	Excessive street flow from Riverside Ave. down to Concho River	31	63	Residential	2 year	25 year	2.46	0.10	84	4	None	0	0
41	College Hills Blvd. north of Valleyview Blvd.	Low water crossing	26	64	Residential	2 year	100 year	2.17	0.31	102	2	Low	0	0
33A	W. Avenue P upstream of Bryant Blvd.	Excessive street flow, reported house flooding, ponding	23	65	Residential	2 year	100 year	6.31	-	28	0	None	0	0
24A	Robinhood Tr. At Amistad Rd.	Excessive ponding at intersection	16	66	Residential	10 year	100 year	7.96	-	20		None		0
27A	Cornell Dr. at College Hills Blvd.	Street, yard, and house flooding start of College Hills Blvd. street flooding.	14	67	Residential	10 year	100 year	5.32	-	10	0	None	0	0

Section 4 Proposed Solutions

Conceptual solutions were developed for the 25 highest ranked key study elements shown in Table 3-3, and the locations of these solutions are shown on Plate 2, located in Appendix A of this report. The conceptual solutions included regional detention facilities, storm drain systems, culvert enlargements, street regrading, and channel improvements. The naming convention for the conceptual solutions consists of the ranking, key element number, and option number. For instance, the first option for the highest priority element at Key Element 50 is referred to as Solution 1-50-1.

Although the construction of the recommended solutions would improve the most significant drainage problems in San Angelo, once they are constructed the City should continue to make improvements to address the remaining 32 key study element locations. In addition, the City may wish to periodically review and update the list of key study element locations. The following sections describe the solutions that were developed for each key study element. For additional ease of reference, the ranking and key element number are provided in a box in the upper left hand corner of each section.

4.1 Bell Street at Koberlin Street

Ranking: 1
Key Element 50

4.1.1 Problem Description

Excessive flooding occurs as flow from East Angelo Draw crosses the road at the intersections of Bell and Koberlin as well as one block upstream at Archer and Spaulding. East Angelo Draw has a very large drainage area of 19.65 square miles which contributes to this location, producing peak discharges of 6,450 cfs during the 100-year storm event and 3,030 cfs during the 10-year storm event. According to the FEMA FIRM Panel 40, the 100-year floodplain at Bell and Koberlin is 740 feet wide and 6 feet deep at the intersection. Key Elements 51 and 52 are located further downstream on East Angelo Draw.

4.1.2 Possible Solutions

Solution 1-50-1 is to construct a regional detention facility along East Angelo Draw upstream of the Santa Fe railroad that will help lower the 100-year peak discharge rate, as well as the flood levels at Bell Street. Although the current Santa Fe railroad bridge and embankment provides some detention effect, it can be enhanced by excavating an 85 acre area up to 28th Street, constructing an earthen embankment with a top elevation at 1864 ft msl and a 45-foot wide concrete spillway with a crest at 1847 ft msl. However, the size of the regional detention pond is limited by not raising the base flood elevation of 1862 ft msl at 28th Street.

Solution 1-50-2 consists of street regrading to raise the Spaulding intersection by 5.4 feet and the Bell intersection by 2.5 feet, installing four 9' x 8' box culverts under Spaulding and four 9' x 9' box culverts under Bell, with a 40-foot wide gabion lined channel from just upstream of Spaulding down to the culverts at Bell and Koberlin. Both the culverts and the channel were sized to contain the 10-year storm event using the current effective HEC-RAS model. The lack of available land and relief makes a channel to contain the 100-year storm impractical.

4.1.3 Advantages / Disadvantages

Advantages to Solution 1-50-1 is that it lowers the 100-year peak discharge for the entire reach from the Santa Fe railroad downstream to Bell Street and lowers the base flood elevation at Spaulding by 1.24 feet and at Bell by 1.30 feet, but it requires a large amount of land and excavation to construct the detention facility.

Solution 1-50-2 is able to contain the 10-year storm, which will provide a practical level of protection for frequent storm events. The disadvantage is that in order to lower the flowline of the channel at Bell Street, the channel solutions for Key Elements 51 and 52 must be constructed as well. An alternative would be to use a wider arrangement of culverts, such as five 8' x 8' culverts, and raise the flowline by 1 foot, which would allow channel excavation downstream to Preusser Street to establish a positive slope. This would allow Solution 1-50-2 to be constructed as a separate project, with additional channel excavation and gabion lining between Bell Street and Preusser Street to be constructed at a later date as part of Solution 5-51-2.

4.1.4 Conceptual Estimate of Probable Project Cost

The conceptual probable project cost for the regional detention in Solution 1-50-1 is $5,736,700, and that for installing the culverts and channel of Solution 1-50-2 is $2,087,800, as shown in Table B-1 of Appendix B.

4.1.5 Recommendation

Since the regional detention pond still results in flooding at Bell and Koberlin during frequent storms, we recommend that the City construct Solution 1-50-2, along with Solution 5-51-2 and Solution 17-52-2.

4.2 West Avenue P at Bryant Boulevard

Ranking: 2
Key Element 34

4.2.1 Problem Description

During storm events, an excessive amount of street flow occurs across Bryant Boulevard, flowing down Avenue P. The existing six 5' x 3' culverts under Bryant discharge directly onto Avenue P, and after crossing Bryant Boulevard, the flow continues to the east along Avenue P, cuts through an alley between Avenues P and Q, then continues south in a channel between Irving Street and Chadbourne Street until it reaches the Red Arroyo. The drainage area which contributes to Bryant Boulevard at Avenue P is 467 acres, resulting in a peak discharge of 810 cfs during the 10-year storm event and 1,506 cfs during the100-year storm event, which causes extensive flooding from Bryant Boulevard downstream to the Red Arroyo.

4.2.2 Possible Solutions

Solution 2-34-1 is to construct an additional 8' x 8' box culvert downstream of Bryant Boulevard, continuing along Avenue P downstream to Chadbourne Street, at which point it discharges into an open channel that empties into the Red Arroyo. Since the elevation of Avenue P is the same as the existing six 5' x 3' culverts under Bryant, in order for the new 8' x 8' culvert to be below street level it's flowline would have to be at least 9 feet below that of the existing culverts. This would allow a side weir discharge channel to be constructed across the width of the existing roadway immediately downstream of the existing 5' x 3' culverts, intercepting the flow from the culverts and conveying it to the new 8' x 8' culvert. Flow would not begin along Avenue P until the side weir discharge channel is submerged and the 8' x 8' culvert is flowing at full capacity.

4.2.3 Advantages / Disadvantages

An advantage to this solution is that it significantly reduces the amount of street flow along Avenue P. The existing TxDOT structure under Bryant Boulevard appears to be undersized, and TxDOT should consider extending the proposed 8' x 8' box culvert under Bryant Boulevard, with the side weir discharge channel on the upstream side of the existing culverts, in order to allow the 100-year storm to pass under Bryant Boulevard. However, disadvantages to this solution is the large amount of street removal and replacement required for construction and the resulting high construction cost.

4.2.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 2-34-1 is $1,489,500, as shown in Table B-2 of Appendix B.

4.2.5 Recommendation

To reduce the amount of street flow along Avenue P, we recommend that Solution 2-34-1 be constructed.

4.3 Pecan Street at 3rd Street

Ranking: 3
Key Element 14

4.3.1 Problem Description

A large amount of street flow has been reported at the intersection of Pecan Street and 3rd Street. Just over one square mile drains to this point, producing a peak discharge of 1,003 cfs during the 10-year storm and 1,868 cfs during 100-year storm event. A house located on the northwest corner of the intersection has also reported flooding. According to the hydraulic model we developed for this intersection, the 100-year flow is about 3 feet deep at the intersection.

4.3.2 Possible Solutions

Solution 3-14-1 would be to construct a detention facility upstream of Pecan Street and 3rd Street to reduce the 100-year peak discharge.

Solution 3-14-2 is street regrading to raise the intersection of Pecan Street and 3rd Street by 2 feet, and install two 12' x 5' box culverts under the intersection that are 175' long. Channel improvements will be required upstream and downstream of the intersection with a channel that is 25' wide with vertical gabion walls.

4.3.3 Advantages / Disadvantages

A major disadvantage for Solution 3-14-1 is the lack of available land. Most of the land in this drainage area is currently developed. In order to construct the detention facility, the City would have to buy developed land from property owners and demolish the improvements, which is very costly.

For Solution 3-14-2, some advantages are that it can pass the 10-year frequency storm and it lowers the water level at the intersection by 1.34 feet. Assuming that the finished floor of the house on the northwest corner is at the average ground elevation of 1840 ft msl, the improvements also remove the house from the 100-year floodplain. Some disadvantages are that the minimal available land limits the size of the channel and this option requires a large amount of road work.

4.3.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost of Solution 3-14-2 is $719,100, as shown in Table B-3 of Appendix B.

4.3.5 Recommendation

To prevent frequent flooding of this intersection and remove a house from the 100-year floodplain, we recommend that the City construct Solution 3-14-2.

4.4 Taylor Street at Conchita Street

Ranking: 4
Key Element 11

4.4.1 Problem Description

The excessive street flow in this neighborhood at starts at the intersection of Beauregard Avenue and Campus Boulevard (Key Element 10), flows to the east-southeast down to the intersection of Taylor Street and Conchita Street (Key Element 11), continues to the east to Monroe Street and Avenue H (Element 13) and finally to Madison Street and Sulfur Draw (Element 12). The drainage area contributing to Key Element 11 is 273 acres, producing a peak flow of 485 cfs during the 10-year storm and 907 cfs during the 100-year storm event. This far exceeds the flow capacity of the streets and waist deep flow depths have been reported at this intersection.

4.4.2 Possible Solutions

Solution 4-11-1 consists of installing an 84" CMP storm drain line along Lincoln Street from Colorado Avenue to Live Oak Street, an 84" to 108" CMP along Live Oak Street down to Madison Street and a 108" CMP in Madison Street down to Sulfur Draw, with the storm drain outfall located just downstream of the existing culverts in Madison Street. By intercepting much of the flow three blocks upstream of the intersection of Taylor and Conchita, inlets can be located at the intersection to catch the rest of the runoff. The proposed storm drain for this solution is sized to accommodate the flow from future solutions for Key Elements 10, 12, and 13.

Solution 4-11-2 consists of installing the same storm drain lines in Lincoln Street from Colorado Avenue to Live Oak Street and in Live Oak Street down to Avenue H, at which point the 108" CMP storm drain line is located down Avenue H down to an outfall below the intersection of Avenue H and Monroe Street instead of continuing along Live Oak Street.

4.4.3 Advantages / Disadvantages

The Solution 4-11-1 storm drain line would reduce severe flooding at Key Elements 11, and provide additional capacity for the solutions at Key Elements 10, 12, and 13 in the future. It has the added benefit of discharging the additional flow into Sulfur Draw downstream of Madison Street, reducing the need to enlarge the existing Madison Street crossing.

Although the storm drain line of Solution 4-11-2 is shorter, the additional flow through Sulfur Draw between Monroe Street and Madison Street could increase erosion along this reach. However, a gabion detention structure was recently constructed just downstream of Monroe Street, which reduces the potential for erosion along this reach.

4.4.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 4-11-1 is $3,764,300, and that for Solution 4-11-2 is $2,486,200, as shown in Table B-4 of Appendix B.

4.4.5 Recommendation

In this case, we recommend that the City construct Solution 4-11-2, and at the same time construct Solution 25-12-2 to alleviate the overtopping of Madison Street.

4.5 Preusser Street from Lowrie to Schroeder

Ranking: 5
Key Element 51

4.5.1 Problem Description

After crossing Bell Street, East Angelo Draw continues to flow in a shallow channel until it crosses Preusser Street between Lowrie and Schroeder Streets. By this point, the drainage area of East Angelo Draw is 20.13 square miles, resulting in peak discharges of 6,364 cfs during the 100-year storm event and 3,007 cfs during the 10-year storm event. According to the FEMA FIRM Panel 40, the 100-year floodplain is 750 feet wide and 7 feet deep at the intersection of Preusser and Lowrie.

4.5.2 Possible Solutions

Solution 5-51-1 is the regional detention pond described in Section 4.1.2 of this report, since it would also lower the peak 100-year discharge at Preusser Street by 1.00 feet.

Solution 5-51-2 is to extend the 40-foot wide gabion channel of Solution 1-50-2 from Bell Street downstream to the culverts under Preusser Street and install four 9' x 9' box culverts under Preusser Street. To reduce the need for additional culverts under Koberlin Street, we suggest that the City abandon the section of Koberlin Street between Bell Street and Marie Avenue since there are no houses along this block and access to the neighborhood is provided by other streets. As with Solution 1-50-2, the lack of available land and relief makes construction of a channel to contain the 100-year storm impractical.

4.5.3 Advantages / Disadvantages

Solution 5-51-2 is also sized to contain the 10-frequency, providing a practical level of protection from frequent storm events. The disadvantage is that in order to lower the flowline of the channel, the channel solution for Key Elements 52 must be constructed at the same time as this solution.

4.5.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 5-51-2 is $582,000, as shown in Table B-5 of Appendix B.

4.5.5 Recommendation

Once Solution 1-50-2 has been constructed, we recommend that the City construct Solution 5-51-2, and at the same time construct Solution 17-52-2.

4.6 Sul Ross Street at Sunset Drive

Ranking: 6
Key Element 37

4.6.1 Problem Description

An excessive amount of street flow occurs along Sul Ross Street from Loop 306 down to Sunset Drive. Runoff from the 282 acre drainage area south of Loop 306 generates approximately 725 cfs during the 10-year storm and 1,361 cfs during 100-year storm event. The flow from the culvert under Loop 306 discharges at the intersection of the Loop 306 access road and Sul Ross Street at the street grade, and continues down Sul Ross Street to Sunset Drive.

4.6.2 Possible Solutions

Rerouting of the flow from the Loop 306 culverts is not feasible since the existing topography does not allow for cost effective redirection along either side of Loop 306 and the residential streets can not come close to carrying the volume of flow generated. Due to these constraints, in Solution 6-37-1 the flow is conveyed underground along Sul Ross Avenue through an 8' x 6' box culvert from Loop 306 to the intersection of Sul Ross Avenue and Sunset Drive. To provide positive drainage for the box culvert at Sunset Drive, Solution 14-38-1 must be constructed prior to Solution 6-37-1.

Solution 6-37-2 is identical to Solution 6-37-1 except that the capacity of the box culvert is increased by using a 9' x 8' box culvert, which is capable of accommodating the 100-year storm event. To provide positive drainage for the box culvert at Sunset Drive, Solution 14-38-2 must be constructed prior to Solution 6-37-2.

4.6.3 Advantages / Disadvantages

Solution 6-37-1 relieves the excessive street flow and associated flooding problems occurring all along Sul Ross Street. This solution provides for the construction of a stormwater drainage structure sized to accommodate the 10-year storm.

Solution 6-37-2 also relieves the excessive street flow and associated flooding problems along Sul Ross Street. This solution provides for the construction of a stormwater drainage structure sized to accommodate the 100-year storm.

4.6.4 Conceptual Opinion of Probable Project Cost

The opinion of probable project cost for Solution 6-37-1 is $1,115,500, and that for Solution 6-37-2 is $1,231,400, as shown in Table B-6 of Appendix B.

4.6.5 Recommendation

Solution 6-37-1 and 6-37-2 provide for the construction of drainage structures to accommodate the 10-year and 100-year storm, respectively. The collection of runoff for either of the solutions will help reduce the street flow along Sul Ross, however, the most beneficial solution would be to collect as much runoff as possible. Due to the relatively small difference in cost between the two solutions, Solution 6-37-2 is recommended for construction by the City, along with Solution 14-38-2 at the same time.

4.7 Southwest Boulevard at South Fork Red Arroyo

Ranking: 7
Key Element 29

4.7.1 Problem Description

Flow from the South Fork Red Arroyo overtops the low water crossing at Southwest Boulevard on a frequent basis. In addition, a large amount of street flow along Southwest Boulevard exacerbates the situation. The drainage area contributing to the flow in Southwest Boulevard is156 acres, which produces peak street flow rates of 298 cfs during the 10-year and 569 cfs during the 100-year storm event. According to the FEMA FIRM Panel 10, the 100-year floodplain at Southwest Boulevard is 440 feet wide and approximately 4.5 feet deep. This depth of flow is caused by both lack of capacity of the three culverts under Southwest Boulevard and backwater conditions caused by the TxDOT culverts under Loop 306, which appear to be undersized.

4.7.2 Possible Solutions

Solution 7-29-1 would be to construct a regional detention facility along the South Fork Red Arroyo and West Branch South Fork Red Arroyo upstream of Southwest Boulevard. The most likely location of this detention facility would be the undeveloped property west of Oak Grove Road. In addition to the direct inflow from the South Fork Arroyo, a channel dam could be constructed in the West Branch with a box culvert under Oak Grove Road to divert much of the West Branch flow into the same detention facility. However, the topography of this site increases towards the west, requiring increasing amounts of excavation. For this reason, we estimated that the maximum cost-effective size of the detention facility would be approximately 21.5 acres.

Solution 7-29-2 would be to widen the channel from just upstream of Loop 306 to just downstream of Southwest Boulevard, install a 300 foot bridge with high chord at 1888 msl, and install a storm drain line in Southwest Boulevard to convey runoff to the South Fork of Red Arroyo. TxDOT should also consider installing two additional 7' x 5' box culverts under Loop 306 to provide the required capacity, but these culverts are not included in this solution.

4.7.3 Advantages / Disadvantages

Although the regional detention pond of Solution 7-29-1 was expected to have a significant impact on the peak flow rates, it only lowers the 100-year water level at Southwest Boulevard and Loop 306 by 2.0% and 0.8%, respectively. In addition, Solution 7-29-1 is very costly to complete.

During a 25-year frequency storm Southwest Boulevard empties 402 cfs into the South Fork Red Arroyo. Advantages to Solution 7-29-2 is that the storm line can carry 320 cfs which leaves 82 cfs for the road to carry. Southwest Boulevard has a capacity of 86.2 cfs. Reconstruction of Southwest Boulevard is necessary to pass the 25-year frequency flood. Raising the road to 1888 msl and widening the channel under Southwest Boulevard to 50 feet will allow the 25-year storm to pass.

4.7.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 7-29-1 is $5,679,600, and that for Solution 7-29-2 is $3,318,400, as shown in Table B-7 of Appendix B.

4.7.5 Recommendation

Both of these solutions have their merits, but both are costly to construct. Due to the minimal impact of the regional detention facility, we recommend that the City construct Solution 7-29-2.

4.8 Beauregard Avenue - Campus to North Concho River

Ranking: 8
Key Element 10

4.8.1 Problem Description

A large amount of street flow occurs along Beauregard Avenue from Campus Boulevard down to the North Concho River, a distance of 7,200 feet, and tends to be relatively deep for the upper two-thirds of this reach due to the very flat slope of Beauregard Avenue. The drainage area which contributes to the intersection of Beauregard Avenue and Campus Boulevard is 208 acres, producing peak flows of 410 cfs during the 10-year storm and 761 cfs during the 100-year storm event. This exceeds the flow capacity of the street at this point, and the street flow continues to increase toward the North Concho River as additional drainage area is added from Sherwood Way.

4.8.2 Possible Solutions

Due to the length of this reach, a storm drain line down Beauregard would be impractical, and it would be better to extend the storm drain system of Solution 4-11-1 to intercept flows at several locations along Beauregard Avenue. Solution 8-10-1 consists of the construction of four laterals to extend the storm drain system, and assumes that Solution 4-11-1 has been constructed. The first lateral is a 30" CMP along Beauregard from Campus Boulevard to Lincoln Street, and connects with the second 48" CMP lateral along Lincoln Street from Sherwood Way to Colorado Avenue. The third lateral is a 66" CMP along Garrett Street from Sherwood Way to Live Oak Street, and the fourth lateral is a 36" CMP along Madison Street from Beauregard Avenue to Live Oak Street.

Solution 8-10-2 also includes four laterals to extend the storm drain system of Solution 4-11-2, and assumes that Solution 4-11-2 has been constructed. The first three laterals are the same as described above for Solution 8-10-1. However, since there is no storm drain in Madison Street, the fourth lateral is a 36" CMP along Madison Street from Beauregard Avenue down to Sulphur Draw.

4.8.3 Advantages / Disadvantages

The storm drain laterals proposed in Solution 8-10-1 would significantly reduce the street flow along Beauregard Avenue towards the North Concho River by intercepting the street flow at several points along Beauregard Avenue and Sherwood Way. This also has the added benefit of discharging the additional flow into Sulfur Draw downstream of Madison Street, reducing the need to enlarge the existing Madison Street crossing.

The storm drain laterals proposed in Solution 8-10-2 would also significantly reduce the street flow by intercepting the street flow at the same points along Beauregard Avenue and Sherwood Way. Due to the additional flow in Sulfur Draw, the improvements in Solution 25-12-2 are also necessary.

4.8.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 8-10-1 is $2,005,800, and that for Solution 8-10-2 is $2,212,100, as shown in Table B-8 of Appendix B.

4.8.5 Recommendation

Since we recommended that the City construct Solution 4-11-2, the City would need to construct Solution 8-10-2 and Solution 25-12-2 if it hasn't already been constructed.

4.9 Howard Street from North to Webster

Ranking:	**9**
Key Element	**7**

4.9.1 Problem Description

Flooding has been reported along Howard Street due to runoff from the alley between North Street and Webster Avenue. Runoff drains from the alley across Howard Street and turns due north flowing behind homes along Howard Street until it is redirected back onto Howard Street just south of Forest Park and Key Element 5. The drainage area which contributes to Howard Street is 380 acres, producing peak flow rates of 584 cfs during the 10-year storm and 1,115 cfs during 100-year storm event.

4.9.2 Possible Solutions

There are no existing drainage structures in this area. For Solution 9-7-1, a storm drain is proposed along the west side of Howard Street, collecting runoff from inlets located in the alley between Webster Avenue and North Street. Stormwater would then be conveyed in a 6' x 5' box culvert under Howard Street from the inlet between Webster Avenue and North Street to the alley between Woodlawn Drive and Forest Park Avenue. This will accommodate the 10-year storm and is in conjunction with Solution 24-5-1. To convey the flows under Howard Street, Solution 24-5-1 must be constructed prior to Solution 9-7-1.

Solution 9-7-2 is the same as Solution 9-7-1 except that it has a 7' x 7' box culvert along Howard Street to contain the 100-year storm. To convey the flows under Howard Street, Solution 24-5-2 must be constructed prior to Solution 9-7-2.

4.9.3 Advantages / Disadvantages

An advantage of Solution 9-7-1 is that minimizes street flow. A disadvantage is that it can only contain the 10-year frequency storm.

Advantages of Solution 9-7-2 is that it can contain the 100-year frequency storm and it minimizes street flow.

4.9.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 9-7-1 is $255,500, and that for Solution 9-7-2 is $294,300, as shown in Table B-9 of Appendix B.

4.9.5 Recommendation

Both solutions utilize a box culvert along Howard Street. Solution 9-7-1 is sized to contain the 10-year frequency storm and Solution 9-7-2 is sized to contain the 100-year frequency storm. We recommend that the City construct Solution 9-7-2 to provide 100-year protection at this location, concurrent with Solution 24-5-2.

4.10 Glenwood Drive at Howard Street

Ranking: 10
Key Element 2

4.10.1 Problem Description

A large amount of street flow occurs along Glenwood Drive from Howard Street down to Harrison Street. Runoff from both directions along Howard Street concentrates at the intersection of Howard Street and Glenwood Drive before flowing down Glenwood Drive. The drainage area which contributes to this intersection is 275 acres, which produces peak flow rates of 381 cfs during the 10-year storm and 732 cfs during the 100-year storm event.

4.10.2 Possible Solutions

For Solution 10-2-1, four curb inlets with 36" diameter collector pipes are located at the intersection of Glenwood Drive and Howard Street and a box culvert is installed under Glenwood Drive to convey the flow from the inlets from Howard Street down to the existing retention pond located between Glenwood Drive and Van Buren Street. A 6' x 4' box culvert has the capacity to carry 453 cfs, which exceeds the anticipated peak flow rate during the 10-year storm event.

Solution 10-2-2 is the same as 10-2-1 except an 8' x 5' box culvert is used to provide the capacity to carry 898 cfs, which exceeds the peak flow rate anticipated during the 100-year storm event.

4.10.3 Advantages / Disadvantages

An advantage of Solution 10-2-1 is that it limits the flow down Glenwood Drive, and it is sized to contain the 10-year discharge. Solution 10-2-2 is sized to contain the 100-year discharge, and is slightly more expensive. A disadvantage of both solutions is that in order to handle the intervening flow in the street, Solution 23-3-1 should be constructed along with Solution 10-2-1 or Solution 10-2-2.

4.10.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 10-2-1 is $574,900, and that for Solution 10-2-2 is $781,700, as shown in Table B-10 of Appendix B.

4.10.5 Recommendation

The existing street capacity is inadequate to carry the amount of runoff at this location, and will require an underground drainage system. Both solutions utilize a box culvert along Glenwood Drive. Solution 10-2-1 is sized to contain the 10-year frequency storm and Solution 10-2-2 is sized to contain the 100-year frequency storm. We recommend that the City construct Solution 10-2-2 to provide 100-year protection at this location, concurrent with Solution 23-3-1.

4.11 Regent Boulevard at Gordon Boulevard

Ranking: 11
Key Element 54

4.11.1 Problem Description

During storm events, flow from an undeveloped area west of Gregory Drive crosses the intersection of Gregory Drive and Regent Boulevard and flows down Regent Boulevard to the existing pond downstream of Gordon Boulevard. The drainage area which contributes to Regent Boulevard is 2.8 square miles, producing peak flow rates of 1,181 cfs during the 10-year storm and 2,454 cfs during the 100-year storm event. This far exceeds the flow capacity of the street.

4.11.2 Possible Solutions

Solution11-54-1 is to construct a detention pond west of Gregory Drive and Regent Boulevard, consisting of an earthen embankment with a top elevation of 1860 ft msl and a spillway which discharges into two 10' x 6' box culverts under Regent Boulevard which outfall into the park downstream of Gordon Boulevard.

4.11.3 Advantages / Disadvantages

Some advantages to Solution 11-54-1 is that it contains the 100-year frequency storm, and keeps the 100-year storm from flooding Gregory Drive. This solution will also alleviate flow down Regent Boulevard, and the lower peak discharge rates will help reduce overtopping at Ricks Drive and Smith Boulevard further downstream. Some disadvantages are that this solution requires removal and replacement of a large part of Regent Boulevard, as well as purchase of a significant amount of undeveloped land, and as such has a relatively high construction cost.

4.11.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost of Solution 11-54-1 is $2,132,700, as shown in Table B-11 of Appendix B.

4.11.5 Recommendation

Due to the large drainage area and resulting high flow rates along Regent Boulevard, we recommend that the City construct Solution11-54-1 to alleviate the street flow.

4.12 College Hills Boulevard at North Fork Red Arroyo

Ranking: 12
Key Element 28

4.12.1 Problem Description

Both the North Fork Red Arroyo (Key Element 28) and South Fork Red Arroyo (Key Element 31) significantly overtop College Hills Boulevard. According to the FEMA FIRM Panel 15, the 100-year floodplain is 3,500 feet wide and approximately 4 feet deep along the roadway.

4.12.2 Possible Solutions

Solution 12-28-1 is to raise College Hills Boulevard to an elevation of 1870 msl from north of the North Fork Red Arroyo to south of the South Fork Red Arroyo and install a 600 foot bridge over the North Fork Red Arroyo. This is done to raise the roadway out of the floodplain without increasing flooded areas upstream, and was verified using the current effective hydraulic model of the North Fork Red Arroyo. Solution 12-28-1 also requires the construction of Solution 15-31-1 to raise the southern portion of College Hills Boulevard.

4.12.3 Advantages / Disadvantages

Advantages of Solution 12-28-1 is that it raises College Hills Boulevard out of the 100-year floodplain and doesn't raise the base flood elevation for existing conditions. The major disadvantage is the cost of construction.

4.12.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 12-28-1 is $3,542,300, as shown in Table B-12 of Appendix B.

4.12.5 Recommendation

College Hills Boulevard is a major thoroughfare, and in order to remove this thoroughfare from the 100-year floodplain, we recommend that the City construct Solution 12-28-1, along with Solution 15-31-1.

4.13 30th Street at Day Elementary

Ranking: 13
Key Element 43

4.13.1 Problem Description

An earthen channel running adjacent to the east side of the Day Elementary property provides drainage from 31th Street south to 30th Street. The channel is inadequately sized for the amount of runoff draining through the channel. The peak discharge rates in this channel are approximately 174 cfs during the10-year storm and 344 cfs during the100-year storm. The current capacity of the channel is approximately 30 cfs.

4.13.2 Possible Solutions

Solution 13-43-1 to contain the 10-year flow would be to improve and reshape the existing channel by constructing a concrete channel and widening the bottom from approximately 9 to 10 feet with 2:1 side slopes. The resulting improved flow coefficients and channel area would accommodate a flow of approximately 172 cfs.

Solution 13-43-2 to address the 100-year flow would require the widening of the existing channel from 9 feet to approximately 22 feet.

Solution 13-43-3 is an alternate to Solution 13-43-2 and also addresses the 100-year flow by installing a 9 foot wide by 5 foot high concrete box culvert in place of the existing channel.

4.13.3 Advantages / Disadvantages

The advantages of Solution 13-43-1 is that due to the presence of an existing earthen channel at the site that could easily be improved to accommodate the 10-year storm event by reshaping and lining with concrete, Solution 13-43-1 would provide for a very cost effective approach.

Advantages of Solutions 13-43-2 and 13-43-3 is that they both pass the 100-year storm event. A disadvantage to Solutions 13-43-2 and 13-43-3 is the large amount of construction required.

4.13.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 13-43-1 is $155,200, for Solution 13-43-2 is $256,000, and for Solution 13-43-3 is $186,200, as shown in Table B-13 of Appendix B.

4.13.5 Recommendation

The adaption of the existing channel would require minimal construction resulting in very effective cost for the resulting improved flow capacity. Although Solution 13-43-2 would require more construction, it would also provide more benefit. Due to the relatively small incremental cost to provide 100-year protection, Solution 13-43-2 is the recommended solution.

4.14 Lindenwood Drive at Vista Del Arroyo Street

Ranking: 14
Key Element 38

4.14.1 Problem Description

Stormwater runoff at this location is basically a continuation of the problem at Sul Ross Street and Sunset Drive (Key Element 37). The street flow passing through the intersection of Sul Ross Street and Sunset Drive continues north along Sul Ross Street to Lindenwood Drive, where it is routed to the east along Lindenwood Drive down to its intersection with Vista Del Arroyo, at which point it enters a flume between two elevated residences which discharges into two storage ponds prior to discharging into the Red Arroyo. This flow path follows a former naturally occurring drainage way where the streets were constructed in the flow channel. The drainage area contributing to the intersection of Lindenwood Drive and Vista Del Arroyo Street is 331 acres, which produces peak flow rates of 792 cfs during the 10-year storm and 1,491 cfs during the 100-year storm event.

4.14.2 Possible Solutions

Solution 14-38-1 is an extension of Solution 6-37-1, and consists of extending the 8' x 6' box culvert of Solution 6-37-1 from the intersection of Sunset Drive and Sul Ross Avenue to the intersection of Lindenwood Drive and Sul Ross Avenue, at which point the culverts then go east along Lindenwood Drive and discharge into the storage ponds.

Solution 14-38-2 is an extension of Solution 6-37-2, and is identical to Solution 14-38-1, except that the capacity of the box culverts is increased by using a 9' x 8' box culvert, which is capable of accommodating the 100-year storm event.

4.14.3 Advantages / Disadvantages

Solution 14-38-1 relieves the excessive street flow and associated flooding problems occurring along Sul Ross Street and Lindenwood Drive down to the storage ponds. This solution provides for the construction of a stormwater drainage structure sized to accommodate the 10-year storm.

Solution 14-38-2 also relieves the excessive street flow and associated flooding problems occurring along Sul Ross Street and Lindenwood Drive down to the storage ponds. This solution provides for the construction of a stormwater drainage structure sized to accommodate the 100-year storm.

4.14.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 14-38-1 is $494,600, and that for Solution 14-38-2 is $553,500, as shown in Table B-14 of Appendix B.

4.14.5 Recommendation

Solution 14-38-1 and 14-38-2 provide for the construction of a drainage structure to accommodate the 10- and 100-year storm, respectively. Since Solution 6-37-2 was recommended, Solution 14-38-2 must be constructed at the same time in order to provide the connection between the storm drain at Sunset Drive and the ponds downstream of Vista Del Arroyo Street.

4.15 College Hills Boulevard at South Fork Red Arroyo

Ranking: 15
Key Element 31

4.15.1 Problem Description

Both the North Fork Red Arroyo (Element 28) and South Fork Red Arroyo (Element 31) significantly overtop College Hills Boulevard. According to the FEMA FIRM Panel 15, the 100-year floodplain is 3,500 feet wide and approximately 4 feet deep along the roadway.

4.15.2 Possible Solutions

Solution 15-31-1 is to raise College Hills Boulevard to an elevation of 1870 msl from north of the North Fork Red Arroyo to south of the South Fork Red Arroyo and install a 500 foot bridge over the South Fork Red Arroyo while regrading Millbrook Drive. This is done to raise the roadway out of the floodplain without increasing flooded areas upstream and was verified using the current effective hydraulic model of the South Fork Red Arroyo. Solution 15-31-1 also requires the construction of Solution 12-28-1 to raise the northern portion of College Hills Boulevard.

4.15.3 Advantages / Disadvantages

Advantages of Solution 15-31-1 is that it raises College Hills Boulevard out of the 100-year floodplain and doesn't raise the base flood elevation for existing conditions. The major disadvantage is the cost of construction.

4.15.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 15-31-1 is $3,486,600, as shown in Table B-15 of Appendix B.

4.15.5 Recommendation

College Hills Boulevard is a major thoroughfare, and in order to remove this thoroughfare from the 100-year floodplain, we recommend that the City construct Solution 15-31-1, at the same time that Solution 12-28-1 is constructed.

4.16 Monroe Street at Sulphur Draw Park

Ranking: 16
Key Element 13

4.16.1 Problem Description

After the excessive street flow crosses the intersection of Taylor Street and Conchita Street (Key Element 11) it continues towards the east down to the intersection of Monroe Street and Avenue H, at which point it flows into Sulfur Draw. The drainage area contributing to the intersection of Monroe Street and Avenue H is 496 acres, which produces peak flow rates of 803 cfs during the 10-year and 1,527 cfs during the 100-year storm event. This far exceeds the flow capacity of the street.

4.16.2 Possible Solutions

As with the solutions along Beauregard Avenue, the excessive street flow at this location can be rectified by extending the storm drain system of Solution 4-11-1. Solution 16-13-1 assumes that Solution 4-11-1 has been constructed, and consists of installing a 36" CMP storm drain lateral along Monroe Street from Avenue H to the storm drain in Live Oak Street.

Solution 16-13-2 assumes that Solution 4-11-2 has been constructed, and consists of installing a 36" CMP storm drain lateral along Jackson Street from Avenue I to the storm drain in Avenue H, with gabion channel improvements along Sulfur Draw from the outlet in Solution 4-11-2 downstream to Madison Street. A gabion detention structure was recently constructed just downstream of Monroe Street, which reduces the potential for erosion along this reach.

4.16.3 Advantages / Disadvantages

The storm drain laterals proposed in Solution 16-13-1 would significantly reduce the street flow Monroe Street and Avenue H by intercepting the street flow and conveying it to the Solution 4-11-1 storm drain line in Live Oak Street. This also has the added benefit of discharging the additional flow into Sulfur Draw downstream of Madison Street, reducing the need to enlarge the existing Madison Street crossing.

The storm drain laterals proposed in Solution 16-13-2 would also significantly reduce the street flow by intercepting the flow and conveying it directly to Sulfur Draw. Due to the additional flow in Sulfur Draw, the improvements in Solution 25-12-2 are also necessary to prevent additional erosion and overtopping at Madison Street.

4.16.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 16-13-1 is $205,000, and that for Solution 16-13-2 is $456,200, as shown in Table B-16 of Appendix B.

4.16.5 Recommendation

Since we recommended that the City construct Solution 4-11-2 and Solution 8-10-2, the City would need to construct Solution 16-13-2 and Solution 25-12-2 if it hasn't already been constructed.

4.17 Coke Street at East Angelo Draw

Ranking: 17
Key Element 52

4.17.1 Problem Description

After crossing Lowrie Street, East Angelo Draw continues to flow in a shallow earthen channel until it crosses Coke Street near Schroeder Avenue. By this point the drainage area of East Angelo Draw is 20.26 square miles, resulting in a peak discharge of 6,340 cfs during the 100-year storm event and 2,970 cfs during the 10-year storm event. According to the FEMA FIRM Panel 40, the 100-year floodplain is 650 feet wide and 8 feet deep at the Coke Street crossing.

4.17.2 Possible Solutions

Solution 17-52-1 is the construction of the regional detention pond described in Section 4.1.2 of this report, since it would also lower the peak 100-year discharge at Coke Street by 1.25 feet.

Solution 17-52-2 is to extend the 40-foot wide gabion lined channel from Preusser Street downstream to the culverts under Coke Street and install four 9' x 11' box culverts under Coke Street. To tie back into the existing flow line of East Angelo Draw, the channel will need to extend 800 feet downstream of Coke Street and will include straightening a small section of the existing channel.

4.17.3 Advantages / Disadvantages

Solution 17-52-2 is able to contain the 10-year storm and provides a practical level of protection during frequent storm events. The disadvantage is that in order to lower the flowline of the channel for the channel solutions for Key Element 51, this downstream section must be constructed first, and is the most expensive section since it includes the channel excavation downstream.

4.17.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 17-52-2 is $1,510,600, as shown in Table B-17 of Appendix B.

4.17.5 Recommendation

We recommend that the City construct Solution 17-52-2 at the same time that Solution 5-51-2 is constructed.

4.18 Loop 306 Access Road at Eckerd's

Ranking: 18
Key Element 30

4.18.1 Problem Description

The flow from an existing culvert under Loop 306 east of College Hills Boulevard discharges out into an earthen channel which runs through a vacant lot. When it reaches the end of the channel it backs up and starts to flow across the Eckerd's parking lot and down College Hills Boulevard, contributing to the large amount of street flow along College Hills Boulevard. The earthen channel is experiencing severe erosion, but has relatively low flow of 119 cfs for the 100-year storm from the 29 acre drainage area.

4.18.2 Possible Solutions

Solution 18-30-1 is to place a gabion lined drainage ditch downstream of Loop 306 and install a 84" CMP storm drain from the end of the channel down to Sunset Drive. The storm drain continues along Sunset Drive to College Hills Boulevard and north on College Hills Boulevard down to the South Fork Red Arroyo, with two 10 foot curb inlets located every other block along College Hills Boulevard beginning with Sunset Drive.

Solution 18-30-2 consists of the installation of a storm drain line along the Loop 306 right-of-way to convey the 100-year flow down to the South Fork Red Arroyo. The storm drain line is a 72" CMP down to College Hills Boulevard, a 78" CMP down to Forest Trail, and an 84" CMP from there down to the South Fork Red Arroyo, with curb inlets located along the storm drain to intercept local runoff from the commercial parking lots along the Loop 306 service road.

4.18.3 Advantages / Disadvantages

Advantages of Solution 18-30-1 is that it can carry the 100-year frequency storm and greatly reduces flow through the Eckerd's parking lot. The storm drain along College Hills Boulevard also has the added benefit of reducing the excessive street flow which occurs along College Hills, much of which comes from areas other than the Loop 306 culvert. However, the cost of construction is high.

An advantage of Solution 18-30-2 is that by installing the storm drain along the Loop 306 right-of-way the pavement removal and replacement is greatly reduced, and the interruption of the traffic along College Hills Boulevard is greatly reduced, only having to cross College Hills Boulevard at the Loop 306 intersection. However, although there is less pavement along the right-of-way, there may be more utilities in this area to relocate.

4.18.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 18-30-1 is $2,713,400, and that for Solution 18-30-2 is $1,688,400, as shown in Table B-18 of Appendix B.

4.18.5 Recommendation

To minimize flows through the Eckerd's parking lot and significantly reduce street flow along College Hills Boulevard, we recommend that the City construct Solution 18-30-1.

4.19 Lester Lane at Tres Rios Drive

Ranking: 19
Key Element 18

4.19.1 Problem Description

Ponding occurs at the intersection of Lester Lane and Tres Rios Drive. At this intersection, Tres Rios Drive is several feet above the grade of Lester Lane, and the differentiation in grade effectively creates a dam at the end of Lester Lane. An existing 24" x 36" CMP arch pipe under Tres Rios Drive drains this area and discharges across the park to the west and into the South Concho River. However, the size of the existing pipe (effectively 30" diameter) is inadequate for the quantity of runoff from the drainage basin, and the flow backs up causing excessive ponding at the inlet to the pipe. The flow for the 100-year storm event is approximately 253 cfs at this location.

4.19.2 Possible Solutions

The capacity of the current 24" x 36" CMP arch pipe under Tres Rios Drive is approximately 32 cfs. Solution 19-18-1 consists of the replacement of this CMP with a 5' x 3' concrete box culvert to increase the flow capacity to approximately 308 cfs, which can accommodate the 100-year storm.

4.19.3 Advantages / Disadvantages

Advantages of this solution is that the culvert can carry the 100-year frequency storm and this solution is inexpensive.

4.19.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 19-18-1 is $104,100, as shown in Table B-19 of Appendix B.

4.19.5 Recommendation

Due to the large benefit of alleviating the ponding at this intersection for the relatively small construction cost, we recommend that the City construct Solution 19-18-1.

4.20 Goodfellow Draw at Evelyn Avenue

Ranking: 20
Key Element 20

4.20.1 Problem Description

Flow has been reported between houses along Goodfellow Draw, which flows in shallow channels and ditches and overtops Era Street and Evelyn Avenue. The drainage area of Goodfellow Draw that contributes to Evelyn Avenue is 591 acres, which produces peak flow rates of 947 cfs during the 10-year storm and 1,867 cfs during the 100-year storm event. Based on the FEMA FIRM Panel 35, the 100-year floodplain is approximately 2 feet deep at both of these intersections.

4.20.2 Possible Solutions

Solution 20-20-1 is to install four 10' x 5' box culverts under both Era Street and Evelyn Avenue, which includes gabion lined channelization 495 feet upstream of Evelyn Avenue and 670 feet downstream of Era Street. The channel is 45 feet wide with vertical gabion walls.

Solution 20-20-2 is to install five 11' x 5' box culverts under both Era Street and Evelyn Avenue, and includes gabion lined channelization 495 feet upstream of Evelyn Avenue and 670 feet downstream of Era Street. The channel is 61 feet wide with vertical gabion walls.

4.20.3 Advantages / Disadvantages

An advantage of Solution 20-20-1 is that it prevents water from overtopping Era Street and Evelyn Avenue up to the 25-year storm. A disadvantage is that it does not pass the 100-year storm.

An advantage of Solution 20-20-2 is that it prevents water from overtopping Era Street and Evelyn Avenue up to the 100-year storm. Disadvantages of this option is that it requires a large amount of excavation and channelization in an area that lacks available space.

4.20.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 20-20-1 is $976,000, and that for Solution 20-20-2 is $1,753,700, as shown in Table B-20 of Appendix B.

4.20.5 Recommendation

Due to the high cost providing 100-year protection at these crossings, we recommend that the City construct Solution 20-20-1 which will pass the 25-year frequency storm.

4.21 24th Street at Blum Street

Ranking: 21
Key Element 46

4.21.1 Problem Description

A significant amount of street flow occurs along the alley between 24th and 25th Streets across Blum. The runoff at Blum Street originates along Oaklawn Boulevard, continues through the alley between 24th and 25th Streets, crosses Marx Street and Blum Street, eventually flowing through Bradford Park and into East Angelo Draw. The crossing of the runoff at Blum Street creates a low water crossing across the street. The peak flow rates at Blum Street are estimated to be 143 cfs during the 10-year storm and 277 cfs during the 100-year storm event.

4.21.2 Possible Solutions

Intercepting the street flow in this area with a storm drain system is difficult due to the flat topography, and would be very costly since the distance from Blum Street to East Angelo Draw is almost a mile. Thus, Solution 21-46-1 seeks to alleviate the excessive flow at Blum Street by diverting the flow which originates from 28th Street through 25th Street along to Oaklawn Boulevard. This would be accomplished by reconstructing 25th, 26th, 27th, and 28th Streets to direct flow to the west towards Pecan Street, where it can be intercepted as inflow to the Lakeview Park detention facility. A diversion of the runoff from these streets to the adjacent watershed would greatly reduce the quantity of flow through the alley and consequently across Blum Street.

4.21.3 Advantages / Disadvantages

An advantage of Solution 21-46-1 is that it redirects runoff to Pecan Street which is more capable of handling the runoff as opposed to the alley between 24th and 25th Streets. Disadvantages of this solution is that it requires a large amount of road work and is costly to complete.

4.21.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 21-46-1 is $2,777,200, as shown in Table B-21 of Appendix B.

4.21.5 Recommendation

The flat topography of this basin does not allow for runoff to be conveyed underground along the current flow pattern or to another feasible discharge point, so the diversion of runoff upstream of this location is the most effective solution and realistically the only feasible solution. To provide for the needed diversion of runoff, we recommend that the City construct Solution 21-46-1.

4.22 Bradford Street at 24th Street

Ranking: 22
Key Element 47

4.22.1 Problem Description

Ponding has been reported at the intersection of Bradford Street and s4th Street, at the low water crossing into Bradford Park. Runoff flowing down 24th Street creates ponding at the Bradford Street intersection. The peak flow rates at Bradford Street are estimated to be 222 cfs during the 10-year storm and 437 cfs during the 100-year storms event.

4.22.2 Possible Solutions

The existing carrying capacity of 24th Street is approximately 23 cfs. Regrading 24th Street will not accommodate much additional flow. Reconstructing the street with a 6 inch inverted crown section would increase the carrying capacity to approximately 144 cfs, which is approximately the flow from a 2-year storm event. In addition, the entire street would be 6 to 12 inches deep in water creating traffic safety concerns. As such, an underground storm drain system is required to convey the flows from a 10-year or 100-year storm event.

Solution 22-47-1 to alleviating the ponding and low water crossing situation is to drain the runoff out of the intersection using an underground stormwater drainage system. Curb inlets are placed at all four corners of the intersection of 24th Street and Bradford Street to intercept the runoff and are connected to a 6' x 3' concrete box culvert installed behind the back of the curb along the south side of Bradford Street in the Park, from 24th Street to Poe Street, at which point the culvert crosses under the intersection of Bradford Street and Poe Street and discharges into East Angelo Draw. A 6' x 3' stormwater box can carry approximately 222 cfs, which would accommodate the 10-year storm.

Solution 22-47-2 uses the same arrangement to provide the capacity to accommodate a 100-year storm by using a 7' x 4' box culvert which has the capacity to carry approximately 400 cfs of the 437 cfs anticipated peak flow rate, leaving the remaining 37 cfs to be carried by the street as overflow.

4.22.3 Advantages / Disadvantages

An advantage to Solution 22-47-1 is that it minimizes the ponding in Bradford Park.

An advantage to Solution 22-47-2 is that is minimizes the ponding in Bradford Park and can carry the 100-year frequency storm.

4.22.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 22-47-1 is $259,100, and that for Solution 22-47-2 is $509,700, as shown in Table B-22 of Appendix B.

4.22.5 Recommendation

Constructing the curb inlets and providing underground stormwater drainage as described in both solutions is recommended, and both systems can be installed with minimal impact to traffic and inconvenience to residents by utilizing the available frontage along Bradford Park. Since Solution 22-47-2 provides for greater capacity at a small incremental cost, it is the recommended solution.

4.23 Glenwood Drive from Harrison to Greenwood

Ranking:	**23**
Key Element	**3**

4.23.1 Problem Description

A low water crossing is located along Glenwood Drive between Harrison Street and Greenwood Street, which allows the channelized water running down Glenwood Drive to discharge into the retention pond located between Glenwood Drive and Van Buren Street. The drainage area contributing to the low water crossing is 311 acres, producing a peak discharge rate of 425 cfs during the 10-year storm and 820 cfs during the 100-year storm event.

4.23.2 Possible Solutions

Realizing that the discharge from the intersection of Howard Street and Glenwood Drive is the primary contributor to the flow at the low water crossing, the flow from the intervening drainage area is only 57 cfs during the 10-year storm and 112 cfs during the 100-year storm. Once the construction of either Solution 10-2-1 or Solution 10-2-2 is completed to provide 10-year protection or 100-year protection, Solution 23-3-1 consists of reconstructing the Glenwood Drive with a 6 inch inverted crown section would increase the flow capacity of the street to approximately 203 cfs, which would be more than adequate to accommodate the balance of either of the design storm events.

4.23.3 Advantages / Disadvantages

Solution 23-3-1 will minimize the street flow for Greenwood Street. However, it does require a large amount of road work.

4.23.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 23-3-1 is $747,800, as shown in Table B-23 of Appendix B.

4.23.5 Recommendation

The existing street profile is inadequate to carry the runoff from the intervening drainage area along Glenwood Drive. Since Solution 10-2-2 was recommended to provide 100-year protection at the intersection of Howard Street and Glenwood Drive, we also recommend that Solution 23-3-1 be constructed concurrently with the Solution 10-2-2 improvements.

4.24 Howard Street at Brentwood Park

Ranking: 24
Key Element 5

4.24.1 Problem Description

Stormwater runoff flows along Howard Street and concentrates at the low water crossing located between Woodlawn Avenue and Forest Park Avenue before draining into the existing channel which runs through Brentwood Park. The drainage area contributing to Howard Street at Brentwood Park is 552 acres, producing peak flow rates of 867 cfs during the 10-year storm and 1,653 cfs during the 100-year storm event.

4.24.2 Possible Solutions

Solution 24-5-1 consists of a 7' x 6' box culvert under Howard Street which accepts flow from inlets in the alley between Woodlawn Drive and Forest Park Avenue as well as the 6' x 5' box culvert of Solution 9-7-1 and discharges into the existing open drainage channel in Brentwood Park. This will accommodate the peak flow during the 10-year storm.

Solution 24-5-2 is the same as Solution 24-5-1 except that it has a 9' x 8' box culvert to accept the flow from the inlets in the alley as well as the 7' x 7' box culvert of Solution 9-7-2, in order to accommodate the 100-year storm.

Solution 24-5-3 involves the reconstruction and raising of Howard Street between Forest Park Avenue and Woodlawn Drive, creating a 20-foot wide bridge along Howard Street between these two points. The runoff from Howard Street would be redirected into concrete channels leading into the existing rock-lined channel in Brentwood Park from the north and south. The open channel section below Howard Street would be used to accommodate flow from Solutions 9-7-1 and 9-7-2 depending on the frequency of storm being contained.

4.24.3 Advantages / Disadvantages

An advantage of Solution 24-5-1 is that minimizes street flow. A disadvantage is that it can only pass the 10-year frequency storm.

Advantages of Solution 24-5-2 is that it can pass the 100-year frequency storm and it minimizes street flow.

An advantage of Solution 24-5-3 is that it can pass either the 10- or 100-year frequency storm depending on which solution from Key Element 9 is constructed. This solution also minimizes street flow.

4.24.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 24-5-1 is $36,700, for Solution 24-5-2 is $43,800, and for Solution 24-5-3 is $71,500, as shown in Table B-24 of Appendix B.

4.24.5 Recommendation

Although both solutions utilize a box culvert, Solution 24-5-1 is sized to pass the 10-year frequency storm and Solution 24-5-2 is sized to pass the 100-year frequency storm. Since the 100-year design for Solution 9-7-2 was recommended, Solution 24-5-2 is also recommended.

4.25 Madison Street from Avenue J to Algerita

Ranking: 25
Key Element 12

4.25.1 Problem Description

The majority of the Sulfur Draw watershed is composed of highly urbanized residential areas. The drainage area of Sulfur Draw contributing to the Madison Street crossing is 543 acres, which produces peak flow rates of 844 cfs during the 10-year and 1,615 cfs during the 100-year storm event. This far exceeds the capacity of the existing two 9' x 9' box culverts under Madison Street, resulting in overtopping of the roadway.

4.25.2 Possible Solutions

As with the solutions along Beauregard Avenue and Monroe Street, much of the street flow problem in this area can be rectified by extending the storm drain system of Solution 4-11-1. Solution 25-12-1 assumes that Solution 4-11-1 has been constructed, as well as Solution 8-10-1, and consists of installing a 48" CMP storm drain line in Madison Street from Avenue J to Algerita Drive. No improvements are required to the Madison Street culverts since much of the flow in Sulfur Draw has been intercepted by the Solution 4-11-1 storm drain system and discharged downstream of Madison Street.

Solution 25-12-2 assumes that Solution 4-11-2 has been constructed, and also includes a 48" CMP storm drain line in Madison Street from Avenue J to Algerita Drive. Due to the higher flows in Sulfur Draw upstream of Madison Street, two additional 9' x 9' box culverts are added under Madison Street.

4.25.3 Advantages / Disadvantages

The storm drain laterals proposed in Solutions 4-11-1 and 8-10-1 would significantly reduce the overtopping of Madison Street by discharging much of the flow into Sulfur Draw downstream of Madison Street, reducing the need to enlarge the existing Madison Street crossing.

The storm drain laterals proposed in Solution 4-11-2 and 8-10-2 would increase the amount of flow in Sulfur Draw, requiring additional culvert improvements to reduce overtopping at Madison Street.

4.25.4 Conceptual Opinion of Probable Project Cost

The conceptual opinion of probable project cost for Solution 25-12-1 is $310,000, and that for Solution 25-12-2 is $171,900, as shown in Table B-25 of Appendix B.

4.25.5 Recommendation

Since we recommended that the City construct Solution 4-11-2 and Solution 8-10-2, the City would need to construct Solution 25-12-2.

4.26 Implementation Plan

Although each of the top 25 Key Elements has a priority associated with it, several of the elements are closely related to each other and must be constructed together. The following is a list of the recommended solutions and order in which they should be constructed.

Solution (Rank-Element-Option)	Key Study Element Description	Project	Conceptual Project Cost
1-50-2	Bell Street at Koberlin Street	1	$2,087,800
2-34-1	West Avenue P at Bryant Boulevard	2	$1,489,500
3-14-2	Pecan Street at 3rd Street	3	$719,100
4-11-2	Taylor Street at Conchita Street	4	$2,486,200
5-51-2	Preusser Street (Lowrie to Schroeder)	5	$582,000
17-52-2	Coke Street at East Angelo Draw	5	$1,510,600
6-37-2	Sul Ross Street at Sunset Drive	6	$1,231,400
14-38-2	Lindenwood Drive at Vista Del Arroyo	6	$553,300
7-29-2	Southwest Blvd at S. Fork Red Arroyo	7	$3,318,400
8-10-2	Beauregard Ave (Campus to N. Concho)	8	$2,212,100
25-12-2	Madison Street (Avenue J to Algerita)	8	$171,900
9-7-2	Howard Street (North to Webster)	9	$294,300
24-5-2	Howard Street at Brentwood Park	9	$43,800
10-2-2	Glenwood Drive at Howard Street	10	$781,700
23-3-1	Glenwood Drive(Harrison to Greenwood)	10	$747,800
11-54-1	Regent Boulevard at Gordon Boulevard	11	$2,132,700
12-28-1	College Hills Blvd at N. Fork Red Arroyo	12	$3,542,300
15-31-1	College Hills Blvd at S. Fork Red Arroyo	12	$3,486,600
13-43-2	30th Street at Day Elementary	13	$256,000
16-13-2	Monroe Street at Sulphur Draw Park	14	$456,200
18-30-1	Loop 306 Access Road at Eckerd's	15	$2,713,400
19-18-1	Lester Lane at Tres Rios Drive	16	$104,100
20-20-1	Goodfellow Draw at Evelyn Avenue	17	$976,000
21-46-1	24th Street at Blum Street	18	$2,777,200
22-47-2	Bradford Street at 24th Street	19	$509,700
		Total	$35,184,100

Section 5 Funding Strategies

Currently the City of San Angelo has no dedicated funding sources for drainage improvements or maintenance. As part of the San Angelo Master Drainage Plan, the following nine potential sources of funding for drainage improvements were reviewed:

- General Fund Financing
- Grants
- Drainage Improvement Districts
- Sales Tax Increase
- Drainage Utility Fee
- Drainage Impact Fees
- Roadway Impact Fees
- Developer Participation in Adjacent Channel Improvements
- Developer Participation in Downstream Drainage Improvements

Approximately 75% of the City of San Angelo is currently developed, and the City has been growing slowly but steadily over the last few years. Continued growth may make flooding problems worse due to the potential for increased runoff with urbanization and because some of the new development is likely to occur in or upstream of the areas that are already prone to flooding. San Angelo has not experienced major damage from flooding recently, and the City has not constructed any major flood control projects.

The proposed Stormwater Ordinance, a copy of which is included as Appendix C of this report, will allow San Angelo to require developers to handle on-site drainage problems and avoid aggravating downstream problems. Development must include facilities to convey stormwater through the site and must either keep downstream peak flows at pre-development levels or keep them within the capacity of channels and culverts.

In recent years, the Environmental Protection Agency (EPA) has applied the National Pollutant Discharge Elimination System (NPDES) permitting requirements to storm water discharges for cities with populations ranging from 10,000 to 100,000, and is described in further detail in Section 6 of this report. These regulations will apply to the City of San Angelo and will also require significant funding. Each of the nine potential funding sources are described below. A combination of funding sources would also be feasible.

5.1 General Fund Financing

General fund financing is by far the most common source of funds for drainage improvements and for operation and maintenance of drainage facilities. Drainage improvements are often financed by general obligation bond issues, requiring voter approval. In San Angelo, operation and maintenance expenditures related to drainage have been limited and have been funded from general fund tax revenues.

Advantages: This source of funding is clearly permissible. The requirement of voter approval for general obligation bond issues assures that the projects funded have public support.

Disadvantages: General funds in San Angelo, as in most cities, are limited, and many services compete for the funds available. As a result, many needed or desired services may be inadequately funded. Most Texas cities have drainage improvement needs in excess of available funding. Public attention tends to focus on drainage problems only when floods occur, which makes reliable funding from this source difficult. In addition, support for drainage bonds tends to be concentrated among those affected by flooding.

5.2 Grants

Grants for flood control improvements are sometimes available through the Corps of Engineers (COE) Section 205 program, Community Development Block Grants (CDBG), FEMA's Hazard Mitigation Grants, and other programs. Most of these are on a matching basis.

Advantages: Financing drainage projects by federal grants would substantially reduce the City's cost for the flood protection.

Disadvantages: Federal funding for these programs is very limited and competitive. It is unlikely that many projects will be funded by grants in the near future and many of those will likely be limited to economically disadvantaged communities. Federal grant programs often include significant restrictions, limitations, and requirements, making the completion of projects difficult, time-consuming, and inconvenient.

5.3 Special Improvement Districts

In some cases, drainage improvements are funded by special improvement districts. Local examples of such districts include the Tarrant Regional Water District Number One, which also provides water supply and levee districts.

Advantages: With their dedicated tax revenues, such districts are often successful in addressing drainage problems.

Disadvantages: The formation of a special improvement district is a complex process.

5.4 Sales Tax Increase

Voters in some cities have passed a sales tax dedicated to flood control and other improvements. All improvements, as well as operations and maintenance, could be financed from this source.

Advantages: Flood control improvements could be readily funded with a sales tax program. The funding source can generate funds for increased bonding capacity for capital improvements, as well as pay for operations and maintenance. It would also help to address NPDES requirements. Many view a sales tax as having an advantage of taxing all citizens as well as visitors, rather than just property owners.

Disadvantages: Flood control improvements would require dedication of a sales tax increase to pay for improvements and will likely meet significant public resistance.

5.5 Drainage Utility Fee

Many municipalities in Texas and across the nation are forming drainage utilities to address flood control and stormwater quality issues. The recent Environmental Protection Agency (EPA) implementation of NPDES permitting requirements for urban stormwater discharge has encouraged the formation of such utilities, as cities seek ways to fund this new program and/or to improve their drainage facilities. Drainage utilities are a mechanism for assessing fees to property owners on the basis of estimated runoff generation, and are regulated under Chapter 402 of the Local Government Code. Area, land use, zoning, and impervious area are often to estimate runoff and establish a fee for each type of property. Funding can also be generated through fees attached to water bills rather than property.

Advantages: The legality of drainage utilities is well established. In the DFW metroplex area, North Richland Hills, Bedford, Euless, Dallas, Garland, Grapevine, and Arlington have implemented these utilities, as have other cities across the state and the country. Drainage utilities can raise substantial funds with fairly small widespread monthly fees. This can allow cities to address drainage needs which are often chronically underfunded from conventional sources. Drainage utility fees provide a source of revenue to allow the issuance of revenue bonds. Drainage utility funds can be used both for capital investments and for operation and maintenance. Capital investments can cover protection of both existing and future development. In the case of San Angelo, establishing a drainage utility could give the City a way to finance on-going maintenance and to construct the projects identified in Section 4 to reduce the risk of flooding. The utility would also provide funding to help address NPDES requirements for stormwater.

Disadvantages: Drainage utilities and their fees can be unpopular with residents, who may feel that the fee is just another form of taxation. It could be argued that it is not fair to charge property owners all over the city for flood control improvements which benefit property near the streams.

5.6 Drainage Impact Fees

Texas law allows cities to charge fees to new development to cover the cost of off-site drainage improvements under Chapter 395 of the Local Government Code. Such fees are intended to cover only the impact caused by the new development. Only a few Texas cities have implemented impact fees for drainage. Impact fees for water and sewer improvements are much more common, and impact fees for roadway improvements have also been implemented in some cases. The City of North Richland Hills studied a drainage impact fee, but it was not implemented. Instead, North Richland Hills implemented a drainage utility district.

Advantages: The legality of the drainage impact fee is well established. It assigns a fair share of the cost of drainage improvements to new development based on its impacts. Impact fees provide some relief from drainage improvement costs for stream-side developers. They also obtain some funding from off-stream developers.

Disadvantages: Impact fees have not commonly been used to fund drainage improvements in Texas. They would be limited to improvements needed because of flows generated by new development. Impact fees can only be used for improvements needed to provide capacity for new development and cannot easily be used for operation and maintenance expenses. Currently inadequate channel or structure improvements would need another source of funds.

5.7 Roadway Impact Fees

Texas law allows cities to charge impact fees for roadway improvements to serve new development as well as for drainage improvements. For example, the City of Southlake has developed roadway impact fees, and the roadway projects covered by the fees include 27 critical drainage structures on roads in the city.

Advantages: The legality of roadway impact fees is well established, and they have been implemented by a number of cities in Texas. As roads are improved to handle future development, bridges and culverts can be built to handle flood flows and decrease upstream flooding.

Disadvantages: Roadway impact fees are limited to funding improvements associated with roads. They cannot fund channel improvements except within street right-of-ways. This funding would be limited to those improvements directly related to growth operation and maintenance costs are not fundable from this source.

5.8 Developer Participation in Adjacent Channel Improvements

San Angelo could require developers to make channel improvements for the stream channel fronting included in their property. The improvements required could be based on the solutions developed un Section 4 of this Master Drainage Plan. With this approach, if the development were on both sides of 2,000 feet of a stream channel, the developer would be expected to make all channel improvements in that 2,000 feet. If the property were only on one side of the channel, the developer would be expected to pay for half of the needed channel improvements. If the property is not on a drainage channel, there would be no charge to the developer for channel improvements, although internal drainage would still be required.

Advantages: Developer participation in adjacent channel improvements is required by many Texas cities, and there are few legal questions about such requirements. Requiring developers to improve the channel as they develop decreases the chance that the City will have to make expensive improvements after development occurs.

Disadvantages: The cost of channel improvements could discourage the development of tracts adjacent to streams. When development does occur, the resulting channel improvements might be in isolated sections. In some cases, improvements at the development (without the related downstream and upstream improvements) would not fully protect the development. It can also be argued that this system is not equitable, since the developers along the streams do not create all of the flooding problems but do bear all of the cost of improvements. In addition, developer participation in improving adjacent channels does not protect existing development in other areas.

5.9 Developer Participation in Downstream Drainage

Some cities require developers to improve (or participate in improving) undersized downstream drainage facilities and channels as a condition of development. San Angelo has required pro-rata developer participation in downstream improvements in the past but has no such requirements now.

Advantages: This type of policy helps assure that development does not cause flooding problems downstream. It also broadens the participation in drainage improvements to include developers not immediately on a stream channel.

Disadvantages: It may not be equitable to require a developer to make all needed improvements downstream, since a portion of the improvements needed are usually related to existing development and to other future developments. As a result, this sort of program usually funds only a part of the needed drainage work. This type of financing would also tend to discourage development. It can be difficult for cities to require off-site improvements, unless development agreements are negotiated.

Section 6 Environmental Regulation Review

6.1 Previous Studies

In 1992 and 1994, the Texas Clean River Program Water Quality Assessment Reports prepared for the Colorado River Basin identified the North Concho River in the upper portion of stream segment 1421 (Concho River) as being severely impacted by non-point source urban runoff water pollution. In response, a joint study was prepared for the Upper Colorado River Authority and City of San Angelo by SK Engineering Inc., entitled "North Concho River Urban Runoff / Non-Point Source Abatement Master Plan". This study evaluated a range of structural and non-structural control alternatives to improve water quality in the North Concho watershed. Based on preliminary engineering analyses and preliminary cost estimates, the citizen's advisory committee for the project selected the following six projects for design development:

1. Alternative 1-A: Upgrade of the Stormwater Pump Station and Treatment Plant on North Concho River between Irving Street and Johnson Dam
2. Alternative 10-A: Civic League Park Gabion Dam and Santa Fe Dry Pond
3. Alternatives 6-A / 16-A: Retention Pond and Retrofitting the Caddo (6th Street) and First Street Dams
4. Alternative 24-B: Brentwood Park Detention Ponds and Gabion Dams
5. Alternative 30-A: Detention Pond and Gabion Dam south of Santa Rita Elementary School (downstream of Monroe Street)
6. Alternative 26-A: Series of Stormwater Retention Structures along Classen Boulevard from North Street to Abilene Street

This plan also evaluated non-structural control techniques which focused on prevention, including any action with the specific intent to reduce the generation of contaminants at the source. Most of these techniques are suggested activities in public information, such as posters, public advertisements, utility bill stuffers, public service announcements, public school poster or slogan contests, costumed mascot characters, and inlet stenciling.

6.2 NPDES Phase 2 Requirements

The Clean Water Act (CWA) is the primary federal legislation that protects surface waters, such as lakes, rivers, and coastal areas, and was enacted in 1972. The CWA focused on establishing effluent limitations on point sources ("any discernable, confined, and discrete conveyance ... from which pollutants are or may be discharged"), increasing the level of accountability on dischargers of pollutants, provided certain funding mechanisms to help communities meet their goals. The CWA was amended in 1987 to introduce the National Pollutant Discharge Elimination System (NPDES), which was established to be the fundamental regulatory mechanism of the CWA. The NPDES program requires anyone discharging a pollutant from a point source into the waters of the U.S. to obtain a NPDES permit. The 1987 amendments also added Section 402(p), which required the EPA to develop a comprehensive phased program to regulate storm water discharges under the NPDES program. The EPA issued the Phase 1 rule in November of 1990, which addressed storm water discharges from medium and large municipal separate storm sewer systems (MS4s), defined as those systems serving communities with a population of at least 100,000, as well as storm water discharges from certain categorical industrial facilities and construction sites larger than 5 acres.

The Phase II proposed rule for small MS4s was signed by the EPA administrator on December 15, 1997, and the final Phase II regulations were signed October 29, 1999. The City of San Angelo is identified in Appendix 6 of the final Phase II rule as a small MS4 which will have to comply with these regulations. In Texas, the Texas Natural Resources Conservation Commission (TNRCC) has been authorized to administer the Phase II program, and is the official permitting authority. As such, the TNRCC has to prepare a Phase II General Permit by December 2002 which satisfies at least the six minimum control measures outlined in the final Phase II rule, although they also have the authority to add provisions to their Phase II General Permit as they see fit. As a regulated small MS4, once the TNRCC has developed their Phase II General Permit, the City of San Angelo can either apply to be covered under this permit, which means following all of its requirements, or the City can apply for an Individual Phase II Permit. The City will have until March 2003 to develop and submit their permit application (3 years and 90 days after the final regulations were issued), and until March 2008 to fully implement their Phase II program. At the time of this writing, the indications are that the City will at least have to enact programs which satisfy the following six minimum control measures:

1. Public Education and Outreach on Storm Water Impacts
   A public education program must be implemented to distribute educational materials to the citizens of San Angelo to make them aware of the impacts of storm water discharges to waterbodies and the steps needed to decrease storm water pollution.
2. Public Involvement and Participation
   The citizens of San Angelo must be involved in developing the municipality's storm water program by following public notice requirements, and should include all economic and ethnic groups.
3. Illicit Discharge Detection and Elimination
   The City of San Angelo must demonstrate awareness of their system, develop a storm sewer system map that shows all outfalls and the name of receiving waters, enact ordinances that effectively prohibit illicit discharges into the MS4 and include enforcement procedures, and develop and implement a plan to detect and address illicit discharges, including illegal dumping.
4. Construction Site Storm Water Runoff Control
   The City of San Angelo must develop, implement, and enforce a program to reduce pollutants in any storm water from construction sites of more than one acre, utilizing an ordinance to control erosion and sediment to the maximum extent practicable and provide sanctions to ensure compliance, including provisions to address water quality impacts through site plan review and procedures for site inspection and public input.
5. Post-Construction Storm Water Management in New Development / Redevelopment
   The City of San Angelo must develop, implement, and enforce a program that addresses storm water runoff from new development and redevelopment projects larger than one acre, by requiring the use of structural and non-structural BMPs that ensure that water quality impacts are minimized, including provisions for long term operation and maintenance.
6. Pollution Prevention and Good Housekeeping for Municipal Operations
   The City of San Angelo must develop and implement a cost-effective operation and maintenance program as well as employee training programs with the goal of preventing or reducing pollutant runoff from municipal operations.

Developing a storm water management web page for the City's current web site would help satisfy many of the public education requirements. Some of the public involvement efforts could be satisfied by joint efforts with the Upper Colorado River Authority, as described in the North Concho River Master Plan. Due to the relatively small number of storm drains in San Angelo, the illicit discharge detection and elimination efforts will be less intense than those of many other cities, but the City will still need to develop an accurate map which shows the storm drain systems that are in place. Probably the most significant impact of the Phase II regulations on San Angelo will be the requirement to establish and maintain the programs for construction site and post-construction runoff controls. These will likely be accomplished with the development of a new erosion control ordinance and accompanying Erosion Control Manual which lists the BMPs which will be required for construction in San Angelo, the contents of which will need to be tailored to satisfy the TNRCC's Phase II General Permit once they are known. Any new municipal operations facilities should be designed to incorporate good housekeeping procedures. In addition, indications are that the current exemption that small cities have for industrial facilities will be discontinued, meaning that any industrial facilities currently owned by the City and City sponsored construction activities may also need to be permitted.

6.3 Corps 404 Permitting Requirements

In addition to water quality issues, the Corps of Engineers regulates discharges of dredged or fill material into the "waters of the U.S." under Section 404 of the Clean Water Act. Using a broad definition of "waters of the U.S.", these regulations apply to a wide range of aquatic environments, including wetlands. Under this program, the Corps issues Nationwide 404 Permit verifications for activities below a certain level of impact and Individual 404 Permits for activities above that level. Each Nationwide 404 Permit has specific threshold limits, above which an Individual 404 Permit is required.

While a detailed discussion of the Corps 404 permitting process is beyond the scope of this report, a few recent changes in the 404 permitting process have made it more difficult to construct large drainage improvement projects, which typically rely on large concrete channels. In 1997, the Corps significantly lowered the thresholds for the Nationwide 404 Permits, resulting in more drainage improvements projects requiring the more detailed Individual 404 Permit process. Currently the majority of drainage improvement projects over 500 feet in length are covered under Nationwide Permit 26 for "Discharges into the Headwaters of the U.S.". In July of 2000 Nationwide Permit 26 expired, and the Corps replaced it with five activity-specific permits, each of which states it is not to be used for channel improvements. Without Nationwide Permit 26, it is very important that the City start the permitting process in the preliminary study phase, allowing planning efforts to be focused on improvements that the Corps will allow. By incorporating the 404 permitting in the design of the improvements, many of the project goals can be accomplished through the use of more pervious materials such as gabions or bioengineering, although it still may require additional easement and mitigation.

Appendix A

Plates

PLATE 1
CITY OF SAN ANGELO
MASTER DRAINAGE STUDY

KEY STUDY ELEMENTS

LEGEND

- 1850 — GROUND ELEVATION CONTOUR
- DRAINAGE AREA BOUNDARY
- (15) — KEY STUDY ELEMENT LOCATION
- SAN ANGELO CITY LIMITS

N

0 2000' 4000'
1"=2000'

FREESE • NICHOLS

O.C. FISHER LAKE

LAKE NASWORTHY

TWIN BUTTES RESERVOIR

GRAPE CREEK RD.
S.H. 208
ARMSTRONG ST.
26TH ST.
EAST ANGELO DRAW
U.S. HWY 67 & 277
CHADBOURNE ST.
19TH ST.
BRYANT BLVD.
NORTH CONCHO
U.S. HWY 67
PULLIAM ST.
CHILDRESS ST.
BEAUREGARD AVE.
LOOP 306
ARDEN RD.
SHERWOOD
COLLEGE HILL DR.
RED ARROYO
KNICKERBOCKER RD.
SOUTH CONCHO
GOODFELLOW DRAW
PAINT ROCK RD.
GOODFELLOW AIR FORCE BASE
1850
NORTH FORK
SOUTH FORK
HWY 84
COUNTRY CLUB RD.
CHRISTOVAL RD.
SAN ANGELO MUNICIPAL AIRPORT
OUTSIDE CORPORATE LIMITS
SUMP

Appendix B

Conceptual Opinion of Project Costs

Table B-1
Conceptual Opinion of Probable Construction Cost
Bell Street (Koberlin to Spaulding)

Ranking:	**1**
Key Element	**50**

Item	Description	Unit Price	Unit	Solution 1-50-1 Quantity	Solution 1-50-1 Price	Solution 1-50-2 Quantity	Solution 1-50-2 Price
1	Mobilization (5%)	varies	LS	1	$192,375	1	$70,003
2	Clear and Grub	$3,000	AC	10	$30,000	2	$6,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	228,400	$3,654,400	12,100	$193,600
6	Excavation (only)	$6	CY	21,600	$129,600	0	$0
7	Fill for Road	$15	CY	0	$0	13,000	$195,000
8	Remove/Replace Asphalt w/ subgrade	$45	SY	0	$0	14,500	$652,500
9	Remove/Replace 6" curb w/ 18" gutter	$15	LF	0	$0	4,500	$67,500
10	Gabion Channel Walls; 1-3 foot Deep	$100	LF	200	$20,000	700	$70,000
11	9' x 9' Direct Drive Box Culvert	$305	LF	0	$0	360	$109,800
12	9' x 11' Direct Drive Box Culvert	$359	LF	0	$0	240	$86,160
13	Culvert Outlet Structure	$3,500	EA	0	$0	4	$14,000
14	Grass Sod/Seed	$2	SY	5,000	$10,000	1,000	$2,000
	Subtotal				**$4,039,900**		**$1,470,100**
	Contingency	**15%**			**$606,000**		**$220,600**
	Utilities Conflicts	**15%**			**$606,000**		**$220,600**
	Engineering/Survey	**12%**			**$484,800**		**$176,500**
	Total				**$5,736,700**		**$2,087,800**

Table B-2
Conceptual Opinion of Probable Construction Cost
West Avenue P at Bryant Boulevard

Ranking:	**2**
Key Element	**34**

Item	Description	Unit Price	Unit	Solution 2-34-1 Quantity	Solution 2-34-1 Price
1	Mobilization (5%)	varies	LS	1	$49,943
2	Clear and Grub	$3,000	AC	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Excavation Including Removal	$16	CY	8,800	$140,800
6	Remove/Replace Asphalt w/ subgrade	$45	SY	3,650	$164,250
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	2,300	$34,500
8	Remove/Replace Driveway 6", 3000psi	$35	SY	200	$7,000
9	8' x 8' Direct Drive Box Culvert	$244	LF	2,300	$561,200
10	Culvert Outlet Structure	$3,500	EA	2	$7,000
11	Gabion Channel Walls; 4-6 foot Deep	$250	LF	300	$75,000
12	Grass Sod/Seed	$2	SY	1,300	$2,600

Subtotal		**$1,048,800**
Contingency	**15%**	**$157,400**
Utilities Conflicts	**15%**	**$157,400**
Engineering/Survey	**12%**	**$125,900**
Total		**$1,489,500**

Table B-3
Conceptual Opinion of Probable Construction Cost
Pecan Street at 3rd Street

Ranking:	**3**
Key Element	**14**

Item	Description	Unit Price	Unit	Solution 3-14-2 Quantity	Solution 3-14-2 Price
1	Mobilization (5%)	varies	LS	1	$24,108
2	Clear and Grub	$3,000	AC	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Excavation Including Removal	$16	CY	700	$11,200
6	Remove/Replace Asphalt w/ subgrade	$45	SY	2,000	$90,000
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	1,200	$18,000
8	Remove/Replace Driveway 6", 3000psi	$35	SY	200	$7,000
9	12' x 5' Direct Drive Box Culvert	$421	LF	350	$147,350
10	Culvert Outlet Structure	$3,500	EA	2	$7,000
11	Concrete Channel Lining	$350	CY	550	$192,500
12	Grass Sod/Seed	$2	SY	1,300	$2,600

Subtotal		**$506,300**
Contingency	**15%**	**$76,000**
Utilities Conflicts	**15%**	**$76,000**
Engineering/Survey	**12%**	**$60,800**
Total		**$719,100**

Table B-4
Conceptual Opinion of Probable Construction Cost
Taylor Street at Conchita Street

Ranking:	**4**
Key Element 11	

Item	Description	Unit Price	Unit	Solution 4-11-1 Quantity	Solution 4-11-1 Price	Solution 4-11-2 Quantity	Solution 4-11-2 Price
1	Mobilization (5%)	varies	LS	1	$126,225	1	$83,365
2	Clear and Grub	$3,000	AC	2	$6,000	2	$6,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	11,000	$176,000	8,200	$131,200
6	Remove/Replace Asphalt w/ subgrade	$45	SY	10,600	$477,000	7,000	$315,000
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	800	$12,000	800	$12,000
8	Remove/Replace Driveway 6", 3000psi	$35	SY	600	$21,000	400	$14,000
9	36" CMP Storm Drain	$87	LF	300	$26,100	300	$26,100
10	84" CMP Storm Drain	$250	LF	2,500	$625,000	4,200	$1,050,000
11	108" CMP Storm Drain	$332	LF	3,200	$1,062,400	0	$0
12	Junction Box / Manholes	$3,000	EA	5	$15,000	3	$9,000
13	Culvert Outlet Structure	$3,500	EA	1	$3,500	1	$3,500
14	12' Curb Inlet	$2,500	EA	2	$5,000	2	$5,000
15	20' Curb Inlet	$4,000	EA	2	$8,000	2	$8,000
16	25' Curb Inlet	$5,000	EA	14	$70,000	14	$70,000
17	30' Curb Inlet	$6,000	EA	2	$12,000	2	$12,000
18	Grass Sod/Seed	$2	SY	1,000	$2,000	1,000	$2,000
	Subtotal				**$2,650,800**		**$1,750,700**
	Contingency	**15%**			**$397,700**		**$262,700**
	Utilities Conflicts	**15%**			**$397,700**		**$262,700**
	Engineering/Survey	**12%**			**$318,100**		**$210,100**
	Total				**$3,764,300**		**$2,486,200**

Table B-5
Conceptual Opinion of Probable Construction Cost
Preusser Street (Lowrie to Schroeder)

Ranking:	**5**
Key Element 51	

Item	Description	Unit Price	Unit	Solution 5-51-2 Quantity	Solution 5-51-2 Price
1	Mobilization (5%)	varies	LS	1	$19,510
2	Clear and Grub	$3,000	AC	2	$6,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Excavation Including Removal	$16	CY	8,850	$141,600
6	Remove/Replace Asphalt w/ subgrade	$45	SY	500	$22,500
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	200	$3,000
8	Gabion Channel Walls; 1-3 foot Deep	$100	LF	1,600	$160,000
9	9' x 9' Direct Drive Box Culvert	$305	LF	120	$36,600
10	Culvert Outlet Structure	$3,500	EA	2	$7,000
11	Grass Sod/Seed	$2	SY	5,000	$10,000

Subtotal		**$409,800**
Contingency	**15%**	**$61,500**
Utilities Conflicts	**15%**	**$61,500**
Engineering/Survey	**12%**	**$49,200**
Total		**$582,000**

Table B-6
Conceptual Opinion of Probable Construction Cost
Sul Ross Street at Sunset Drive

Ranking:	**6**
Key Element	**37**

Item	Description	Unit Price	Unit	Solution 6-37-1 Quantity	Solution 6-37-1 Price	Solution 6-37-2 Quantity	Solution 6-37-2 Price
1	Mobilization (5%)	varies	LS	1	$37,400	1	$41,290
2	Clear and Grub	$3,000	AC	1	$3,000	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	6,500	$104,000	9,000	$144,000
6	Remove/Replace Asphalt w/ subgrade	$45	SY	2,800	$126,000	3,000	$135,000
7	8' x 6' Direct Drive Box Culvert	$275	LF	1,800	$495,000	0	$0
8	9' x 8' Direct Drive Box Culvert	$291	LF	0	$0	1,800	$523,800
9	Junction Box / Manholes	$3,000	EA	4	$12,000	4	$12,000
10	Culvert Outlet Structure	$3,500	EA	1	$3,500	1	$3,500
11	Grass Sod/Seed	$2	SY	500	$1,000	500	$1,000
	Subtotal				**$785,400**		**$867,100**
	Contingency	**15%**			**$117,900**		**$130,100**
	Utilities Conflicts	**15%**			**$117,900**		**$130,100**
	Engineering/Survey	**12%**			**$94,300**		**$104,100**
	Total				**$1,115,500**		**$1,231,400**

Table B-7
Conceptual Opinion of Probable Construction Cost
Southwest Boulevard at South Fork Red Arroyo

Ranking:	7
Key Element	29

Item	Description	Unit Price	Unit	Solution 7-29-1 Quantity	Solution 7-29-1 Price	Solution 7-29-2 Quantity	Solution 7-29-2 Price
1	Mobilization (5%)	varies	LS	1	$190,455	1	$111,268
2	Clear and Grub	$3,000	AC	25	$75,000	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	200,000	$3,200,000	12,400	$198,400
6	Excavation (only)	$6	CY	2,600	$15,600	0	$0
7	Remove/Replace Asphalt w/ subgrade	$45	SY	0	$0	4,400	$198,000
8	Remove/Replace 6" curb w/ 18" gutter	$15	LF	0	$0	50	$750
9	42" CMP Storm Drain	$105	LF	0	$0	510	$53,550
10	54" CMP Storm Drain	$158	LF	0	$0	510	$80,580
11	66" CMP Storm Drain	$194	LF	0	$0	510	$98,940
12	72" CMP Storm Drain	$216	LF	0	$0	510	$110,160
13	78" CMP Storm Drain	$232	LF	0	$0	510	$118,320
14	84" CMP Storm Drain	$250	LF	0	$0	510	$127,500
15	90" CMP Storm Drain	$269	LF	0	$0	250	$67,250
16	96" CMP Storm Drain	$288	LF	0	$0	300	$86,400
17	7' x 5' Direct Drive Box Culvert	$238	LF	0	$0	0	$0
18	Bridge - 4 Lanes	$3,200	LF	0	$0	300	$960,000
19	Junction Box / Manholes	$3,000	EA	0	$0	8	$24,000
20	Gabion Channel Lining	$150	CY	3,300	$495,000	0	$0
21	Gabion Channel Walls; 1-3 foot Deep	$100	LF	0	$0	300	$30,000
22	10' Curb Inlet	$2,000	EA	0	$0	32	$64,000
23	Grass Sod/Seed	$2	SY	10,000	$20,000	500	$1,000
	Subtotal				**$3,999,600**		**$2,336,700**
	Contingency	**15%**			**$600,000**		**$350,600**
	Utilities Conflicts	**15%**			**$600,000**		**$350,600**
	Engineering/Survey	**12%**			**$480,000**		**$280,500**
	Total				**$5,679,600**		**$3,318,400**

Table B-8
Conceptual Opinion of Probable Construction Cost
Beauregard Avenue (Campus to North Concho River)

Ranking:	**8**
Key Element	**10**

Item	Description	Unit Price	Unit	Solution 8-10-1 Quantity	Solution 8-10-1 Price	Solution 8-10-2 Quantity	Solution 8-10-2 Price
1	Mobilization (5%)	varies	LS	1	$67,260	1	$74,175
2	Clear and Grub	$3,000	AC	2	$6,000	2	$6,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	8,200	$131,200	9,400	$150,400
6	Remove/Replace Asphalt w/ subgrade	$45	SY	7,600	$342,000	8,600	$387,000
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	800	$12,000	1,100	$16,500
8	Remove/Replace Driveway 6", 3000psi	$35	SY	500	$17,500	500	$17,500
9	30" RCP Storm Drain	$75	LF	1,000	$75,000	1,000	$75,000
10	36" CMP Storm Drain	$87	LF	1,400	$121,800	2,200	$191,400
11	48" CMP Storm Drain	$112	LF	1,200	$134,400	1,200	$134,400
12	78" CMP Storm Drain	$232	LF	1,900	$440,800	1,900	$440,800
13	Junction Box / Manholes	$3,000	EA	2	$6,000	2	$6,000
14	10' Curb Inlet	$2,000	EA	1	$2,000	1	$2,000
15	15' Curb Inlet	$3,000	EA	5	$15,000	5	$15,000
16	20' Curb Inlet	$4,000	EA	9	$36,000	9	$36,000
17	Grass Sod/Seed	$2	SY	1,000	$2,000	1,000	$2,000

Subtotal		**$1,412,500**	**$1,557,700**
Contingency	**15%**	**$211,900**	**$233,700**
Utilities Conflicts	**15%**	**$211,900**	**$233,700**
Engineering/Survey	**12%**	**$169,500**	**$187,000**
Total		**$2,005,800**	**$2,212,100**

Table B-9
Conceptual Opinion of Probable Construction Cost
Howard Street (North to Webster)

Ranking:	**9**
Key Element	**7**

Item	Description	Unit Price	Unit	Solution 9-7-1 Quantity	Solution 9-7-1 Price	Solution 9-7-2 Quantity	Solution 9-7-2 Price
1	Mobilization (5%)	varies	LS	1	$8,565	1	$9,865
2	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
3	Barricading	$2,500	LS	1	$2,500	1	$2,500
4	Excavation Including Removal	$16	CY	1,100	$17,600	1,500	$24,000
5	Remove/Replace Asphalt w/ subgrade	$45	SY	100	$4,500	100	$4,500
6	Remove/Replace Driveway 6", 3000psi	$35	SY	100	$3,500	100	$3,500
7	6' x 5' Direct Drive Box Culvert	$191	LF	700	$133,700	0	$0
8	7' x 7' Direct Drive Box Culvert	$219	LF	0	$0	700	$153,300
9	Culvert Outlet Structure	$3,500	EA	1	$3,500	1	$3,500
10	5' Grate Inlet	$2,000	EA	2	$4,000	2	$4,000
11	Grass Sod/Seed	$2	SY	500	$1,000	500	$1,000
	Subtotal				**$179,900**		**$207,200**
	Contingency	**15%**			**$27,000**		**$31,100**
	Utilities Conflicts	**15%**			**$27,000**		**$31,100**
	Engineering/Survey	**12%**			**$21,600**		**$24,900**
	Total				**$255,500**		**$294,300**

Table B-10
Conceptual Opinion of Probable Construction Cost
Glenwood Drive at Howard Street

Ranking:	**10**
Key Element	**2**

Item	Description	Unit Price	Unit	Solution 10-2-1 Quantity	Solution 10-2-1 Price	Solution 10-2-2 Quantity	Solution 10-2-2 Price
1	Mobilization (5%)	varies	LS	1	$19,267	1	$26,207
2	Clear and Grub	$3,000	AC	1	$3,000	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	3,400	$54,400	4,700	$75,200
6	6' x 4' Direct Drive Box Culvert	$186	LF	1,500	$279,000	0	$0
7	8' x 5' Direct Drive Box Culvert	$254	LF	0	$0	1,500	$381,000
8	36" CMP Storm Drain	$87	LF	120	$10,440	120	$10,440
9	10' Curb Inlet	$2,000	EA	4	$8,000	4	$8,000
10	Excavation Including Removal	$16	CY	1,500	$24,000	2,500	$40,000
11	Grass Sod/Seed	$2	SY	1,500	$3,000	1,500	$3,000
	Subtotal				**$404,700**		**$550,400**
	Contingency	**15%**			**$60,800**		**$82,600**
	Utilities Conflicts	**15%**			**$60,800**		**$82,600**
	Engineering/Survey	**12%**			**$48,600**		**$66,100**
	Total				**$574,900**		**$781,700**

Table B-11
Conceptual Opinion of Probable Construction Cost
Regent Boulevard at Gordon Boulevard

Ranking:	**11**
Key Element	**54**

Item	Description	Unit Price	Unit	Solution 11-54-1 Quantity	Solution 11-54-1 Price
1	Mobilization (5%)	varies	LS	1	$71,510
2	Clear and Grub	$3,000	AC	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Excavation Including Removal	$16	CY	4,000	$64,000
6	Excavation (only)	$6	CY	7,500	$45,000
7	Remove/Replace Asphalt w/ subgrade	$45	SY	5,000	$225,000
8	Remove/Replace 6" curb w/ 18" gutter	$15	LF	3,100	$46,500
9	Gabion Channel Lining	$150	CY	500	$75,000
10	10' x 6' Direct Drive Box Culvert	$311	LF	3,100	$964,100
11	Culvert Outlet Structure	$3,500	EA	1	$3,500
12	Grass Sod/Seed	$2	SY	300	$600

Subtotal		**$1,501,800**
Contingency	**15%**	**$225,300**
Utilities Conflicts	**15%**	**$225,300**
Engineering/Survey	**12%**	**$180,300**
Total		**$2,132,700**

Table B-12
Conceptual Opinion of Probable Construction Cost
College Hills Boulevard at North Fork Red Arroyo

Ranking:	**12**
Key Element	**28**

Item	Description	Unit Price	Unit	Solution 12-28-1 Quantity	Solution 12-28-1 Price
1	Mobilization (5%)	varies	LS	1	$118,785
2	Clear and Grub	$3,000	AC	5	$15,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Excavation (only)	$6	CY	1,700	$10,200
6	Fill for Road	$15	CY	4,300	$64,500
7	Remove/Replace Asphalt w/ subgrade	$45	SY	7,600	$342,000
8	Remove/Replace 6" curb w/ 18" gutter	$15	LF	1,100	$16,500
9	Bridge - 4 Lanes	$3,200	LF	600	$1,920,000
10	Grass Sod/Seed	$2	SY	2,000	$4,000

Subtotal		**$2,494,500**
Contingency	**15%**	**$374,200**
Utilities Conflicts	**15%**	**$374,200**
Engineering/Survey	**12%**	**$299,400**
Total		**$3,542,300**

Table B-13
Conceptual Opinion of Probable Construction Cost
30th Street at Day Elementary

Ranking:	13
Key Element	43

Item	Description	Unit Price	Unit	Solution 13-43-1 Quantity	Solution 13-43-1 Price	Solution 13-43-2 Quantity	Solution 13-43-2 Price	Solution 13-43-3 Quantity	Solution 13-43-3 Price
1	Mobilization (5%)	varies	LS	1	$5,200	1	$8,575	1	$6,235
2	Clear and Grub	$3,000	AC	1	$3,000	1	$3,000	1	$3,000
3	Construction Staking/Surve	$1,000	LS	1	$1,000	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500	1	$2,500
5	Excavation Including Remo	$16	CY	500	$8,000	1,000	$16,000	1,200	$19,200
6	Concrete Channel Lining	$350	CY	250	$87,500	420	$147,000	0	$0
7	9' x 5' Direct Drive Box Cul	$250	LF	0	$0	0	$0	360	$90,000
8	Culvert Outlet Structure	$3,500	EA	0	$0	0	$0	2	$7,000
9	Grass Sod/Seed	$2	SY	1,000	$2,000	1,000	$2,000	1,000	$2,000
	Subtotal				**$109,200**		**$180,100**		**$131,000**
	Contingency	**15%**			**$16,400**		**$27,100**		**$19,700**
	Utilities Conflicts	**15%**			**$16,400**		**$27,100**		**$19,700**
	Engineering/Survey	**12%**			**$13,200**		**$21,700**		**$15,800**
	Total				**$155,200**		**$256,000**		**$186,200**

Table B-14
Conceptual Opinion of Probable Construction Cost
Lindenwood Drive at Vista Del Arroyo Street

Ranking:	**14**
Key Element	**38**

Item	Description	Unit Price	Unit	Solution 14-38-1 Quantity	Solution 14-38-1 Price	Solution 14-38-2 Quantity	Solution 14-38-2 Price
1	Mobilization (5%)	varies	LS	1	$16,578	1	$18,548
2	Clear and Grub	$3,000	AC	1	$3,000	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	2,900	$46,400	4,000	$64,000
6	Remove/Replace Asphalt w/ subgrade	$45	SY	1,200	$54,000	1,400	$63,000
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	50	$750	50	$750
8	8' x 6' Direct Drive Box Culvert	$275	LF	800	$220,000	0	$0
9	9' x 8' Direct Drive Box Culvert	$291	LF	0	$0	800	$232,800
10	Culvert Outlet Structure	$3,500	EA	1	$3,500	1	$3,500
11	Grass Sod/Seed	$2	SY	200	$400	200	$400
	Subtotal				**$348,200**		**$389,500**
	Contingency	**15%**			**$52,300**		**$58,500**
	Utilities Conflicts	**15%**			**$52,300**		**$58,500**
	Engineering/Survey	**12%**			**$41,800**		**$46,800**
	Total				**$494,600**		**$553,300**

Table B-15
Conceptual Opinion of Probable Construction Cost
College Hills Boulevard at South Fork Red Arroyo

Ranking:	**15**
Key Element	**31**

Item	Description	Unit Price	Unit	Solution 15-31-1 Quantity	Solution 15-31-1 Price
1	Mobilization (5%)	varies	LS	1	$116,915
2	Clear and Grub	$3,000	AC	6	$18,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Excavation (only)	$6	CY	1,000	$6,000
6	Fill for Road	$15	CY	9,500	$142,500
7	Remove/Replace Asphalt w/ subgrade	$45	SY	11,700	$526,500
8	Remove/Replace 6" curb w/ 18" gutter	$15	LF	2,520	$37,800
9	Bridge - 4 Lanes	$3,200	LF	500	$1,600,000
10	Grass Sod/Seed	$2	SY	2,000	$4,000

Subtotal		**$2,455,300**
Contingency	**15%**	**$368,300**
Utilities Conflicts	**15%**	**$368,300**
Engineering/Survey	**12%**	**$294,700**
Total		**$3,486,600**

Table B-16
Conceptual Opinion of Probable Construction Cost
Monroe Street at Sulphur Draw Park

Ranking:	**16**
Key Element	**13**

Item	Description	Unit Price	Unit	Solution 16-13-1 Quantity	Solution 16-13-1 Price	Solution 16-13-2 Quantity	Solution 16-13-2 Price
1	Mobilization (5%)	varies	LS	1	$6,863	1	$15,295
2	Clear and Grub	$3,000	AC	5	$15,000	5	$15,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	700	$11,200	500	$8,000
6	Remove/Replace Asphalt w/ subgrade	$45	SY	800	$36,000	600	$27,000
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	100	$1,500	100	$1,500
8	Remove/Replace Driveway 6", 3000psi	$35	SY	100	$3,500	50	$1,750
9	36" CMP Storm Drain	$87	LF	650	$56,550	450	$39,150
10	Gabion Channel Walls; 1-3 foot Deep	$100	LF	0	$0	2000	$200,000
11	20' Curb Inlet	$4,000	EA	2	$8,000	2	$8,000
12	Grass Sod/Seed	$2	SY	1000	$2,000	1000	$2,000
	Subtotal				**$144,200**		**$321,200**
	Contingency	**15%**			**$21,700**		**$48,200**
	Utilities Conflicts	**15%**			**$21,700**		**$48,200**
	Engineering/Survey	**12%**			**$17,400**		**$38,600**
	Total				**$205,000**		**$456,200**

Table B-17
Conceptual Opinion of Probable Construction Cost
Coke Street at East Angelo Draw

Ranking:	**17**
Key Element	**52**

Item	Description	Unit Price	Unit	Solution 17-52-2 Quantity	Price
1	Mobilization (5%)	varies	LS	1	$50,650
2	Clear and Grub	$3,000	AC	3	$9,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Excavation Including Removal	$16	CY	36,200	$579,200
6	Remove/Replace Asphalt w/ subgrade	$45	SY	500	$22,500
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	200	$3,000
8	Gabion Channel Walls; 1-3 foot Deep	$100	LF	3200	$320,000
9	9' x 9' Direct Drive Box Culvert	$305	LF	160	$48,800
10	Culvert Outlet Structure	$3,500	EA	2	$7,000
11	Grass Sod/Seed	$2	SY	10,000	$20,000

Subtotal		**$1,063,700**
Contingency	**15%**	**$159,600**
Utilities Conflicts	**15%**	**$159,600**
Engineering/Survey	**12%**	**$127,700**
Total		**$1,510,600**

Table B-18
Conceptual Opinion of Probable Construction Cost
Loop 306 Access Road at Eckerd's

Ranking:	**18**
Key Element	**30**

Item	Description	Unit Price	Unit	Solution 18-30-1 Quantity	Solution 18-30-1 Price	Solution 18-30-2 Quantity	Solution 18-30-2 Price
1	Mobilization (5%)	varies	LS	1	$90,984	1	$56,610
2	Clear and Grub	$3,000	AC	6	$18,000	2	$6,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	12,000	$192,000	11,400	$182,400
6	Remove/Replace Asphalt w/ subgrade	$45	SY	6,500	$292,500	300	$13,500
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	200	$3,000	200	$3,000
8	Gabion Channel Lining	$150	CY	720	$108,000	0	$0
9	72" CMP Storm Drain	$216	LF	0	$0	800	$172,800
10	78" CMP Storm Drain	$232	LF	0	$0	2,000	$464,000
11	84" CMP Storm Drain	$250	LF	1,470	$367,500	1,050	$262,500
12	90" CMP Storm Drain	$269	LF	1,970	$529,930	0	$0
13	108" CMP Storm Drain	$332	LF	820	$272,240	0	$0
14	10' Curb Inlet	$2,000	EA	10	$20,000	6	$12,000
15	Culvert Outlet Structure	$3,500	EA	2	$7,000	1	$3,500
16	Grass Sod/Seed	$2	SY	3,000	$6,000	4,500	$9,000
	Subtotal				**$1,910,700**		**$1,188,900**
	Contingency	**15%**			**$286,700**		**$178,400**
	Utilities Conflicts	**15%**			**$286,700**		**$178,400**
	Engineering/Survey	**12%**			**$229,300**		**$142,700**
	Total				**$2,713,400**		**$1,688,400**

Table B-19
Conceptual Opinion of Probable Construction Cost
Lester Lane at Tres Rios Drive

Ranking:	**19**
Key Element	**18**

Item	Description	Unit Price	Unit	Solution 19-18-1 Quantity	Price
1	Mobilization (5%)	varies	LS	1	$3,490
2	Clear and Grub	$3,000	AC	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Excavation Including Removal	$16	CY	1000	$16,000
6	5' x 3' Direct Drive Box Culvert	$115	LF	200	$23,000
7	Culvert Outlet Structure	$3,500	EA	1	$3,500
8	Gabion Channel Walls; 1-3 foot Deep	$100	LF	200	$20,000
9	Grass Sod/Seed	$2	SY	400	$800

Subtotal		**$73,300**
Contingency	**15%**	**$11,000**
Utilities Conflicts	**15%**	**$11,000**
Engineering/Survey	**12%**	**$8,800**
Total		**$104,100**

Table B-20
Conceptual Opinion of Probable Construction Cost
Goodfellow Draw at Paint Rock Road

Ranking:	**20**
Key Element	**20**

Item	Description	Unit Price	Unit	Solution 20-20-1 Quantity	Solution 20-20-1 Price	Solution 20-20-2 Quantity	Solution 20-20-2 Price
1	Mobilization (5%)	varies	LS	1	$32,724	1	$58,804
2	Clear and Grub	$3,000	AC	1	$3,000	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	1,900	$30,400	7,100	$113,600
6	Remove/Replace Asphalt w/ subgrade	$45	SY	1,700	$76,500	1,900	$85,500
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	1,000	$15,000	1,200	$18,000
8	Remove/Replace Driveway 6", 3000psi	$35	SY	200	$7,000	400	$14,000
9	10' x 5' Direct Drive Box Culvert	$296	LF	380	$112,480	0	$0
10	11' x 5' Direct Drive Box Culvert	$361	LF	0	$0	475	$171,475
11	Culvert Outlet Structure	$3,500	EA	4	$14,000	4	$14,000
12	Gabion Channel Lining	$150	CY	2,600	$390,000	5,000	$750,000
13	Grass Sod/Seed	$2	SY	1,300	$2,600	1,500	$3,000
	Subtotal				**$687,300**		**$1,234,900**
	Contingency	**15%**			**$103,100**		**$185,300**
	Utilities Conflicts	**15%**			**$103,100**		**$185,300**
	Engineering/Survey	**12%**			**$82,500**		**$148,200**
	Total				**$976,000**		**$1,753,700**

Table B-21
Conceptual Opinion of Probable Construction Cost
24th Street at Blum Street

Ranking:	21
Key Element	46

Item	Description	Unit Price	Unit	Solution 21-46-1 Quantity	Solution 21-46-1 Price
1	Mobilization (5%)	varies	LS	1	$93,125
2	Clear and Grub	$3,000	AC	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000
4	Barricading	$2,500	LS	1	$2,500
5	Remove/Replace Asphalt w/ subgrade	$45	SY	36,000	$1,620,000
6	Remove/Replace 6" curb w/ 18" gutter	$15	LF	10,800	$162,000
7	Remove/Replace Driveway 6", 3000psi	$35	SY	2,000	$70,000
8	Grass Sod/Seed	$2	SY	2,000	$4,000

Subtotal		**$1,955,700**
Contingency	**15%**	**$293,400**
Utilities Conflicts	**15%**	**$293,400**
Engineering/Survey	**12%**	**$234,700**
Total		**$2,777,200**

Table B-22
Conceptual Opinion of Probable Construction Cost
Bradford Street at 24th Street

Ranking:	22
Key Element	47

Item	Description	Unit Price	Unit	Solution 22-47-1 Quantity	Solution 22-47-1 Price	Solution 22-47-2 Quantity	Solution 22-47-2 Price
1	Mobilization (5%)	varies	LS	1	$8,685	1	$17,085
2	Clear and Grub	$3,000	AC	1	$3,000	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	1,500	$24,000	2,000	$32,000
6	Remove/Replace 6" curb w/ 18" gutter	$15	LF	200	$3,000	200	$3,000
7	Remove/Replace Driveway 6", 3000psi	$35	SY	150	$5,250	150	$5,250
8	6' x 3' Direct Drive Box Culvert	$140	LF	800	$112,000	0	$0
9	7' x 4' Direct Drive Box Culvert	$340	LF	0	$0	800	$272,000
10	36" CMP Storm Drain	$87	LF	120	$10,440	120	$10,440
11	10' Curb Inlet	$2,000	EA	4	$8,000	4	$8,000
12	Culvert Outlet Structure	$3,500	EA	1	$3,500	1	$3,500
13	Grass Sod/Seed	$2	SY	500	$1,000	500	$1,000

Subtotal		**$182,400**	**$358,800**
Contingency	**15%**	**$27,400**	**$53,900**
Utilities Conflicts	**15%**	**$27,400**	**$53,900**
Engineering/Survey	**12%**	**$21,900**	**$43,100**
Total		**$259,100**	**$509,700**

Table B-23
Conceptual Opinion of Probable Construction Cost
Glenwood Drive (Harrison to Greenwood)

Ranking:	**23**
Key Element	**3**

Item	Description	Unit Price	Unit	Solution 23-3-1 Quantity	Solution 23-3-1 Price	Solution 23-3-2 Quantity	Solution 23-3-2 Price
1	Mobilization (5%)	varies	LS	1	$25,073	1	$25,073
2	Clear and Grub	$3,000	AC	1	$3,000	1	$3,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Remove/Replace Asphalt w/ subgrade	$45	SY	10,400	$468,000	10,400	$468,000
6	Remove/Replace 6" curb w/ 18" gutter	$15	LF	1,550	$23,250	1,550	$23,250
7	Culvert Outlet Structure	$3,500	EA	1	$3,500	1	$3,500
8	Grass Sod/Seed	$2	SY	100	$200	100	$200
	Subtotal				**$526,600**		**$526,600**
	Contingency	**15%**			**$79,000**		**$79,000**
	Utilities Conflicts	**15%**			**$79,000**		**$79,000**
	Engineering/Survey	**12%**			**$63,200**		**$63,200**
	Total				**$747,800**		**$747,800**

Table B-24
Conceptual Opinion of Probable Construction Cost
Howard Street at Brentwood Park

Ranking:	24
Key Element	5

Item	Description	Unit Price	Unit	Solution 24-5-1 Quantity	Solution 24-5-1 Price	Solution 24-5-2 Quantity	Solution 24-5-2 Price	Solution 24-5-3 Quantity	Solution 24-5-3 Price
1	Mobilization (5%)	varies	LS	1	$1,228	1	$1,458	1	$48,788
2	Clear and Grub	$3,000	AC	1	$3,000	1	$3,000	1	$3,000
3	Construction Staking/Surve	$1,000	LS	1	$1,000	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500	1	$2,500
5	Excavation Including Remo	$16	CY	125	$2,000	150	$2,400	0	$0
6	Bridge - 2 Lanes	$1,600	LF	0	$0	0	$0	600	$960,000
7	7' x 6' Direct Drive Box Cul	$207	LF	50	$10,350	0	$0	0	$0
8	9' x 8' Direct Drive Box Cul	$291	LF	0	$0	50	$14,550	0	$0
9	5' Grate Inlet	$2,000	EA	1	$2,000	1	$2,000	0	$0
10	Fill for Road	$15	CY	0	$0	0	$0	150	$2,250
11	Culvert Outlet Structure	$3,500	EA	1	$3,500	1	$3,500	2	$7,000
12	Grass Sod/Seed	$2	SY	100	$200	100	$200	0	$0
	Subtotal				**$25,800**		**$30,700**		#########
	Contingency	**15%**			**$3,900**		**$4,700**		**$153,700**
	Utilities Conflicts	**15%**			**$3,900**		**$4,700**		**$153,700**
	Engineering/Survey	**12%**			**$3,100**		**$3,700**		**$123,000**
	Total				**$36,700**		**$43,800**		#########

Table B-25
Conceptual Opinion of Probable Construction Cost
Madison Street (Avenue J to Algerita)

Ranking:	**25**
Key Element	**12**

Item	Description	Unit Price	Unit	Solution 25-12-1 Quantity	Solution 25-12-1 Price	Solution 25-12-2 Quantity	Solution 25-12-2 Price
1	Mobilization (5%)	varies	LS	1	$10,388	1	$5,755
2	Clear and Grub	$3,000	AC	2	$6,000	2	$6,000
3	Construction Staking/Survey	$1,000	LS	1	$1,000	1	$1,000
4	Barricading	$2,500	LS	1	$2,500	1	$2,500
5	Excavation Including Removal	$16	CY	1,200	$19,200	300	$4,800
6	Remove/Replace Asphalt w/ subgrade	$45	SY	1,200	$54,000	1,200	$54,000
7	Remove/Replace 6" curb w/ 18" gutter	$15	LF	150	$2,250	200	$3,000
8	Remove/Replace Driveway 6", 3000psi	$35	SY	100	$3,500	100	$3,500
9	48" CMP Storm Drain	$112	LF	900	$100,800	0	$0
10	9' x 9' Direct Drive Box Culvert	$305	LF	0	$0	60	$18,300
11	Junction Box / Manholes	$3,000	EA	1	$3,000	1	$3,000
12	Culvert Outlet Structure	$3,500	EA	1	$3,500	2	$7,000
13	25' Curb Inlet	$5,000	EA	2	$10,000	2	$10,000
14	Grass Sod/Seed	$2	SY	1,000	$2,000	1,000	$2,000
	Subtotal				**$218,200**		**$120,900**
	Contingency	**15%**			**$32,800**		**$18,200**
	Utilities Conflicts	**15%**			**$32,800**		**$18,200**
	Engineering/Survey	**12%**			**$26,200**		**$14,600**
	Total				**$310,000**		**$171,900**

Appendix C

Draft Stormwater Ordinance

Appendix D

Drainage Design Manual (separate volume)

Appendix E

Drainage Maintenance Manual (separate volume)

City of San Angelo Stormwater Ordinance

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SECTION 12.401 GENERAL PROVISIONS

A. Statutory Authorization

The Legislature of the State of Texas has delegated the responsibility to local governments to adopt regulations designed to minimize flood losses and manage the floodplains in areas under their jurisdiction. Therefore, the City Council of the City of San Angelo, Texas, does ordain as follows:

B. Findings of Fact

1. The drainage ways, creeks and flood hazard areas of the City of San Angelo, Texas, are subject to periodic inundation which may result in the loss of life and property, health and safety hazards, disruption of commerce and governmental services and extraordinary public expenditures for flood protection and relief, all of which adversely affect the public health, safety and general welfare.

2. These flood losses could be created by the cumulative effect of obstructions in floodplains that increase flood heights and velocities and by placing structures and other improvements vulnerable to floods in flood hazard areas.

3. Watersheds within the City's jurisdiction are undergoing development or are facing development pressure, which, if not properly regulated, can adversely impact stormwater flows.

4. Watersheds within the City's jurisdiction, and especially those with abrupt topography, sparse vegetation, and thin and easily disturbed soil, are vulnerable to degradation resulting from development activities.

5. Streams and floodplain areas in the City of San Angelo are valuable resources to the citizens of San Angelo in that they provide recreational opportunities, improve the aesthetics of the community, convey stormwater runoff and filter out water quality pollutants.

C. Statement of Purpose

Stormwater management policies shall govern the planning, design, construction, operation and maintenance of storm drainage and erosion control facilities within the City of San Angelo. This Ordinance sets forth the minimum requirements necessary to provide and maintain a safe, efficient and effective drainage system within the City of San Angelo and to establish the various public and private responsibilities for the provision thereof. Further, it is the purpose of this Ordinance to:

1. Protect human life, health and property;

2. Minimize the expenditure of public money for building and maintaining flood control and storm drainage projects and cleaning sediment out of storm drains, streets, sidewalks and watercourses;

3. Minimize damage due to drainage and erosion to public facilities and utilities, such as water and gas mains, electric service, telephone and sewer lines, streets, bridges and drainage ways;

4. Help maintain a stable tax base and preserve land values;

5. Insure that potential buyers are notified that property is in an area of special flood hazard;

6. Manage stormwater runoff, the sediment load in that runoff, from points and surfaces within subdivisions;

7. Establish a reasonable standard of design for development which prevents potential flood and erosion damage;

8. Reduce the pollutant loading to streams, ponds and other watercourses;

9. Minimize the need for rescue and relief efforts associated with flooding which are generally undertaken at the expense of the general public;

10. Minimize prolonged business interruptions.

D. Methods of Reducing Flood Loss

In order to accomplish its purposes, this Section uses the following methods:

1. Restrict or prohibit uses that are dangerous to health, safety or property in times of flood, or cause excessive increases in flood heights or velocities;

2. Require that uses vulnerable to floods, including facilities which serve such uses, be protected against flood damage at the time of initial construction ;

3. Control the alteration of natural floodplains, stream channels, and natural protective barriers, which are involved in the accommodation of flood waters;

4. Control filling, grading, dredging and other development which may increase flood damage;

5. Prevent or regulate the construction of flood barriers which will unnaturally divert flood waters or which may increase flood hazards to other lands.

E. Scope of Authority

Any person, firm, utility, corporation or business proposing to develop land or improve property within the jurisdiction of the City of San Angelo is subject to the provisions of this Ordinance. This Ordinance also applies to individual building structures, subdivisions, excavation and fill operations and similar activities.

F. Lands to Which This Ordinance Applies

This Ordinance shall apply to all areas of land within the incorporated limits and extraterritorial jurisdiction of the City of San Angelo, Texas. The erosion control provisions of this Section do not apply to land under active agricultural use. As soon as construction or modification to the lands under active agricultural use is proposed so that the use of land will change from agriculture to any other use, then the provisions of this Ordinance shall be applicable to the once-exempted land.

G. San Angelo Stormwater Manual

This Ordinance is designed to require an accompanying Stormwater Manual, which will describe in detail the technical procedures to be used to comply with the provisions contained in the Ordinance. The criteria specified in the San Angelo Stormwater Manual shall become part of the official stormwater management plan for streams, channels, NRCS Lakes and pipe drainage systems in the City of San Angelo. Although the intention of this manual is to establish uniform design practices, it neither replaces the need for engineering judgment nor precludes the use of information not presented. Other accepted engineering procedures may be used to conduct hydrologic and hydraulic studies if approved by the Public Works Director.

H. Basis for Establishing the Areas of Special Flood Hazard

The areas of special flood hazard, identified by the Federal Emergency Management Agency in a scientific and engineering report entitled "Flood Insurance Study, Tom Green County, Texas and Incorporated Areas", with the accompanying Flood Insurance Rate Maps dated March 2, 1994 and any revisions thereto, are hereby adopted by reference and declared to be a part of this Ordinance.

I. Abrogation and Greater Restrictions

This Ordinance is not intended to repeal, abrogate or impair any existing easements,

covenants or deed restrictions. However, where this Ordinance and another municipal ordinance, easement, covenant or deed restriction conflict or overlap, whichever ordinance imposes the more stringent restrictions shall prevail.

J. Interpretation

In the interpretation and application of this Ordinance, all provisions shall be:

(1) Considered as minimum requirements;

(2) Liberally construed in favor of the governing body; and

(3) Deemed neither to limit nor repeal any other powers granted under state or federal statutes.

K. Warning and Disclaimer of Liability

The degrees of flood, storm drainage, and erosion protection required by this Ordinance are considered reasonable for regulatory purposes and are based on scientific and engineering considerations. Larger floods can and will occur. Flood heights may be increased by manmade or natural causes. This Ordinance does not imply that land outside the areas of flood hazard or uses permitted within such areas will be free from flooding or flood damages. In addition, this Ordinance does not imply that erosion controls will survive inundation by runoff from storms greater than the design flood for erosion controls. This Ordinance shall not create liability on the part of the City of San Angelo, any officer or employee thereof for any flood damages that result from reliance on this Ordinance or any administrative decision lawfully made thereunder.

L. Severability

If any section, paragraph, clause, phrase, or provision of this Ordinance shall be judged invalid or held unconstitutional, the same shall not affect the validity of this Ordinance as a whole or any part or provision thereof, other than the part so decided to be invalid or unconstitutional; nor shall such unconstitutionality or invalidity have an effect on any other ordinances or provisions of ordinances of the City of San Angelo.

M. Regulatory Permits

It shall be the Developer's responsibility to secure all regulatory permits associated with development of drainage improvements. These include but are not limited to U.S. Corps of Engineer 404 Permits, Texas Natural Resource Conservation Commission Section 401 permits, Federal Emergency Management Agency floodplain revision permits, U.S.

Environmental Protection Agency National Pollutant Discharge Elimination System permits, and any City of San Angelo permits.

N. Variances

Request for variances and deviations from this Ordinance are to be submitted, and will be received and approved or disapproved in accordance with provisions of this Ordinance.

O. Maintenance

Public drainage improvements dedicated (in right-of-way or by fee simple dedication to the public) and accepted by the City may be, subject to funding or other considerations, maintained and operated by the City such that the drainage system can properly and safely convey the design storm discharge.

P. Compliance

No structure or land shall hereafter be located, altered, or have its use changed without full compliance with the terms of this ordinance and other applicable regulations.

SECTION 12.402 DEFINITIONS

Unless specifically defined below, words or phrases used in this Ordinance shall be interpreted to give them the meaning they have in common usage and to give this Ordinance its most reasonable application:

10-year storm event: Given fully developed watershed conditions, the flood having a ten percent chance of being equaled or exceeded in any given year. This is also the 10-year mean recurrence interval storm event based on fully developed watershed conditions.

100-year storm event: Given fully developed watershed conditions, the flood having a one percent chance of being equaled or exceeded in any given year. This is also the 100-year mean recurrence interval storm event based on fully developed watershed conditions, (see also "Base flood," and "Design flood").

Area of shallow flooding: A designated AO or AH zone on the Flood Insurance Rate Map (FIRM) with a one percent or greater annual chance of flooding to an average depth of one to three feet, where a clearly defined channel does not exist, and the path of flooding is unpredictable and indeterminate. Such flooding is characterized by ponding or sheet flow.

Area of special flood hazard: The land in the floodplain within a community subject to a one percent or greater chance of flooding in any given year. This area may be designated as Zone A on the Flood Hazard Boundary Map (FHBM). After detailed rate making has been completed in preparation for publication of the FIRM, Zone A usually is refined into Zones A, AE, AH, AO, A1-99, VO, VI-30, VE, or V.

Base flood: The flood having a one percent chance of being equaled or exceeded in any given year, based upon the FEMA guidelines and as shown in the current effective Flood Insurance Study, (FIS). This 100-year mean recurrence interval storm event is based on existing watershed conditions.

Base flood elevation: The water surface elevation resulting from the base flood.

Basement: Any area of the building having its lowest floor subgrade (below ground level) on all sides.

Best Management Practices (BMPs): A wide range of management procedures, schedules of activities, and prohibitions on practices which have been demonstrated to effectively control the quality and/or quantity of stormwater runoff and which are compatible with the planned land use.

City of San Angelo Jurisdiction: All land located within the corporate limits of the City if San Angelo or its extra-territorial jurisdiction.

Design flood: When in the context of floods, floodplains or flood hazards, the design flood is that level of flood upon which a structure impacted by that flood is designed to withstand. This is assumed to be the flood with a one percent chance of being equaled or exceeded in any given year, based upon fully developed watershed conditions, unless specifically stated otherwise.

Detention basin: A dry basin or depression constructed for the purpose of temporarily storing stormwater runoff and discharging all of that water over time at a rate reduced from the rate that would have otherwise occurred.

Development: Any manmade change to improved or unimproved real estate, including, but not limited to, adding buildings or other structures, mining, dredging, filling, grading, paving, excavation, drilling operations, grading, clearing or removing the vegetative cover.

Elevated building: Means a nonbasement building (i) built, in the case of a building in Zones AI-30, AE, A99, AO, AH, B, C, X, and D, to have the top of the elevated floor, or in the case of a building in Zones VI-30, VE, or V, to have the bottom of the lowest horizontal structure member of the elevated floor elevated above the ground level by means of pilings, columns (posts and piers), or shear walls parallel to the flow of the water and (ii) adequately anchored so as not to impair the structural integrity of the building during a flood of up to the magnitude of the base flood. In the case of Zones AI-30, AE, A, A99, AO, AH, B, C, X and D, "elevated building" also includes a building elevated by means of fill or solid foundation perimeter walls with openings sufficient to facilitate the unimpeded movement of flood waters. In the case of Zones VI-30, VE, or V, "elevated building" also includes a building otherwise meeting the definition of "elevated building", even though the lower area is enclosed by means of breakaway walls if the breakaway walls meet the standards of Section 60.3(e)(5) of the National Flood Insurance Program regulations.

Erosion: The wearing away of land by action of wind and water.

Existing construction: For the purposes of determining rates, structures for which the "start of construction" commenced before the effective date of the FIRM for the community, July 27, 1976. "Existing construction" may also be referred to as "existing structures."

Existing manufactured home park or subdivision: A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) was completed before the effective date, July 27, 1976, that floodplain management regulations were adopted by the community.

Expansion to an existing manufactured home park or subdivision: The preparation of additional sites by the construction of facilities for servicing lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) in an existing manufactured home park or subdivision beyond those that had been completed prior to the effective date, July 27, 1976, that floodplain management regulations were adopted by the community.

Federal Emergency Management Agency (FEMA): The federal agency which administers the National Flood Insurance Program.

Flood or flooding: A general and temporary condition of partial or complete inundation of normally dry land areas from either the overflow of inland waters and/or the unusual and rapid accumulation or runoff of surface waters from any source.

Flood Insurance Rate Map (FIRM): The official map on which the Federal Emergency Management Agency has delineated both the areas of special flood hazard and the risk premium zones applicable to the community.

Flood Insurance Study (FIS): The official report provided in which the Federal Emergency Management Agency has provided flood profiles, as well as the flood boundary/floodway map and the water surface elevation of the base flood.

Floodplain or flood-prone area: Any land area susceptible to being inundated by water.

Floodplain management: The operation of an overall program of corrective and preventive measures for reducing flood damage, including but not limited to emergency preparedness plans, flood control works, and floodplain management regulations.

Floodplain management regulations: Zoning ordinances, subdivision regulations, building codes, health regulations, special purpose ordinances (such as a floodplain ordinance, grading ordinance, and erosion control ordinance) and other applications of police power. The term describes such state or local regulations, in any combination thereof, which provide standards for the purpose of flood damage prevention and reduction.

Flood proofing: Any combination of structural and non-structural additions, changes or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures, and their contents.

Flood protection system: Those physical structural works which have been constructed specifically to modify flooding in order to reduce the extent of the areas within a community subject to a "special flood hazard" and the extent of the depths of associated flooding. Such a system typically includes dams, reservoirs, channels, levees or dikes.

Floodway (regulatory floodway): The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

Fully Developed Conditions: The level of development anticipated when all of the land within a watershed is developed to the maximum extent allowable, typically determined by comparing existing and projected land uses on vacant and nonconforming properties based upon existing zoning or the latest Land Use Plan, whichever is more intense.

Functionally dependent use: A use which cannot perform its intended purpose unless it is located or carried out in proximity to water.

Highest adjacent grade: The highest natural elevation of the ground surface prior to construction next to the proposed walls of a structure.

Historic structure: Any structure that is:

A. Listed individually in the National Register of Historic Places (a listing maintained by the Department of Interior) or preliminarily determined by the Secretary of Interior as meeting the requirements for individual listing on the National Register;

B. Certified or preliminarily determined by the secretary of the interior as contributing to the historical significance of a registered historic district or a district preliminarily determined by the Secretary to qualify as a registered historic district;

C. Individually listed on a state inventory of historic places in states with historic preservation programs which have been approved by the Secretary of Interior; or;

D. Individually listed on a local inventory of historic places in communities with historic preservation programs that have been certified either:

    A. By an approved state program as determined by the Secretary of the Interior or;

    B. Directly by the Secretary of the Interior in states without approved programs.

Lowest Floor: The lowest floor of the lowest enclosed area (including basement). An unfinished or flood resistant enclosure, usable solely for parking or vehicles, building access or storage in an area other than a basement area is not considered a building's lowest floor;

provided that such enclosure is not built so as to render the structure in violation of the applicable no-elevation design requirement of Section 60.3 of the National Flood Insurance Program regulations.

Manufactured home: A structure, transportable in one or more sections, which is built on a permanent chassis and is designed for use with or without a permanent foundation when connected to the required utilities. For floodplain management purposes, the term "manufactured home" also includes park trailers, travel trailers and other similar vehicles placed on a site for greater than 180 consecutive days. For insurance purposes, the term "manufactured home" does not include park trailers, travel trailers and other similar vehicles.

Manufactured home park or subdivision: A parcel or contiguous parcels of land divided into two or more manufactured home lots for rent or sale.

Mean sea level (M.S.L.): For the purposes of the National Flood Insurance Program, the National Geodetic Vertical Datum (NGVD) of 1929 or other datum to which base flood elevations shown on a community's flood insurance rate map are referenced.

New construction: Structures for which the "start of construction" commenced on or after July 27, 1976.

New manufactured home park or subdivision: A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of street, and either final site grading or the pouring of concrete pads) is to be completed on or after the effective date, July 27, 1976, that floodplain management regulations were adopted by the community.

Recreational Vehicle: A vehicle which is (1) built on a single chassis; (2) 400 square feet or less when measured at the largest horizontal projections; (3) designed to be self propelled or permanently towable by a light duty truck; and (4) designed primarily not for use as a permanent dwelling but as temporary living quarters for recreational, camping, travel, or seasonal use.

Regulatory floodway: The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the "base flood," as determined by the Federal Emergency Management Agency, without cumulatively increasing the water surface elevation more than a designated height. This floodway is used by FEMA to determine compliance with its regulations.

Standard Project Flood: A flood that has a magnitude of approximately one-half of the Probable Maximum Flood, as determined on a case-by-case basis using accepted engineering methods.

Start of construction: For a structure, "start of construction" includes substantial improvement and means the date the building permit was issued, provided the actual start of construction, repair, reconstruction, placement or other improvement was within 180 days of the permit date. The actual start means either the first placement of permanent construction of a structure on a site, such as the pouring of a slab or footings, the installation of piles, the construction of columns or any work beyond the stage of excavation or the placement of a manufactured home on a foundation. Permanent construction of a structure does not include land preparation, such as clearing, grading and filling; nor does it include the installation of streets and/or walkways; nor does it include excavation for a basement, footings, piers or foundations or the erection of temporary forms; nor does it include the installation on the property of accessory buildings, such as garages or sheds not occupied as dwelling units or not part of the main structure.

Stormwater Manual: The design manual used to establish standard principles and practices for the design and construction of storm drainage facilities within the City of San Angelo, Texas and within its extraterritorial jurisdiction.

Structure: A walled and roofed building, a manufactured home, a substation or a gas or liquid storage tank that is principally above ground. When used in the context of stormwater, the term means a drainage improvement, such as dams, levees, bridges, culverts, channels, headwalls, flumes, etc.

Substantial improvement: Means any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before "start of construction" of the improvement. This includes structures which have incurred "substantial damage", regardless of the actual repair work performed. The term does not, however, include either:

(1) Any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary conditions or

(2) any alteration of a "historic structure", provided that the alteration will not preclude the structure's continued designation as a "historic structure".

Variance: A grant of relief to a person from the requirements of this Ordinance when specific enforcement would result in unnecessary hardship. A variance, therefore, permits construction or development in a manner otherwise prohibited by this Ordinance. Variance requirements shall comply with Section 60.6 of the National Flood Insurance Program regulations.

Violation: The failure of a structure or other development to be fully compliant with this Ordinance. A structure or other development without the elevation certificate, other certifications, other evidence of compliance required in the National Flood Insurance Program regulations, or other evidence as required by the Public Works Director, is presumed to be in violation until such time as that documentation is provided.

Water surface elevation: The height, in relation to the National Geodetic Vertical Datum (NGVD) of 1929 (or other datum, where specified), of floods of various magnitudes and frequencies in the floodplains of riverine areas.

SECTION 12.403 ADMINISTRATION

A. Duties of City Officials

The Public Works Director, or his designated agent, is hereby appointed the floodplain administrator to administer and implement the provisions of this section and other appropriate sections of 44 CFR (National Flood Insurance Program Regulations) pertaining to floodplain management. The duties of the Public Works Director shall include, but not be limited to:

A. Review and approve or disapprove all Development Permits to determine that the permit requirements of this Ordinance have been met;

B. Maintaining for public inspection all records pertaining to the provisions of this Ordinance, including floodproofing certifications;

C. Notify, in riverine situations, adjacent communities and the Texas Natural Resource Conservation Commission prior to any alteration or relocation of a watercourse and submitting evidence of such notification to the Federal Emergency Management Agency;

D. Make interpretations, where needed, as to the exact location of the boundaries of the areas of special flood hazard (for example, where there appears to be a conflict between a mapped boundary and actual field conditions);

E. Inspect sites to determine compliance with the erosion control guidelines.

F. Review permit application to determine whether proposed building site, including the placement of manufactured homes will be reasonably safe from flooding;

G. Review permits for proposed development to see what permits have been obtained from those federal, state, or local governmental agencies (including Section 404 of the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C 1334) from which prior approval is required;

H. Assure that the flood carrying capacity within the altered or relocated portion of any watercourse is maintained;

I. When base flood elevation data has not been provided in accordance with Article 1, Section I of this Ordinance, the Public Works Director shall obtain, review and reasonably utilize any base flood elevation data and floodway

data available form a federal, state, or other source, in order to administer the provisions of this Ordinance.

J. When a regulatory floodway has not been designated, the Public Works Director must require that no new construction, substantial improvements, or other developments (including fill) shall be permitted within Zones A1-30 and AE on the community's FIRM, unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation on the base flood more than one foot at any point within the community.

K. Under provisions of 44 CFR Chapter 1, Section 65.12, of the National Flood Insurance Program regulations, the Public Works Director may approve certain development in Zones A1-30, AE, AH, on the community's FIRM which increases the water surface elevation of the base flood by more than one foot, provided that an application and approval for a conditional FIRM revision is made and received from FEMA.

B. Responsibilities of Property Owners

1. The owner or developer of a property to be developed shall be responsible for managing all storm drainage flowing through or abutting such property. This responsibility also includes drainage directed to that property by ultimate development as well as the drainage naturally flowing through the property by reason of topography. The owner, builder or developer of a property shall be responsible for any silt or soils from his property that are transported downstream from the property by drainage. It is the intent of this Ordinance that provisions be made for managing storm drainage and preventing erosion and sedimentation problems.

2. Where the improvement or construction of a storm drainage facility is required along a property line common to two or more owners, the owner hereafter proposing the development of the property shall be responsible for obtaining the necessary City permits, making the required improvements at the time of development and acquiring or dedicating the necessary rights-of-way or easements to accommodate the improvements. The initial developer may recover a portion of the cost from the adjacent developer in accordance with a Predetermined Facilities Agreement. Also, the cost of oversized drainage structures will be participated in by the City in accordance with Provisions of this Ordinance, or any subsequent amendment thereto.

3. Where an applicant proposes development or use of only a portion of the property, provisions for storm drainage and erosion control shall only be required in that portion of the property proposed for immediate development, except as construction or improvements of a drainage facility or erosion controls outside that designated portion of the property are deemed essential to the development of that designated portion.

4. The owner or developer of a property must insure that all necessary, local, state and federal permits have been obtained.

C. Plat Review and Approval Process

The City of San Angelo has several approval processes and permits in place which relate to stormwater drainage and floodplains. These processes and permits include but are not limited to:

1. Platting process: In accordance with the City's subdivision regulations, a construction plan and profile sheets for all public improvements, including drainage facilities, shall be submitted with the final plat. Requirements for preliminary and final plat submission are outlined in the Stormwater Manual of the City of San Angelo.

2. Dedication of Drainage Easement: Public drainage systems designed to convey the design storm runoff shall be contained within a drainage easement or a floodplain/floodway easement or property dedicated to the Public.

3. Platting of Property Along Drainage Channels: Platting along streams and drainage channels within the 100-year storm event floodplain, based on fully developed watershed conditions, will require compliance with one of the following conditions:

    a. Dedication of a floodplain easement.
    b. Dedication of a floodway easement if floodplain reclamation is approved.

4. Development Permit (flood-prone areas). All developers, owners or builders shall obtain a Development Permit before beginning any projects in floodplain areas, including but not limited to: constructing new buildings and infrastructure, filling land, altering waterways, substantially improving existing structures located in flood hazard areas or channelizing, impounding, realigning, deepening or other altering of a natural drainage way. Construction or renovation projects cannot begin until the City issues the

Development Permit, nor can Building Permits be issued before obtaining a Development Permit.

Approval or denial of a Development Permit by the Public Works Director shall be based on the provisions of this Ordinance and the following relevant factors:

1. The danger to life and property due to flooding or erosion damage;

2. The susceptibility of the proposed facility and its contents to flood damage and the effect of such damage on the individual owner;

3. The danger that materials may be swept onto other lands to the injury of others;

4. The compatibility of the proposed use with existing and anticipated development;

5. The safety of access to the property in times of flood for ordinary and emergency vehicles;

6. The cost of providing governmental services during and after flood conditions including maintenance and repair of streets and bridges, and public utilities and facilities such as sewer, gas, electrical, and water systems;

7. The expected heights, velocity, duration, rate of rise and sediment transportation of the flood waters and the effects of wave action, if applicable, expected at the site;

8. The necessity to the facility of a waterfront location, where applicable;

9. The availability of alternative location, not subject to flooding or erosion damage, for the proposed use;

10. The relationship of the proposed use to the comprehensive plan for that area.

D. Deviations from Permit Terms

Permits may be revoked by the Public Works Director if, upon periodic inspection, it is determined that the work is not progressing in accordance with specifications of the approved plan and permit, or if it is determined that erosion from a building or construction site is not being controlled in a satisfactory manner.

Field changes to drainage system plans can be made upon the approval of the Public Works Director. Record drawings of the drainage system shall be submitted to the Public Works Director at the completion of the project.

E. Plan Requirements

Application materials and plan requirements for drainage systems or floodplain alterations are listed below. All engineering plans for storm drainage and floodplain alteration projects shall be sealed by a professional engineer who is licensed in the State of Texas and experienced in civil engineering work. The total cost for preparing the engineering plans and implementing the plans shall be borne by the applicant:

1. Storm Drainage Plans

As part of the development process, storm drainage reports and plans shall be prepared. These reports and plans shall include drainage facilities for both off-site and on-site drainage, so that the proper transition between the two can be maintained. Criteria for on-site development shall also apply to off-site improvements. The construction of all improvements shall be in accordance with the current specifications and regulations adopted by the City of San Angelo. Storm drainage plans shall be prepared in accordance with the Stormwater Manual.

2. Application Materials for Development Permits

Owners or builders who are planning to renovate existing structures or construct new structures shall apply for a Building Permit. If it is determined during the permit review that the proposed project is located in a flood-prone area, then the Building Permit applicant shall also be required to apply for a Development Permit through the Public Works Director and submit for review copies of the appropriate materials listed below.

A. For projects involving an existing structure located in flood-prone areas:

1. Plan view to scale, showing existing and proposed locations, dimensions, lowest finished floor elevations (including basements) and extent or elevation of the base flood and the 100-year storm event; and

2. A cost estimate of the proposed improvements or a copy of the contract amount for making the improvements; and either

3. Plans, sealed by a licensed professional engineer in the State of Texas, of any floodproofing techniques and elevation in relation to mean sea level to which any nonresidential structure shall be floodproofed; or

4. A certificate from a licensed professional engineer or architect, stating that the floodproofing techniques used on nonresidential structures meet the requirements of this Ordinance.

B. For all subdivisions and new construction in floodplain areas:

1. An engineering report with the following recommended format, as applicable:

   a. Project description.

   b. Description of the hydrologic and hydraulic analyses used, including the method used to determine historic rainfall and stream data, soils reports used to determine erosive velocity values and discharges and water surface elevations for both the base flood and the 100-year storm event.

   c. Vicinity map.

   d. Table of values for existing and proposed water surface elevations and velocities.

   e. Documentation that the principle of equal conveyance has been achieved.

   f. Engineering calculations for existing and proposed conditions for both the base flood and 100-year storm event discharges.

2. Engineering drawings consisting of the following recommended elements, as applicable:

   a. Water surface profile, including channel flow line, existing and proposed water surface elevations and location and number designation of cross sections.

   b. Plans as specified in the Stormwater Manual for preliminary and final submittal.

SECTION 12.404 DRAINAGE STUDIES

A. General

It is the policy of the City of San Angelo to require a drainage study on industrial, commercial, or multiple lot residential developments to be developed in the City. If a Final Drainage Study was not completed on an area that was previously platted, a Final Drainage Study may be required at the time of permitting for improvements.

B. Preliminary Drainage Study

1. When Required: It is the policy of the City of San Angelo to discuss and conceptually resolve drainage issues of a development at the Preliminary Plat stage. The applicant shall submit a Preliminary Drainage Study with the submittal of any preliminary plat of a proposed development. A Preliminary Drainage Study may also be required by the City when reviewing the merits of a change in zoning, especially when the proposed use is more intense than the current land use. Approval of the preliminary plat or zoning change may be contingent on the acceptability of the solutions proposed by the Preliminary Drainage Study.

2. Qualification to Prepare the Study: The Preliminary Drainage Study shall be prepared by a Professional Engineer licensed in the State of Texas, experienced in Civil Engineering, and having a thorough knowledge of the study of drainage issues. The Preliminary Drainage Study shall be signed, sealed, and dated by the person preparing the study.

3. Requirements: The requirements for a Preliminary Drainage Study shall be established and periodically updated by the Public Works Director. These requirements are found in the Stormwater Manual.

4. Exemptions: The Public Works Director may waive the requirement of the Preliminary Drainage Study or may limit certain requirements where the Director determines that such requirements are not necessary for a proper review of the development.

C. Final Drainage Study

1. When Required: It is the policy of the City of San Angelo to resolve drainage issues of a development at the Final Plat stage. The applicant may be required to submit a Final Drainage Study with the submittal of the Final Plat, Plat Revision, Plat Showing, or construction permitting phase, if a Final Drainage Study has not been previously completed for the proposed

development or conditions have been modified. Approval of the above mentioned plats or construction may be contingent on the acceptability of the solutions proposed by the Final Drainage Study.

2. Qualification to Prepare the Study: The Final Drainage Study shall be prepared by a Professional Engineer licensed in the State of Texas, experienced in Civil Engineering, and having a thorough knowledge of the study of drainage issues. The Final Drainage Study shall be signed, sealed, and dated by the person preparing the study.

3. Requirements: The requirements for a Final Drainage Study shall be established and periodically updated by the Public Works Director. These requirements are found in the Stormwater Manual.

4. Exemptions: The Public Works Director may waive the requirement of the Final Drainage Study or may limit certain requirements where the Director determines that such requirements are not necessary for a proper review of the development.

SECTION 12.405 RUNOFF CALCULATIONS AND LIMITATIONS

A. General

The selection of an appropriate method for calculating runoff depends upon the size of drainage area contributing runoff at a most downstream point of a project. The Rational Method is acceptable for situations in which the drainage area is generally less than 200 acres. A unit hydrograph method is required for situations with larger drainage areas. These methods are described in the Stormwater Manual.

Runoff computations shall be based upon fully developed watershed conditions in accordance with the City's latest land use projections.

B. Limitation of Runoff

Calculations to verify downstream adequacy shall be performed to the nearest major receiving stream for each proposed development. Runoff from that development shall be limited as follows:

1. If the downstream analysis demonstrates that there is adequate capacity for the fully developed watershed conditions the developer may proceed with site discharge equivalent to the maximum developed for the site in the drainage analysis.

2. If the downstream analysis demonstrates only partially adequate capacity for fully developed watershed condition, the developer may:

    a. Improve downstream structures to handle the fully developed watershed conditions and proceed with site discharge equivalent to the maximum developed for the site in the drainage analysis;

    b. Improve downstream structures to handle the increased capacity for fully developed discharge of the site under development;

    c. Limit discharge increase form existing conditions to that of available capacity demonstrated downstream; or

    d. Limit discharge to existing conditions or less.

3. If downstream analysis demonstrates no additional capacity, the developer may:

    a. Improve downstream structures to capacities equivalent or greater than

the fully developed watershed condition and proceed with site discharge equivalent to or less than the maximum flow developed for the site in the drainage analysis;

b. Improve downstream structures to handle the increased capacity for fully developed discharge of the site under development; or

c. Limit discharge to existing conditions or less.

C. Drainage Improvements Required for Development

All developments shall provide for any new drainage facilities, the improvement of any existing drainage facilities, channel improvements or grading, driveway adjustments, culvert improvements or any other improvement, drainage facility, or work which is necessary to provide for the stormwater drainage needs of the development and the downstream areas impacted.

No proposed development shall be constructed which impedes or constricts runoff from an upstream watershed based on fully developed conditions.

It shall be the developer's responsibility to determine the type, sizes, grades and capacities of all downstream drainage systems that convey runoff from the proposed development. The developer shall verify that the capacities of these systems are not exceeded as a result of the proposed development, and if off-site improvements are required as a result of the proposed development, the developer shall be responsible for constructing the needed improvements.

If no Drainage Plan for a given watershed addressing downstream drainage systems has been prepared or the factors upon which a previous Drainage Plan was based have been substantially changed, as determined by the Public Works Director, the developer shall, at the developer's sole cost and expense, have a Drainage Plan prepared in accordance with the Stormwater Manual Criteria by a Licensed Professional Engineer to determine:

1. The necessary future capacities of the drainage systems to adequately convey the 100-year design flows from the watershed at full development,

2. The existing100-year flows and runoff coefficients within the watershed prior to the proposed development,

3. The 100-year flows and runoff coefficients generated by each undeveloped tract within the watershed at full development based on current zoning or proposed zoning,

4. The existing 100-year flows in excess of the existing system's capacities within the watershed, if any,

5. The various facilities and total cost of construction to provide downstream drainage systems with adequate capacities for the 100-year full development flows within the watershed,

6. The proportionate share attributable to development of each respective undeveloped tract within the watershed based upon the incremental increase in stormwater runoff from each undeveloped tract at full development compared to the total increase above the existing 100-year flows resulting from full development in the watershed. Portions of the watershed which lie outside the city limits of San Angelo shall be analyzed and accommodated as if fully developed.

7. In the event the Drainage Plan identifies that the existing downstream drainage systems are undersized for the fully developed 100-year flows, the developer shall be required to either:

    a. Restrict stormwater discharge to predevelopment flows.

    b. Provide for the design and construction of the downstream improvements necessary to accommodate the fully developed watershed condition.

    c. Restrict stormwater flows within the development and provide for the design and construction of improvements to accommodate a revised fully developed watershed condition which accounts for the restricted flows from the development.

    d. Provide for the design and construction of the downstream improvements to accommodate the fully developed discharge from the site and existing watershed conditions.

SECTION 12.406 DESIGN OF LOCAL DRAINAGE SYSTEMS

A. Design Storm Frequencies

The calculations of runoff quantities that must be accommodated in drainage facilities requires the selection of the design storm frequency. The design flood levels for various drainage structures are found in the Stormwater Manual.

B. Storm Drain Design Standards

Stormwater design standards are found in the Stormwater Manual. This includes but is not limited to street and alley capacity, placement of inlets and manholes, standard methods and formulas for calculation of flow and depth.

C. Lot to Lot Drainage

Existing drainage between developed lots will remain the responsibility of the affected property owners. Future developments are required to drain surface runoff from an individual lot to a public right-of-way or to a drainage system contained in a public drainage easement.

D. Drainage Easements for Enclosed Storm Sewers

All storm sewer conduits to be dedicated to the City of San Angelo shall be located in Right-Of-Way (R.O.W.) or in a drainage easement dedicated to the City of San Angelo at the time of final recording of a plat.

SECTION 12.407 SPECIAL DRAINAGE FACILITIES

A. Lakes and Dams

1. General

In the event that a property owner or developer desires to create or modify an existing pond or lake or desires to impound stormwater by filling or constructing an above ground dam, thereby creating a lake, pond, lagoon or basin as part of the development of that property, the criteria listed in the Stormwater Manual shall be met before City approval of the impoundment can be given. Ponds or lakes created by excavation of a channel area without erecting a dam above natural ground elevation or instream low water check dams are also subject to the criteria. The dam safety requirements of the State of Texas must also be met for the construction of dams, lakes and other impoundments.

2. Maintenance and Liability

a. The owner or developer shall retain their private ownership of the constructed lake, pond or lagoon or basin and shall assume full responsibility for the protection of the general public from any health or safety hazards related to the lake, pond or lagoon constructed.

b. The owner or developer shall assume full responsibility for the maintenance of the lake, pond or lagoon or basin constructed. The owner or developer shall keep the Public Works Director advised of the currently responsible agent for this maintenance.

B. Levees

In the event that developers or owners wish to build levees to protect an area from flooding, applicable FEMA guidelines, State of Texas dam safety guidelines and the criteria listed in the Stormwater Manual shall apply.

C. Detention and Retention Facilities

1. Detention/retention facilities to reduce runoff rates may be required due to inadequate storm drainage facilities or a change in land use resulting in a significant increase in runoff. Inadequate storm drainage facilities to be considered are downstream structures or other identifiable flood prone areas.

2. Detention/retention facilities shall be in compliance with all applicable design requirements of all Local, State or Federal ordinances, laws or regulations, including the regulations for dam safety of the Texas Natural Resource Conservation Commission.

3. Detention/retention pond design criteria is outlined in the Stormwater Manual.

D. Connections from Buildings to Storm Sewers

Drainage from areas such as roof tops should be allowed to flow overland before joining the storm drain system. Seepage into basements that is pumped to ground level, seepage from springs and runoff from roof drains on nonresidential buildings that would flow onto or across driveways, sidewalks or other areas commonly crossed by pedestrians or vehicles that create a public hazard or nuisance shall be tied directly to the nearest storm drain.

SECTION 12.408 FLOODPLAIN GUIDELINES

A. General Standards

In all areas of special flood hazards the following provisions are required for all new construction and substantial improvements:

1. All new construction or substantial improvements shall be designed (or modified) and adequately anchored to prevent flotation, collapse or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy;

2. All new construction or substantial improvements shall be constructed by methods and practices that minimize flood damage;

3. All new construction or substantial improvements shall be constructed with materials resistant to flood damage;

4. All new construction or substantial improvements shall be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding;

5. All new construction or substantial improvements shall be constructed with materials resistant to flood damage;

6. New and replacement sanitary sewage system shall be designed to minimize or eliminate infiltration of flood waters into the system and discharge from the systems into the flood waters; and,

7. On-site waste disposal systems shall be located to avoid impairment to them or contamination from them during flooding.

B Specific Standards

In all areas of special flood hazards, where base flood elevation data has been provided, the following provisions are required:

1. Residential Construction - new construction and substantial improvement of any residential structure shall have the lowest floor (including basement) elevated to a minimum of one foot (1') above the base flood elevation. A registered professional engineer, architect, or land surveyor shall submit a

certification to the flood plain administrator that the standard of this subsection is satisfied.

2. Nonresidential Construction - new construction and substantial improvements of any commercial, industrial, or other nonresidential structure shall either have the lowest floor (including basement) elevated to at a minimum of one foot (1') above the base flood level or, together with attendant utility and sanitary facilities, be designed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy. A registered professional engineer or architect shall develop and/or review structural design, specifications, and plans for the construction, and shall certify that the design and methods of construction are in accordance with accepted standards of practice as outlined in this subsection. A record of such certification which includes the specific elevation (in relation to mean sea level) to which such structures are floodproofed shall be maintained by the floodplain administrator.

3. Enclosures - new construction and substantial improvements, with fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a licensed professional engineer or architect or meet or exceed the following minimum criteria:

   a. A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided.

   b. The bottom of all openings shall be not higher than one foot above grade.

   c. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of floodwaters.

4. Manufactured Homes:

   a. Require that all manufactured homes to be placed within Zone A, shall be installed using methods and practices which minimize flood

damage. For the purpose of this requirement, manufactured homes must be elevated and anchored to resist flotation, collapse, or lateral movement. Methods of anchoring may include, but are not limited to, use of over-the-top or frame ties to ground anchors. This requirement is in addition to applicable state and local anchoring requirements for resisting wind forces.

b. Require that manufactured homes that are placed or substantially improved within Zones A1-30, AH, and AE on the community's FIRM on sites that are:

   i. outside of a manufactured home park or subdivision,

   ii. in a new manufactured home park or subdivision,

   iii. in an expansion to an existing manufactured home park or subdivision, or

   iv. in an existing manufactured home park or subdivision on which a manufactured home has incurred "substantial damage" as a result of a flood,

   v. be elevated on a permanent foundation such that the lowest floor of the manufactured home is elevated to one foot (1') above the base flood elevation and be securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement.

c. Require that manufactured homes to be placed or substantially improved on sites in an existing manufactured home park or subdivision within Zones A1-30, AH and AE on the community's FIRM that are not subject to provisions in this Ordinance be elevated so that either:

   i. the lowest floor of the manufactured home is at or above the base flood elevation, or

   ii. the manufactured home chassis is supported by reinforced piers or other foundation elements of at least equivalent strength that are no less than 36 inches in height above grade and be securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement.

5. Recreational Vehicles - Require that recreational vehicles placed on sites within Zones A1-30, AH, and AE on the community's FIRM either:

   a. be on the site for fewer than 180 consecutive days,

   b. be full licensed and ready for highway use, or

   c. meet the permit requirements of this Ordinance and the elevation and anchoring requirements for manufactured homes.

   A recreational vehicle is ready for highway use if it is on its wheels or jacking system, is attached to the site only by quick disconnect type utilities and security devices, and has no permanently attached additions.

C. Standards for Subdivision Proposals

1. All proposals for the development of subdivisions including manufactured home parks and subdivisions shall meet development permit requirements of this Ordinance.

2. Base flood elevation data shall be generated for subdivision proposals and other proposed development including manufactured home parks and subdivisions which are greater than 50 lots or 5 acres, whichever is lesser, if not otherwise provided pursuant to this Ordinance.

3. All subdivision proposals including manufactured home parks and subdivisions shall have adequate drainage provided to reduce exposure to flood hazards.

4. All subdivision proposals including manufactured home parks and subdivisions shall have public utilities and facilities such as sewer, gas, electrical and water systems located and constructed to minimize or eliminate flood damage.

D. Standards for Areas of Shallow Flooding (AO/AH Zones)

Located within the areas of special flood hazard are areas designated as shallow flooding. These areas have special flood hazard associated with base flood depths of 1 to 3 feet where a clearly defined channel does not exist and where the path of flooding is unpredictable and where velocity flow may be evident. Such flooding is characterized by ponding or sheet flow. The following provisions apply:

1. All new construction and substantial improvements of residential structures shall have the lowest floor (including basement) elevated above the highest adjacent grade at least as high as the depth number specified in feet on the community's FIRM (at least two feet if no depth number is specified).

2. All new construction and substantial improvements of nonresidential structures shall:

   a. have the lowest floor (including basement) elevated above the highest adjacent grade at least as high as the depth number specified in feet on the community's FIRM (at least two feet if no depth number is specified), or:

   b. together with attendant utility and sanitary facilities be designed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads of effects of buoyancy.

3. A registered professional engineer or architect shall submit a certification to the floodplain administrator that the standards of this section are satisfied.

4. Within Zones AH or AO adequate drainage paths around structures on slopes, to guide flood waters around and away from proposed structures, are required.

E. Floodways

Floodways - Located within areas of special flood hazard are areas designated as floodways. Since the floodway is an extremely hazardous area due to the velocity of flood waters which carry debris, potential projectiles and erosion potential, the following provisions shall apply:

1. Encroachments are prohibited, including fill, new construction, substantial improvements and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses preformed in accordance with standard engineering practice by a licenced professional engineer or architect that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge.

2. All new construction and substantial improvements shall comply with all applicable flood hazard reduction provisions of this Ordinance.

3. Under the provisions of 44 CFR Chapter 1, Section 65.12, of the National Flood Insurance Regulations, encroachments with in the adopted regulatory floodway that would result in an increase in base flood elevations may be permitted, provided that an application and approval for a conditional FIRM and floodway revision to FEMA is made and received.

F Verification of Floodplain Alterations

1. Certified Minimum Proposed Finished Floor Elevations

Prior to final acceptance by the city of utilities, street or other public construction for projects involving floodplain alterations or adjacent to defined floodplains, creeks, channels and drainage ways, a certified statement shall be prepared by a registered public surveyor or licensed professional engineer, showing that all lot elevations, as developed within the subject project, meet or exceed the required minimum finished floor elevations shown on the development permit. This certification shall be filed with the Public Works Director.

2. Certified Elevations of Constructed Finished Floor

In addition, at any time in the future when a Building Permit is desired for existing platted property which is subject to flooding or carries a specified or recorded minimum finished flood elevation, a registered public surveyor or a licensed professional engineer shall prepare a certified statement that sites are built to the design elevations. The certified survey data showing the property to be at or above the specified elevation shall be furnished to the Public Works Director for approval. A certificate of compliance with the provisions of this Ordinance, pertaining to specified finished floor elevations, shall be required.

3. Issuance of Building Permits

The applicants shall furnish, at their expense, to the Public Works Director the above certifications and any other certified engineering and surveying information requested by the Public Works Director to confirm that the required minimum floor and pad elevations have been achieved. Building permits will not be issued until:

a. A letter of map revision or amendment has been issued by FEMA; and/or

b. Lots and/or sites are certified by a registered public surveyor or a licensed professional engineer that they are elevated from the floodplain according to FEMA-approved revisions to the floodplain and the requirements of this Ordinance.

SECTION 12.409 EROSION CONTROL GUIDELINES

A. Lands to Which This Section Applies

Private property owners, developers or builders shall be accountable for any erosion of their property or construction site which results in measurable accumulation of sedimentation in dedicated streets, alleys, easements, any waterway or other private properties. Any accumulation or deposit of soil material beyond the limits of the property or in City streets, alleys, easements or drainage facilities in an amount sufficient to constitute a threat to public safety or require additional or interfere with normal maintenance procedures shall constitute a violation of this Ordinance. The only exceptions to this provision are lands under active agricultural use. As soon as construction or modification to the exempted land is to begin so that the use of the land will change from agriculture to any other use, then the land shall lose its exemption and become subject to the provisions of this section.

B. General Guidelines

1. Maximum use shall be made of vegetation to minimize soil loss.

2. Natural vegetation should be retained wherever possible.

3. Where inadequate natural vegetation exists, or where it becomes necessary to remove existing natural vegetation, temporary controls should be installed promptly to minimize soil loss and ensure that erosion and sedimentation does not occur.

4. Wherever possible during construction, Best Management Practices shall be used on hillsides to slow the drainage flow rate.

5. Best Management Practices should be implemented as soon as practical in the development process.

6. Waste or disposal areas and construction roads should be located and constructed in a manner that will minimize the amount of sediment entering streams.

7. When work areas or material sources are located adjacent to streams, such areas shall be separated from the stream by a dike or other barrier to keep sediment from entering the stream. Care shall be taken during the construction and removal of such barriers to minimize the sediment transport into the stream.

8. Should preventative measures fail to function effectively, the Responsible Party shall act immediately to bring the erosion and/or siltation under control by whatever means are necessary.

9. Erosion control devices shall be placed to trap any losses from stockpiled topsoil.

10. The selection and timing of the installation of Best Management Practices shall be based upon weather and seasonal conditions that could make certain controls not practicable.

11. Vegetation used for vegetative cover shall be suitable for local soil and weather conditions. Ground cover plants should comply with listings from the Texas Agricultural Extension Service for West Texas.

12. Runoff shall be diverted away from construction areas as much as possible.

13. Stripping of vegetation from project sites shall be phased so as to expose the minimum amount of area to soil erosion for the shortest possible period of time. Phasing shall also consider the varying requirements of an erosion control plan at different stages of construction.

C. Erosion Control Requirements

When land disturbing activities are conducted, the Responsible Party shall comply with all applicable local, state or federal ordinances, laws or regulations.

1. Federal Requirements: The Environmental Protection Agency (EPA) regulates stormwater discharges from construction sites. Prior to initiating any construction project, the federal requirements should be reviewed to determine the current requirements. To obtain coverage under the general permit for construction activities which disturb more than the threshold area limit, a Notice of Intent (NOI) must be prepared and submitted to the EPA. The NOI must include a Storm Water Pollution Prevention Plan (SWP3) prepared in accordance with the requirements of the general permit.

2. Application of Section: A Responsible Party engaging in land disturbing activity or any construction activities may be required to prepare an Erosion Control Plan and submit that Plan to the Public Works Director for approval. If a SWP3 has been prepared for a construction activity, it will serve as the Erosion Control Plan. This Section shall apply regardless of whether a Responsible Party is required to obtain a permit from the City in order to conduct such land disturbing or construction activity. The Responsible Party

shall also be held liable for violations of this Section committed by third parties engaging in activities related to the Responsible Party's site.

3. Erosion Control Plan Implementation and Compliance: Each Responsible Party shall implement and maintain the erosion control measures shown on its approved Erosion Control Plan in order to minimize the erosion and the transport of silt, earth, topsoil, etc., by water runoff or construction activities, beyond the limits of the Responsible Party's site onto City streets or alleys, drainage easements, drainage facilities, storm drains of other City property prior to beginning any land disturbing activity.

4. Off-Site Borrow, Spoil and Staging Areas: Where applicable, off-site borrow areas, spoil areas and construction staging areas shall be considered as part of the project site and shall be governed by this Section.

5. Related Land Areas: The erosion control requirements of this Section shall apply to all related land areas. Additionally, when land disturbing activity occurs on a project, all disturbed land areas related to the project shall have permanent erosion control in place before final occupancy of structures located thereon or final acceptance of the subdivision may be obtained. This Section applies whether or not a building permit is required.

D. Erosion Control Plans

In order to clearly identify erosion and sediment control measures to be installed and maintained throughout the duration of the project, a detailed Erosion Control Plan may be required to be prepared and submitted for approval to the Public Works Director. The Responsible Party shall install and maintain erosion control devices in accordance with the City approved Erosion Control Plan.

E. Erosion Control Security

In addition to the other requirements of this Section, when construction or land disturbing activities are conducted as part of a Residential Subdivision project, the following shall apply:

1. Erosion Control Deposit Account: Prior to recording of the final plat, the Developer shall submit an Erosion Control Plan for approval by the City and shall pay an erosion control deposit in the form of cash, letter of credit, performance bond or other security acceptable to the City in an amount as determined by the Public Works Director which would include the cost of installation and maintenance of the erosion control facilities.

2. Final Acceptance: Permanent erosion control devices and when applicable, temporary erosion control devices, as specified in the approved Erosion Control Plan shall be installed and maintained prior to final acceptance of a subdivision. The Developer for such subdivision shall continue to maintain all temporary erosion control devices until permanent erosion control has been established on all those lots for which a Building Permit has not been issued.

3. Transfer of Property by Developer. If the Developer sells all of the lots in a subdivision to one purchaser, that purchaser becomes the Responsible Party for the subdivision. As required by this Section, such purchaser shall post an erosion control deposit with the City.

4. City Inspection: The City shall inspect the erosion control devices located at a site for compliance with the approved Erosion Control Plan for that site.

5. Correction Time Period: The Developer shall have twenty-four (24) hours to bring his erosion control devices into compliance with the approved Erosion Control Plan for the site to which notice of noncompliance was issued. Correction shall include sediment clean-up, erosion control device repair, erosion control device maintenance and/or installation of additional erosion control devices to prevent re-occurrence of the violation. The twenty-four (24) hour cure period, may be extended for inclement weather or other factors at the discretion of the Public Works Director.

6. City Re-Inspection: At the end of twenty-four (24) hour correction period, the City may re-inspect the site. If, at the time of such re-inspection, the erosion control devices at the site have not been brought into compliance with the approved Erosion Control Plan, the City may issue a stop work order and issue a citation for each violation of this Section.

7. The balance of the Erosion Control Deposit shall be released to the depositor once permanent erosion control has been established.

SECTION 12.410 FUNDING OF IMPROVEMENTS

A. On-Site Drainage Improvements

The on-site drainage system improvements required by a proposed development shall be identified in the Preliminary Drainage Study and Final Drainage Study for that development, and located completely within the limits of the proposed development. The cost of any on-site drainage system improvements shall be financed entirely by the developer. If enlargement of the on-site drainage facility beyond the requirements of this Ordinance is determined to be beneficial to the City, the City shall fund the difference between the enlarged facility and the required on-site improvements.

B. Off-Site Drainage Improvements

1. Developer's Options: If the Preliminary Drainage Study or Final Drainage Study demonstrates that off-site drainage improvements are not required due to adequate downstream capacity for the fully developed watershed conditions, the developer may proceed with site discharge equivalent to or less than the maximum developed for the site in the Preliminary or Final Drainage Study. If however the Preliminary or Final Drainage Study identifies necessary off-site drainage system improvements due to only partially adequate downstream capacity for the fully developed conditions, the developer may:

    a. Improve downstream structures to handle the fully developed watershed condition and proceed with site discharge equivalent to or less than the maximum developed for the site in the Drainage Study, or

    b. Improve downstream structures to handle the flow of fully developed discharge of the site under development and the discharge for existing conditions on other areas in the watershed, or

    c. Limit the post-development discharge to pre-development discharge or less.

2. Payback Contracts: If the off-site drainage structures serve acreage within the watershed other than the proposed development, the developer may be eligible to receive a pro rata rebate from future developments utilizing such drainage structures which develop within seven years after completion of such structures. At the expiration of the seventh year, the developer will no longer be entitled to receive any reimbursement for the cost of construction of the drainage structures.

SECTION 12.411 Appeals, Variances, and Penalties

A. Appeal

Any person aggrieved by a decision of the Public Works Director may appeal from any order, requirement, decision or determination of the Public Works Director to the City Manager. The aggrieved person shall file an appeal in writing with the City Manager within seven (7) days from the date of the decision. If no resolution of the appeal can be reached with the City Manager within twenty-eight (28) days, the aggrieved person may appeal in writing to the City Council.

B. Variance

Deviations from the provisions of this Ordinance will not be permitted unless the following criteria are met: (1) it can be clearly shown by approved procedures that the deviation will not adversely affect conditions either upstream or downstream of the point of deviation, and (2) the owners directly affected by the deviation are in written agreement, and (3) the deviation is not in conflict with any other plans adopted by the City, the state or federal agencies. Requests for deviation shall be approved by the Public Works Director.

Variances concerning development permits may be issued for the reconstruction, rehabilitation or restoration of structures listed on the National Register of Historic Places or the state inventory of historic places, without regard to the procedures set forth in the remainder of this section provided the proposal work will not preclude the structure's continued designation as a historic structure. Variances for any type of permit or storm drainage facilities shall be issued only upon a determination that the variance is the minimum necessary to afford relief considering the flood hazard, drainage problems and soil loss. The variance may be issued only upon meeting the criteria listed below:

a. A showing of good and sufficient cause;

b. A determination that failure to grant the variance would result in exceptional hardship to the applicant; and

c. A determination that the granting of a variance will not result in increased flood heights, additional threats to public safety or extraordinary public expense, create nuisances, cause fraud on or victimization of the public or conflict with existing local, state, or federal laws or regulations.

Any applicant to whom a variance for building or renovating in a floodplain is granted shall be given written notice that the structure will be permitted to be built with a lowest floor elevation below the base flood elevation, and that the cost of flood insurance will be commensurate with the increased risk resulting from the reduced lowest floor elevation.

C. Penalty Clause

Any person, firm or corporation violating any of the provisions of this Ordinance may be deemed guilty of a misdemeanor and, upon conviction, may be punished by a penalty or fine. Each and every day such offense is continued shall constitute a new and separate offense. In addition, the violator shall pay all costs and expenses involved in the case. Nothing herein contained shall prevent the City of San Angelo from taking such other lawful action as is necessary to prevent or remedy any violation.

Any developer, owner or builder who fails to obtain a Development Permit before beginning the subject project is in violation of this Ordinance. No Building Permit, plat, site plan, Certificate of Occupancy or other use permit may be issued for any construction, reconstruction or development upon any land where such construction, reconstruction or development is not in conformity with the requirements of this Ordinance. It shall be an offense for a Responsible Party or a third party performing work on a project to violate any of the requirements of this Ordinance.