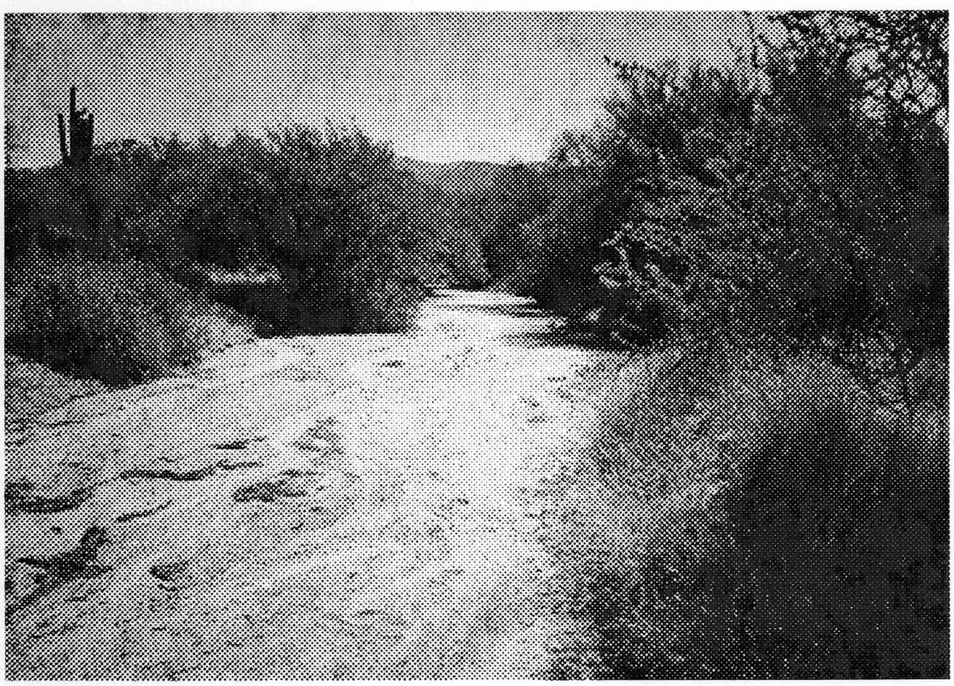
FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
PHOENIX, ARIZONA

RIO VERDE SOUTH FLOODPLAIN DELINEATION STUDY

FCD 93-07

TECHNICAL DATA NOTEBOOK
HYDROLOGY
Existing Condition

Book 1 of 2



Registered Professional Engineer (Civil)
CERTIFICATE NO.
23969
FRANK EDWARD
BROWN
Date Signed 1 AUG 95
ARIZONA, U.S.A.

McLaughlin Kmetty Engineers, Ltd.
In Association with George V. Sabol Consulting Engineers, Inc.
Phoenix, Arizona

AUGUST 1995

Registered Professional Engineer (Civil)
CERTIFICATE NO.
17928
GEORGE V.
SABOL
Date Signed 21 Aug 95
ARIZONA, U.S.A.

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PHOENIX, ARIZONA

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ADDENDUM

MKE

McLaughlin Kmetty Engineers, Ltd.

3501 North 16th Street Phoenix, Arizona 85016-6419 (602) 248-7702 Fax (602) 248-7851

MEMORANDUM

GEZA E. KMETTY
RONALD C. McLAUGHLIN
LEO M. EISEL

FRANK E. BROWN

ROBERT E. CONSONI
ROBERT J. STAVER

CHARLES L. JOY
RONALD E. HAUGHT

TO: Hasan Mushtaq
FROM: Frank Brown *Frank Brown*
DATE: December 19, 1996

SUBJECT: Rio Verde Area South
Contract No. FCD 93-07
MKE Job No. 89-407.003

Enclosed is a memorandum and 3.5 inch computer disk concerning revised hydrologic values within the Rio Verde South watershed. While preparing Table 3-1 of the Hydraulic Technical Data Notebook (TDN), we noticed some drainage areas summed by hand did not match those reported by the HEC-1 model. This issue was brought to the attention of the hydrology sub-consultant, George V. Sabol Consulting Engineers, and was resolved to everyone's satisfaction by adding a footnote to Table 3-1, and the Flood Control District submitted the project to FEMA for approval. Subsequently, George Sabol investigated the matter more thoroughly and discovered a basic logic error in the HEC-1 model. When we met to discuss this issue in February 1996 (at the Arizona Floodplain Management Association meeting in Wickenburg), Pedro Calza recommended we wait for FEMA review comments and proceed from there. At this point in time, FEMA has approved both the hydrology and the hydraulics.

The enclosed memorandum discusses the logic error in more detail, and provides a flow rate comparison table. In light of the enclosed memorandum, we recommend that anyone needing hydrology information within the study watershed replace the Hydrology TDN HEC-1 files with those on the enclosed disk.

We investigated the effect of the revised flowrate on the HEC-2 floodplain analysis and concluded that there is an insignificant change in floodplain and floodway elevations for regulatory purposes. Therefore, the floodplain and floodway values as found in the Hydraulic TDN remain valid. For the case of anyone doing major channel improvements or realignment that requires a new HEC-2 analysis, we recommend that the revised hydrologic values be used in any new HEC-2 models.

Please insert this material in the front portion of the Hydrology TDN and the Hydraulic TDN.

We hope that this memo and the enclosed memo from George V. Sabol Consulting Engineers clarify these issues for you. Please call me or George Sabol if you have any further questions.

Enclosures: HEC-1 disk and memorandum from GVSCE

G:\P\89407003\WP\RevHydro.Mem

George V. Sabol Consulting Engineers, Inc.

MEMORANDUM

TO: Frank Edward Brown, PE, MKE

FROM: George V. Sabol, PhD, PE, GVSCE

DATE: 1 November 1996

SUBJECT: Rio Verde (South) Floodplain Delineation Study

At your request, we have reviewed the HEC-1 models and results that were used to set the discharges for the delineation of floodplains for washes for the referenced project. That review resulted in detection of logic errors in the HEC-1 models. Those have been corrected and the HEC-1 models rerun. A diskette is provided containing the corrected HEC-1 models. Tables 1 and 2 summarize the results and provide a comparison of results from the original HEC-1 model that was used for delineation purposes. Table 1 is for the "with levee" condition. Table 2 is for concentration points that are affected under the "without levee" condition. Those tables contain a column that has a heading "Percent Difference." That value is the difference between the larger of either the 6-hour or 24-hour discharge for the original model and the larger of either the 6-hour or 24-hour discharge for the revised model. A (+) indicates that discharge increased and a (-) indicates a decrease. Notice that there are some instances where the design storm shifted from the 24-hour to the 6-hour storm.

The original HEC-1 model became suspect when it was noted that there were unusual contributing drainage areas being reported as output for a few concentration points. Upon inspection, the following error was detected. At C504 and C581 flow enters from the north study area (Wood/Patel model). Because of modeling difficulties with JD records and the use of Tape 21 files, the input hydrographs for C504 and C581 were written out and brought back several times. The flow diagram logic was in error. Instead of combining C512 and C519 at C520, C512 was combined with one of the Wood/Patel hydrographs (TEMP 2) sitting in the stack. The logic error was corrected.

The following is a summary of the discharge changes that have bearing on the floodplain delineations. For Wash 10, discharge at C540 decreased by 0.42% (Table 1), C542 decreased by 0.35% (Table 2), C543 increased by 3.70% (Table 2), and C545 at the confluence of Washes 10 and 11 increased by 6.82% (Table 2). For Wash 11, C546 increased by 6.89% (Table 2). For Wash 9, there are slight changes (±1%) for C566, C567, C568, C569 and C570 (Table 1). For Wash 9, the 24-hour storm produced the larger discharges in the original model, but this shifted to the 6-hour storm in the revised model.

There are some meaningful changes to the hydrology at certain locations within the watershed; for example, TEMP2 (Table 1). Those changes, although meaningful in regard to use of the HEC-1 model as a planning tool, resulted in only minor impact, as discussed, to the discharges for washes being delineated. Overall, the corrected and revised discharges for the washes that were delineated for this study changed somewhat from those that were used for the FEMA submittal. No meaningful difference in floodplain delineation would be expected because of these slight changes in hydrology.

Table 1

Comparison of Peak Discharges for the 100-year, 6-hour and 24-hour storms
with the Levee in place

HEC-1 ID	Revised Area Model Discharge, in cfs		Original Area Model Discharge, in cfs		Revised Area Model Control	Percent Difference
	6-hour	24-hour	6-hour	24-hour		
500A	421	280	421	280	6-hour controls	0.00
500B	325	227	325	227	6-hour controls	0.00
500C	248	160	248	160	6-hour controls	0.00
500D	371	250	371	250	6-hour controls	0.00
500E	219	137	219	137	6-hour controls	0.00
500F	647	442	647	442	6-hour controls	0.00
500G	349	228	349	228	6-hour controls	0.00
500H	340	226	340	226	6-hour controls	0.00
500I	644	430	644	430	6-hour controls	0.00
500J	204	124	204	124	6-hour controls	0.00
500K	219	144	219	144	6-hour controls	0.00
500L	292	190	292	190	6-hour controls	0.00
500M	228	142	228	142	6-hour controls	0.00
500N	228	138	228	138	6-hour controls	0.00
500O	182	120	182	120	6-hour controls	0.00
500P	201	125	201	125	6-hour controls	0.00
501A	111	63	111	63	6-hour controls	0.00
501B	151	89	151	89	6-hour controls	0.00
502A	113	69	113	69	6-hour controls	0.00
502B	139	86	139	86	6-hour controls	0.00
502C	100	63	100	63	6-hour controls	0.00
503A	458	292	458	292	6-hour controls	0.00
503B	171	115	171	115	6-hour controls	0.00
503C	278	176	278	176	6-hour controls	0.00
504A	428	290	428	290	6-hour controls	0.00
505A	341	237	341	237	6-hour controls	0.00
505B	378	228	378	228	6-hour controls	0.00
509A	674	498	674	498	6-hour controls	0.00
509B	638	479	638	479	6-hour controls	0.00
509C	279	193	279	193	6-hour controls	0.00
509D	453	324	453	324	6-hour controls	0.00
509E	340	241	340	241	6-hour controls	0.00
509F	367	257	367	257	6-hour controls	0.00
509G	196	134	196	134	6-hour controls	0.00
509H	109	72	109	72	6-hour controls	0.00
509I	61	36	61	36	6-hour controls	0.00
509J	161	106	161	106	6-hour controls	0.00
509K	60	36	60	36	6-hour controls	0.00
509L	209	125	209	125	6-hour controls	0.00
509M	150	101	150	101	6-hour controls	0.00
509N	250	151	250	151	6-hour controls	0.00
509O	100	59	100	59	6-hour controls	0.00
509P	325	193	325	193	6-hour controls	0.00
509Q	244	148	244	148	6-hour controls	0.00

Table 1

Comparison of Peak Discharges for the 100-year, 6-hour and 24-hour storms
with the Levee in place

HEC-1	Revised Area Model Discharge, in cfs		Original Area Model Discharge, in cfs		Revised Area Model	Percent
ID	6-hour	24-hour	6-hour	24-hour	Control	Difference
509R	245	147	245	147	6-hour controls	0.00
509S	431	273	431	273	6-hour controls	0.00
510A	994	806	994	806	6-hour controls	0.00
510B	518	374	518	374	6-hour controls	0.00
510C	850	675	850	675	6-hour controls	0.00
510D	126	75	126	75	6-hour controls	0.00
510E	282	195	282	195	6-hour controls	0.00
510F	207	134	207	134	6-hour controls	0.00
510G	316	208	316	208	6-hour controls	0.00
511A	941	704	941	704	6-hour controls	0.00
511B	948	792	948	792	6-hour controls	0.00
511C	878	747	878	747	6-hour controls	0.00
511D	195	140	195	140	6-hour controls	0.00
511E	579	430	579	430	6-hour controls	0.00
511F	340	225	340	225	6-hour controls	0.00
511G	961	768	961	768	6-hour controls	0.00
511H	458	312	458	312	6-hour controls	0.00
511I	382	236	382	236	6-hour controls	0.00
511J	238	136	238	136	6-hour controls	0.00
511K	1001	788	1001	788	6-hour controls	0.00
511L	336	221	336	221	6-hour controls	0.00
511M	182	116	182	116	6-hour controls	0.00
511N	132	85	132	85	6-hour controls	0.00
511O	78	49	78	49	6-hour controls	0.00
511P	493	353	493	353	6-hour controls	0.00
511Q	164	106	164	106	6-hour controls	0.00
B502L	299	239	299	239	6-hour controls	0.00
B508L	277	380	277	380	24-hour controls	0.00
B515L	166	223	166	223	24-hour controls	0.00
B531L	528	551	528	551	24-hour controls	0.00
B532AL	468	494	468	494	24-hour controls	0.00
B532R	877	921	877	921	24-hour controls	0.00
B534L	240	251	240	251	24-hour controls	0.00
B535R	896	941	896	941	24-hour controls	0.00
B537R	746	631	746	631	6-hour controls	0.00
B539R	158	113	158	113	6-hour controls	0.00
B553R	367	305	367	305	6-hour controls	0.00
B554R	261	227	261	227	6-hour controls	0.00
B557L	144	131	144	131	6-hour controls	0.00
B558R	263	223	263	223	6-hour controls	0.00
B559L	76	70	76	70	6-hour controls	0.00
B560L	40	39	40	39	6-hour controls	0.00
B573L	53	57	53	57	24-hour controls	0.00
B574R	211	223	211	223	24-hour controls	0.00

Table 1

Comparison of Peak Discharges for the 100-year, 6-hour and 24-hour storms with the Levee in place

HEC-1 ID	Revised Area Model Discharge, in cfs 6-hour	24-hour	Original Area Model Discharge, in cfs 6-hour	24-hour	Revised Area Model Control	Percent Difference
B578L	234	247	234	247	24-hour controls	0.00
BB519	512	606	BB519 is a new recorded		24-hour controls	
C502	491	406	491	406	6-hour controls	0.00
C503	395	297	395	297	6-hour controls	0.00
C504	162	193	162	193	24-hour controls	0.00
C506	265	277	265	277	24-hour controls	0.00
C507	279	346	279	346	24-hour controls	0.00
C508	528	682	528	682	24-hour controls	0.00
C509	371	249	371	249	6-hour controls	0.00
C510	311	365	466	365	24-hour controls	-21.67
C511	447	645	509	670	24-hour controls	-3.73
C512	517	727	579	754	24-hour controls	-3.58
C515	214	278	214	278	24-hour controls	0.00
C517	424	517	424	517	24-hour controls	0.00
C518	462	550	463	550	24-hour controls	0.00
C519	512	606	513	606	24-hour controls	0.00
C520	957	1264	818	1007	24-hour controls	25.52
C522	307	209	307	209	6-hour controls	0.00
C523	1099	1402	949	1108	24-hour controls	26.53
C526	1594	1472	1594	1472	6-hour controls	0.00
C527	1780	1709	1780	1709	6-hour controls	0.00
C528	2229	2257	2229	2257	24-hour controls	0.00
C529	2175	2211	2175	2211	24-hour controls	0.00
C530	2274	2387	2274	2387	24-hour controls	0.00
C531	2232	2337	2232	2337	24-hour controls	0.00
C533	757	791	757	791	24-hour controls	0.00
C534	800	839	800	839	24-hour controls	0.00
C535	1055	1107	1055	1107	24-hour controls	0.00
C536	703	743	703	743	24-hour controls	0.00
C538	863	913	895	930	24-hour controls	-1.83
C540	1277	1409	1288	1415	24-hour controls	-0.42
C541	208	220	208	220	24-hour controls	0.00
C542	1289	1425	1300	1430	24-hour controls	-0.35
C543	1429	1599	1323	1543	24-hour controls	3.63
C545	1876	2132	1592	1996	24-hour controls	6.81
C545L	695	735	695	735	24-hour controls	0.00
C545R	1440	1618	1336	1562	24-hour controls	3.59
C546	1961	2224	1666	2085	24-hour controls	6.67
C550	886	570	886	570	6-hour controls	0.00
C550L	717	456	717	456	6-hour controls	0.00
C553	779	649	779	649	6-hour controls	0.00
C554	410	347	410	347	6-hour controls	0.00
C555	394	387	394	387	6-hour controls	0.00
C556	618	528	618	528	6-hour controls	0.00

Table 1

Comparison of Peak Discharges for the 100-year, 6-hour and 24-hour storms with the Levee in place

HEC-1 ID	Revised Area Model Discharge, in cfs 6-hour	24-hour	Original Area Model Discharge, in cfs 6-hour	24-hour	Revised Area Model Control	Percent Difference
C557	755	722	755	722	6-hour controls	0.00
C558	612	531	612	531	6-hour controls	0.00
C559	192	178	192	178	6-hour controls	0.00
C560	127	121	127	121	6-hour controls	0.00
C561	128	122	128	122	6-hour controls	0.00
C562	199	190	199	189	6-hour controls	0.00
C564	347	209	347	209	6-hour controls	0.00
C565	657	635	657	637	6-hour controls	0.00
C566	759	744	762	746	6-hour controls	-0.39
C567	967	958	876	958	6-hour controls	0.94
C568	1007	1002	915	1005	6-hour controls	0.20
C569	1010	1006	920	1008	6-hour controls	0.20
C570	1134	1145	1044	1139	24-hour controls	0.53
C571	325	303	315	302	6-hour controls	3.17
C572	443	423	429	422	6-hour controls	3.26
C575	705	741	705	741	24-hour controls	0.00
C576	1068	1369	875	1063	24-hour controls	28.79
C577	908	812	908	812	6-hour controls	0.00
C579	807	845	807	845	24-hour controls	0.00
C580	518	536	518	536	24-hour controls	0.00
C581	208	267	208	267	24-hour controls	0.00
CLEAR	2767	3362	240	1772	24-hour controls	89.73
CLEAR	1332	1751	2387	3216	24-hour controls	-45.55
CLEAR	240	278	1358	278	24-hour controls	-79.53
D502L	299	239	299	239	6-hour controls	0.00
D502R	192	166	192	166	6-hour controls	0.00
D508L	277	380	277	380	24-hour controls	0.00
D508R	251	303	251	303	24-hour controls	0.00
D510L	126	148	190	148	24-hour controls	-22.11
D510R	185	216	276	217	24-hour controls	-21.74
D515L	166	223	166	223	24-hour controls	0.00
D515R	49	61	49	61	24-hour controls	0.00
D531L	528	551	528	551	24-hour controls	0.00
D531R	1694	1779	1694	1779	24-hour controls	0.00
D532AL	468	494	468	494	24-hour controls	0.00
D532AR	341	353	341	353	24-hour controls	0.00
D532L	810	848	810	848	24-hour controls	0.00
D532R	877	921	877	921	24-hour controls	0.00
D534L	240	251	240	251	24-hour controls	0.00
D534R	560	586	560	586	24-hour controls	0.00
D535L	158	166	158	166	24-hour controls	0.00
D535R	896	941	896	941	24-hour controls	0.00
D537L	248	175	248	175	6-hour controls	0.00
D537R	746	631	746	631	6-hour controls	0.00

Table 1

Comparison of Peak Discharges for the 100-year, 6-hour and 24-hour storms
with the Levee in place

HEC-1 ID	Revised Area Model Discharge, in cfs 6-hour	Revised Area Model Discharge, in cfs 24-hour	Original Area Model Discharge, in cfs 6-hour	Original Area Model Discharge, in cfs 24-hour	Revised Area Model Control	Percent Difference
D539L	295	211	295	211	6-hour controls	0.00
D539R	158	113	158	113	6-hour controls	0.00
D553L	411	344	411	344	6-hour controls	0.00
D553R	367	305	367	305	6-hour controls	0.00
D554L	149	120	149	120	6-hour controls	0.00
D554R	261	227	261	227	6-hour controls	0.00
D557L	144	131	144	131	6-hour controls	0.00
D557R	610	591	610	591	6-hour controls	0.00
D558L	348	308	348	308	6-hour controls	0.00
D558R	263	223	263	223	6-hour controls	0.00
D559L	76	70	76	70	6-hour controls	0.00
D559R	116	108	116	108	6-hour controls	0.00
D560L	40	39	40	39	6-hour controls	0.00
D560R	86	82	86	82	6-hour controls	0.00
D573L	53	57	53	57	24-hour controls	0.00
D573R	179	188	179	188	24-hour controls	0.00
D574L	685	717	685	717	24-hour controls	0.00
D574R	211	223	211	223	24-hour controls	0.00
D578L	234	247	234	247	24-hour controls	0.00
D578R	234	247	234	247	24-hour controls	0.00
TEMP1	371	249	371	249	6-hour controls	0.00
TEMP2	1300	365	466	365	6-hour controls	178.97
WP504	162	193	162	193	24-hour controls	0.00
WP581	208	267	208	267	24-hour controls	0.00
501502	365	240	365	240	6-hour controls	0.00
502503	294	233	294	233	6-hour controls	0.00
502506	189	164	189	164	6-hour controls	0.00
503508	356	271	356	271	6-hour controls	0.00
504509	155	181	155	181	24-hour controls	0.00
506507	264	275	264	275	24-hour controls	0.00
507508	273	324	273	324	24-hour controls	0.00
508511	271	357	271	357	24-hour controls	0.00
508517	249	291	249	291	24-hour controls	0.00
509510	361	236	361	236	6-hour controls	0.00
510511	184	215	272	215	24-hour controls	-20.96
511512	433	622	492	647	24-hour controls	-3.86
513512	201	130	201	130	6-hour controls	0.00
514518	199	121	199	121	6-hour controls	0.00
515517	159	204	159	204	24-hour controls	0.00
515575	49	57	49	57	24-hour controls	0.00
517518	422	511	423	511	24-hour controls	0.00
518519	454	542	455	542	24-hour controls	0.00
520576	955	1260	817	1004	24-hour controls	25.50
521522	175	114	175	114	6-hour controls	0.00

Table 1

Comparison of Peak Discharges for the 100-year, 6-hour and 24-hour storms
with the Levee in place

HEC-1 ID	Revised Area Model Discharge, in cfs		Original Area Model Discharge, in cfs		Revised Area Model Control	Percent Difference
	6-hour	24-hour	6-hour	24-hour		
524526	871	638	871	638	6-hour controls	0.00
525526	943	788	943	788	6-hour controls	0.00
526527	1562	1432	1562	1432	6-hour controls	0.00
527528	1764	1686	1764	1686	6-hour controls	0.00
528529	2180	2188	2180	2188	24-hour controls	0.00
530531	2238	2337	2238	2337	24-hour controls	0.00
531532	1687	1769	1687	1769	24-hour controls	0.00
531533	523	544	523	544	24-hour controls	0.00
532538	866	901	866	901	24-hour controls	0.00
532580	339	350	339	350	24-hour controls	0.00
533579	754	788	754	788	24-hour controls	0.00
534506	239	250	239	250	24-hour controls	0.00
534535	550	571	550	571	24-hour controls	0.00
535515	156	164	156	164	24-hour controls	0.00
536545	696	735	696	735	24-hour controls	0.00
537538	237	165	237	165	6-hour controls	0.00
537577	735	619	735	619	6-hour controls	0.00
538540	840	884	876	900	24-hour controls	-1.78
539555	152	108	152	108	6-hour controls	0.00
539577	292	208	292	208	6-hour controls	0.00
540542	1271	1402	1282	1407	24-hour controls	-0.36
541543	205	215	205	215	24-hour controls	0.00
542543	1283	1419	1294	1424	24-hour controls	-0.35
543545	1414	1585	1311	1530	24-hour controls	3.59
545546	1866	2116	1581	1982	24-hour controls	6.76
549550	445	283	445	283	6-hour controls	0.00
552553	626	458	626	458	6-hour controls	0.00
553554	408	339	408	339	6-hour controls	0.00
553556	365	301	365	301	6-hour controls	0.00
554555	148	119	148	119	6-hour controls	0.00
555557	392	371	392	371	6-hour controls	0.00
556558	613	521	613	521	6-hour controls	0.00
557559	143	129	143	129	6-hour controls	0.00
557565	606	583	606	584	6-hour controls	0.00
558557	347	307	347	307	6-hour controls	0.00
558571	260	219	260	219	6-hour controls	0.00
559560	115	107	115	107	6-hour controls	0.00
559561	76	69	76	69	6-hour controls	0.00
560561	40	39	40	39	6-hour controls	0.00
560566	85	80	85	80	6-hour controls	0.00
561562	128	121	128	121	6-hour controls	0.00
562567	198	188	198	188	6-hour controls	0.00
564570	326	195	326	195	6-hour controls	0.00
565566	655	634	655	635	6-hour controls	0.00

Table 1

Comparison of Peak Discharges for the 100-year, 6-hour and 24-hour storms with the Levee in place

HEC-1 ID	Revised Area Model Discharge, in cfs 6-hour	Revised Area Model Discharge, in cfs 24-hour	Original Area Model Discharge, in cfs 6-hour	Original Area Model Discharge, in cfs 24-hour	Revised Area Model Control	Percent Difference
566567	757	740	760	742	6-hour controls	-0.39
567568	966	951	875	955	6-hour controls	1.15
568569	1003	990	911	993	6-hour controls	1.01
569570	1008	1002	918	1001	6-hour controls	0.70
571572	321	294	311	294	6-hour controls	3.22
573580	179	186	179	186	24-hour controls	0.00
574541	208	220	208	220	24-hour controls	0.00
574575	680	710	680	710	24-hour controls	0.00
575536	702	737	702	737	24-hour controls	0.00
576523	1066	1367	874	1061	24-hour controls	28.84
577540	881	772	881	772	6-hour controls	0.00
578573	232	244	232	244	24-hour controls	0.00
579534	803	839	803	839	24-hour controls	0.00
580535	511	526	511	526	24-hour controls	0.00
581510	206	265	206	265	24-hour controls	0.00

Table 2

Comparison of Peak Discharges for the 100-year, 6-hour and 24-hour storms without the Levee in place

HEC-1	Revised Area Model Discharge, in cfs		Original Area Model Discharge, in cfs		Revised Area Model	Percent
ID	6-hour	24-hour	6-hour	24-hour	Control	Difference
510D	126	75	126	75	6-hour controls	0.00
510E	282	195	282	195	6-hour controls	0.00
510G	316	208	316	208	6-hour controls	0.00
511L	336	221	336	221	6-hour controls	0.00
511M	182	116	182	116	6-hour controls	0.00
511N	132	85	132	85	6-hour controls	0.00
511O	78	49	78	49	6-hour controls	0.00
511Q	164	106	164	106	6-hour controls	0.00
B535R	896	941	896	941	24-hour controls	0.00
B574R	211	223	211	223	24-hour controls	0.00
C515	214	278	214	278	24-hour controls	0.00
C535	1055	1107	1055	1107	24-hour controls	0.00
C536	272	319	272	319	24-hour controls	0.00
C541	208	220	208	220	24-hour controls	0.00
C542	1289	1425	1300	1430	24-hour controls	-0.35
C543	1756	1961	1615	1891	24-hour controls	3.70
C545	1899	2147	1611	2010	24-hour controls	6.82
C545L	294	331	294	331	24-hour controls	0.00
C545R	1765	1984	1634	1914	24-hour controls	3.66
C546	1986	2249	1688	2104	24-hour controls	6.89
C575	111	157	111	157	24-hour controls	0.00
C582	884	925	884	925	24-hour controls	0.00
D515L	166	223	166	223	24-hour controls	0.00
D515R	49	61	49	61	24-hour controls	0.00
D535L	158	166	158	166	24-hour controls	0.00
D535R	896	941	896	941	24-hour controls	0.00
D574L	685	717	685	717	24-hour controls	0.00
D574R	211	223	211	223	24-hour controls	0.00
515575	49	57	49	57	24-hour controls	0.00
535515	156	164	156	164	24-hour controls	0.00
536545	266	301	266	301	24-hour controls	0.00
541582	207	218	207	218	24-hour controls	0.00
542543	1283	1419	1294	1424	24-hour controls	-0.35
543545	1749	1946	1609	1876	24-hour controls	3.73
545546	1888	2136	1598	1996	24-hour controls	7.01
574541	208	220	208	220	24-hour controls	0.00
574582	681	711	681	711	24-hour controls	0.00
575536	109	148	109	148	24-hour controls	0.00
582543	879	917	879	917	24-hour controls	0.00

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LIST OF EXHIBITS

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Appendix **Description**

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BOOK 2 OF 2
LIST OF APPENDICES (continued)

Registered Professional Engineer (Civil)
CERTIFICATE NO.
23969
FRANK EDWARD
BROWN
Date Signed 21 AUG 95
ARIZONA, U.S.A.

Registered Professional Engineer (Civil)
CERTIFICATE NO.
17928
GEORGE V.
SABOL
Date Signed 21 Aug 95
ARIZONA, U.S.A.

PREFACE

The Rio Verde South Floodplain Delineation Study (Contract No. FCD 93-07) was performed for:

Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009
(602)506-1501 FAX (602)506-4601

Floodplain Management Branch
Branch Manager: Mr. Pedro Calza
Project Manager: Mr. Hasan Mushtaq

Watershed Management Branch
Branch Manager: Mr. Amir Motamedi
Project Manager: Ms. Sandy Story

By:
McLaughlin Kmetty Engineers, Ltd.
3501 N. 16th Street, Suite A
Phoenix, Arizona 85016
(602)248-7702
FAX (602)248-7851

Project Manager: Mr. Geza E. Kmetty, PE
Project Engineer: Mr. Frank Edward Brown, PE

and,

George V. Sabol Consulting Engineers, Inc.
7950 E. Acoma Dr, Suite 211
Scottsdale, Arizona 85260-6962
(602)483-3368
FAX (602)483-3990

Project Co-Manager: George V. Sabol, PhD, PE
Project Engineer: Mr. Thomas R. Loomis, PE, RLS

INTRODUCTION

The following report is a comprehensive document which contains the results and supporting computations for the hydrology portion of the Rio Verde (South) Floodplain Delineation Study located in Maricopa County, Arizona. Our sincere appreciation is extended to the following agencies for their help and perspective while studying this watershed:

- Arizona Department of Water Resources
- Flood Control District of Maricopa County
- Maricopa County Department of Transportation
- Maricopa County Parks and Recreation Department
- Rio Verde Homeowners Association
- US Soil Conservation Service

The purpose of this study is to provide estimates of peak discharges from the 100-year storm at key locations on the watershed. Those discharges are then used to estimate the horizontal limits of flooding in designated study reaches, and to define floodway limits. The study was ordered by the Flood Control District of Maricopa County (District). The hydraulics portion of this study is contained under separate cover. The hydrology portion of this study is done using the methodology contained in the Drainage Design Manual for Maricopa County, Arizona (Design Manual) [10], prepared by the Special Projects Branch, Hydrology Division, of the District. Hydrologic modeling is accomplished using the US Army Corps of Engineers (COE) HEC-1 computer program [8]. There are three existing floodplains in the study area which have been defined by approximate methods in previous studies by the Federal Emergency Management Agency (FEMA). The hydraulics portion of this study defines floodplains and floodways on the following washes:

FEMA Wash 9;

FEMA Wash 10; and

FEMA Wash 11.

Another wash (Wash 12) was added to the floodplain study during Phase II of the Hydraulic Modeling - please refer to the separate Hydraulic Report. The study limits for each previously studied wash are identified in Exhibit A.

Special problems which were encountered are flow splits caused by natural obstructions to flow. Other hydrology studies of record for the watershed are the studies done by land developers in the area.

The study watershed is approximately 17 square miles in area. Refer to Exhibit A. Rio Verde is a small community with a population of approximately 1,600 people during the winter and 300 during the summer. The community has only been in existence since the early 1970's, and because of the arid desert environment, has not experienced many significant rainfall events. Flooding consists of street flooding at wash crossings and the potential for flooding of homes situated near the major watercourses. Drainage channels in the urbanized areas are well defined and typically have significant hydraulic capacity. Existing flood protection measures consist of constructed drainage channels and swales through the golf course areas. The typical rainfall cycle consists of short duration, high intensity thunder storms during the summer months, and general storms of longer duration during the winter months. Refer to the hydraulics report for other Community information.

STUDY DOCUMENTATION ABSTRACT							
INITIAL STUDY		RESTUDY	X	LOMR		OTHER	

SECTION 1: GENERAL INFORMATION

1A	COMMUNITY	Rio Verde (unincorporated)
1B	COMMUNITY NUMBER	04013
1C	COUNTY	Maricopa
1D	STATE	Arizona
1E	DATE STUDY ACCEPTED	
1F	STUDY CONTRACTOR	McLaughlin Kmetty Engineers, Ltd.
	CONTACTS	Frank Edward Brown, PE Geza E. Kmetty, PE, RLS
	ADDRESS	3501 N. 16th Street Phoenix, Arizona 85016
	PHONE	(602)248-7702 (602)248-7851 (FAX)
	SUBCONSULTANTS	George V. Sabol Consulting Engineers, Inc.
1G	TECH. REVIEWER (FEMA)	
	PHONE	
1H	FEMA REGIONAL REVIEWER	
	PHONE	
1I	STATE REVIEWER	Arizona Department of Water Resources
	PHONE	(602) 542-1541
1J	LOCAL REVIEWER	Flood Control District of Maricopa County Catherine Regester Hasan Mushtaq Sandra Story Pedro Calza
	PHONE	(602) 506-1501
1K	RIVER OR STREAM NAME	Wash 9, Wash 10, Wash 11 & Wash 12
1L	REACH DESCRIPTION	Refer to Exhibit A
1M	STUDY TYPE	Floodplain/Floodway Delineations

STUDY DOCUMENTATION ABSTRACT (continued)

SECTION 2: MAPPING INFORMATION

2A	USGS QUAD SHEETS	Bartlett Dam
		McDowell Peak
		Wildcat Hill
		Fort McDowell
2B	MAPPING FOR HYDROLOGIC STUDY TYPE/SOURCE	2-foot contour interval in ACAD Format Burgess and Niple, Inc.
	SCALE	1 inch = 200 feet
	DATE	12-22-93
2C	MAPPING FOR HYDRAULIC STUDY TYPE/SOURCE	Same as 2B
	SCALE	1 inch = 200 feet
	DATE	12-22-93 and 8-22-94

SECTION 3: HYDROLOGY

3A	MODEL OR METHOD USED (Including vendor and version description)	HEC-1 version 4.0.1E dated May 1991 Dodson & Associates, Inc.
3B	STORM DURATION	6-hour, 24-hour
3C	HYETOGRAPH TYPE	In accordance with Design Manual
3D	FREQUENCIES DETERMINED	100-year
3E	LIST OF GAGES USED IN FREQUENCY ANALYSIS OR CALIBRATION (Location, Years of Record, Gage Ownership)	None available.
3F	RAINFALL AMOUNTS AND REFERENCE	100-year, 6-hour = 3.4 inches 100-year, 24-hour = 4.4 inches NOAA Atlas II
3G	UNIQUE CONDITIONS AND PROBLEMS	Flow Diversions
3H	COORDINATION OF Q'S (Agency, date, comments	

STUDY DOCUMENTATION ABSTRACT (continued)

SECTION 4: HYDRAULICS

4A	MODEL OR METHOD USED (including vendor and version description)	HEC-2 version 4.6.2 dated May 1991 Dodson & Associates, Inc.
4B	REGIME	Subcritical, with supercritical reaches
4C	FREQUENCIES FOR WHICH PROFILES WERE COMPUTED	100-year
4D	METHOD OF FLOODWAY CALCULATION	Method 1
4E	UNIQUE CONDITIONS AND PROBLEMS	island flow

SECTION 1: GENERAL DOCUMENTATION and CORRESPONDENCE

The entire contents of Study Documentation Section 1 are found in "Rio Verde South Floodplain Delineation Study, Technical Data Notebook, Hydraulics".

SECTION 2: MAPPING AND SURVEY INFORMATION

2.1 Description of Mapping

The mapping and survey data used for the hydrology portion of this project is described by exhibit drawing as follows:

Exhibit A - The base mapping used for Exhibit A consists of United States Geological Survey (USGS) 7.5 minute quadrangle maps. The maps were raster scanned and converted to a vector based AutoCAD format, and merged to form a single drawing. Only the area specific to this project was scanned. The original quadrangle maps are at a scale of 1 inch = 2000 feet. The Exhibit A base mapping is plotted at a scale of 1 inch = 1500 feet. The following are the USGS quadrangle maps used for this study:

Barlett Dam:	1964, 1962 photo date, 40-foot contour interval (CI), 20-foot supplementary CI (SCI). Orthophoto dated 1971.
McDowell Peak:	1965, 1962 photo date, 1982 photorevised, 10-foot CI. Orthophoto dated 1971.
Fort McDowell:	1964, 1962 photo date, 1974 photorevised, 1978 photoinspected, 20-foot CI, 10-foot SCI. Orthophoto dated 1971.
Wildcat Hill:	1965, 1962 photo date, 1981 photorevised, 20-foot CI. Orthophoto dated 1971.

Exhibit B - Exhibit B is the hydrology soils map. The SCS Soil Map Unit boundaries shown in this exhibit are derived from the soil maps contained in the *Soil Survey of Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona* (SCS Soil Survey) [21]. The soil survey maps are at a scale of 1 inch = 2000 feet. The boundaries were provided by the District in ARCInfo format. The boundaries are converted to AutoCAD and plotted at a scale of 1 inch = 1000 feet in combination with the subbasin boundaries. The street planimetrics are provided by the District in ARCInfo and are also converted to AutoCAD.

Exhibit C - Exhibit C is the hydrology land use map. This exhibit, plotted at a scale of 1 inch = 1000 feet, contains land use boundaries, subbasin and major basin boundaries, and street planimetrics. The land use boundaries were provided by the District in ARCInfo format and converted to AutoCAD. The landuse boundaries were checked against the aerial photographs and revised as necessary. Refer to Section 3.2.2.1 for a description of how similar zoning classifications are generalized into land use categories.

Exhibit D - Exhibit D is the hydrology subbasin, time of concentration, and flood routing map of the entire watershed, plotted at a scale of 1-inch=500 feet. The exhibit contains subbasin and major basin boundaries, time of concentration or lag flow paths and elevations, HEC-1 hydrograph flood routing flow paths and elevations, and subbasin concentration point locations. The exhibit is plotted on base topography from the USGS quadrangle maps described under Exhibit A.

Exhibit E - Exhibit E is the hydrology subbasin, time of concentration and flood routing map of the portion of the watershed which is developing most rapidly. This exhibit is plotted at a scale of 1 inch = 200 feet with a 2-foot contour interval. The exhibit shows the same information as Exhibit D, except in more detail. The exhibit covers approximately 5.3 square miles of the eastern end of the watershed.

The base mapping used for Exhibit E, hereinafter referred to as "200 Scale Mapping", is provided by the District. The 200 Scale Mapping covers the following areas:

T4N, R6E: Portions of Sections 1 and 2;

T4N, R7E: Section 6 and portions of Sections 5, 7 and 8;

T5N, R6E: Section 6 and portions of Sections 25 and 35; and

T5N, R7E: Section 31 and portions of Sections 29, 30 and 32.

The 200 Scale Mapping was prepared by Aerial Mapping company, Inc. (AMC) in 1994 under a subcontract with Burgess and Niple, Inc. who was under contract with the District for a flood insurance study of the Rio Verde North area. Horizontal and vertical control was done by Burgess and Niple, Inc. The aerial photography date was 22 December 1993, and the AMC project number is 93168. The coordinate grid and elevations are on the NAD 1983 state plane coordinate system and the NGVD 1929 vertical datum.

Reduced copies of Exhibits A through E are provided in Appendix H for convenience. Full size copies of the exhibits are provided in folders in this report.

SECTION 3: HYDROLOGIC ANALYSIS

3.1 Hydrologic Method Description

The watershed is modeled utilizing the methodology set forth in the *Hydrologic Design Manual for Maricopa County, Arizona* (Design Manual) [10], prepared by the Special Projects Branch, Hydrology Division, Flood Control District of Maricopa County, dated September 1990. That manual is specified for use in the Contract Scope of Work, which is contained under Section 1.5 of this report. The watershed is modeled for the 100-year, 6-hour and 24-hour duration storms for the existing condition. Two storm durations are used in order to determine which storm results in the higher magnitude of discharge at various locations on the watershed. The temporal rainfall distributions used are the SCS Type II for the 24-hour duration storm, and the rainfall patterns and distributions suggested in the Design Manual for the 6-hour duration storm. The Clark unit hydrograph is used for hydrograph development in the urban or urbanizing areas. The S-Graph method is used for undeveloped desert areas. Rainfall losses are estimated using the Green-Ampt infiltration equation with an estimate for surface retention loss. Hydrographs are routed through the watershed using normal depth Modified Puls routing. The watershed is modeled using the US Army Corps of Engineers (COE) HEC-1 Computer Program, version 4.0.1E, dated May 1991, as implemented by Dodson & Associates, Inc. [7].

The purpose in undertaking this study is to estimate peak discharges from the 100-year recurrence interval storm at designated locations on the watershed. In general, these locations are:

1. Wash confluences and street crossings mutually agreed upon between the District and George V. Sabol Consulting Engineers, Inc. (GVSCE);

2. Beginning and ending points of washes designated for floodplain delineation; and

3. Locations on the watershed where a significant flow split or diversion occurs.

The peak discharges are then used for the hydraulic analysis portion of this study for estimating floodplain and floodway limits for the washes designated for detailed study. All peak discharges estimated in this report are for the existing condition.

The study watershed in relationship to the State of Arizona is depicted on the Location Map, Figure 3-1. The study watershed in relationship to the City of Phoenix and Maricopa County is shown on the Vicinity Map, Figure 3-2.

3.2 Parameter Estimation

3.2.1 Drainage Area Boundaries

The study watershed is approximately 17 square miles in area. Refer to Exhibit A in Section 2.2 for the study watershed delineation. The study area is bounded on the north by the Rio Verde North Floodplain Delineation Study area (predominately defined by Rio Verde Drive), on the east by the Verde River, on the south by a ridge line progressing upstream from the south end of the existing Rio Verde community, and on the west by the McDowell Mountains.

The watershed contains significant washes which are designated for floodplain and floodway delineation. These are FEMA Wash 9, FEMA Wash 10 and FEMA Wash 11, plus Wash 12 added under Hydraulic Modeling Phase II.

All three washes are tributaries of the Verde River. FEMA Wash 9 and Wash 12 are isolated streams. FEMA Wash 10 is a tributary of FEMA Wash 11. FEMA Wash 10 joins FEMA Wash 11 approximately 0.76 miles upstream of the confluence with the Verde River. The watershed drains from west to east, from the McDowell Mountain divide east to the Verde River.

The watershed is a mix of undeveloped mountain and hillslope areas and urban development. The existing urban development consists of the community of Rio Verde located in Section 6, T4N, R7E. The community is made up of low, medium and high density residential development and golf course land uses. There is very little commercial land use and no industrial use. The adjacent community of Tonto Verde is located in Section 31, T5N, R7E. That community is currently being developed and is expected to be substantially completed by early summer of 1996. The Tonto Verde development is considered to be urban for the purposes of this study.

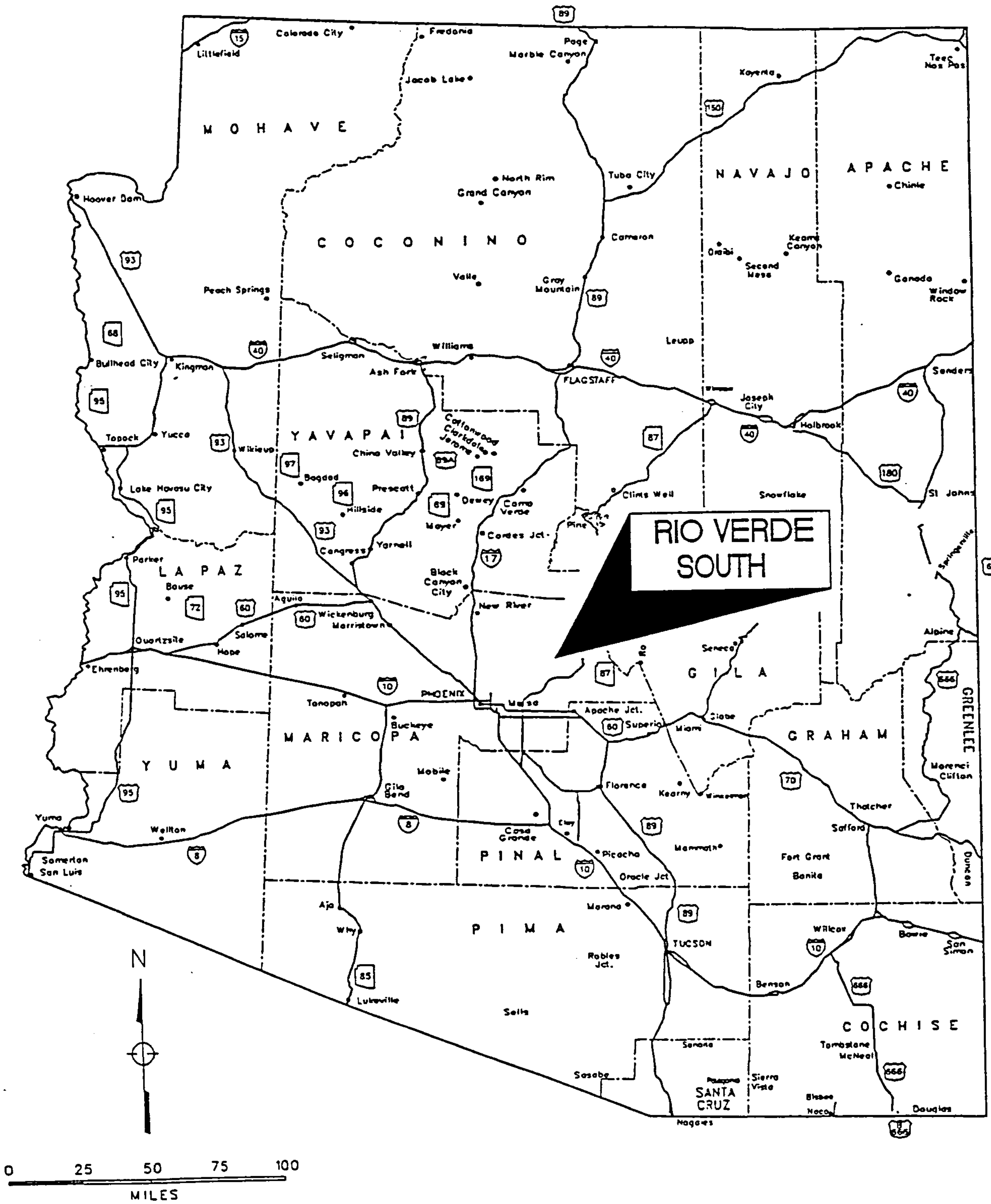


FIGURE 3-1

Location Map

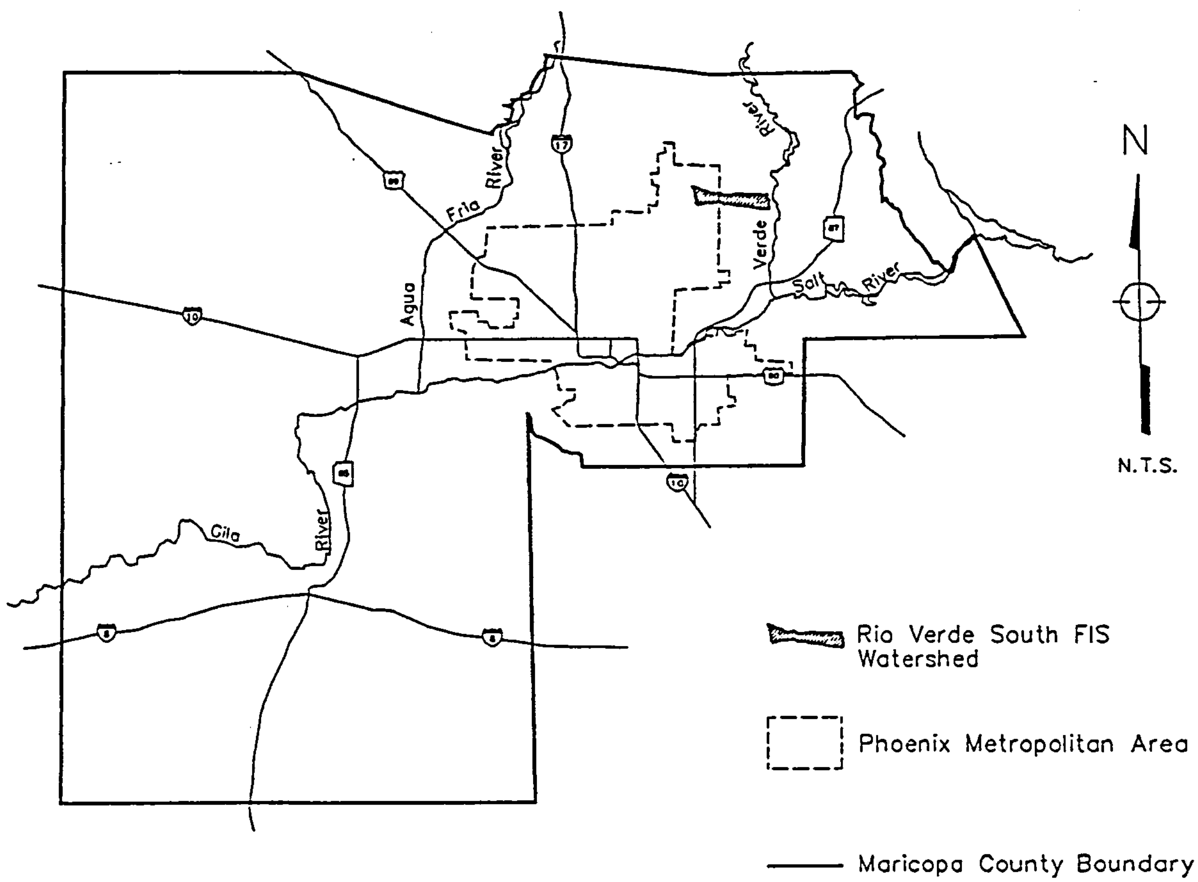


FIGURE 3-2

Vicinity Map

The watershed is divided into 9 major basins to facilitate the modeling of the complex routing situations found on the watershed. That approach allows the use of naming conventions which make it easier to follow the logic of the HEC-1 model. Hydraulic flow splits created by natural obstructions cause diversions of runoff from one major basin into another at various locations. Most of the diversions are located in the middle third of the watershed.

The existing urban development contains constructed channels that are maintained and follow the pre-development drainage patterns. Most of the urban channel network lies within the golf course areas. The urban area comprises about 2.1 square miles of the 17 square mile study area.

The watershed is characterized by rugged hillslope terrain along the west side of the study area, and hillslope, desert rangeland and wash bottom for the remainder. The watershed ranges in elevation from a low of 1,486 feet to a high of 2,850 feet in the McDowell Mountains. The typical soil type in the steep hillslopes areas is a clay loam, in the hillslope and desert rangeland areas is a sandy loam, and in the wash bottom areas is a loamy sand. The upper hillslope areas therefore have a high runoff potential and the lower hillslope and desert rangeland areas have a moderate runoff potential.

The target criteria for delineating the watershed into subbasins was to use an average subbasin size for the urban and desert rangeland areas of 0.16 square miles and an average size of 0.5 to 1.0 square miles for the hillslope areas. The average subbasin size after the watershed delineation was approved by the District, is 0.243 square miles. The total number of subbasins in the study is 70.

3.2.2 Physical Parameters

3.2.2.1 Watershed Subbasin Parameters

General

The watershed subbasin parameters are estimated in conformance with the Design Manual. The procedures used for estimating parameters are contained in the following sections. The SCS Soil Map Units and the land use categories present on the watershed are listed in Tables 3-1 and 3-2, respectively. The parameters used for input to the HEC-1 computer program are summarized in Tables 3-3 and 3-4.

TABLE 3-1

Rainfall loss characteristics for each soil class in its natural condition

Soil Map Unit (1)	Bare Ground XKSAT in/hr (2)	Natural RTIMP % (3)	Veg. Cover % (4)	Slope Range % (5)	Terrain Class (6)	IA in (7)
6	0.62	0	57	0-3	Rangeland	0.35
12	0.01	0	15	1-8	Hillslope	0.15
22	0.04	0	55	0-3	Rangeland	0.35
33	0.23	0	45	1-8	Rangeland	0.35
41	0.17	0	15	20-40	Hillslope	0.15
44	0.03	0	60	1-8	Rangeland	0.35
60	0.26	0	50	0-3	Rangeland	0.35
61	0.15	0	54	1-10	Rangeland	0.35
63	0.14	25	50	10-65	Hillslope	0.15
72	0.09	30	15	8-65	Hillslope	0.15
93	0.33	0	56	8-30	Hillslope	0.15
96	0.07	0	60	1-10	Rangeland	0.35
111	0.40	0	10	15-40	Hillslope	0.15
115	0.39	0	55	1-5	Rangeland	0.35
121	0.12	0	57	1-5	Rangeland	0.35
122	0.33	0	40	1-5	Rangeland	0.35

TABLE 3-2

Rainfall loss characteristics for each land-use class in its developed condition

Land Use ID (1)	RTIMP % (2)	Developed Veg. Cover % (3)	IA in (4)
LDR	25	15	0.10
MFR	65	10	0.10
C	75	5	0.07
AG	10	5	0.40
GC	10	90*	0.20
NC	0	0	0.00

* The vegetation cover for the golf course land-use is reduced from 100% to correct for the natural desert out-of bounds area included in the land-use polygon.

Land-Use Class	Description	Maricopa County Zoning Classifications
VLDR	Very Low Density Residential	N/A
LDR	Light Density Residential	R1-35, R1-18
MDR	Medium Density Residential	N/A
HDR	High Density Residential	N/A
MFR	Multi - Family Residential	R-2, R-3, R-4, R-5,
C	Commercial	C-S, C-O, C-1, C-2, C-3
I	Industrial	N/A
S	School	N/A

TABLE 3-3

Watershed characteristics for each subbasin
Existing Conditions

Sub Basin ID (1)	Area sq. mi. (2)	Green and Ampt Loss Parameters IA inches (3)	DTHETA (4)	PSIF inches (5)	XKSAT in/hr (6)	RTIMP % (7)	Hydrograph Method (8)	Time-Area Relation * (9)
500A	0.2143	0.35	0.37	5.30	0.28	0.0	Mountain	---
500B	0.2049	0.35	0.38	5.40	0.27	0.0	Mountain	---
500C	0.1228	0.35	0.35	4.65	0.37	0.0	Mountain	---
500D	0.2337	0.35	0.35	4.35	0.44	0.0	Mountain	---
500E	0.1057	0.35	0.35	4.35	0.44	0.0	Mountain	---
500F	0.4373	0.35	0.35	4.40	0.43	0.0	Mountain	---
500G	0.2022	0.16	0.27	4.70	0.35	22.3	Clark	A
500H	0.2109	0.35	0.35	4.30	0.46	0.0	Mountain	---
500I	0.4090	0.35	0.35	4.25	0.47	0.0	Mountain	---
500J	0.0902	0.34	0.35	4.45	0.41	1.1	Mountain	---
500K	0.0958	0.23	0.32	5.60	0.25	9.5	Mountain	---
500L	0.1605	0.35	0.35	4.35	0.44	0.2	Mountain	---
500M	0.1231	0.15	0.26	4.65	0.36	19.8	Clark	A
500N	0.1133	0.34	0.39	6.20	0.20	0.0	Clark	C
500O	0.1008	0.18	0.19	7.30	0.13	16.1	Clark	A
500P	0.0831	0.30	0.26	8.40	0.09	4.9	Clark	B
501A	0.0399	0.36	0.28	4.70	0.28	7.3	Clark	A
501B	0.0739	0.35	0.33	4.90	0.32	1.9	Clark	B
502A	0.0401	0.35	0.25	9.70	0.06	0.0	Clark	C
502B	0.0526	0.35	0.25	9.70	0.06	0.0	Clark	C
502C	0.0460	0.35	0.25	9.70	0.06	0.0	Clark	C
503A	0.2163	0.14	0.17	7.60	0.11	19.5	Clark	A
503B	0.1128	0.27	0.24	8.40	0.09	8.3	Clark	B
503C	0.1209	0.35	0.27	8.80	0.08	0.0	Clark	C
504A	0.2419	0.29	0.26	8.00	0.10	4.8	Clark	B
505A	0.1797	0.34	0.37	6.60	0.18	0.5	Mountain	---
505B	0.1446	0.13	0.16	7.00	0.14	17.7	Clark	A
509A	0.5728	0.30	0.35	6.40	0.18	4.6	Mountain	---
509B	0.6374	0.35	0.36	5.10	0.31	0.0	Mountain	---
509C	0.1465	0.35	0.38	6.40	0.19	0.0	Mountain	---
509D	0.3374	0.35	0.40	6.00	0.22	0.0	Mountain	---
509E	0.1897	0.35	0.35	7.00	0.15	0.0	Mountain	---
509F	0.2007	0.35	0.37	6.60	0.18	0.0	Mountain	---
509G	0.0936	0.35	0.36	6.80	0.16	0.0	Mountain	---
509H	0.0691	0.34	0.35	7.00	0.15	0.0	Clark	C
509I	0.0297	0.35	0.38	5.60	0.26	0.0	Clark	C
509J	0.1034	0.21	0.32	5.10	0.28	9.0	Clark	B

TABLE 3-3 (continued)

Watershed characteristics for each subbasin
Existing Conditions

Sub Basin ID (1)	Area sq. mi. (2)	Green and Ampt Loss Parameters IA inches (3)	DTHETA (4)	PSIF inches (5)	XKSAT in/hr (6)	RTIMP % (7)	Hydrograph Method (8)	Time-Area Relation * (9)
509K	0.0292	0.28	0.39	6.20	0.19	0.1	Clark	C
509L	0.0799	0.16	0.25	6.40	0.16	16.8	Clark	A
509M	0.1040	0.33	0.38	5.70	0.24	1.7	Clark	B
509N	0.1139	0.11	0.26	5.40	0.24	28.1	Clark	A
509O	0.0369	0.07	0.25	5.00	0.26	53.5	Clark	A
509P	0.1102	0.10	0.19	6.60	0.15	29.4	Clark	A
509Q	0.1073	0.12	0.22	6.40	0.16	19.5	Clark	A
509R	0.0970	0.32	0.32	7.00	0.15	3.8	Clark	B
509S	0.1953	0.27	0.27	7.30	0.13	8.1	Clark	B
510A	0.9125	0.35	0.39	6.20	0.20	0.0	Mountain	---
510B	0.3587	0.35	0.35	7.00	0.15	0.0	Mountain	---
510C	0.8509	0.30	0.39	6.20	0.19	0.0	Mountain	---
510D	0.0588	0.21	0.38	5.40	0.22	0.0	Clark	C
510E	0.1822	0.23	0.25	7.00	0.14	10.0	Clark	B
510F	0.1147	0.26	0.36	6.00	0.20	6.0	Clark	B
510G	0.1794	0.23	0.33	5.70	0.22	12.9	Clark	B
511A	0.6486	0.35	0.39	6.20	0.21	0.0	Mountain	---
511B	1.0998	0.32	0.37	6.60	0.17	4.4	Mountain	---
511C	1.1960	0.34	0.39	6.20	0.21	0.9	Mountain	---
511D	0.1280	0.35	0.36	6.80	0.17	0.0	Mountain	---
511E	0.5684	0.34	0.37	6.40	0.19	1.2	Mountain	---
511F	0.1538	0.34	0.38	6.20	0.20	1.0	Mountain	---
511G	0.8681	0.33	0.36	5.10	0.30	2.9	Mountain	---
511H	0.3097	0.35	0.35	4.45	0.44	0.4	Mountain	---
511I	0.2108	0.35	0.35	4.00	0.57	0.0	Mountain	---
511J	0.1194	0.35	0.35	3.81	0.65	0.0	Mountain	---
511K	0.7914	0.33	0.37	6.60	0.18	0.0	Mountain	---
511L	0.1927	0.35	0.35	4.35	0.44	0.0	Mountain	---
511M	0.0833	0.35	0.37	5.20	0.30	0.0	Mountain	---
511N	0.0686	0.18	0.18	7.00	0.15	12.9	Clark	A
511O	0.0455	0.35	0.39	6.20	0.20	0.3	Clark	C
511P	0.3140	0.31	0.25	8.80	0.08	3.4	Clark	B
511Q	0.0861	0.15	0.16	7.30	0.13	17.5	Clark	A

* Note: Time-Area Relations

A = Urban

B = HEC1 Default (partially urbanized)

C = Desert/Rangeland (natural)

TABLE 3-4

Summary of Clark Unit Hydrograph and S-Graph parameters for each Subbasin and Storm Event

Sub-basin ID (1)	Lag hrs (2)	100-year 6-hour Tc hrs (3)	100-year 6-hour R hrs (4)	100-year 24-hour Tc hrs (5)	100-year 24-hour R hrs (6)
500A	0.31	---	---	---	---
500B	0.43	---	---	---	---
500C	0.28	---	---	---	---
500D	0.39	---	---	---	---
500E	0.26	---	---	---	---
500F	0.43	---	---	---	---
500G	---	0.37	0.38	0.41	0.43
500H	0.37	---	---	---	---
500I	0.38	---	---	---	---
500J	0.23	---	---	---	---
500K	0.28	---	---	---	---
500L	0.32	---	---	---	---
500M	---	0.31	0.34	0.36	0.41
500N	---	0.28	0.28	0.34	0.34
500O	---	0.34	0.42	0.38	0.49
500P	---	0.25	0.23	0.30	0.28
501A	---	0.18	0.15	0.22	0.19
501B	---	0.25	0.24	0.31	0.30
502A	---	0.20	0.18	0.24	0.22
502B	---	0.22	0.22	0.27	0.27
502C	---	0.25	0.32	0.31	0.39
503A	---	0.30	0.33	0.35	0.39
503B	---	0.35	0.53	0.40	0.60
503C	---	0.30	0.26	0.35	0.31
504A	---	0.37	0.38	0.41	0.42
505A	0.36	---	---	---	---
505B	---	0.23	0.22	0.28	0.28
509A	0.73	---	---	---	---
509B	0.74	---	---	---	---
509C	0.35	---	---	---	---
509D	0.56	---	---	---	---
509E	0.41	---	---	---	---
509F	0.38	---	---	---	---
509G	0.32	---	---	---	---
509H	---	0.35	0.44	0.39	0.51

TABLE 3-4 (continued)

Summary of Clark Unit Hydrograph and S-Graph parameters for each Subbasin and Storm Event

Sub-basin ID (1)	Lag hrs (2)	100-year 6-hour Tc hrs (3)	100-year 6-hour R hrs (4)	100-year 24-hour Tc hrs (5)	100-year 24-hour R hrs (6)
509I	---	0.24	0.26	0.30	0.33
509J	---	0.37	0.40	0.41	0.46
509K	---	0.23	0.28	0.29	0.36
509L	---	0.20	0.21	0.24	0.27
509M	---	0.38	0.41	0.43	0.46
509N	---	0.25	0.30	0.30	0.37
509O	---	0.17	0.22	0.21	0.28
509P	---	0.19	0.17	0.23	0.21
509Q	---	0.24	0.29	0.29	0.36
509R	---	0.22	0.18	0.27	0.23
509S	---	0.30	0.25	0.35	0.30
510A	0.65	---	---	---	---
510B	0.56	---	---	---	---
510C	0.78	---	---	---	---
510D	---	0.25	0.26	0.31	0.33
510E	---	0.43	0.46	0.46	0.50
510F	---	0.34	0.32	0.39	0.37
510G	---	0.36	0.34	0.40	0.39
511A	0.47	---	---	---	---
511B	0.95	---	---	---	---
511C	1.04	---	---	---	---
511D	0.51	---	---	---	---
511E	0.84	---	---	---	---
511F	0.28	---	---	---	---
511G	0.61	---	---	---	---
511H	0.43	---	---	---	---
511I	0.29	---	---	---	---
511J	0.24	---	---	---	---
511K	0.57	---	---	---	---
511L	0.34	---	---	---	---
511M	0.26	---	---	---	---
511N	---	0.30	0.38	0.35	0.45
511O	---	0.28	0.37	0.34	0.45
511P	---	0.46	0.45	0.48	0.48
511Q	---	0.31	0.40	0.36	0.47

The supporting calculations for these parameters are contained in Tables S-1 through S-9, in Appendix A.

Subbasin naming and concentration point numbering conventions are used for the Rio Verde South study. The conventions are as follows:

	South Study
Major Basin names	500 and greater
Subbasin names	A, B, C...
Concentration Point numbers	501 and greater

The smaller major basins are named 500 through 505 and do not contain washes previously delineated by FEMA. The major basins which are drained by FEMA Washes 9, 10 and 11 are named 509, 510 and 511 respectively.

Watershed Delineation and Areas

The watershed delineation is accomplished using the various available mapping, aerial photographs, and by field reconnaissance. The urbanized and urbanizing areas are delineated using the 200 Scale Mapping and the stereo aerial photograph contact prints, (Stereo Photos) which were taken of the entire watershed at an approximate scale of 1 inch = 1000 feet. Areas of questionable topography, such as street intersections where subtle drainage patterns are not identifiable with 2-foot contour interval mapping, are verified by field reconnaissance.

The watershed delineation of the natural area west of the 200 Scale Mapping coverage is done using the USGS mapping and the Stereo Photos. Concentration points were first identified on the Stereo Photos and then a stereo scope was used to trace watershed boundaries on the photographs. The USGS mapping was plotted on clear acetate at a scale of 1 inch = 1000 feet and overlaid on the Stereo Photos. The boundaries on the Stereo Photos were used as a guide to define watershed boundaries on the USGS mapping. Questionable areas were evaluated during the field reconnaissance. The watershed boundaries were then digitized from the 1000 scale acetate into AutoCAD. Those boundaries are plotted on Exhibits D and E. Refer to Section 3.2.2.2 for a description of the information gathered by field reconnaissance.

Soils Parameters

General - Rainfall losses are estimated using the Green-Ampt infiltration equation. Soil textures are obtained from the SCS Soil Survey. The boundaries of SCS soil map units were provided in ARCInfo format by the District and converted to AutoCAD format.

Green-Ampt Parameters by SCS Soil Map Unit - The first step in determining rainfall loss values is to estimate Green-Ampt values for each SCS soil map unit present on the watershed. Table S-1 in Appendix A is an interpolation table used to determine the DTHETA and PSIF parameters given an XKSAT value. That table is derived from Figure 4.3 of the Design Manual. The PSIF values in Table S-1 are read directly from Figure 4.3. The DTHETA values are calculated using a linear logarithmic interpolation between the angle points on Figure 4.3. Table 3-1 (included in Appendix A as Table S-2) is a listing of the Green-Ampt parameters for every SCS soil map unit present on the study watershed. It is important to note that the XKSAT values listed in column 2 of Table 3-1 are composite values based on the major and minor soils described in the SCS Soil Survey. The value of RTIMP in column 3 is from the SCS Soil Survey. The XKSAT column in Table 3-1 is listed as "Bare Ground" because vegetation cover density (VCD) correction factors are not applied in that table. The vegetation cover estimates in column 4 are described in detail in a later section. The slope ranges in column 5 are derived from the SCS Soil Survey. The terrain class designation for each soil map unit shown in column 6, is assigned based on the VCD and slope range values in columns 4 and 5. The Rangeland terrain class is typified by flat slopes and high vegetation cover densities. The opposite is typical for the Hillslope terrain class. The Mountain terrain class is not used for this watershed. The initial abstraction (IA) is then selected from Table 4.1 of the Design Manual using the terrain class from column 6, and the selected value placed in column 7.

Green-Ampt Parameters by Subbasin - The XKSAT, RTIMP, VCD and IA parameters are estimated for the natural areas of each subbasin by calculating composite values based on area. The soil map unit boundaries were provided in digital format by the District. The subbasin and major basin boundaries are digitized into AutoCAD as a part of the subbasin delineation process. The AutoCAD drawing files are then converted to ARCInfo format for calculation of soils and subbasin areas. The total area of all polygons for each soil map unit within a subbasin was calculated using ARC/CAD. ARC/CAD is a geographic information system software package that interfaces with AutoCAD, and is a more efficient tool for computing areas of multiple polygons than AutoCAD itself.

The composite values of XKSAT, RTIMP, VCD and IA are calculated for each subbasin using a spreadsheet after the polygon areas are calculated. Refer to Table S-3 in Appendix A. Table S-3 is the calculations summary for estimating the composite XKSAT, natural RTIMP and natural VCD and initial abstraction (IA) for each subbasin. The data in this table is sorted by subbasin. The calculations for subbasin 500P, extracted from Table S-3, are as follows:

Soil Map Unit No. ...	22	96	0	0	0	0	0	0	0	0	0	0
Sub-Area (acres) ...	11.1	42.1	—	—	—	—	—	—	—	—	—	—
XKSAT (bare ground) ...	0.04	0.07	—	—	—	—	—	—	—	—	—	—
RTIMP (rock) ...	0%	0%	—	—	—	—	—	—	—	—	—	—
Vegetation Cover ...	55%	60%	—	—	—	—	—	—	—	—	—	—
IA (natural only) ...	0.35	0.35	—	—	—	—	—	—	—	—	—	—

XKSAT log avg (bare ground) = **0.06**
PSIF = **8.40**
DTHETA (Dry) = **0.29**
DTHETA (Normal) = **0.15**
RTIMP avg. = **0.00 %**
Veg. Cover avg. = **58.96 %**
IA avg. = **0.35**

Total Sub Basin Area in sq. miles = 0.0831

The soil map units present in each subbasin, the corresponding area and the bare ground XKSAT values, are listed in the first three rows of each subbasin data group. The RTIMP, VCD and IA values associated with each soil map unit are listed in rows 4, 5 and 6 respectively. The composite XKSAT parameter, shown in row 7, is calculated by area-averaging the common logarithm of the XKSAT values from row 3. This is accomplished by multiplying the total area of each soil map unit in the subbasin by the common logarithm of the associated XKSAT value. The resultant products are then totaled, the sum divided by the total area of the subbasin, and the antilogarithm calculated. The result is the composite XKSAT parameter. The values of PSIF, DTHETA (Dry) and DTHETA (normal) in rows 8, 9, and 10, respectively, are extracted from Table S-1 for the corresponding log-averaged value of XKSAT. The RTIMP, VCD and IA parameters, listed in rows 11, 12 and 13, respectively, and are calculated by area-averaging the appropriate values from rows 4, 5, and 6. The log-averaging method is not used for RTIMP, VCD or IA. The source of the VCD values in row 5 is discussed under "Land Use Parameters". The effects of urbanization on RTIMP, VCD, IA and DTHETA are also discussed under "Land Use Parameters".

The coordinate basis for the 200 scale mapping and all field surveys for this project is the National Geodetic Survey North American Datum of 1983 (NAD 1983). The vertical basis is the National Geodetic Vertical Datum of 1929 (NGVD 1929). The delineated subbasins are digitized into AutoCAD using this coordinate system. Section corners, USGS quadrangle map corners, and aerial mapping control points were used for calibration of the digitizer.

The subbasin, soils and land use polygon areas are calculated from the AutoCAD drawings using Arc/CAD version 11.2.

Land Use Parameters

General - Land use characteristics are assigned using the general terms "natural" and "urban". The "natural" characteristic includes all undeveloped land. The "urban" characteristic includes a number of land use categories.

Land use Parameters by Zoning Designation - The Rio Verde North area is unincorporated and lies within Maricopa County. The District provided Maricopa County zoning boundaries and designations in AutoCAD format for the watershed area. The coordinate basis for the AutoCAD file was NAD1927. The file was translated to NAD1983 for use on this project. The zoning classifications designated in the AutoCAD file are:

AG - Agriculture;
C - Commercial;
LDR - Low density residential:

MFR - Multi-family residential;

GC - Golf Course; and

Lake - Golf Course lakes.

All areas which are outside the above zoning classifications are designated Natural Desert (ND) for the purposes of this study. The Lake areas are designated Non-Contributing (NC). The C, LDR, MFR, GC and AG land uses are urban and have urban RTIMP, VCD and IA parameter associations. The selected parameter values for each land use classification are listed in Table 3-2. Table 3-2 is included in Appendix A as Table S-2.

The RTIMP values for the LDR and MFR land uses are taken from the District's land use parameter spreadsheet which is provided with the Design Manual. Those values were checked against aerial photographs of the watershed and were found to be reasonable estimates of urban RTIMP. The RTIMP estimates shown in Table 3-2 for the AG, C, and GC land uses are based on estimates made using the Stereo Photos. The urban VCD estimates are based on examination of the Stereo Photos and field reconnaissance. The IA values for the LDR and MFR land uses correspond to the commercial desert landscape category in Table 4.1 of the Design Manual. The C land use IA estimate is a composite of the values for commercial desert landscape and commercial pavement from that table. The AG land use IA estimate is based on engineering judgement. A lower value of 0.4 inches is used in lieu of the 0.5 inch value from Table 4.1 of the Design Manual because the agriculture areas on the watershed do not appear to be actively farmed. The GC land use IA estimate corresponds with the value for developed lawn and turf from Table 4.1 of the Design Manual.

Land Use Parameters by Subbasin - The urban RTIMP, VCD and IA parameters are estimated for the urban areas of each subbasin by calculating composite values based on area. That is done in a manner similar to that used to calculate composite Green-Ampt parameters for each subbasin. The total area of all polygons for each land use within a subbasin was calculated using ARC/CAD. A spreadsheet was then used to calculate the composite parameters. Refer to Table S-5 in Appendix A. Table S-5 is the calculations summary for estimating composite values of urban

RTIMP, VCD and IA for each subbasin. The data in the table is sorted by subbasin. The calculations for subbasin 500P, extracted from Table S-5, are as follows:

Land Use ID ...	GC	LDR	MFR	ND	0	0	0	0	0	0	0	0
Natural or Developed ...	D	D	D	N	—	—	—	—	—	—	—	—
Sub-Area (acres) ...	3.7	4.8	1.6	43.2	—	—	—	—	—	—	—	—
RTIMP (Developed) ...	10%	25%	65%	—	—	—	—	—	—	—	—	—
Veg. Cover (Developed) ...	81%	11%	4%	—	—	—	—	—	—	—	—	—
IA (Developed) ...	0.18	0.08	0.04	—	—	—	—	—	—	—	—	—

Natural Area =	81.1 %
Developed Area =	18.9 %
RTIMP (Dev.) avg. =	4.89 %
Veg Cover (Dev.) avg. =	6.70 %
IA (Dev.) avg. =	0.02

Total Sub Basin Area in sq. miles = 0.0831

The land uses present in the subbasin are listed in row 1. Row 2 contains a label to identify the land use as natural (N) or developed (D). The urban areas are referred to as developed for the purposes of Table S-5. Row 3 contains the total area of all polygons of that land use within the subbasin. Rows 4, 5 and 6 contain the urban RTIMP, VCD and IA values, respectively, from Table 3-2. Row 7 is the calculated percentage of natural area within the subbasin, based on rows 2 and 3. Row 8 is the calculated percentage of developed (urban) area with the subbasin, also based on rows 2 and 3. The composite values of RTIMP, VCD and IA are shown in rows 9, 10 and 11. These values are calculated by area-averaging the values from rows 4, 5 and 6.

Area Weighted Rainfall Loss Parameters for each Subbasin

General - The calculation of natural and urban rainfall loss parameters for each subbasin are discussed in the preceding sections. Area weighted parameters which include the effects of the natural and urban areas within each subbasin are necessary for input to the HEC-1 models. The area weighted parameter calculations are accomplished using a spreadsheet. The results of the calculations are shown in Table S-6 in Appendix A. There are five parameters for which area weighted values are calculated based on percentage of natural and urban area within the subbasin.

These are IA, RTIMP, VCD, DTHETA and XKSAT. Each parameter is discussed separately, referring to the data in Table S-6.

IA - The percent of natural and urban land use within each subbasin is taken from Table S-5 and placed in columns 3 and 4 of Table S-6 respectively. The natural and urban values of IA for each subbasin are taken from Tables S-3 and S-5, and placed in columns 5 and 6 of Table S-6, respectively.

The area weighted IA values are in column 7 of Table S-6 and calculated as follows:

$$[7] = \frac{[5][3]+[6][4]}{100}$$

where: The numbers in brackets are the column numbers from Table S-6 (typical).

Keep in mind that the natural and urban values of IA in columns 5 and 6 are both the average for the entire subbasin and thus are area averaged.

RTIMP - The natural and urban values of RTIMP for each subbasin are taken from Tables S-3 and S-5, and placed in columns 8 and 9 of Table S-6, respectively. The area weighted RTIMP values are in column 10 and calculated as follows:

$$[10] = [8] + [9]$$

The natural and urban values of RTIMP in columns 8 and 9 are both percentages of the entire subbasin and thus can be directly summed.

VCD - The natural and urban values of VCD for each subbasin are taken from Tables S-3 and S-5, and placed in columns 11 and 12 of Table S-6, respectively. The area weighted VCD values are in column 13 and calculated as follows:

$$[13] = \frac{[11][3]+[12][4]}{100}$$

The natural and urban values of VCD for each subbasin are both representative of the entire subbasin and thus are area averaged.

DTHETA - Both DTHETA dry and DTHETA normal for each subbasin are taken from Table S-3 and placed in columns 16 and 17 of Table S-6 respectively. The composite DTHETA values are in column 18 and calculated as follows:

$$[18] = \frac{[16][3]+[17][4]}{100}$$

XKSAT - The log-averaged value of XKSAT for each subbasin is taken from Table S-3 and placed in column 14 of Table S-6. The bare ground value of XKSAT is then adjusted for the effects of VCD and the result placed in column 19. The calculation is done as follows:

$$[19] = (0.889 + 1.111\,[13])\;[14]$$

The area weighted Green and Ampt parameters for each subbasin are summarized in Table 3-3.

Unit Hydrograph

General - The Clark Unit Hydrograph and the S-Graph method are both used for this study. The Clark Unit Hydrograph is used for subbasins that are urbanized or urbanizing and meet the assumptions upon which the Clark Unit Hydrograph method is based. The S-Graph method is used for all subbasins which do not meet the Clark Unit Hydrograph assumptions. In particular, the duration of the most intense portion of rainfall excess should not be less than the time of concentration, when using the Clark Unit Hydrograph. A check for this guideline was made for every subbasin in the model. The unit hydrograph method used to model each subbasin is identified in column 2 of Table S-7 in Appendix A.

The Phoenix Mountain S-Graph is used for all subbasins modeled using the S-graph method. The Phoenix Mountain S-Graph is defined in the Design Manual. That S-Graph is deemed most appropriate based on a comparison of the Rio Verde watershed with the gaged watersheds which were used to create that S-Graph.

Clark Unit Hydrograph Time of Concentration - The time of concentration (Tc) for use with the Clark Unit Hydrograph is estimated using the Papadakis and Kazan empirical equation:

$$T_c = 11.4\ L^{0.50}\ K_b^{0.52}\ S^{-0.31}\ i^{-0.38}$$

where: T_c = subbasin time of concentration in hours;

L = length of the hydraulically longest flow path in miles;

S = watercourse slope in feet per mile;

K_b = representative watershed resistance coefficient; and

i = average rainfall excess intensity, during the time T_c, in inches/hour.

Solution of the T_c equation is an iterative process dependent on *i*, accomplished using a modified version of the MCUHP1 computer program provided by the District with the Design Manual.

The length, L, is listed for each subbasin in column 5 of Table S-7. The slope, S, is calculated using top and bottom elevations of the reach, listed in columns 3 and 4 of Table S-7, respectively, and L. The calculated slopes for all subbasins are listed in column 6. The slope of steep water courses is adjusted using Figure 5.4 of the Design Manual. The following expressions are mathematical approximations of the curve plotted on Figure 5.4 and are used to calculate the adjusted slope:

$$S_{adj} = b + m\,(\ln(S))$$

where: $S < 225$ no adjustment is necessary

and: $225 < S < 400$
$m = 133.8009$
$b = -500.865$

and: $S > 400$
$m = 61.54998$
$b = -74.6827$

The adjusted slopes for subbasins modeled using the Clark Unit Hydrograph are listed in column 7 of Table S-7.

The selection of the k_b parameter for each subbasin is made using engineering judgement. The basis for the selection are the terrain classifications for each soil map unit listed in column 6 of Table 3-1, and examination of the subbasin topography. The watershed soils map (Exhibit B) was carefully examined to determine the dominate soil map units present. The aerial photographs and Exhibits D and E were examined with the goal of estimating the dominate roughness characterics of each subbasin. Both sources of information were compared and a selection of roughness type made. The roughness type selection matches the types listed in Table 5.1 of the Design Manual. In addition , three intermediate types are used. These are types A/B, B/C and C/D. These are interpolated values between the four standard types listed in Table 5.1 of the Design Manual. The intermediate types are plotted on a revised copy of Figure 5.5 of the Design Manual which is included in Appendix A. The intermediate values of coefficients m and b for use in the Kb equation are:

Type	m	b
A/B	-0.01000	0.060
B/C	-0.01938	0.115
C/D	-0.02750	0.175

The selected roughness type for each subbasin is listed in column 9 of Table S-7 in Appendix A. The corresponding values of Kb, calculated using the equation from Table 5.1 of the Design Manual, are listed in column 10 of Table S-7.

The storage coefficient, R, is estimated using the calculated Tc value and equation 5.6 of the Design Manual. The results of the calculation of Tc and R are summarized in Tables S-8 and S-9 for the 100-year, 6-hour and 24-hour storms, respectively. The rainfall excess values, listed in order by decreasing rank, for the most intense 90 minute period for both storms are shown in columns 2 through 19 of Tables S-8 and S-9. The total rainfall excess for each subbasin is listed in column 20. The duration of 90% of the total rainfall excess is listed in column 21. That time, in minutes, is assumed to be the duration of the most intense portion of rainfall excess. The calculated Tc values are listed in minutes in column 22, and in hours in column 23. A key assumption upon which the Clark Unit Hydrograph is based is that the Tc should be less than the duration of the most intense portion of rainfall excess. This assumption can be checked for the subbasins modeled using the Clark Unit Hydrograph by comparing the values in columns 21 and 22 of Tables S-8 and S-9. The estimated value of R for each subbasin is listed in column 24. The values of Tc and R for each subbasin modeled using the Clark Unit Hydrograph are summarized in Table 3-4.

Clark Unit Hydrograph Time-Area Relation

The time-area relation is a required parameter for use with the Clark Unit Hydrograph. A time-area relation is selected for each subbasin, depending on the characteristics of that subbasin. It is impractical to develop individual time-area relations for each subbasin in a model with numerous subbasins. Synthetic time-area relations are therefore used for this study. The watershed can generally be characterized using three categories:

A. Urbanized;
B. Urbanizing; and
C. Natural.

Three synthetic time-area relations are available for use in the Design Manual. The N-D relation on Figure 5.7 of the Design Manual is used for subbasins categorized as natural. The U-D relation on Figure 5.6 of the Design Manual is used for subbasins categorized as urban. The HEC-1 default time-area relation is used for subbasins categorized as urbanizing. An urbanizing subbasin is defined as having an urban percentage of subbasin area greater than 5 and less than 50 percent. An urban subbasin is defined as having an urban percentage of subbasin area greater than or equal to 50 percent, or will be expected to reach that percentage within 18 months after the date of this study.

The selection of a time-area relation for each subbasin is made based on engineering judgement using the above criteria. The aerial photographs and Exhibits C, D and E were examined and used as a basis for the selection. The percent urban of each subbasin is estimated in Table S-5 and summarized in Table S-6. The selected time-area relation for each subbasin is listed in column 9 of Table 3-3 as type A, B, or C in accordance with the categories described above.

S-Graph Lag Parameter - The basin lag parameter (T_L) is estimated using equation 5.11 of the Design Manual. That equation, using the COE exponents, is:

$$T_L = 24 K_n \left[\frac{L L_{ca}}{S^{0.5}} \right]^{0.38}$$

where:
T_L = basin lag in hours;
L = length of the hydraulically longest flow path in miles;
Lca = length along the watercourse used to define L from the subbasin concentration point to a point opposite the subbasin centroid in miles;
S = watercourse slope in feet per mile; and
K_n = estimated mean Manning's n for all the channels in the subbasin.

The length, L, is listed for each subbasin in column 5 of Table S-7. Variables S and L_{ca} are listed in columns 6 and 8 of that table, respectively.

The value of K_n selected for each subbasin is based on the surface roughness types listed in column 9 of Table S-7, Figure 5.11 of the Design Manual and engineering judgement. The surface roughness type and the corresponding selected value of K_n are:

Surface Roughness Type	K_n
B	0.030
BC	0.040
C	0.050
C/D	0.055
D	0.060

The selected values of K_n for each subbasin modeled using the S-Graph method are listed in column 11 of Table S-7. The calculated values of T_L for each subbasin modeled using the S-Graph method are summarized in Table 3-4.

Sample Calculation of Subbasin Parameters

The following is an example of the calculation procedures used in preparing the data in Tables S-3 through S-9. Subbasin 509A will used for this example.

Green-Ampt Parameter Calculations for Subbasin 509A -

Note: Some disparity between sample calculations and values in the tables can exist due to greater precision of spreadsheet numerics.

Step 1: *Calculate the log-average value of XKSAT.* Refer to Table S-3, page 10, Appendix A.

Log-Avg XKSAT = 10^a, where

$$a = \left(\frac{\log(0.23)(46.0) + \log(0.15)(203.3) + \log(0.14)(1.6) + \log(0.33)(5.9) + \log(0.07)(109.7)}{46.0 + 203.3 + 1.6 + 5.9 + 109.7} \right)$$

$= -0.8943$

Log-Avg. XKSAT $= 10^{-0.8943}$

$= 0.13$ inches per hour

That value is then placed in Table S-3, page 10, in row 7 of the calculation set for subbasin 509A.

Step 2: *Determine the DTHETA and PSIF parameters corresponding to Log-Avg. XKSAT.* Use the log-averaged XKSAT value of 0.13 to look up the values for PSIF, DTHETA (dry), and DTHETA (normal), in Table S-1.

PSIF	=	6.4 inches
DTHETA (dry)	=	0.38
DTHETA (normal)	=	0.21

Those values are then placed in Table S-3, page 10, rows 8, 9 and 10, respectively, and Table S-6, columns 15, 16 and 17, respectively. The PSIF value is also placed in Table 3-3, column 5.

Step 3: Calculate the weighted value of natural RTIMP (rock) for the subbasin. Refer to Table S-3, page 10.

RTIMP (weighted) =

$$\frac{(0)(46.0)+(0)(203.3)+(25)(1.6)+(0)(5.9)+(0)(109.7)}{46.0+203.3+1.6+5.9+109.7} = 0.11\%$$

That value is then placed in column 8 of Table S-6.

Step 4: *Calculate the average natural Vegetation Cover Density (VCD) for the subbasin.* Refer to Table S-3, page 10.

VCD (weighted) =

$$\frac{(45)(46.0)+(54)(203.3)+(50)(1.6)+(56)(5.9)+(60)(109.7)}{46.0+203.3+1.6+5.9+109.7}$$

= 54.68%

That value is then entered in Table S-3, row 12, and Table S-6, page 3, column 11.

Step 5: Calculate the average natural Initial Abstraction (IA) for the subbasin. Refer to Table S-3, page 10.

IA (weighted) =

$$\frac{(0.35)(46.0)+(0.35)(203.3)+(0.15)(1.6)+(0.15)(5.9)+(0.35)(109.7)}{46.0+203.3+1.6+5.9+109.7}$$

= 0.35 inches

That value is then entered in Table S-3, page 10, in row 13 of the subbasin 509A calculation set, and in Table S-6, column S.

Green-Ampt Parameter Calculations for Subbasin 509A - (continued)

Step 6: *Calculate the percentage of natural area in the subbasin.* Refer to Table S-5, page 10. A land use is "natural" if the identifier in row 2 is "N".

$$\text{Natural Area} = \left(\frac{301.4}{65.2+301.4}\right)100$$

$$= 82.2\%$$

That value is placed in Table S-5, row 7 and Table S-6, column 3.

Step 7: *Calculate the percentage of urban (developed) area in the subbasin.* Refer to Table S-5, page 10. A land use in considered "Urban" if the identifier in row 2 is "D".

$$\text{Developed Area} = \left(\frac{65.2}{65.2 + 301.4}\right) 100$$

$$= 17.8\%$$

That value is then placed in Table S-5, row 8 and Table S-6, column 4.

Step 8: *Calculate the urban percent impervious for the subbasin.* Refer to Table S-5, page 10. The percent impervious for each land use shown in row 4 of the calculation set for subbasin 509A in Table S-5 is taken from Table S-4.

$$\text{RTIMP(Dev.) avg.} = \frac{(25)(65.2) + (0)(301.4)}{65.2+301.4} = 4.45\%$$

That value is placed in row 9 of the subbasin 509A calculations on page 10 of Table S-5 and in Table S-6, column 9.

Step 9: Calculate the urban vegetation cover density for each land use in the *subbasin, adjusted to reflect impervious area.* The urban VCD for LDR land use is 15% (refer to Table S-4). The urban RTIMP for LDR land use is 25%. The composite VCD for the LDR land use in subbasin 509A is therefore:

$$\text{VCD (Developed)} = \left(\frac{100 - 25}{100}\right)(15)$$

$$= 11\%$$

That value is placed in row 5 of the subbasin 509A calculations on page 10 of Table S-5.

Step 10: Calculate the weighted urban vegetation cover density for the subbasin. Refer to Table S-5, page 10.

$$\text{VCD (Dev.) avg.} = \frac{(11)(65.2) + (0)(301.4)}{65.2 + 301.4}$$

$$= 2.00\%$$

That value is placed in row 10 of the subbasin 509A calculations on page 10 of Table S-5.

Step 11: *Calculate the urban IA for each land use, adjusted to reflect impervious area.* The urban IA for LDR land use 0.10 inches (refer to Table S-4). The urban RTIMP for LDR land use is 25%. The composite VCD for the LDR land use in subbasin 509A is therefore:

$$\text{IA (Developed)} = \left(\frac{100 - 25}{100}\right)(0.10)$$

$$= 0.08 \text{ inches}$$

That value is placed in row 6 of the subbasin 509A calculations on page 10 of Table S-5.

Step 12: *Calculate the weighted urban IA value for the* subbasin. Refer to Table S-5, page 10.

$$IA\ (Dev.)\ avg. = \frac{(0.08)(65.2) + (0)(301.4)}{65.2 + 301.4}$$

$$= 0.01 \text{ inches}$$

That value is placed in Table S-5, row 11, and Table S-6, column 6.

Step 13: *Calculate the weighted IA in inches for the subbasin.* Refer to Table S-6, columns 5, 6 and 7. Keep in mind that the natural IA value in Table S-6, column 5, is the average value for the subbasin, assuming no urbanization. That value must be adjusted to account for the percentage of urbanized area. The urban IA value in column 7 is the average value for the subbasin and requires no adjustment. The number in brackets is the column number of the referenced table, typically.

$$IA\ composite = [7]$$

$$= \frac{[5][3]}{100} + [6]$$

$$= \frac{(0.35)(82.2)}{100} + 0.01$$

$$= 0.30 \text{ inches}$$

That value is placed in Table S-6, column 7 and Table 3-3, column 3.

Step 14: *Calculate the total percent impervious for the subbasin, including rock and urbanization.* Refer to Table S-6, columns 8, 9 and 10. The natural RTIMP value in Table S-6, column 8, is the average value for the subbasin, assuming no urbanization. That value is not adjusted to account for the percentage urbanized area. It is assumed that the rock present in natural areas prior to urbanization is still present after urbanization. No adjustment is made for overlap of rock impervious areas and urban impervious areas.

$$\begin{aligned} \text{RTIMP (total)} &= [10] \\ &= [8] + [9] \\ &= 0.11 + 4.45 \\ &= 4.56\% \end{aligned}$$

Use RTIMP (total) = 4.6 percent. That value is placed in Table 3-3, column 7.

Step 15: *Calculate the weighted value of VCD for the subbasin, considering the natural and urban land use types.* Refer to Table S-6, columns 11, 12 and 13. Keep in mind that the natural VCD value in Table S-6, column 11, is the average value for the subbasin, assuming no urbanization. That value must be adjusted to account for the percentage of urbanized area. The urban VCD value in column 12 is the average value for the subbasin and requires no adjustment.

$$\text{VCD (weighted)} = [13]$$

$$= \frac{[11]\ [3]}{100} + [12]$$

$$= \frac{(54.68)(82.2)}{100} + 2.0$$

$$= 46.95\%$$

That value is placed in Table S-6, Column 13.

Step 16: *Calculate the weighted value of DTHETA for the subbasin, considering the natural and urban land use types.* Refer to Table S-6, columns 16, 17 and 18.

$$\text{DTHETA (weighted)} = [18]$$

$$= \frac{[16][3] + [17][4]}{100}$$

$$= \frac{(0.38)(82.2) + (0.21)(17.8)}{100}$$

$$= 0.35$$

That value is placed in Table S-3, column 18 and in Table 3-3, column 4.

Step 17: *Adjust XKSAT to reflect the effects of vegetation cover.* Refer to Table S-6, columns 13,14 and 19.

$$C_k = 0.899 + 1.111[13]$$

$$= 0.889 + 1.111\left(\frac{46.95}{100}\right)$$

$$= 1.41$$

$$\text{XKSAT (ADJUSTED)} = [19]$$

$$= (1.41)[14]$$

$$= (1.41)(0.13)$$

$$= 0.18 \text{ inches per hour}$$

That value is placed in Table S-6, column 19, and Table 3-3, column 6.

Step 18: *Select the hydrograph method.* S-Graph method is selected because subbasin 509A is upstream of the urban area and has a small percentage of urban land use. Refer to columns 3 and 4 of Table S-6. The selected hydrograph method is listed in Table 3-3, column 8.

3.2.2.2 Reach Route Parameters

General

Routing of subbasin hydrographs is done utilizing the normal depth channel option under HEC-1. The routing reach paths are shown on Exhibits D and E. Plots of the cross sections used for each route are shown in Appendix C. Each route is identified by a name which consists of the upper and lower concentration point numbers which define the reach. Reach 501502, for instance, starts at concentration point 501 at the upper end, and extends to concentration point 502 at the lower end.

Field Reconnaissance

A field reconnaissance was conducted from 6 June 1994 through 10 June 1994 and on 7 July 1994. Critical locations in the upper watershed, west of the area covered by the 200 Scale Mapping, were visited and cross sections of washes were surveyed. The locations visited were the locations of naturally occurring flow splits. The cross sections were taken in order to estimate the hydraulic characteristics of each split and to obtain typical cross sections that could be used for hydrograph routing. The cross sections were taken using Global Positioning System (GPS) satellite surveying equipment manufactured by Wild-Heerbrugg.

A significant portion of the watershed is located in McDowell Mountain Park, which is a part of the Maricopa County Parks system. Vehicular access in the park is restricted to paved roads. The flow split locations in the park were accessed on horseback, due to the remote and rugged nature of the watershed. Other areas of the watershed were accessed by vehicle or on foot. Photographs were taken at each location and are available for review at the District.

The field reconnaissance also included visual estimates of vegetation cover density and verification of watershed boundaries at critical locations.

Reach Route Cross Sections

Reach route cross sections were estimated using following data sources:

1. The 200 Scale Mapping;
2. USGS quadrangle maps; and
3. By field reconnaissance.

Cross sections were surveyed during the field reconnaissance in reaches where the only maps available are USGS quadrangle maps. The cross section used for any particular reach is deemed representative of the hydraulic characteristics of that reach. The USGS quadrangle maps were used to supplement the cross sections obtained during the field reconnaissance. Those maps were used to estimate overbank slopes and widths. The cross sections taken by field reconnaissance were applied to other similar reaches where cross sections were not taken. The similarity of reaches was determined using engineering judgement based on examination of the Stereo Photos and the available mapping.

The source used to develop a cross section for each reach is listed in column 4 of Table 3-5. That table also lists the name of the subbasin that contains the reach, the reach length, the reach top and bottom elevations and the average reach slope. Those physical characteristics are obtained from the available mapping.

TABLE 3-5

Reach Route Physical Data

Reach Route Concentration Points		In		Length		Elevation (feet)		Slope
Top (1)	Bottom (2)	Subbasin (3)	Cross Section Source (4)	Feet (5)	Miles (6)	Top (7)	Bottom (8)	(ft/ft) (9)
501	502	500B	Hydrology Field Reconnaissance	6289	1.1910	2327	2187	0.0223
502	503	500C	Hydrology Field Reconnaissance	4578	0.8671	2187	2065	0.0266
502	506	500H	Hydrology Field Reconnaissance	6884	1.3039	2187	2004	0.0266
503	508	500I	Hydrology Field Reconnaissance	7224	1.3682	2065	1871	0.0269
504	509	500D	Hydrology Field Reconnaissance	9180	1.7386	2129	1878	0.0273
506	507	500H	Hydrology Field Reconnaissance	1485	0.2812	2004	1964	0.0269
507	508	500I	Hydrology Field Reconnaissance	3461	0.6555	1964	1871	0.0269
508	511	500F	200 Scale 2' CI Mapping, sheet 8	7575	1.4347	1871	1678.1	0.0255
508	517	500L	200 Scale 2' CI Mapping, sheet 8	7904	1.4970	1871	1672	0.0252
509	510	500E	200 Scale 2' CI Mapping, sheet 8	5926	1.1223	1878	1720	0.0267
510	511	500F	200 Scale 2' CI Mapping, sheet 8	1447	0.2741	1720	1678.1	0.0289
511	512	500G	200 Scale 2' CI Mapping, sheet 7	5718	1.0829	1678.1	1564.3	0.0199
512	520	500N	Too short to route	795	0.1505	1564.3	1551	0.0167
513	512	500G	200 Scale 2' CI Mapping, sheet 7	3192	0.6045	1621.6	1564.3	0.0180
514	518	500M	200 Scale 2' CI Mapping, sheet 7	1322	0.2504	1664.2	1635.6	0.0216
515	517	500L	200 Scale 2' CI Mapping, sheet 8	2653	0.5025	1733.2	1672	0.0231
515	575	511M	200 Scale 2' CI Mapping, sheet 8	2236	0.4235	1733.2	1679	0.0242
517	518	500M	200 Scale 2' CI Mapping, sheet 7	1745	0.3305	1672	1635.6	0.0209
518	519	500N	200 Scale 2' CI Mapping, sheet 7	3094	0.5859	1635.6	1569	0.0215
519	520	500N	Too short to route	788	0.1492	1569	1551	0.0228
520	576	500N	200 Scale 2' CI Mapping, sheet 6	1203	0.2279	1551	1533	0.0150
521	522	500P	200 Scale 2' CI Mapping, sheet 7	2928	0.5545	1598.6	1537.9	0.0207
522	576	500N	Too short to route	828	0.1569	1537.9	1533	0.0059
524	526	511D	Hydrology Field Reconnaissance	5989	1.1343	2621	2512	0.0182
525	526	511D	Hydrology Field Reconnaissance	1012	0.1917	2533	2512	0.0208
526	527	511F	Hydrology Field Reconnaissance	3129	0.5927	2512	2453	0.0189
527	528	511C	Hydrology Field Reconnaissance	1420	0.2690	2453	2427	0.0183
528	529	511H	Hydrology Field Reconnaissance	6398	1.2117	2427	2332	0.0148
529	530	511G	Too short to route	513	0.0972	2332	2316	0.0312
530	531	511I	Hydrology Field Reconnaissance	5786	1.0958	2316	2194	0.0211
531	532	510B	Hydrology Field Reconnaissance	1524	0.2886	2194	2157	0.0243
531	533	511J	Hydrology Field Reconnaissance	3188	0.6037	2194	2108	0.0270
532	538	510B	Hydrology Field Reconnaissance	7389	1.3994	2157	1960	0.0267
532	578	511K	Too short to route	892	0.1689	2157	2130	0.0303
532	580	511J	Hydrology Field Reconnaissance	4121	0.7805	2157	2042	0.0279
533	579	511J	Hydrology Field Reconnaissance	1524	0.2886	2108	2069	0.0256
534	506	500H	Hydrology Field Reconnaissance	1113	0.2109	2035	2004	0.0278
534	535	511K	Hydrology Field Reconnaissance	9570	1.8125	2035	1800	0.0246
535	515	511L	200 Scale 2' CI Mapping, sheet 8	2814	0.5329	1800	1733.2	0.0237
535	574	511M	Too short to route	530	0.1003	1800	1784.1	0.0300

TABLE 3-5 (continued)

Reach Route Physical Data

Reach Route Concentration Points		In		Length		Elevation (feet)		Slope
Top (1)	Bottom (2)	Subbasin (3)	Cross Section Source (4)	Feet (5)	Miles (6)	Top (7)	Bottom (8)	(ft/ft) (9)
536	545	511O	200 Scale 2' CI Mapping, sheet 5	5132	0.9720	2100	1960	0.0162
537	538	510B	Hydrology Field Reconnaissance	5132	0.9720	2100	1960	0.0273
537	577	510C	Hydrology Field Reconnaissance	4714	0.8928	2100	1969	0.0278
538	540	510C	Hydrology Field Reconnaissance	11259	2.1323	1960	1663.1	0.0264
539	555	509E	Hydrology Field Reconnaissance	4876	0.9235	2008	1869	0.0285
539	577	510C	Hydrology Field Reconnaissance	1292	0.2447	2008	1969	0.0302
540	542	510F	200 Scale 2' CI Mapping, sheet 5	1205	0.2282	1663.1	1642.4	0.0172
541	582	510E	200 Scale 2' CI Mapping, sheet 8	1707	0.3233	1744	1707	0.0218
542	543	510E	200 Scale 2' CI Mapping, sheet 5	1600	0.3030	1642.4	1616	0.0165
543	545	510G	200 Scale 2' CI Mapping, sheet 5	5179	0.9808	1616	1532.1	0.0162
545	546	511P	200 Scale 2' CI Mapping, sheet 6	3093	0.5858	1532.1	1495.1	0.0120
549	550	503C	Hydrology Field Reconnaissance	3454	0.6542	1550	1496	0.0156
552	553	509B	Hydrology Field Reconnaissance	17590	3.3314	2378	1960	0.0238
553	554	509C	Hydrology Field Reconnaissance	2350	0.4451	1960	1898	0.0264
553	556	509F	Hydrology Field Reconnaissance	2769	0.5245	1960	1880	0.0289
554	555	509E	Hydrology Field Reconnaissance	1086	0.2057	1898	1869	0.0267
554	556	509F	Too short to route	629	0.1191	1898	1880	0.0286
555	557	509G	Hydrology Field Reconnaissance	5621	1.0645	1869	1724	0.0258
556	558	509F	Hydrology Field Reconnaissance	4703	0.8907	1880	1779	0.0215
557	559	509H	Hydrology Field Reconnaissance	1207	0.2285	1724	1698	0.0215
557	565	509M	Hydrology Field Reconnaissance	3901	0.7387	1724	1639.5	0.0217
558	557	509G	Hydrology Field Reconnaissance	1564	0.2963	1779	1724	0.0352
558	571	505A	Hydrology Field Reconnaissance	5068	0.9599	1779	1643.6	0.0267
559	560	509I	Hydrology Field Reconnaissance	1062	0.2011	1698	1677	0.0198
559	561	509K	Hydrology Field Reconnaissance	2023	0.3832	1698	1651.9	0.0228
560	561	509K	Hydrology Field Reconnaissance	1065	0.2017	1677	1651.9	0.0236
560	566	509L	200 Scale 2' CI Mapping, sheet 3	3583	0.6785	1677	1604.9	0.0201
561	562	509J	200 Scale 2' CI Mapping, sheet 5	1843	0.3491	1651.9	1615.6	0.0197
562	567	509P	200 Scale 2' CI Mapping, sheet 3	3314	0.6277	1615.6	1561.2	0.0164
563	564	509N	Too short to route	458	0.0868	1579.8	1570.8	0.0196
564	570	509S	200 Scale 2' CI Mapping, sheet 2	5346	1.0125	1570.8	1491.3	0.0149
565	566	509L	200 Scale 2' CI Mapping, sheet 3	1757	0.3327	1639.5	1604.9	0.0197
566	567	509P	200 Scale 2' CI Mapping, sheet 3	2359	0.4467	1604.9	1561.2	0.0185
567	568	509Q	200 Scale 2' CI Mapping, sheet 2	1527	0.2892	1561.2	1540.5	0.0136
568	569	509R	200 Scale 2' CI Mapping, sheet 2	1820	0.3446	1540.5	1510.1	0.0167
569	570	509S	200 Scale 2' CI Mapping, sheet 2	1501	0.2842	1510.1	1491.3	0.0125
571	572	505B	200 Scale 2' CI Mapping, sheet 3	4644	0.8796	1643.6	1560.7	0.0179
573	579	511K	Too short to route	520	0.0985	2080	2069	0.0211
573	580	511K	Hydrology Field Reconnaissance	1455	0.2756	2080	2042	0.0261
574	541	510D	200 Scale 2' CI Mapping, sheet 8	1821	0.3449	1784.1	1744	0.0220
574	582	510E	200 Scale 2' CI Mapping , sheet 8	3140	0.5947	1784.1	1707	0.0245
575	536	511Q	200 Scale 2' CI Mapping, sheet 5	4398	0.8330	1679	1584.6	0.0215

TABLE 3-5 (continued)

Reach Route Physical Data

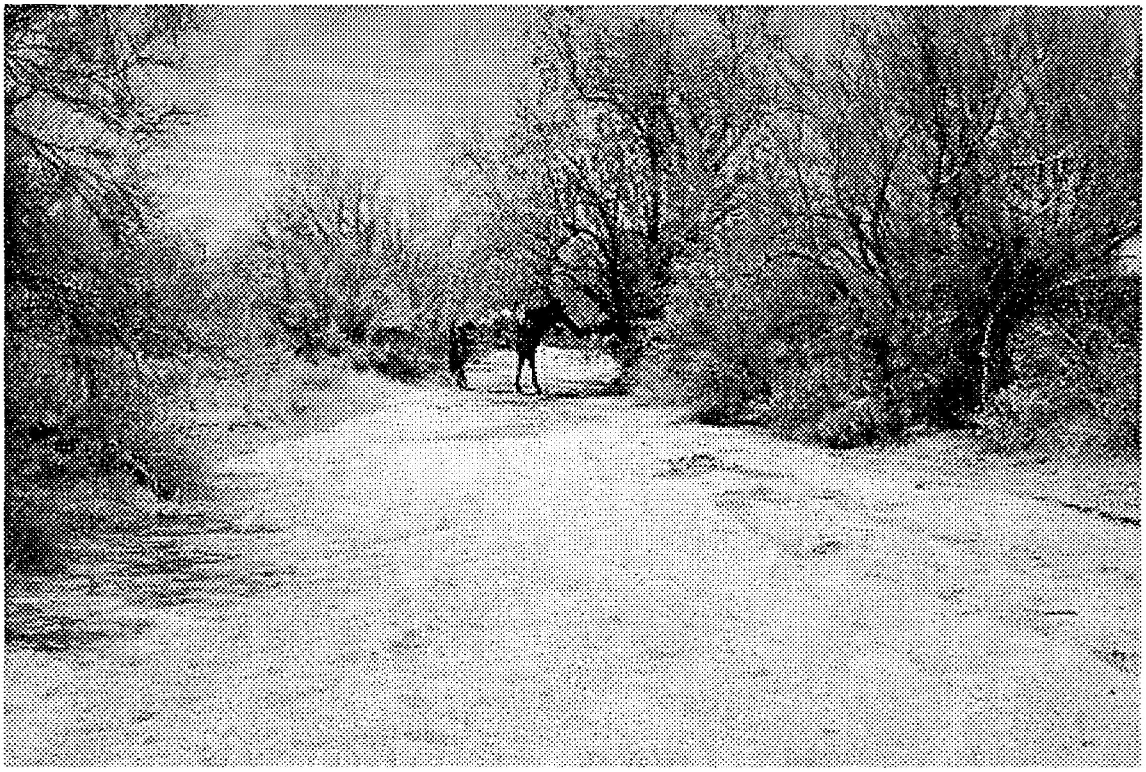
Reach Route Concentration Points		In		Length		Elevation (feet)		Slope
Top (1)	Bottom (2)	Subbasin (3)	Cross Section Source (4)	Feet (5)	Miles (6)	Top (7)	Bottom (8)	(ft/ft) (9)
576	523	500N	200 Scale 2' CI Mapping, sheet 6	1429	0.2706	1533	1495.6	0.0262
577	540	510C	Hydrology Field Reconnaissance	11694	2.2148	1969	1663.1	0.0262
578	533	511J	Too short to route	846	0.1603	2130	2108	0.0260
578	573	511J	Hydrology Field Reconnaissance	1857	0.3518	2130	2080	0.0269
579	534	511J	Hydrology Field Reconnaissance	1310	0.2480	2069	2035	0.0260
580	535	511K	Hydrology Field Reconnaissance	9537	1.8063	2042	1800	0.0254
581	510	500E	North Study Area 200 Scale Mapping	3150	0.5966	1800	1720	0.0254
582	543	510E	200 Scale 2' CI Mapping, sheet 8	3140	0.5947	1707	1616	0.0226

Reach Route n Values

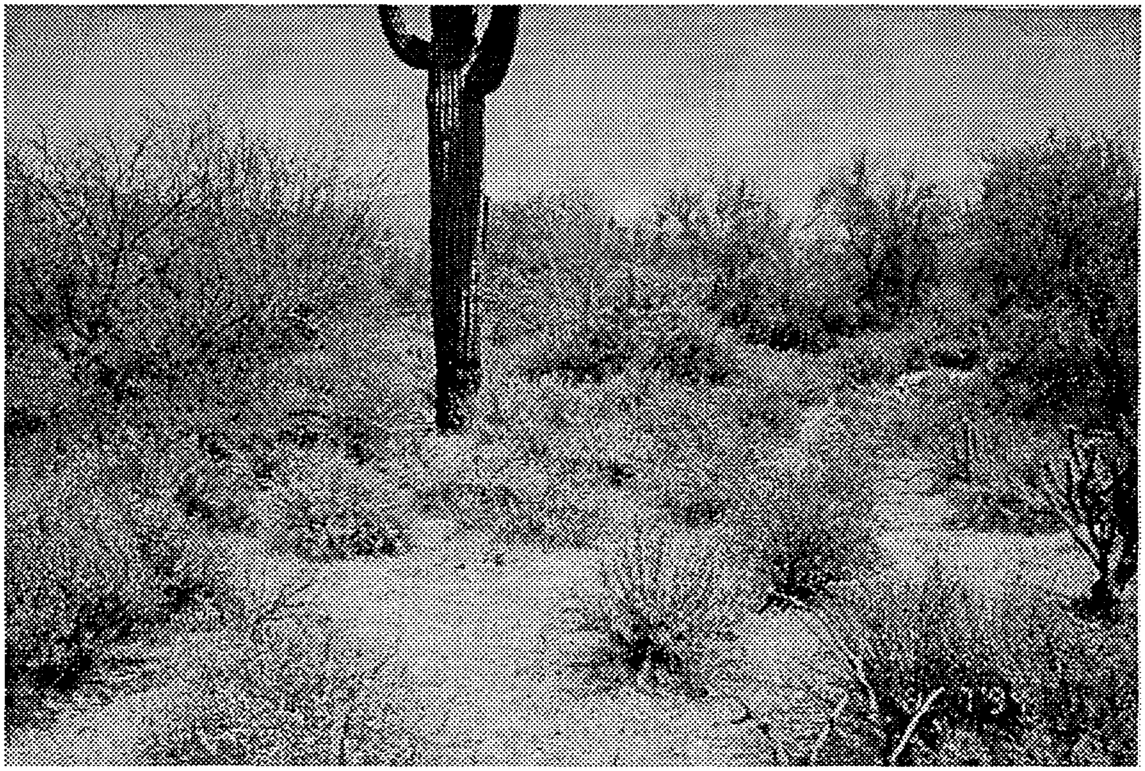
The Mannings n value report prepared for the floodplain delineation portion of this project was used as the basis for n value estimation. The n values selected are representative of the average values for the channel and both overbanks for the reach. The n values selected for each reach are shown on the cross section plots in Appendix C. The n values were checked for reasonableness using USGS values and methodology [6.5:27].

Photographs were taken during the field reconnaissance of the channels upstream and downstream of where field cross sections were taken. Those photographs were used as an aid for n value estimation. The photographs are bound in notebook format and are available for review at the District. The following photographs are an example of a typical wash in the middle reaches of the watershed. Those photographs are taken in reach 556558. Refer to sheet 3 of Exhibit D.

Reach 556558 lies in subbasin 509F and is named FEMA Wash 9. Note the flat, sandy bottom, free of vegetation and the dense vegetation on the channel banks and in the overbank areas. The n values selected for routing computations for this reach are 0.045 for the channel and 0.060 for the overbank areas. These are typical values used for the routing reaches in the upper watershed.



Channel of Reach 556558



Right Overbank of Reach 556558

Hydraulic Computations

General - Routing computations are accomplished using the Normal Depth channel routing option in HEC-1. The eight point cross section for each reach was determined as described above. The other parameters necessary for the hydraulic computations are:

1. Number of routing computation steps;
2. Main time interval; and
3. Channel infiltration losses.

The selection of these parameters, and a check on the reasonableness of the selections, is discussed in the following sections.

Reach Route Step Estimation - Estimation of the number of routing steps for input to the HEC-1 models is an iterative process. The process for estimating the number of steps is as follows:

Step 1: An initial estimate of the number of steps (NSTEPS) for each reach was made, assuming an average velocity of 5 feet per second. The HEC-1 models were run using the assumed values.

Step 2: The reach travel time was calculated by subtracting the time-to-peak (T_p) at the beginning of route operation from the T_p at the end of the route operation. A new estimate of NSTEPS for each reach was then calculated using the reach length and HEC-1 travel time. The HEC-1 models were then rerun using the new NSTEPS estimates.

Step 3: Step 2 was repeated until the travel time from the previous run equaled the travel time from the current run. Convergence normally occurred within three iterations.

The results for the final iteration are shown in columns 15,16 and 17 in Tables 3-6 and 3-7. Table 3-6 contains the results for the 100-year, 6-hour storm and Table 3-7 the results for the 100-year, 24-hour storm. The results in Tables 3-6 and 3-7 reflect the presence of an existing levee in subbasin 510E. Refer to Section 3.4.3 for a discussion of the effects of that levee on routing and peak discharge. The values in those tables are described as follows:

Table 3-6 Description

Column 1: Reach name consisting of the top and bottom concentration point numbers.

Column 2: Average slope of the reach, ft/ft.

Column 3: Length of the reach, in feet.

Column 4: The average n value for the reach cross section, averaged using horizontal width of the left and right overbanks and channel.

Column 5: Discharge, in cfs, entering the top of the reach.

Column 6: Routed discharge, in cfs, calculated by HEC-1 at the bottom of the reach.

Column 7: The average discharge in the reach calculated using columns 5 and 6.

Column 8: Channel base width, in feet.

Column 9: Top width of flow, in feet, calculated using Manning's equation, the average discharge from column 7 and the n values for the left and right overbanks and channel.

Column 10: Depth of flow, in feet, calculated using Manning's equation.

Column 11: Average velocity in the reach, in fps, calculated using Manning's equation.

Column 12: Wave celerity, in fps, calculated by dividing the value in column 3 by that in column 15 and converting the units appropriately. The wave celerity value is accurate to plus or minus one HEC-1 computation time step.

Column 13: Minimum average velocity in the reach, in fps, assuming the reach travel time calculated using HEC-1 is accurate to within plus or minus one time step, calculated as follows:

$$[13] = [3]/(([15] + 0.0167)(3600)(1.67))$$

where: 0.0167 is the main time interval, in hours.

3600 is the conversion factor from hours to seconds.

1.67 is the factor relating wave celerity to average velocity.

Wave celerity for subcritical turbulent streams can be estimated to range from 1.33 to 1.67 times the average velocity [12].

Column 14: Maximum average velocity in the reach, in fps, calculated as follows:

$$[14] = [3] /(([15] - 0.0167)(3600)(1.33))$$

Column 15: Travel time through the reach, in hours, calculated using HEC-1.

Column 16: Value of NSTEPS from the HEC-1 output file calculated as follows:

$$[16] = [15]/0.0167$$

where: 0.0167 is the main time interval, in hours.

The check for reasonableness of routing results included the following:

1. Checking the HEC-1 output file for warning or error messages, and then evaluating those messages (refer to Section 3.4.2).

2. Checking columns 5 and 6 to verify that peak discharges were attenuated and did not increase.

3. Checking the average velocity in column 11 to determine if it falls within, or reasonably close to, the range defined by columns 13 and 14.

4. Checking top width and depth of flow for reasonableness against the cross section plots in Appendix C.

The results presented in Tables 3-6 and 3-7 are found to be reasonable.

Computation Time Interval and Minimum Reach Length - The computation time interval (CTI) should lie within the range of 0.1 and 0.25 times the smallest T_c value. The shortest T_c is 0.171 hours, for the 100-year, 6-storm, with many subbasins having T_c's in the range of 0.200 to 0.400 hours. A CTI of 0.1 times 0.171 is 0.0171 hours or 1 minute. Since this subbasin (5090) is small, about 24 acres, and is not representative of the majority of the subbasins, a larger CTI could be used. However, a CTI value of 1 minute was selected for the 6-hour duration storm in order to resolve routing warning errors given by HEC-1. Refer to Section 3.4.6 for more details. The total number of hydrograph ordinates used for the 6-hour storm is 1150, which provides a model time duration of 19.17 hours.

TABLE 3-6
Reach Route Hydraulic Data for the 100-year, 6-hour Storm
Existing Condition, with Levee

	Reach						Manning's Equation				Computed Using HEC-1 Summary Data					NSTEPS
Routing Reach	Slope in ft/ft	Length in feet	Average n value	Discharge, in cfs Top	Discharge, in cfs Bottom	Discharge, in cfs Average	Channel Base Width in feet	Flow Top Width in feet	Flow Depth in feet	Channel Velocity in fps	Wave Celerity in fps	Velocity Range in fps Min.	Velocity Range in fps Max.	Travel Time in hours	NSTEPS Computed	NSTEPS from HEC-1 Input File
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
501502	0.022	6289	0.068	421	365	393	4.0	243.9	3.0	3.9	2.9	1.7	2.3	0.6000	36	36
502506	0.027	6884	0.044	192	189	191	10.0	23.1	1.8	7.3	8.8	4.9	7.2	0.2167	13	13
502503	0.027	4578	0.040	299	294	297	35.0	60.5	1.5	5.7	6.9	3.8	5.7	0.1833	11	11
503508	0.027	7224	0.065	395	356	376	14.0	200.9	1.8	4.1	3.6	2.1	2.8	0.5500	33	33
504509	0.027	9180	0.039	162	155	159	24.0	95.2	0.8	4.3	5.9	3.4	4.6	0.4333	26	26
506507	0.027	1485	0.052	265	264	265	10.0	34.6	2.1	7.8	12.4	4.9	18.6	0.0333	2	2
507508	0.027	3461	0.065	279	273	276	14.0	155.1	1.6	4.1	3.6	2.0	2.9	0.2667	16	16
508517	0.025	7904	0.056	251	249	250	20.0	74.2	1.6	5.8	2.9	1.7	2.3	0.7500	45	45
508511	0.026	7575	0.058	277	271	274	25.0	96.5	1.3	4.8	2.7	1.6	2.1	0.7667	46	46
509510	0.027	5926	0.042	371	361	366	10.0	31.4	2.4	8.7	9.9	5.4	8.3	0.1667	10	10
510511	0.029	1447	0.050	185	184	185	53.0	84.0	0.8	3.8	4.8	2.4	4.5	0.0833	5	5
511512	0.020	5718	0.066	509	492	501	35.0	261.4	1.7	3.6	3.1	1.8	2.4	0.5167	31	31
513512	0.018	3192	0.045	219	201	210	18.0	183.8	0.9	2.7	3.3	1.9	2.7	0.2667	16	16
514518	0.022	1322	0.045	204	199	202	21.0	57.8	1.3	4.3	5.5	2.6	5.5	0.0667	4	4
515575	0.024	2236	0.045	49	49	49	7.0	16.9	1.1	4.0	9.3	4.5	9.3	0.0667	4	4
515517	0.023	2653	0.045	166	159	163	13.0	180.1	0.7	2.7	2.9	1.7	2.4	0.2500	15	15
517518	0.021	1745	0.045	424	422	423	45.0	67.1	1.5	5.4	7.3	3.5	7.3	0.0667	4	3
518519	0.022	3094	0.061	462	454	458	27.0	142.1	1.4	4.1	4.3	2.4	3.5	0.2000	12	12
520576	0.015	1203	0.043	919	916	918	75.0	243.8	1.4	4.5	6.7	3.0	7.5	0.0500	3	3
521522	0.021	2928	0.051	182	175	179	23.0	103.8	1.0	3.2	3.8	2.1	3.1	0.2167	13	13
524526	0.018	5989	0.068	941	871	906	10.0	380.9	2.0	3.0	3.6	2.1	2.8	0.4667	28	28
525526	0.021	1012	0.068	948	943	946	10.0	378.6	2.0	3.2	3.4	1.7	3.2	0.0833	5	5
526527	0.019	3129	0.069	1594	1562	1578	10.0	471.8	2.4	3.4	4.3	2.4	3.6	0.2000	12	12
527528	0.018	1420	0.069	1780	1764	1772	10.0	494.4	2.5	3.4	3.9	2.0	3.6	0.1000	6	6
528529	0.015	6398	0.058	2229	2180	2205	27.0	293.5	2.6	5.2	7.6	4.3	6.2	0.2333	14	14
530531	0.021	5786	0.060	2274	2238	2256	67.3	437.7	2.1	5.7	6.4	3.6	5.2	0.2500	15	15
531532	0.024	1524	0.060	1694	1687	1691	62.0	332.8	2.0	5.8	6.3	3.0	6.4	0.0667	4	4

TABLE 3-6 (continued)
Reach Route Hydraulic Data for the 100-year, 6-hour Storm
Existing Condition, with Levee

Routing Reach	Reach						Manning's Equation				Computed Using HEC-1 Summary Data					NSTEPS from HEC-1 Input File
	Slope in ft/ft	Length in feet	Average n value	Discharge, in cfs			Channel Base Width in feet	Flow Top Width in feet	Flow Depth in feet	Channel Velocity in fps	Wave Celerity in fps	Velocity Range in fps		Travel Time in hours	NSTEPS Computed	
				Top	Bottom	Average						Min.	Max.			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
531533	0.027	3188	0.042	528	523	526	35.0	109.2	1.4	5.8	8.9	4.5	8.0	0.1000	6	6
532580	0.028	4121	0.046	341	339	340	60.0	104.0	1.1	5.3	7.6	4.1	6.5	0.1500	9	9
532538	0.027	7389	0.059	877	866	872	19.0	185.7	1.7	6.1	6.8	3.9	5.4	0.3000	18	18
533579	0.026	1524	0.044	757	754	756	35.0	122.8	1.7	6.4	8.5	3.8	9.5	0.0500	3	3
534506	0.028	1113	0.050	240	239	240	10.0	30.4	2.0	7.8	9.3	3.7	13.9	0.0333	2	2
534535	0.025	9570	0.041	560	550	555	35.0	73.2	1.9	6.7	9.4	5.3	7.5	0.2833	17	17
535515	0.024	2814	0.045	158	156	157	40.0	53.4	0.9	4.2	6.7	3.5	5.9	0.1167	7	7
536545	0.016	3241	0.059	703	696	700	15.0	272.2	1.4	3.5	4.9	2.7	4.1	0.1833	11	11
537538	0.027	5132	0.040	248	237	243	24.0	85.9	1.1	4.6	6.1	3.4	4.9	0.2333	14	14
537577	0.028	4714	0.045	746	735	741	36.0	111.9	1.8	6.9	8.7	4.7	7.4	0.1500	9	9
538540	0.026	11259	0.068	895	876	886	8.0	233.0	2.1	4.2	5.1	3.0	3.9	0.6167	37	37
539577	0.030	1292	0.040	295	292	294	43.0	143.8	0.9	4.3	5.4	2.6	5.4	0.0667	4	4
539555	0.029	4876	0.042	158	152	155	25.0	87.8	0.8	4.0	5.1	2.9	4.1	0.2667	16	16
540542	0.017	1205	0.059	1288	1282	1285	30.0	286.5	2.5	4.6	5.0	2.4	5.0	0.0667	4	4
541543	0.022	5727	0.055	208	205	207	18.0	108.7	1.1	3.9	4.5	2.6	3.6	0.3500	21	21
542543	0.017	1600	0.030	1300	1294	1297	35.0	126.5	2.2	8.5	13.3	5.3	20.1	0.0333	2	2
543545	0.016	5179	0.030	1323	1311	1317	72.0	74.0	2.0	9.6	12.3	6.5	10.8	0.1167	7	7
545546	0.012	3093	0.051	1592	1581	1587	57.0	253.3	2.3	5.1	7.4	3.9	6.5	0.1167	7	7
549550	0.016	3454	0.051	458	445	452	10.0	29.8	3.8	6.5	9.6	4.9	8.7	0.1000	6	6
552553	0.024	17590	0.061	674	626	650	11.0	77.7	2.7	6.8	7.3	4.3	5.7	0.6667	40	40
553556	0.029	2769	0.062	367	365	366	13.0	104.7	1.6	4.8	5.8	3.1	5.0	0.1333	8	8
553554	0.026	2350	0.060	411	408	410	16.0	234.1	1.5	4.2	4.4	2.3	3.7	0.1500	9	9
554555	0.027	1086	0.040	149	148	149	16.0	60.8	1.0	4.4	6.0	2.7	6.8	0.0500	3	3
555557	0.026	5621	0.045	394	392	393	25.0	52.1	1.7	7.2	10.4	5.6	8.8	0.1500	9	9
556558	0.022	4703	0.058	618	613	616	25.0	106.0	2.1	6.8	7.1	3.9	5.9	0.1833	11	11
557565	0.022	3901	0.059	610	606	608	7.0	169.9	1.9	4.2	5.0	2.8	4.1	0.2167	13	13
557559	0.022	1207	0.061	144	143	144	19.0	149.4	0.9	2.7	2.5	1.3	2.2	0.1333	8	8
558571	0.027	5068	0.056	263	260	262	21.0	100.3	1.3	4.9	5.6	3.2	4.5	0.2500	15	15

TABLE 3-6 (continued)
Reach Route Hydraulic Data for the 100-year, 6-hour Storm
Existing Condition, with Levee

Routing Reach (1)	Reach: Slope in ft/ft (2)	Reach: Length in feet (3)	Reach: Average n value (4)	Reach: Discharge, in cfs: Top (5)	Reach: Discharge, in cfs: Bottom (6)	Reach: Discharge, in cfs: Average (7)	Manning's Equation: Channel Base Width in feet (8)	Manning's Equation: Flow Top Width in feet (9)	Manning's Equation: Flow Depth in feet (10)	Manning's Equation: Channel Velocity in fps (11)	Computed Using HEC-1 Summary Data: Wave Celerity in fps (12)	Computed Using HEC-1 Summary Data: Velocity Range in fps: Min. (13)	Computed Using HEC-1 Summary Data: Velocity Range in fps: Max. (14)	Computed Using HEC-1 Summary Data: Travel Time in hours (15)	Computed Using HEC-1 Summary Data: NSTEPS Computed (16)	NSTEPS from HEC-1 Input File (17)
558557	0.035	1564	0.046	348	347	348	45.0	71.8	1.2	6.6	8.7	3.9	9.8	0.0500	3	3
559561	0.023	2023	0.040	76	76	76	29.0	39.0	0.7	3.8	4.8	2.5	4.2	0.1167	7	7
559560	0.020	1062	0.058	116	115	116	17.0	87.3	1.0	3.3	4.4	2.1	4.4	0.0667	4	4
560561	0.024	1065	0.054	40	40	40	3.8	30.0	1.0	4.0	4.4	2.1	4.4	0.0667	4	4
560566	0.020	3583	0.045	86	85	86	12.0	23.1	1.2	4.3	6.0	3.3	5.0	0.1667	10	10
561562	0.020	1843	0.030	128	128	128	11.0	17.8	1.4	6.9	10.2	4.6	11.5	0.0500	3	3
562567	0.016	3314	0.030	199	198	199	13.0	50.5	1.3	5.3	7.9	4.1	6.9	0.1167	7	7
564570	0.015	5346	0.051	347	326	337	10.0	43.5	2.5	5.8	7.4	4.1	6.1	0.2000	12	12
565566	0.020	1757	0.030	657	655	656	25.0	68.9	1.8	8.0	14.7	5.8	22.0	0.0333	2	2
566567	0.019	2359	0.030	762	760	761	40.0	90.8	1.6	7.5	13.1	5.9	14.8	0.0500	3	3
567568	0.014	1527	0.038	876	875	876	36.0	77.9	3.0	7.1	8.5	3.8	9.6	0.0500	3	3
568569	0.017	1820	0.063	915	911	913	20.0	288.2	3.2	4.1	3.8	2.0	3.3	0.1333	8	8
569570	0.013	1501	0.051	920	918	919	60.0	162.4	2.1	4.3	6.3	3.0	6.3	0.0667	4	4
571572	0.018	4644	0.030	315	311	313	42.0	65.3	1.1	5.9	8.6	4.6	7.3	0.1500	9	9
573580	0.026	1455	0.049	179	179	179	21.0	61.3	1.2	5.1	6.1	2.9	6.1	0.0667	4	4
574575	0.024	4351	0.045	685	680	683	60.0	87.7	1.6	6.2	9.1	4.8	7.8	0.1333	8	8
574541	0.022	1821	0.045	211	208	210	78.0	146.0	0.7	3.2	5.1	2.6	4.6	0.1000	6	6
575536	0.022	4398	0.030	705	702	704	21.0	58.7	2.1	9.1	12.2	6.3	11.0	0.1000	6	6
576523	0.026	1429	0.050	1027	1025	1026	35.0	84.3	2.5	9.4	7.9	3.6	9.0	0.0500	3	3
577540	0.026	11694	0.048	908	881	895	36.0	127.1	1.9	7.0	8.5	4.9	6.7	0.3833	23	23
578573	0.027	1857	0.050	234	232	233	21.0	67.8	1.3	5.4	6.2	3.1	5.8	0.0833	5	5
579534	0.026	1310	0.057	807	803	805	17.3	298.5	1.6	5.1	5.5	2.6	5.5	0.0667	4	4
580535	0.025	9537	0.058	518	511	515	28.0	122.5	1.5	5.2	6.6	3.8	5.2	0.4000	24	24
581510	0.025	3150	0.049	208	206	207	30.0	61.5	1.1	5.4	7.5	3.9	6.6	0.1167	7	7

TABLE 3-7
Reach Route Hydraulic Data for the 100-year, 24-hour Storm
Existing Condition, with Levee

Routing Reach (1)	Reach: Slope in ft/ft (2)	Reach: Length in feet (3)	Reach: Average n value (4)	Reach: Discharge, in cfs: Top (5)	Reach: Discharge, in cfs: Bottom (6)	Reach: Discharge, in cfs: Average (7)	Manning's Equation: Channel Base Width in feet (8)	Manning's Equation: Flow Top Width in feet (9)	Manning's Equation: Flow Depth in feet (10)	Manning's Equation: Channel Velocity in fps (11)	Computed Using HEC-1 Summary Data: Wave Celerity in fps (12)	Computed Using HEC-1 Summary Data: Velocity Range in fps: Min. (13)	Computed Using HEC-1 Summary Data: Velocity Range in fps: Max. (14)	Computed Using HEC-1 Summary Data: Travel Time in hours (15)	Computed Using HEC-1 Summary Data: NSTEPS Computed (16)	NSTEPS from HEC-1 Input File (17)
501502	0.022	6289	0.066	280	240	260	4.0	148.2	2.7	4.8	3.7	2.1	3.0	0.4667	14	14
502506	0.027	6884	0.042	166	164	165	10.0	21.0	1.7	7.0	9.6	4.9	8.6	0.2000	6	6
502503	0.027	4578	0.040	239	233	236	35.0	57.7	1.3	5.3	7.6	3.8	7.2	0.1667	5	5
503508	0.027	7224	0.063	297	271	284	14.0	160.2	1.6	4.1	3.8	2.1	3.0	0.5333	16	16
504509	0.027	9180	0.040	193	181	187	24.0	101.0	0.9	4.5	5.9	3.3	4.8	0.4333	13	13
506507	0.027	1485	0.053	277	275	276	10.0	36.3	2.1	7.8	12.4	3.7	18.6	0.0333	1	1
507508	0.027	3461	0.065	346	324	335	14.0	177.4	1.7	4.0	4.1	2.2	3.6	0.2333	7	7
508517	0.025	7904	0.058	303	291	297	20.0	87.6	1.7	5.7	5.1	2.8	4.1	0.4333	13	13
508511	0.026	7575	0.060	380	357	369	25.0	114.1	1.4	5.0	5.3	2.9	4.3	0.4000	12	12
509510	0.027	5926	0.040	249	236	243	10.0	23.4	2.0	7.6	12.3	5.9	12.4	0.1333	4	4
510511	0.029	1447	0.051	216	215	216	53.0	87.1	0.9	4.0	6.0	2.4	9.1	0.0667	2	2
511512	0.020	5718	0.067	670	647	659	35.0	312.8	1.9	3.5	3.0	1.7	2.4	0.5333	16	16
513512	0.018	3192	0.045	144	130	137	18.0	159.0	0.7	2.4	3.3	1.8	2.9	0.2667	8	8
514518	0.022	1322	0.045	124	121	123	21.0	50.0	1.0	3.8	5.5	2.2	8.3	0.0667	2	2
515575	0.024	2236	0.045	61	57	59	7.0	17.8	1.2	4.3	9.3	3.7	14.0	0.0667	2	2
515517	0.023	2653	0.045	223	204	214	13.0	195.2	0.8	2.9	3.7	1.9	3.3	0.2000	6	6
517518	0.021	1745	0.045	517	511	514	45.0	69.6	1.6	5.8	14.6	4.4	21.9	0.0333	1	1
518519	0.022	3094	0.062	550	542	546	27.0	150.9	1.5	4.2	4.3	2.2	3.9	0.2000	6	6
520576	0.015	1203	0.044	1247	1243	1245	75.0	270.0	1.6	4.9	10.0	3.0	15.1	0.0333	1	1
521522	0.021	2928	0.050	120	114	117	23.0	86.3	0.9	2.8	3.5	1.8	3.1	0.2333	7	7
524526	0.018	5989	0.068	704	638	671	10.0	340.7	1.8	2.8	3.1	1.8	2.5	0.5333	16	16
525526	0.021	1012	0.068	792	788	790	10.0	351.8	1.9	3.1	2.8	1.3	3.2	0.1000	3	3
526527	0.019	3129	0.069	1472	1432	1452	10.0	456.1	2.3	3.4	3.7	2.0	3.3	0.2333	7	7
527528	0.018	1420	0.069	1709	1686	1698	10.0	487.6	2.5	3.4	3.9	1.8	4.4	0.1000	3	3
528529	0.015	6398	0.058	2257	2188	2223	27.0	293.5	2.6	5.2	6.7	3.5	5.7	0.2667	8	8
530531	0.021	5786	0.060	2387	2337	2362	67.3	445.9	2.1	5.7	6.0	3.2	5.2	0.2667	8	8
531532	0.024	1524	0.060	1779	1769	1774	62.0	337.3	2.0	5.8	6.3	2.5	9.5	0.0667	2	2

TABLE 3-7 (continued)
Reach Route Hydraulic Data for the 100-year, 24-hour Storm
Existing Condition, with Levee

Routing Reach (1)	Reach: Slope in ft/ft (2)	Reach: Length in feet (3)	Reach: Average n value (4)	Reach: Discharge, in cfs: Top (5)	Reach: Discharge, in cfs: Bottom (6)	Reach: Discharge, in cfs: Average (7)	Manning's Equation: Channel Base Width in feet (8)	Manning's Equation: Flow Top Width in feet (9)	Manning's Equation: Flow Depth in feet (10)	Manning's Equation: Channel Velocity in fps (11)	Computed Using HEC-1 Summary Data: Wave Celerity in fps (12)	Computed Using HEC-1 Summary Data: Velocity Range in fps: Min. (13)	Computed Using HEC-1 Summary Data: Velocity Range in fps: Max. (14)	Computed Using HEC-1 Summary Data: Travel Time in hours (15)	Computed Using HEC-1 Summary Data: NSTEPS Computed (16)	NSTEPS from HEC-1 Input File (17)
531533	0.027	3188	0.042	551	544	548	35.0	110.1	1.4	5.9	8.9	4.0	10.0	0.1000	3	3
532580	0.028	4121	0.046	353	350	352	60.0	106.4	1.1	5.3	6.9	3.4	6.5	0.1667	5	5
532538	0.027	7389	0.059	921	901	911	19.0	190.8	1.8	6.1	6.8	3.7	5.8	0.3000	9	9
533579	0.026	1524	0.044	791	788	790	35.0	125.4	1.7	6.5	6.3	2.5	9.5	0.0667	2	2
534506	0.028	1113	0.051	251	250	251	10.0	32.1	2.0	7.9	9.3	2.8	13.9	0.0333	1	1
534535	0.025	9570	0.042	586	571	579	35.0	76.9	2.0	6.8	10.0	5.3	8.6	0.2667	8	8
535515	0.024	2814	0.045	166	164	165	40.0	53.7	0.9	4.2	7.8	3.5	8.8	0.1000	3	3
536545	0.016	3241	0.059	743	735	739	15.0	275.7	1.4	3.6	4.5	2.3	4.1	0.2000	6	6
537538	0.027	5132	0.040	175	165	170	24.0	76.3	1.0	4.2	5.3	2.8	4.6	0.2667	8	8
537577	0.028	4714	0.043	631	619	625	36.0	101.2	1.7	6.6	9.8	4.7	9.8	0.1333	4	4
538540	0.026	11259	0.068	930	900	915	8.0	235.8	2.1	4.3	5.2	3.0	4.1	0.6000	18	18
539577	0.030	1292	0.040	211	208	210	43.0	129.0	0.8	3.9	5.4	2.1	8.1	0.0667	2	2
539555	0.029	4876	0.040	113	108	111	25.0	75.4	0.7	3.7	4.5	2.4	3.8	0.3000	9	9
540542	0.017	1205	0.059	1415	1407	1411	30.0	292.2	2.6	4.7	5.0	2.0	7.6	0.0667	2	2
541543	0.022	5727	0.055	220	215	218	18.0	111.5	1.1	3.9	4.8	2.6	4.0	0.3333	10	10
542543	0.017	1600	0.030	1430	1424	1427	35.0	127.3	2.3	8.8	13.3	4.0	20.1	0.0333	1	1
543545	0.016	5179	0.030	1543	1530	1537	72.0	74.1	2.1	10.2	14.4	6.5	16.2	0.1000	3	3
545546	0.012	3093	0.052	1996	1982	1989	57.0	259.5	2.5	5.4	6.4	3.1	6.5	0.1333	4	4
549550	0.016	3454	0.050	292	283	288	10.0	25.1	3.1	5.6	7.2	3.4	7.2	0.1333	4	4
552553	0.024	17590	0.060	498	458	478	11.0	66.6	2.4	6.6	7.3	4.2	5.8	0.6667	20	20
553556	0.029	2769	0.062	305	301	303	13.0	97.1	1.4	4.6	5.8	2.8	5.8	0.1333	4	4
553554	0.026	2350	0.059	344	339	342	16.0	212.8	1.4	4.1	3.9	2.0	3.7	0.1667	5	5
554555	0.027	1086	0.040	120	119	120	16.0	56.7	0.9	4.1	4.5	1.8	6.8	0.0667	2	2
555557	0.026	5621	0.043	387	371	379	25.0	48.6	1.6	7.1	11.7	5.6	11.7	0.1333	4	4
556558	0.022	4703	0.055	528	521	525	25.0	88.4	2.0	6.9	6.5	3.4	5.9	0.2000	6	6
557565	0.022	3901	0.058	591	584	588	7.0	165.7	1.8	4.2	5.4	2.8	4.9	0.2000	6	7
557559	0.022	1207	0.061	131	129	130	19.0	143.4	0.9	2.6	2.5	1.2	2.5	0.1333	4	4
558571	0.027	5068	0.053	223	219	221	21.0	82.5	1.2	4.8	6.0	3.2	5.3	0.2333	7	7
558557	0.035	1564	0.045	308	307	308	45.0	68.5	1.2	6.4	13.0	3.9	19.6	0.0333	1	1
559561	0.023	2023	0.040	70	69	70	29.0	38.5	0.7	3.7	4.2	2.0	4.2	0.1333	4	4
559560	0.020	1062	0.057	108	107	108	17.0	83.6	1.0	3.3	4.4	1.8	6.7	0.0667	2	3
560561	0.024	1065	0.054	39	39	39	3.8	28.9	1.0	4.0	4.4	1.8	6.7	0.0667	2	2

TABLE 3-7 (continued)
Reach Route Hydraulic Data for the 100-year, 24-hour Storm
Existing Condition, with Levee

	Reach						Manning's Equation				Computed Using HEC-1 Summary Data					NSTEPS
Routing Reach	Slope in ft/ft	Length in feet	Average n value	Discharge, in cfs			Channel Base Width in feet	Flow Top Width in feet	Flow Depth in feet	Channel Velocity in fps	Wave Celerity in fps	Velocity Range in fps		Travel Time in hours	NSTEPS Computed	from HEC-1 Input File
				Top	Bottom	Average						Min.	Max.			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
560566	0.020	3583	0.045	82	80	81	12.0	22.8	1.2	4.2	6.0	3.0	5.6	0.1667	5	5
561562	0.020	1843	0.030	122	121	122	11.0	17.7	1.3	6.8	15.4	4.6	23.1	0.0333	1	2
562567	0.016	3314	0.030	189	188	189	13.0	49.6	1.2	5.3	6.9	3.3	6.9	0.1333	4	4
564570	0.015	5346	0.046	209	195	202	10.0	32.4	2.1	5.0	7.4	3.8	6.7	0.2000	6	6
565566	0.020	1757	0.030	637	635	636	25.0	68.4	1.8	8.0	7.3	2.9	11.0	0.0667	2	2
566567	0.019	2359	0.030	746	742	744	40.0	90.2	1.6	7.4	9.8	3.9	14.8	0.0667	2	2
567568	0.014	1527	0.037	958	955	957	36.0	84.4	3.1	7.2	12.7	3.8	19.1	0.0333	1	2
568569	0.017	1820	0.063	1005	993	999	20.0	298.8	3.3	4.1	3.8	1.8	3.8	0.1333	4	4
569570	0.013	1501	0.052	1008	1001	1005	60.0	172.6	2.2	4.4	4.2	1.9	4.7	0.1000	3	2
571572	0.018	4644	0.030	302	294	298	42.0	64.9	1.0	5.9	7.7	3.9	7.3	0.1667	5	5
573580	0.026	1455	0.050	188	186	187	21.0	65.2	1.2	5.1	6.1	2.4	9.1	0.0667	2	2
574575	0.024	4351	0.045	717	710	714	60.0	88.4	1.6	6.3	9.1	4.3	9.1	0.1333	4	4
574541	0.022	1821	0.045	223	220	222	78.0	147.0	0.7	3.2	5.1	2.3	5.7	0.1000	3	3
575536	0.022	4398	0.030	741	737	739	21.0	59.2	2.1	9.3	18.3	7.3	27.6	0.0667	2	2
576523	0.026	1429	0.054	1351	1349	1350	35.0	111.0	2.8	9.5	11.9	3.6	17.9	0.0333	1	1
577540	0.026	11694	0.046	812	772	792	36.0	118.2	1.8	6.8	8.1	4.5	6.7	0.4000	12	12
578573	0.027	1857	0.051	247	244	246	21.0	69.7	1.3	5.5	7.7	3.1	11.6	0.0667	2	2
579534	0.026	1310	0.060	845	839	842	17.3	319.2	1.7	5.0	5.5	2.2	8.2	0.0667	2	2
580535	0.025	9537	0.058	536	526	531	28.0	123.6	1.5	5.2	6.6	3.7	5.4	0.4000	12	12
581510	0.025	3150	0.050	267	265	266	30.0	66.7	1.2	5.6	6.6	3.1	6.6	0.1333	4	4

The shortest T_c for the 100-year, 24-hour storm is 0.213 hours, also for subbasin 5090. Many of the subbasins have T_c's in the range of 0.3 to 0.5 hours. A CTI of 0.1 times 0.213 is 0.0213 hours or 1.3 minutes. A CTI value of 2 minutes was selected for the 24-hour duration storm. The total number of hydrograph ordinates used for the 24-hour storm is 1500, which provides a model time duration of 50 hours.

Assuming an average velocity in any given routing reach of 8 fps, the minimum length of a reach (using NMIN for a 24-hour storm) is estimated as follows:

$$L_{min} = (NMIN)\ (V) = (2)\ (60)\ (8\ fps) = 960\ feet.$$

In general, routing reaches of less than 1000 feet are not included in the HEC-1 models. Routing reaches that are considered too short to route are noted in Table R-1.

Channel Infiltration Losses - Channel infiltration losses are included in the routing computations. There is no stream flow gage data available for this watershed to provide guidance in selection of loss rates; however, it is apparent from the field reconnaissance that transmission losses could be significant for this watershed. The soil types present in the channel and overbanks for each reach were listed and the dominant soil identified by examining Exhibit B. The XKSAT value of the selected soil type is used as an estimate of the steady state loss rate. The rate selected for each routing reach is listed in Table 3-8.

TABLE 3-8

Transmission Loss Rates for each Routing Reach

Routing Reach (1)	Transmission Loss Rate cfs/acre (2)	Routing Reach (1)	Transmission Loss Rate cfs/acre (2)
501502	0.12	540542	0.15
502503	0.33	541582	0.07
502506	0.33	542543	0.07
503508	0.33	543545	0.33
504509	0.33	545546	0.04
506507	0.62	549550	0.09
507508	0.56	552553	0.18
508511	0.31	553554	0.07
508517	0.33	553556	0.07
509510	0.33	554555	0.07
510511	0.33	555557	0.07
511512	0.33	556558	0.15
513512	0.33	557559	0.07
514518	0.33	557565	0.07
515517	0.33	558557	0.15
515575	0.14	558571	0.15
517518	0.33	559560	0.07
518519	0.33	559561	0.15
520576	0.04	560561	0.07
521522	0.06	560566	0.15
524526	0.07	561562	0.07
525526	0.07	562567	0.15
526527	0.07	564570	0.12
527528	0.62	565566	0.15
528529	0.62	566567	0.07
530531	0.43	567568	0.10
531532	0.62	568569	0.26
531533	0.62	569570	0.07
532538	0.12	571572	0.10
532580	0.07	573580	0.62
533579	0.62	574541	0.39
534506	0.62	574582	0.39
535515	0.33	575536	0.07
536545	0.24	576523	0.26
537538	0.08	577540	0.13
537577	0.23	578573	0.62
538540	0.10	579534	0.62
539555	0.07	580535	0.07
539577	0.07	582543	0.07
534535	0.39		

3.2.2.3 Storage Route Parameters

There are no storage routing calculations done as a part of this study. There are existing golf course ponds, small detention and retention structures, and a gravel pit that were considered for modeling. The golf course ponds are situated to minimize the amount of runoff which can enter the ponds. Those ponds do not have a significant effect on peak discharge. The detention and retention basins present on the watershed also do not have a significant effect on 100-year peak discharges. Major detention facilities are planned in the urbanizing areas, but are not included in the models because as-builts are not available. The existing gravel pit at concentration point C522 does have significant storage volume. The effects of that pit are not included in the model for floodplain administration and regulatory reasons.

3.2.3 Statistical Parameters

There are no statistical data available for this watershed other than regional precipitation data and minimal gage data for a few watersheds that may be hydrologically comparable. The precipitation depth-duration-frequency statistics used for this study are derived from the NOAA Atlas 2 for Arizona [22]. Deficiencies of that Atlas are recognized, and a revised precipitation-frequency analysis is currently underway by the National Oceanic and Atmospheric Administration. The results of the revised Atlas may differ from the precipitation statistics that are used herein; however, until the revised Atlas or an equally accepted presentation of precipitation statistics is available, the current Atlas precipitation-frequency statistics are recommended for use.

3.2.4 Precipitation

3.2.4.1 Rainfall Distributions

The storm frequencies specified for analysis in this study are the 100-year, 6-hour and 24-hour duration storms. The rainfall distributions, based on watershed area, for the 6-hour duration storm are furnished by the District and are listed in Section 2.4.2 of the Design Manual. Each precipitation pattern is valid for a certain watershed area. The five precipitation patterns and corresponding watershed areas are input to the HEC-1 model using the JD record option. The 24-hour rainfall distribution used for this study is the SCS Type II, in accordance with the requirements set forth in the Design Manual.

3.2.4.2 Precipitation Data

Point precipitation values used for this study are derived from the isopluvial maps in the Design Manual. Refer to Figures 3-3 and 3-4 for a depiction of the isopluvials for the 100-year, 6-hour and 24-hour storms, respectively, overlaid on the watershed. Those figures are used to estimate an average point precipitation value for the entire watershed for both storms. The point precipitation values used for this study are listed in Table 3-9.

TABLE 3-9

Point Precipitation Values for Rio Verde South

Storm Frequency and Duration (1)	Point Precipitation inches (2)
100-year, 6-hour	3.4
100-year, 24-hour	4.4

3.2.4.3 Aerial Precipitation Reduction

The precipitation reduction for the 6-hour storms is based upon the depth-area curve developed for the historic storm of 1954 over the Queen Creek, Arizona area, as developed by the U.S. Army Corps of Engineers in 1974. That depth-area curve is listed in the Design Manual.

The precipitation reduction factors used for the 24-hour storms are derived from information contained in *NOAA Technical Memorandum NWS HYDRO-40* [14]. The point precipitation values versus watershed drainage area are contained in Table 3-10. Depth-area reduction for all storms was simulated in HEC-1 using the JD record option.

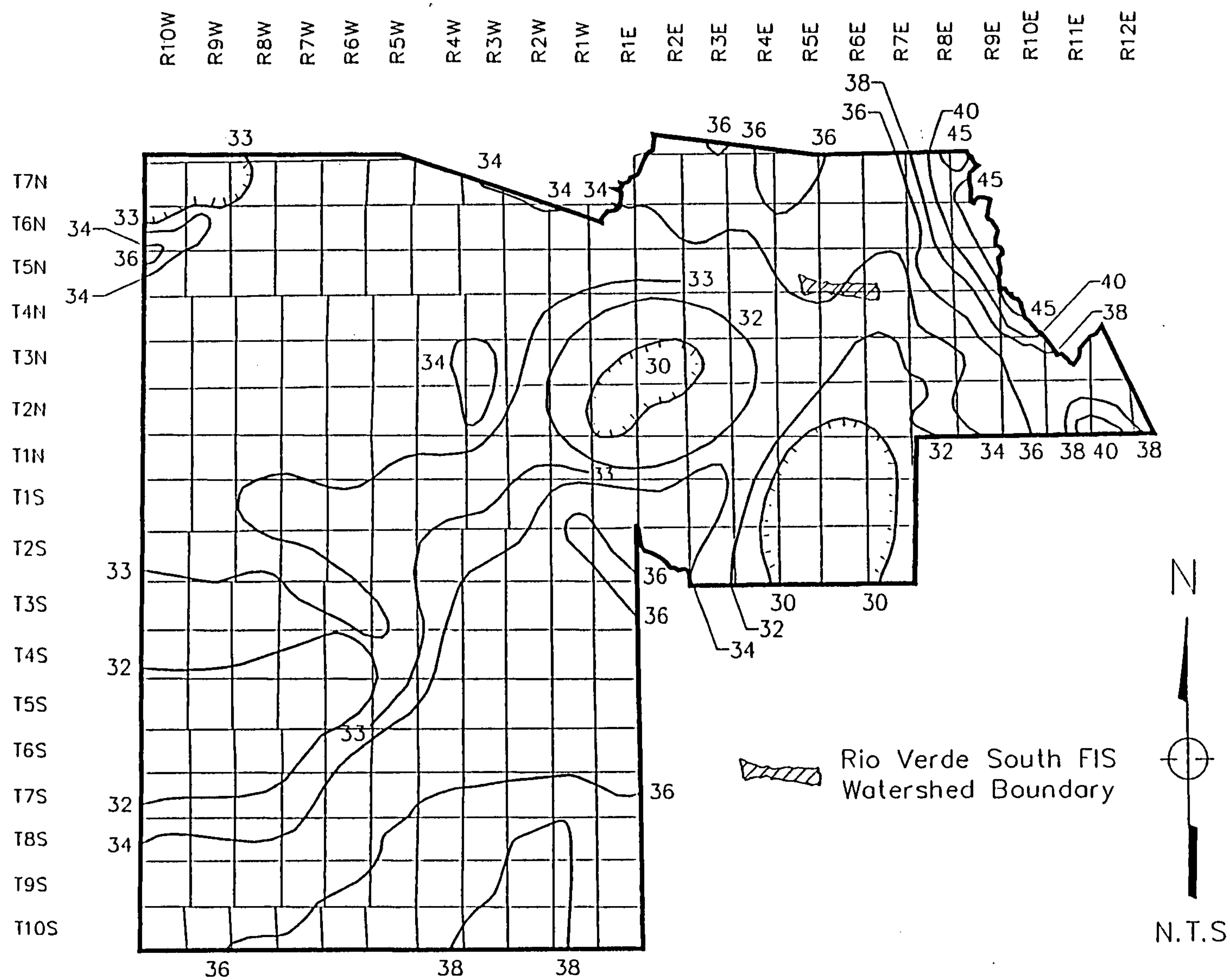


FIGURE 3-3

100-Year, 6-Hour Precipitation Isopluvials

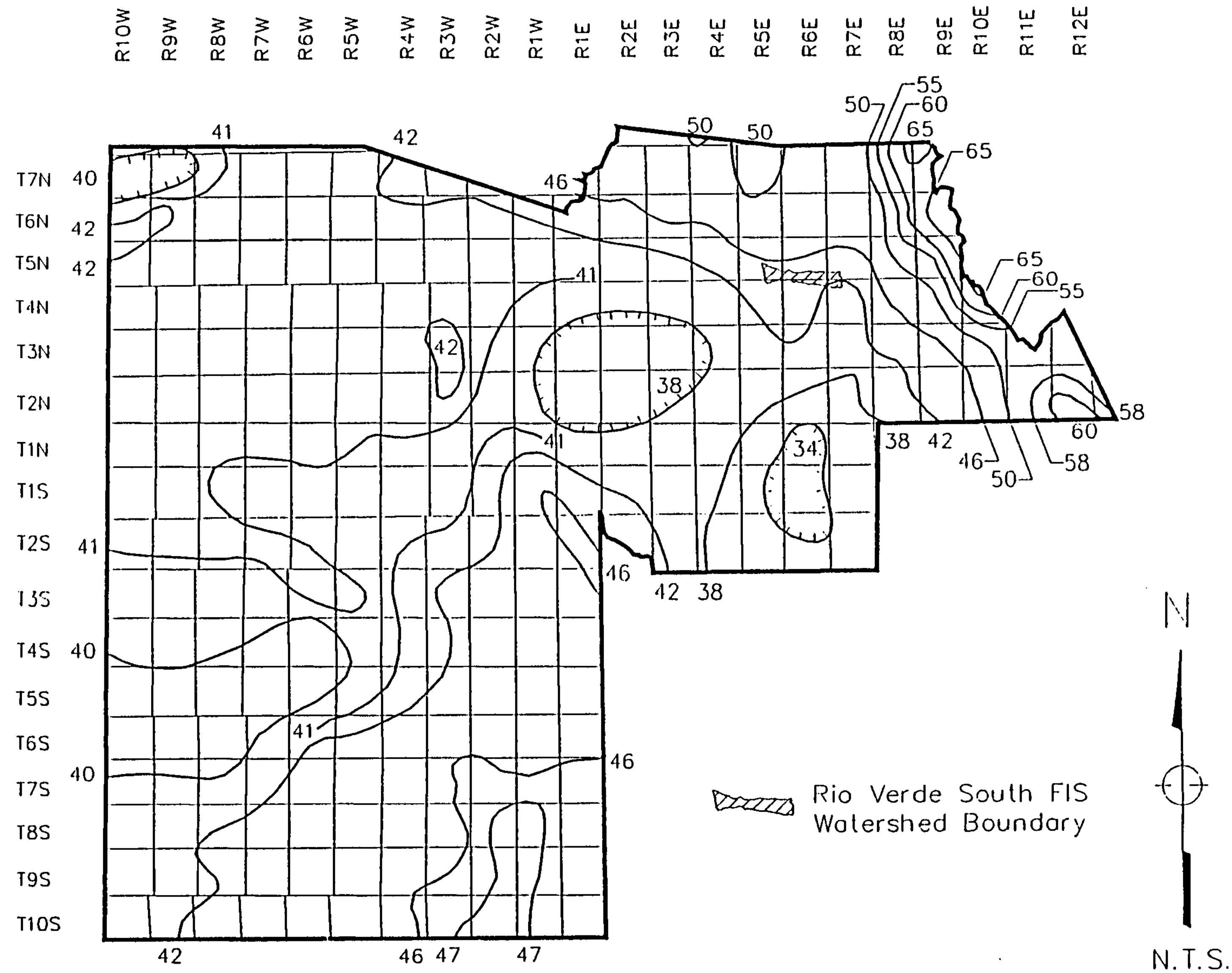


FIGURE 3-4

100-Year, 24-Hour Precipitation Isopluvials

TABLE 3-10
24-Hour Aerial Precipitation Reduction Factors
Zones A and C - Central Arizona
NOAA Technical Memorandum NWS Hydro-40

Watershed Area (1)	Reduction Factor (2)	Point Precipitation inches (3)
0.01	1.000	4.40
5.00	0.980	4.31
10.00	0.949	4.18
50.00	0.883	3.89
80.00	0.861	3.79
100.00	0.850	3.74
200.00	0.819	3.60

3.2.5 Gage Data

3.2.5.1 Streamflow Gaging Stations

The District, ADWR and the USGS have compiled streamflow gage data for various washes in Maricopa County and the State of Arizona. The data is summarized in a state-wide report entitled *Basin Characteristics and Streamflow Statistics in Arizona as of 1989* [23]. In addition to USGS gage data, the District also maintains a series of streamflow gages in Maricopa County. Unfortunately, none of those gages lie in or near the Rio Verde South study area. The results from that study for representative washes in central and southern Arizona are summarized in Table 3-11 and shown graphically in Figure 3-5.

Modeling results for typical subbasins and key concentration points upstream of the flow split area are summarized in Table 3-12. Those modeling results are also plotted on Figure 3-5 for comparison with the USGS data. Refer to Section 3.3 for a discussion of the comparison between the USGS data and the modeling results.

TABLE 3-11

Log Pearson III Analysis Summary for Representative Washes in Central and Southern Arizona

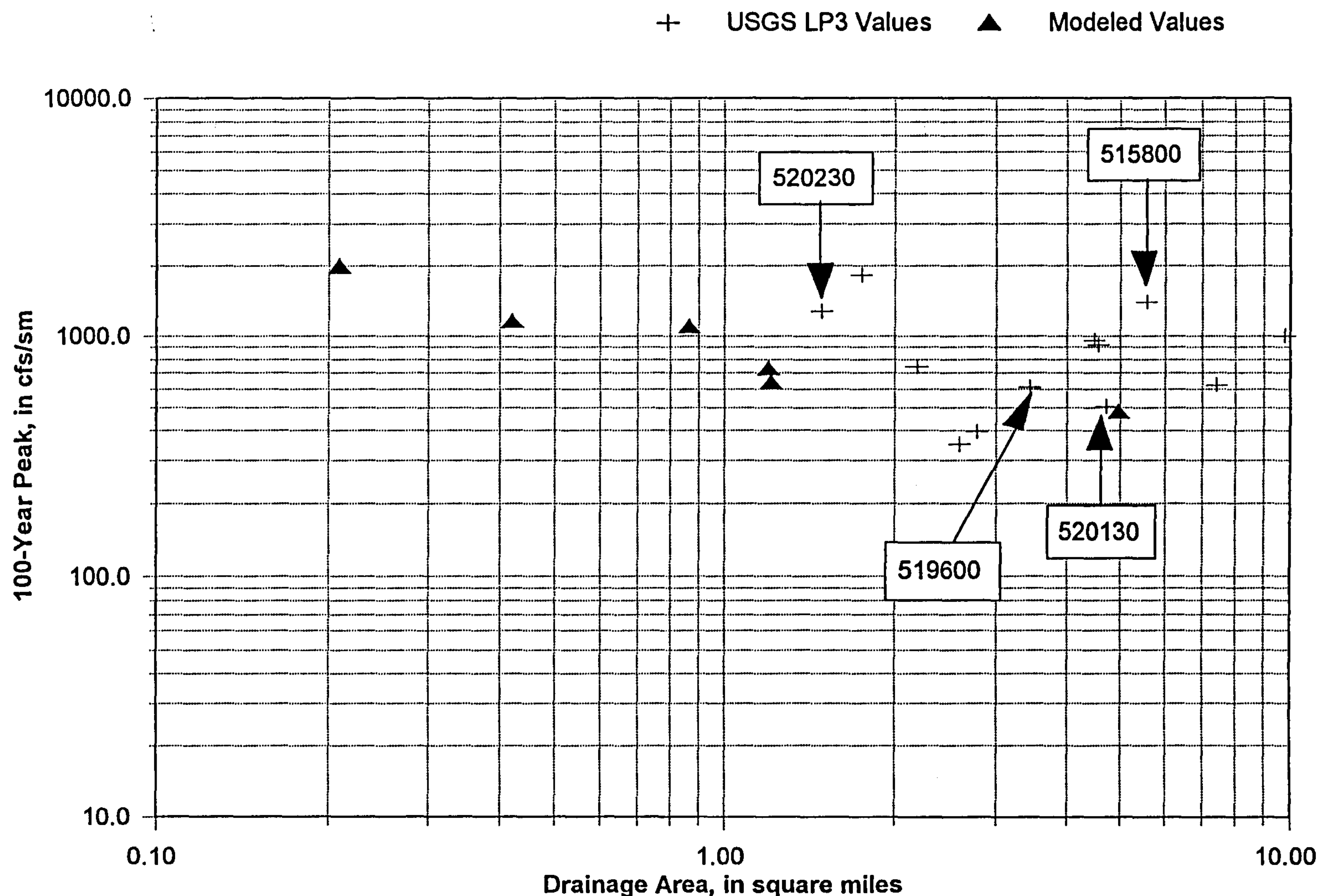
Station Number (1)	Station Name (2)	Drainage Area sm (3)	Mean Elevation feet (4)	Main Channel Slope ft/mi (5)	Record Length years (6)	Qmax cfs (7)	Log Pearson III Discharge For 100-Year Storm cfs (8)	cfs/sm (9)
*510070	West Fork Sycamore Creek Near Sunflower	4.58	5,430	260	11	1,700	4,200	917
510080	West Fork Sycamore Creek Near Sunflower	9.80	5,260	350	18	3,480	9,800	1,000
510100	East Fork Sycamore Creek Near Sunflower	4.49	5,760	370	25	1,940	4,300	958
510170	Camp Creek Near Sunflower	2.60	3,520	498	16	402	900	346
*512200	Salt River Tributary In S. Mountain Park	1.75	1,730	244	27	670	3,200	1,829
515800	Hartman Wash Near Wickenburg	5.57	2,690	72	15	2,600	7,800	1,400
*516600	Ox Wash Near Morristown	7.44	2,290	101	16	2,900	4,600	618
*517200	Centennial Wash Tributary Near Wendon	2.79	2,480	193	16	720	1,100	394
519600	Rainbow Wash Tributary Near Buckeye	3.45	950	34	16	1,430	2,100	609
520100	Military Wash Near Sentinel	8.70	674	56	16	1,530	10,400	1,195
520130	Darby Arroyo Near Ajo, AZ	4.72	1,920	71	16	1,670	2,380	504
*520160	Gibson Arroyo at Ajo, AZ	2.18	2,100	171	15	1,800	1,620	743
*520230	Crater Range Wash Near Ajo	1.49	1,280	69	16	440	1,900	1,275

* Watershed is similar to the Rio Verde area.

TABLE 3-12

Modeling Results at Representative Locations for the 100-year, 6-hour Storm

HEC-1 Identifier (1)	Description (2)	Drainage Area sm (3)	Mean Elevation feet (4)	100-year Peak Discharge cfs (6)	cfs/sm (7)
500A	Subbasin in upper watershed	0.21	2,395	421	2,005
511C	Subbasin in FEMA Wash 11 watershed	1.20	2,594	878	732
511G	Subbasin in FEMA Wash 11 watershed	0.87	2,568	961	1,105
C502	Concentration point in upper watershed	0.42	2,325	491	1,169
C530	Concentration point on FEMA Wash 11	4.97	2,580	2,387	480
C553	Concentration point on FEMA Wash 9	1.21	2,300	779	645



Note:

The USGS gages listed in boxes are on washes that are similiar to the Rio Verde area.

FIGURE 3-5

Comparison of USGS LP3 Values with Modeling Results
100-year Unit Peak Discharges vs Area

3.2.5.2 Precipitation Stations

Two recording precipitation gages are situated on or near the study watershed. Those gages are located as follows:

McDowell Mountain Gage: Established 6 August 1990. Located in Section 16 T4N R6E at Latitude 33°43'00" and Longitude 111°44'42". The gage is at elevation 2,040 feet.

Asher Hills Gage: Established 2 August 1990. Located in Section 1 T4N R6E at Latitude 33°43'03" and Longitude 111°41'01". The gage is at elevation 1,680 feet.

Neither gage has a significant period of record.

3.3 Calibration

3.3.1 General

Calibration of the HEC-1 models is not possible because of the lack of available physical data. In lieu of calibration, confidence checks are performed on the modeling results. The confidence checks consist of:

1. Comparison with USGS gage data for representative watersheds;
2. Comparison of modeled results with estimates made using a USGS regional regression equation; and
3. Comparison of modeled results with results from previous FIS studies completed in Maricopa County.

These checks are only made using the non-urbanized watershed upstream of the natural flow splits. Peak discharges in washes downstream of the flow splits are significantly affected by those diversions. The USGS gage data and regression equations are not representative of urbanized area. The selected locations are 500A, 511C, 511G, C502, C530 and C553.

3.3.2 Comparison with USGS Gage Data

The selected USGS gage data for representative washes are summarized in Table 3-11. The modeled results selected for comparison are listed in Table 3-12. The data from Tables 3-11 and 3-12 is plotted on Figure 3-5. The USGS gaged watersheds which are the most similar to the Rio Verde area are identified on both Table 3-11 and Figure 3-5. The USGS data is for watersheds in the size range of about 1.5 to almost 10 square miles, and the unit peak discharges range from about 350 cfs/square mile to about 1,800 cfs/square mile. The average of the data from Table 3-11 is about 900 cfs/square mile for those small watersheds. The model subbasins for comparison are generally smaller than the gaged watersheds and range in size from 0.21 square miles to 4.97 square miles. The unit peak discharges range from 480 cfs/square mile to 2,005 cfs/square mile, and the average of the data from Table 3-12 is about 880 cfs/square mile. It is reasonable for the smaller modeled subbasins to produce somewhat higher unit peak discharges than the selected gaged watersheds, and this is depicted in Figure 3-5. There is no reason to doubt the validity of the modeled results based on this comparison.

3.3.3 Comparison With USGS Regional Regression Equation

The USGS in Open-File Report 93-419 [25] lists regional regression equations for use in Arizona. The Rio Verde South study watershed lies in flood region 12. The regression equations for flood region 12 are listed in Table 3-13. USGS Figure 40 is also included herein as Figure 3-6. Figure 3-6 is a scatter diagram of mean basin elevation versus drainage area for the gages upon which the regression analysis was performed.

The comparison is made using the higher of the 100-year, 6-hour or 24-hour modeled results for the selected concentration point. The results of the comparison are shown in Table 3-14. The modeled results are significantly lower than those estimated using the 100-year regression equation and fall outside the 31 percent standard error. This result is explained by examining Figure 3-6. The modeled basins in Rio Verde South all have a mean elevation of much less than 3,000 feet. Very few of the USGS gages used to develop the regression equation have a mean elevation of much less than 3,000 feet. The USGS regression equations were developed using data for higher elevation steeper watersheds which have greater rainfall depth-frequency statistics and greater storm runoff. Those equations are probably not reliable for the Rio Verde area. Therefore, this confidence check is disregarded.

TABLE 3-13

Flood Magnitude-Frequency Relations for the Central Arizona Region (R12)

Equation: Q, peak discharge, in cubic feet per second/ AREA, drainage area, in square miles; and ELEV, mean basin elevation, in feet divided by 1,000.

Recurrence interval in years (1)	Equation (2)	Average standard error of model in percent (3)
2	$Q = 41.1\ AREA^{0.629}$	105
5	$Q = 238\ AREA^{0.687}\ ELEV^{-0.358}$	68
10	$Q = 479\ AREA^{0.661}\ ELEV^{-0.398}$	52
25	$Q = 942\ AREA^{0.630}\ ELEV^{-0.383}$	40
50	$LOG\ Q = 7.36 - 4.17\ AREA^{-0.08} -0.440\ LOG\ ELEV$	37
100	$LOG\ Q = 6.55 - 3.17\ AREA^{-0.11} -0.454\ LOG\ ELEV$	39

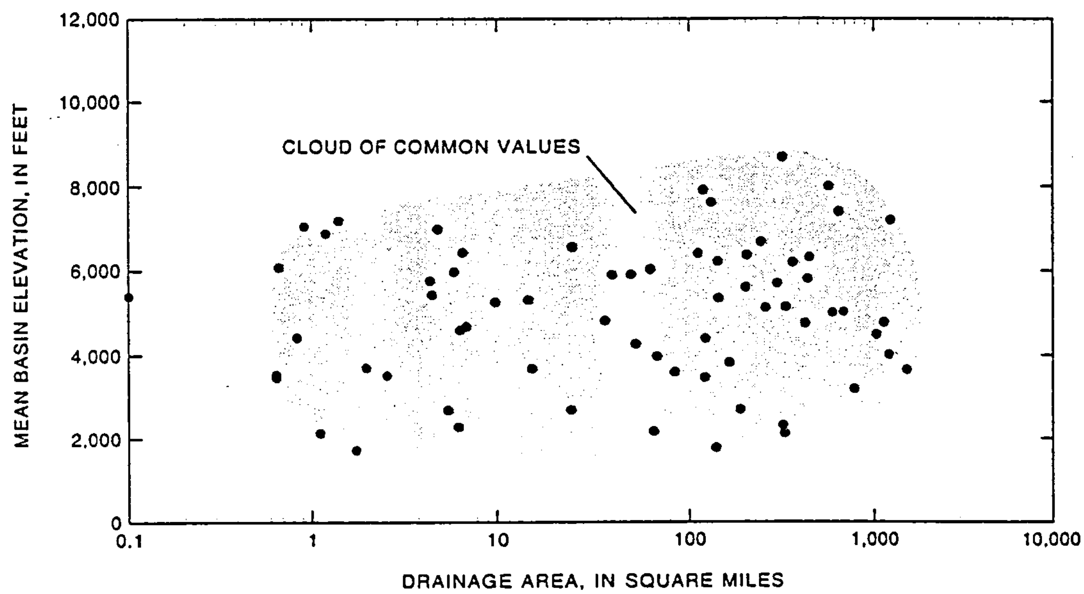


Figure 40. Joint distribution of mean basin elevation and drainage area for gaged sites in the Central Arizona Region 12.

FIGURE 3-6

Scatter Diagram of Independent Variables for R12 Regression Equation

TABLE 3-14

Comparison of Modeled Results with USGS Regional Regression Equation

HEC-1 ID (1)	Drainage Area, sm (2)	Mean Elevation (3)	100-year Discharge, cfs USGS (4)	100-year Discharge, cfs HEC-1 Model (5)
500A	0.21	2,395	411	421
511C	1.20	2,594	1,799	878
511G	0.87	2,568	1,397	961
C502	0.42	2,325	787	491
C530	4.97	2,580	5,078	2,387
C553	1.21	2,300	1,912	779

3.3.4 Comparison with Previous FIS Studies in Maricopa County

The Arizona Department of Water Resources (ADWR) has adopted State Standard SS-2 [2] which includes envelope curves of FIS 100-year peak discharges for each county in the state. The curve for Maricopa County is included herein as Figure 3-7. The 100-year peak discharges for selected concentration points are plotted on Figure 3-7 for comparison. There is no reason to doubt the validity of the HEC-1 model based on this comparison.

3.4 Special Problems and Solutions

3.4.1 Channel Flow Splits

3.4.1.1 Discussion of Problem

There are nineteen (19) significant flow splits on the study watershed identified during the subbasin delineation process. All of those splits occur naturally as a result of natural obstructions to flow such as rock outcrops and large well established trees. The channel approaching the split and the downstream channels are well incised and have stable banks that are heavily vegetated. There is no evidence of significant channel migration, other than within the floodplain itself. Flow splits are defined where peak discharges at downstream concentration points are significantly affected.

The locations of modeled flow splits are identified on Exhibits D and E by a triangle symbol around the concentration point number.

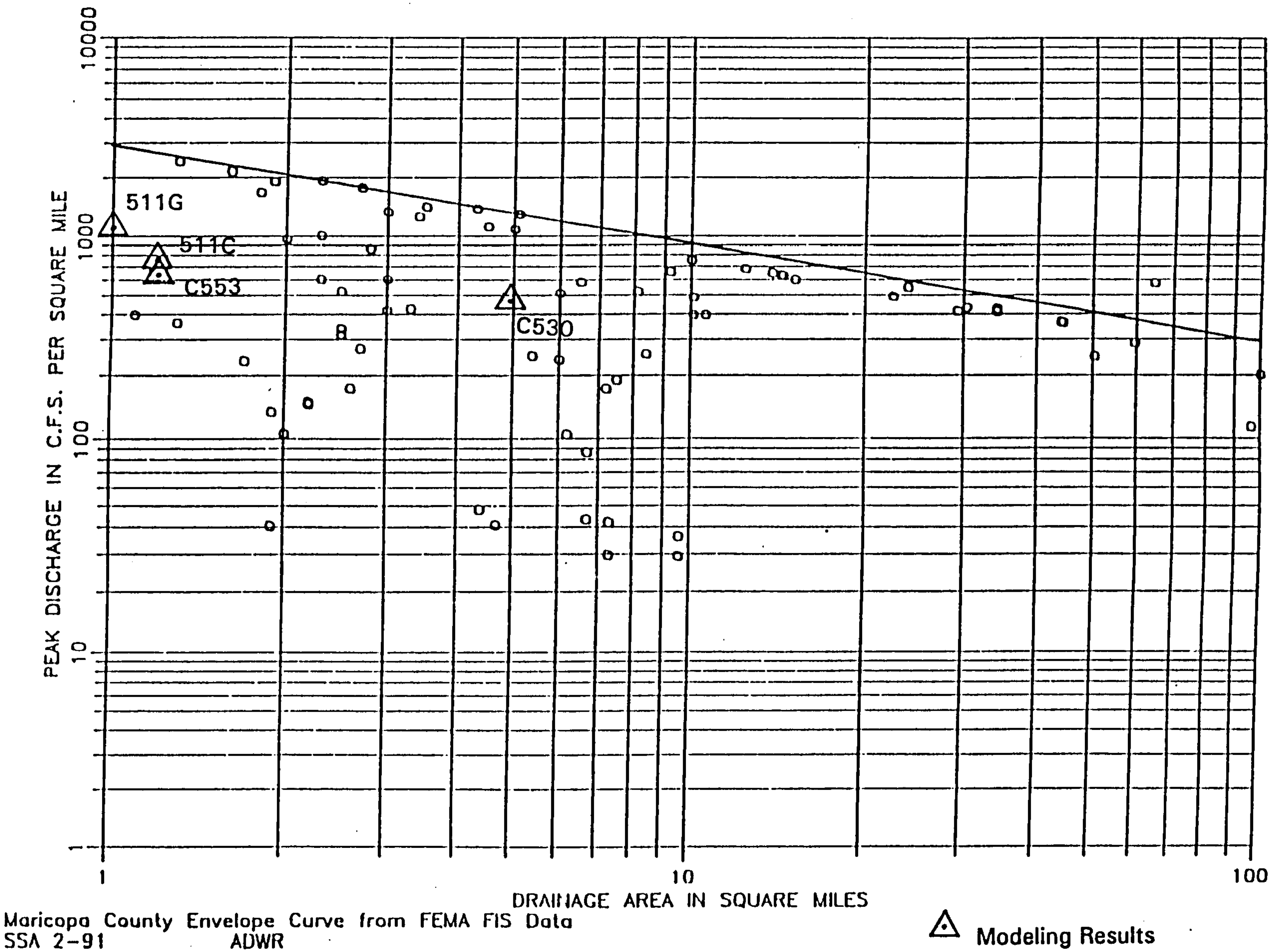


FIGURE 3-7
Comparison of Modeled Results with FEMA FIS Data

3.4.1.2 Solution and Results

The flow splits are accounted for in the hydrologic model by dividing the upstream runoff hydrograph into two hydrographs. The division is accomplished using flow split rating curves developed by hydraulic analysis of the conveyance capacity of each downstream channel. The HEC-2 computer program was used for the hydraulic analyses. The HEC-2 models are based on the cross sections surveyed during the field reconnaissance (refer to Section 2.2.2.2). The cross section used to define the split was taken as close to the point of diversion as possible. The cross section was then divided into two cross sections, one for each downstream channel. An imaginary vertical wall was used to separate the two cross sections.

A separate energy gradient was assumed for both downstream channels. That gradient was estimated using elevations surveyed upstream and downstream of the split. A separate HEC-2 model was prepared for both downstream channels using the multiple profile option to develop a rating curve using multiple discharges. A separate rating curve was prepared for both legs of the split and the results plotted in a stage versus discharge format. The flow split tables were then created by reading the discharge from both rating curves at common stage elevations. The results are summarized in Figures D-1 through D-20 and Tables D-1 through D-20 in Appendix B. The intermediate rating curves and HEC-2 output files are also included in Appendix B, as supporting calculations. The final rating curve for each flow split is included in the HEC-1 models using the hydrograph diversion option.

The above solution is based on the following assumptions:

1. The downstream channels will scour in a similar manner during major storms, resulting in similar conveyance changes.
2. The downstream channels are broad enough that debris clogging will not be a significant problem.
3. The downstream channel hydraulic characteristics will not vary appreciably with time.

Several flow splits were not modeled using field survey cross sections. The 200 Scale Mapping was used where available to define cross sections. The percentage of flow in both downstream channels was estimated using engineering judgement at three locations. The judgement was based on a field review and examination of the Stereo Photos. The source of data used to define the flow split hydraulics at each location are listed in Table 3-15. Also included is an estimate of percentage of flow in each downstream channel for major flows. The flow splits at concentration points C504 and C509 are locations where flow enters the Rio Verde South study area from the Rio Verde North study area. Refer to Section 3.4.2.

TABLE 3-15

Flow Split Rating Curve Basis and Results

HEC-1 Identifier (1)	Basis of Flow Split Estimate (2)	Estimate of Flow, percent Left (3)	Right (4)
C502	Field Survey/HEC-2 Model	61	39
C504	Wood, Patel & Associates	---	---
C508	Field Survey/HEC-2 Model	52	48
C509	Wood, Patel & Associates	---	---
C510	200 Scale Mapping/HEC-2 Model	41	59
C515	200 Scale Mapping/HEC-2 Model	78	22
C531	Field Survey/HEC-2 Model	24	76
C532	Field Survey/HEC-2 Model	48	52
C534	Engineering Judgement	30	70
C535	Engineering Judgement	15	85
C537	Field Survey/HEC-2 Model	75	25
C539	Field Survey/HEC-2 Model	65	35
C553	Field Survey/HEC-2 Model	53	47
C554	Field Survey/HEC-2 Model	64	36
C557	Field Survey/HEC-2 Model	19	81
C558	Field Survey/HEC-2 Model	57	43
C559	Field Survey/HEC-2 Model	40	60
C560	Field Survey/HEC-2 Model	31	69
C573	Field Survey/HEC-2 Model	23	77
C574	200 Scale Mapping/HEC-2 Model	76	24
C578	Engineering Judgement	50	50

The HEC-1 model drops the total watershed area from memory for the diverted hydrograph. The total watershed area at each concentration point must be known because it is required for the proper use of JD records. The HEC-1 HC record option allows the total area to be set at any given hydrograph combination operation. That option was used to reset the watershed area at the first combination downstream of the recalled diversion hydrograph. The new areas are input to the HEC-1 computer models as shown in Table 3-16.

TABLE 3-16

List of Hydrograph Combination Points Where the Watershed Area is Reset

HEC-1 ID (1)	Upstream HEC-1 Operations (2)	Total Area sm (3)
C503	C502, 500C	0.54
C506	C531, C502, 511J	5.72
C511	C502, C510, 500C, 500F, 500H, 500I, C531, 511J	7.49
C515	C531, 511J, 511K, 511L	6.28
C517	C502, 500C, 500H, 500I, 500L, C531, 511J-511L	7.60
C533	C531	5.18
C534	C531, 511J	5.30
C535	C531, 511J, 511K	6.09
C538	C531, 510A, 510B	6.45
C541	C531, 511J, 511K, 510D	6.15
C554	C553, 509C	1.36
C555	C553, 509C-509E	1.88
C556	C553, 509C	1.36
C557	C553, 509C-509G	2.18
C559	C553, 509C-509H	2.25
C560	C553, 509C-509I	2.28
C561	C553, 509C-509I, 509K	2.31
C565	C553, 509C-509G, 509M	2.28
C566	C553, 509C-509I, 509L	2.36
C571	C553, 505A, 509C, 509F	1.74
C575	C531, 511J, 511K, 511L, 511M	6.36
C577	509D, 510A	1.25
C579	C531	5.18
C580	C531	5.18

3.4.2 Offsite Runoff from Rio Verde North Study Area

3.4.2.1 Discussion of Problem

The Rio Verde North study area (North Study Area) is being studied concurrently with the Rio Verde South study area (South Study Area) by the engineering firm Burgess & Niple, Inc., utilizing Wood, Patel & Associates as the hydrology subconsultant. There are two locations in the North Study Area where storm water runoff is diverted into the South Study Area. Those locations are concentration points C504 and C509. Refer to sheet 2 of Exhibit D. Runoff from the South Study Area is diverted into the North Study Area at concentration point C510.

3.4.2.2 Solution and Results

The solution is to exchange runoff hydrographs for input to the HEC-1 computer models for the two study areas. This cannot be readily accomplished using TAPE21 or DSS files because the HEC-1 JD record option is used for both the North and South Study Areas. Instead, the interpolated hydrographs at the points in question were printed in the output files using the level 1 printout option. The hydrographs in question were then read into the HEC-1 models at the appropriate locations using QI records.

A problem with the HEC-1 results was encountered using this approach. The peak discharge for the 6-hour model at C510 was reported to be 1,297 cfs by HEC-1. Operation C510 combines the hydrographs from operations 509510, 500E, and 581510, which have 100-year, 6-hour peak discharges of 361, 219 and 207 cfs, respectively. The total discharge at C510 should not be greater than 787 cfs. This appears to be a HEC-1 computation error. The problem apparently relates to the index hydrographs being set to zero values for the imported hydrographs. The problem was solved by taking the following approach:

1. The two hydrographs from the North Study Areas were imported using QI records at the start of the HEC-1 model. Both hydrographs were saved to the TAPE21 file.

2. Both hydrographs were then read back into the input file at the appropriate locations using the BI record option. The index hydrographs were then found to be populated with the original hydrographs input using QI records.

3. That still did not solve the problem, although the peak discharge at C510 changed from 1297 cfs to 929 cfs. The combination records at C509 and C510 were renamed to TEMP1 and TEMP2, respectively, and written to the TAPE21 file. Both hydrographs were then read back into the model using BI records. A reasonable peak discharge was reported and a plot of the interpolated hydrograph appeared to be reasonable.

4. The HEC-1 results were checked by manual calculation of the interpolated hydrograph at C510. The results were identical to the HEC-1 model output.

3.4.3 Existing Flood Control and Diversion Levees

3.4.3.1 Discussion of Problem

Levee at C540 -There is an existing riprap-lined flood control levee at C540 that diverts FEMA Wash 10 runoff in a more northeasterly direction. Refer to Sheet 5 of Exhibit E. That levee is on property owned by Maricopa County (McDowell Mountain Park) and was evaluated and tested by the District. The levee was found to be basically stable [16]; therefore, the HEC-1 models include the effects of that levee.

Levee in Subbasin 510E - There is an existing concrete flood control levee on the north subbasin boundary of 510E that diverts runoff from FEMA Wash 10 into FEMA Wash 11. Refer to Sheet 8 of Exhibit E. That levee was constructed by the developer of the Tonto Verde subdivision. The levee was designed for the 100-year peak discharge. The levee is maintained and operated by the developer, not by a governmental agency.

3.4.3.2 Solution and Results

No special modeling was done as a result of the presence of the levee at C540. The levee in subbasin 510E was modeled to obtain the highest flow rate, whether the levee remains in place or fails. Two separate HEC-1 models were created for each storm duration. The first set of models are named EX100-6.IH1 and EX100-24.IH1. Those models include the diversion of flow caused by that levee, assuming the levee is not overtopped and does not fail. The second set of models are named L100-6.IH1 and L100-24.IH1. Those models are based on the assumption that the levee is not in place and that all upstream runoff remains in FEMA Wash 10. The higher peak discharge at any given concentration point downstream from the levee is used for floodplain delineation in the hydraulics report. Refer to Section 3.5.

The removal of the levee from the HEC-1 models has an effect on the routing parameters and results for downstream reaches. Tables 3-6 and 3-7 are the routing results assuming the levee is in place. The levee not being in place affects a limited number of reaches. The routing parameters and results for the affected reaches are shown in Tables 3-17 and 3-18 for the 100-year, 6-hour and 24-hour storms, respectively.

TABLE 3-17
Reach Route Hydraulic Data for the 100-year, 6-hour Storm
Existing Condition, without Levee

Routing Reach (1)	Reach: Slope in ft/ft (2)	Reach: Length in feet (3)	Reach: Average n value (4)	Reach: Discharge, in cfs: Top (5)	Reach: Discharge, in cfs: Bottom (6)	Reach: Discharge, in cfs: Average (7)	Manning's Equation: Channel Base Width in feet (8)	Manning's Equation: Flow Top Width in feet (9)	Manning's Equation: Flow Depth in feet (10)	Manning's Equation: Channel Velocity in fps (11)	Computed Using HEC-1 Summary Data: Wave Celerity in fps (12)	Computed Using HEC-1 Summary Data: Velocity Range in fps: Min. (13)	Computed Using HEC-1 Summary Data: Velocity Range in fps: Max. (14)	Computed Using HEC-1 Summary Data: Travel Time in hours (15)	Computed Using HEC-1 Summary Data: Travel NSTEPS Computed (16)	NSTEPS from HEC-1 Input File (17)
515575	0.024	2236	0.045	49	49	49	7.0	16.9	1.1	4.0	9.3	4.5	9.3	0.0667	4	4
535515	0.024	2814	0.045	158	156	157	40.0	53.4	0.9	4.2	6.7	3.5	5.9	0.1167	7	7
536545	0.016	3241	0.056	272	266	269	15.0	223.0	1.0	2.8	3.6	2.0	2.9	0.2500	15	15
541582	0.022	1707	0.055	208	207	208	18.0	110.1	1.1	3.9	4.1	2.1	3.6	0.1167	7	7
542543	0.017	1600	0.030	1300	1294	1297	35.0	126.5	2.2	8.5	13.3	5.3	20.1	0.0333	2	2
543545	0.016	5179	0.030	1615	1609	1612	72.0	74.2	2.2	10.3	1.0	0.6	0.7	0.1900 *	12 *	12
545546	0.012	3093	0.051	1611	1598	1605	57.0	253.6	2.3	5.1	8.6	4.4	7.8	0.1000	6	6
574582	0.025	3140	0.045	685	681	683	60.0	87.5	1.6	6.2	8.7	4.5	7.9	0.1000	6	6
574541	0.022	1821	0.045	211	208	210	78.0	146.0	0.7	3.2	5.1	2.6	4.6	0.1000	6	6
575536	0.022	4398	0.030	111	109	110	21.0	36.2	0.8	5.2	10.5	5.5	9.2	0.1167	7	7
582543	0.023	4020	0.060	884	879	882	18.0	225.1	2.0	4.7	5.2	2.9	4.2	0.2167	13	13

Note: * indicates a travel time and NSTPS associated with HEC-1 operations 582543 to 543545

TABLE 3-18
Reach Route Hydraulic Data for the 100-year, 24-hour Storm
Existing Condition, without Levee

	Reach						Manning's Equation				Computed Using HEC-1 Summary Data					NSTEPS
Routing Reach	Slope in ft/ft	Length in feet	Average n value	Discharge, in cfs			Channel Base Width in feet	Flow Top Width in feet	Flow Depth in feet	Channel Velocity in fps	Wave Celerity in fps	Velocity Range in fps		Travel		from HEC-1 Input File
				Top	Bottom	Average						Min.	Max.	Time in hours	NSTEPS Computed	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
515575	0.024	2236	0.045	61	57	59	7.0	17.8	1.2	4.3	9.3	3.7	14.0	0.0667	2	2
535515	0.024	2814	0.045	166	164	165	40.0	53.7	0.9	4.2	7.8	3.5	8.8	0.1000	3	3
536545	0.016	3241	0.057	319	301	310	15.0	228.8	1.0	2.9	3.9	2.0	3.4	0.2333	7	7
541582	0.022	1707	0.055	220	218	219	18.0	112.9	1.1	3.9	4.7	2.1	5.3	0.1000	3	3
542543	0.017	1600	0.030	1430	1424	1427	35.0	127.3	2.3	8.8	13.3	4.0	20.1	0.0333	1	1
543545	0.016	5179	0.030	1891	1876	1884	72.0	74.4	2.4	11.0	21.6	8.6	32.4	0.0667	2	2
545546	0.012	3093	0.052	2010	1996	2003	57.0	259.8	2.5	5.4	8.6	3.9	9.7	0.1000	3	3
574582	0.025	3140	0.045	717	711	714	60.0	88.2	1.6	6.3	13.1	5.2	19.7	0.0667	2	2
574541	0.022	1821	0.045	223	220	222	78.0	147.0	0.7	3.2	5.1	2.3	5.7	0.1000	3	3
575536	0.022	4398	0.030	157	148	153	21.0	38.9	1.0	5.8	7.3	3.7	6.9	0.1667	5	5
582543	0.023	4020	0.060	925	917	921	18.0	229.2	2.0	4.7	5.6	2.9	5.0	0.2000	6	6

3.4.4 HEC-1 Warnings and Errors

3.4.4.1 General

The warnings encountered in the EX100-6 HEC-1 output are concerning hydrograph routing and subbasin runoff calculations. Examples of the warnings noted are:

537538* ***WARNING*ModifiedPuls Routing May be Numerically Unstable For Outflows Between 4151 To 10857.*

**511J* Warning Excess At Ponding Less Than Zero For Period. Excess Set to Zero.*

The warning messages are discussed below. No errors are reported by HEC-1 for any of the models.

3.4.4.2 Routing Operation Warnings

The first warning listed above specifies a range of peak flows for which the hydrograph may be unstable. For example, in the first warning message above, the routed peak discharge for the reach is 237 cfs (see the 100-year, 6-hour HEC-1 model). Note that the computed peak discharge is less than the range specified in the warning message. All of the reaches for which warning messages were noted were checked for the following:

1. The routed peak discharge was compared to the range listed in the warning message;
2. The routed peak discharge was compared with the inflow peak discharge to determine if the peak discharge increased as a result of the routing computations; and
3. The routed hydrograph was plotted and checked for oscillations if either item 1 or 2 above was a concern.

Only five (5) reaches were found to have hydrographs with discharges in the range of the warning message. Those were the channel route operations at 501502, 508511, 508517, 543545 and 568569. The hydrographs were checked for oscillations and found to have a reasonable shape. None of the routing operations were found to increase the peak discharge as a result of the routing computations. The routing warning messages were inconsequential to the model input and do not affect the veracity of the model results.

3.4.4.3 Subbasin Runoff Calculation Warnings

The second warning listed in Section 3.4.4.1 is in regard to the rainfall loss calculation and it can result from an internal HEC-1 check that is performed when applying the Green-Ampt rainfall excess relationship. The check is performed by HEC-1 for each time interval to answer the following questions:

1. Does ponding (generation of rainfall excess) occur throughout the interval?

2. Does ponding occur at end of the interval?

3. Does ponding begin during the interval?

The warning is given when the second and third checks are true. The rainfall excess calculation for a time interval is done by subtracting the estimated average precipitation loss from the rainfall for the time interval. If ponding begins at the end of the interval during the interval, then the average excess can be less than zero, resulting in the warning. In these cases, the rainfall excess is set to zero. This warning occurs for subbasins 500G, 500N, 500O, 509D, 509Q, 511J and 511N. This warning is not an indication of instability in the model and can be disregarded.

3.5 Final Results

3.5.1 General

The watershed is broken into nine (9) major basins. Those basins represent the following washes:

Basin 500:	Wash 12 is influenced by flow from FEMA Wash 11.
Basin 501:	Minor unnamed washes.
Basin 502:	Minor unnamed washes.
Basin 503:	A minor unnamed wash.
Basin 504:	A minor unnamed wash.
Basin 505:	A minor unnamed wash which is influenced by distributary flow from FEMA Wash 9.
Basin 509:	FEMA Wash 9.
Basin 510:	FEMA Wash 10.
Basin 511:	FEMA Wash 11.

The results of this study are summarized in Tables 3-19 through 3-23. Table 3-19 is a listing of the 100-year, 6-hour results. The left half of Table 3-19 presents the results in HEC-1 run order, the right half of Table 3-19 presents the results in numerical order by operation type (subbasin operations, followed by hydrograph recall operations, followed by reservoir route operations, followed by diversion operations, and finally reach route operations). Table 3-20 is similar to Table 3-19 except the results of the 100-year, 24-hour storm are listed. Table 3-21 is a comparison listing, in numerical order by operation type, of the 100-year, 6-hour and 100-year, 24-hour storm results. Table 3-22 is a listing of rainfall excess in inches and total runoff volume in acre-feet for both the 6-hour and 24-hour storms, listed in numerical order by operation type. Tables 3-19 through 3-22 are based on the assumption that the levee in subbasin 510E is in place (refer to Section 3.4.3). Table 3-23 is similar to Table 3-21, except it represents the HEC-1 models which assume the levee in subbasin 510E is not in place. Only those HEC-1 operations which are affected by the absence of the levee are listed.

The 6-hour storm produces higher peak discharges than the 24-hour storm for watershed areas less than 3 square miles for this watershed. The break points where the 24-hour storm controls peak discharges for FEMA Washes 9, 10 and 11 are as follows:

Wash 9:	24-hour control begins at concentration point C567.
Wash 10:	24-hour control begins in the right branch upstream of concentration point C540 and continues to control downstream of C540.
Wash 11:	24-hour control begins at concentration point C528.

The HEC-1 output files for the 6-hour and 24-hour storms, assuming the concrete levee is in place in subbasin 510E, are included as Appendices D and E, respectively. The HEC-1 output files for the 6-hour and 24-hour storms, assuming the levee in subbasin 510E is not in place, are included as Appendices F and G, respectively. The input files are included in digital form on 3.5 inch diskette.

The modeling results are strongly affected by the flow splits in the middle portion of the watershed. The flow splits are modeled in HEC-1 using the flow diversion option. The rating curves used as input for the diversion option were developed using the HEC-2 computer program.

3.5.2 Summary of HEC-1 Nomenclature and Modeling Results

Subbasin names, concentration point numbers and routing reaches are named according to the following nomenclature.

HEC-1 Computer Model Nomenclature

HEC-1 ID	Description
500A	Hydrograph identifier for subbasin 500A. Refers to subbasin A in major basin 500.
C502	Hydrograph identifier for concentration point 502. More than one hydrograph is combined at this location. Point 502 is a physical location on the watershed which is labeled on Exhibit D and Exhibit E.
C545L C545R	Hydrograph identifiers for concentration point 545. The "L" symbolizes this is an intermediate hydrograph for the left wash (looking downstream) immediately upstream of the confluence with the right wash ("R") at concentration point 545.
D532L D532R	Hydrograph identifiers for concentration point 532 in the left branch ("L"), or right branch ("R"), immediately downstream of concentration point 532. This is a hydrograph created by a diversion operation performed on the hydrograph at concentration point 532.
B532R	This signifies a hydrograph in the right ("R") wash immediately downstream of a flow split at concentration point 532. The "B" signifies the hydrograph is recalled to active memory using the HEC-1 DR record.
511512	Hydrograph resultant from a normal depth channel route from concentration point 511 to concentration point 512.
CLEAR	A hydrograph combine operation used to clear unneeded hydrographs from active memory.

TABLE 3-19
100-year, 6-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
WP504	162	4.67	0.26	623	500A	421	4.13	0.21	2,005
WP581	208	6.75	3.92	53	500B	325	4.22	0.20	1,625
CLEAR	240	5.00	4.18	57	500C	248	4.12	0.12	2,067
511A	941	4.25	0.65	1,448	500D	371	4.17	0.23	1,613
524526	871	4.72	0.65	1,340	500E	219	4.10	0.11	1,991
511B	948	4.63	1.10	862	500F	647	4.20	0.44	1,470
525526	943	4.72	1.10	857	500G	349	4.13	0.20	1,745
511D	195	4.27	0.13	1,500	500H	340	4.17	0.21	1,619
C526	1,594	4.73	1.88	848	500I	644	4.17	0.41	1,571
526527	1,562	4.93	1.88	831	500J	204	4.08	0.09	2,267
511E	579	4.53	0.57	1,016	500K	219	4.12	0.10	2,190
511F	340	4.12	0.15	2,267	500L	292	4.13	0.16	1,825
C527	1,780	4.92	2.60	685	500M	228	4.12	0.12	1,900
527528	1,764	5.02	2.60	678	500N	228	4.17	0.11	2,073
511C	878	4.72	1.20	732	500O	182	4.13	0.10	1,820
C528	2,229	5.00	3.80	587	500P	201	4.10	0.08	2,513
528529	2,180	5.23	3.80	574	501A	111	4.05	0.04	2,775
511H	458	4.20	0.31	1,477	501B	151	4.12	0.07	2,157
C529	2,175	5.23	4.11	529	502A	113	4.10	0.04	2,825
511G	961	4.37	0.87	1,105	502B	139	4.12	0.05	2,780
C530	2,274	5.22	4.97	458	502C	100	4.15	0.05	2,000
530531	2,238	5.47	4.97	450	503A	458	4.12	0.22	2,082
511I	382	4.12	0.21	1,819	503B	171	4.22	0.11	1,555
C531	2,232	5.47	5.18	431	503C	278	4.18	0.12	2,317
D531L	528	5.47	5.18	102	504A	428	4.22	0.24	1,783
D531R	1,694	5.47	5.18	327	505A	341	4.15	0.18	1,894
531532	1,687	5.53	5.18	326	505B	378	4.07	0.14	2,700
D532R	877	5.53	5.18	169	509A	674	4.45	0.57	1,182
D532L	810	5.53	5.18	156	509B	638	4.47	0.64	997
D532AL	468	5.52	5.18	90	509C	279	4.15	0.15	1,860
D532AR	341	5.53	5.18	66	509D	453	4.32	0.34	1,332
532580	339	5.68	5.18	65	509E	340	4.20	0.19	1,789
B532AL	468	5.52	5.18	90	509F	367	4.17	0.20	1,835
D578L	234	5.52	5.18	45	509G	196	4.13	0.09	2,178
D578R	234	5.52	5.18	45	509H	109	4.23	0.07	1,557
578573	232	5.60	5.18	45	509I	61	4.15	0.03	2,033
D573L	53	5.60	5.18	10	509J	161	4.22	0.10	1,610

TABLE 3-19 (continued)
100-year, 6-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
D573R	179	5.62	5.18	35	509K	60	4.13	0.03	2,000
573580	179	5.68	5.18	35	509L	209	4.05	0.08	2,613
C580	518	5.68	5.18	100	509M	150	4.22	0.10	1,500
580535	511	6.08	5.18	99	509N	250	4.08	0.11	2,273
B531L	528	5.47	5.18	102	509O	100	4.05	0.04	2,500
531533	523	5.57	5.18	101	509P	325	4.05	0.11	2,955
B578L	234	5.52	5.18	45	509Q	244	4.08	0.11	2,218
C533	757	5.55	5.18	146	509R	245	4.08	0.10	2,450
533579	754	5.60	5.18	146	509S	431	4.13	0.19	2,268
B573L	53	5.60	5.18	10	510A	994	4.40	0.91	1,092
C579	807	5.60	5.18	156	510B	518	4.32	0.36	1,439
579534	803	5.67	5.18	155	510C	850	4.50	0.85	1,000
511J	238	4.08	0.12	1,983	510D	126	4.15	0.06	2,100
C534	800	5.67	5.30	151	510E	282	4.27	0.18	1,567
D534L	240	5.67	5.30	45	510F	207	4.18	0.12	1,725
D534R	560	5.67	5.30	106	510G	316	4.20	0.18	1,756
534535	550	5.95	5.30	104	511A	941	4.25	0.65	1,448
511K	1,001	4.32	0.79	1,267	511B	948	4.63	1.10	862
C535	1,055	6.00	6.09	173	511C	878	4.72	1.20	732
D535R	896	6.00	6.09	147	511D	195	4.27	0.13	1,500
D535L	158	6.00	6.09	26	511E	579	4.53	0.57	1,016
535515	156	6.12	6.09	26	511F	340	4.12	0.15	2,267
511L	336	4.15	0.19	1,768	511G	961	4.37	0.87	1,105
C515	214	4.27	6.28	34	511H	458	4.20	0.31	1,477
D515L	166	4.27	6.28	26	511I	382	4.12	0.21	1,819
D515R	49	4.38	6.28	8	511J	238	4.08	0.12	1,983
515575	49	4.45	6.28	8	511K	1001	4.32	0.79	1,267
511M	182	4.10	0.08	2,275	511L	336	4.15	0.19	1,768
B535R	896	6.00	6.09	147	511M	182	4.10	0.08	2,275
D574R	211	6.00	6.09	35	511N	132	4.12	0.07	1,886
D574L	685	6.00	6.09	112	511O	78	4.18	0.05	1,560
574575	680	6.13	6.09	112	511P	493	4.28	0.31	1,590
C575	705	6.13	6.36	111	511Q	164	4.12	0.09	1,822
575536	702	6.23	6.36	110	B502L	299	4.22	0.42	712
511Q	164	4.12	0.09	1,822	B508L	277	4.52	6.88	40
511N	132	4.12	0.07	1,886	B515L	166	4.27	6.28	26
C536	703	6.23	6.52	108	B531L	528	5.47	5.18	102
536545	696	6.42	6.52	107	B532AL	468	5.52	5.18	90

TABLE 3-19 (continued)
100-year, 6-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
511O	78	4.18	0.05	1,560	B532R	877	5.53	5.18	169
C545L	695	6.42	6.56	106	B534L	240	5.67	5.30	45
B532R	877	5.53	5.18	169	B535R	896	6.00	6.09	147
532538	866	5.83	5.18	167	B537R	746	4.40	0.91	820
510A	994	4.40	0.91	1,092	B539R	158	4.32	0.34	465
D537R	746	4.40	0.91	820	B553R	367	5.05	1.21	303
D537L	248	4.40	0.91	273	B554R	261	5.18	1.36	192
537538	237	4.63	0.91	260	B557L	144	4.52	2.18	66
510B	518	4.32	0.36	1,439	B558R	263	5.35	1.56	169
C538	895	5.82	5.18	173	B559L	76	4.58	2.25	34
538540	876	6.43	5.18	169	B560L	40	4.63	2.28	18
B537R	746	4.40	0.91	820	B573L	53	5.60	5.18	10
537577	735	4.55	0.91	808	B574R	211	6.00	6.09	35
509D	453	4.32	0.34	1,332	B578L	234	5.52	5.18	45
D539R	158	4.32	0.34	465	C502	491	4.22	0.42	1,169
D539L	295	4.32	0.34	868	C503	395	4.35	0.54	731
539577	292	4.38	0.34	859	C504	162	4.67	0.26	623
C577	908	4.50	1.25	726	C506	265	5.63	5.72	46
577540	881	4.88	1.25	705	C507	279	4.40	5.93	47
510C	850	4.50	0.85	1,000	C508	528	4.52	6.88	77
C540	1,288	4.97	7.28	177	C509	371	4.17	0.49	757
540542	1,282	5.03	7.28	176	C510	466	4.28	0.49	951
510F	207	4.18	0.12	1,725	C511	509	4.52	7.49	68
C542	1,300	5.03	7.40	176	C512	579	4.95	7.79	74
542543	1,294	5.07	7.40	175	C515	214	4.27	6.28	34
B574R	211	6.00	6.09	35	C517	424	4.50	7.60	56
574541	208	6.10	6.09	34	C518	463	4.48	7.69	60
510D	126	4.15	0.06	2,100	C519	513	4.65	7.81	66
C541	208	6.10	6.15	34	C520	818	5.10	8.28	99
541543	205	6.45	6.15	33	C522	307	4.23	0.18	1,706
510E	282	4.27	0.18	1,567	C523	949	4.45	8.58	111
C543	1,323	5.07	13.73	96	C526	1594	4.73	1.88	848
543545	1,311	5.18	13.73	95	C527	1780	4.92	2.60	685
510G	316	4.20	0.18	1,756	C528	2229	5.00	3.80	587
C545R	1,336	5.17	13.91	96	C529	2175	5.23	4.11	529
C545	1,592	5.15	20.47	78	C530	2274	5.22	4.97	458
545546	1,581	5.27	20.47	77	C531	2232	5.47	5.18	431
511P	493	4.28	0.31	1,590	C533	757	5.55	5.18	146

TABLE 3-19 (continued)
100-year, 6-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
502A	113	4.10	0.04	2,825	C534	800	5.67	5.30	151
C546	1,666	5.23	20.82	80	C535	1055	6.00	6.09	173
509A	674	4.45	0.57	1,182	C536	703	6.23	6.52	108
552553	626	5.12	0.57	1,098	C538	895	5.82	5.18	173
509B	638	4.47	0.64	997	C540	1288	4.97	7.28	177
C553	779	5.05	1.21	644	C541	208	6.10	6.15	34
D553R	367	5.05	1.21	303	C542	1300	5.03	7.40	176
D553L	411	5.05	1.21	340	C543	1323	5.07	13.73	96
553554	408	5.20	1.21	337	C545	1592	5.15	20.47	78
509C	279	4.15	0.15	1,860	C545L	695	6.42	6.56	106
C554	410	5.18	1.36	301	C545R	1336	5.17	13.91	96
D554R	261	5.18	1.36	192	C546	1666	5.23	20.82	80
D554L	149	5.18	1.36	110	C550	886	4.20	0.45	1,969
554555	148	5.23	1.36	109	C550L	717	4.20	0.34	2,109
509E	340	4.20	0.19	1,789	C553	779	5.05	1.21	644
B539R	158	4.32	0.34	465	C554	410	5.18	1.36	301
539555	152	4.58	0.34	447	C555	394	4.43	1.88	210
C555	394	4.43	1.88	210	C556	618	5.18	1.36	454
555557	392	4.58	1.88	209	C557	755	4.52	2.18	346
B553R	367	5.05	1.21	303	C558	612	5.35	1.56	392
553556	365	5.18	1.21	302	C559	192	4.60	2.25	85
B554R	261	5.18	1.36	192	C560	127	4.63	2.28	56
C556	618	5.18	1.36	454	C561	128	4.65	2.31	55
556558	613	5.37	1.36	451	C562	199	4.52	2.41	83
509F	367	4.17	0.20	1,835	C564	347	4.07	0.15	2,313
C558	612	5.35	1.56	392	C565	657	4.70	2.28	288
D558R	263	5.35	1.56	169	C566	762	4.73	2.36	323
D558L	348	5.35	1.56	223	C567	876	4.77	4.88	180
558557	347	5.40	1.56	222	C568	915	4.78	4.99	183
509G	196	4.13	0.09	2,178	C569	920	4.90	5.09	181
C557	755	4.52	2.18	346	C570	1044	4.87	5.43	192
D557L	144	4.52	2.18	66	C571	315	4.50	2.13	148
D557R	610	4.52	2.18	280	C572	429	4.37	2.28	188
557565	606	4.73	2.18	278	C575	705	6.13	6.36	111
509M	150	4.22	0.10	1,500	C576	875	5.12	8.47	103
C565	657	4.70	2.28	288	C577	908	4.50	1.25	726
565566	655	4.73	2.28	287	C579	807	5.60	5.18	156
B557L	144	4.52	2.18	66	C580	518	5.68	5.18	100

TABLE 3-19 (continued)
100-year, 6-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
557559	143	4.65	2.18	66	C581	208	6.75	3.92	53
509H	109	4.23	0.07	1,557	CLEAR	240	5.00	4.18	57
C559	192	4.60	2.25	85	CLEAR	2387	5.17	30.43	78
D559L	76	4.58	2.25	34	CLEAR	1358	4.63	17.00	80
D559R	116	4.60	2.25	52	D502L	299	4.22	0.42	712
559560	115	4.67	2.25	51	D502R	192	4.22	0.42	457
509I	61	4.15	0.03	2,033	D508L	277	4.52	6.88	40
C560	127	4.63	2.28	56	D508R	251	4.52	6.88	36
D560L	40	4.63	2.28	18	D510L	190	4.28	0.49	388
D560R	86	4.63	2.28	38	D510R	276	4.28	0.49	563
560566	85	4.80	2.28	37	D515L	166	4.27	6.28	26
509L	209	4.05	0.08	2,613	D515R	49	4.38	6.28	8
C566	762	4.73	2.36	323	D531L	528	5.47	5.18	102
566567	760	4.78	2.36	322	D531R	1694	5.47	5.18	327
B559L	76	4.58	2.25	34	D532AL	468	5.52	5.18	90
559561	76	4.70	2.25	34	D532AR	341	5.53	5.18	66
B560L	40	4.63	2.28	18	D532L	810	5.53	5.18	156
560561	40	4.70	2.28	18	D532R	877	5.53	5.18	169
509K	60	4.13	0.03	2,000	D534L	240	5.67	5.30	45
C561	128	4.65	2.31	55	D534R	560	5.67	5.30	106
561562	128	4.70	2.31	55	D535L	158	6.00	6.09	26
509J	161	4.22	0.10	1,610	D535R	896	6.00	6.09	147
C562	199	4.52	2.41	83	D537L	248	4.40	0.91	273
562567	198	4.63	2.41	82	D537R	746	4.40	0.91	820
509P	325	4.05	0.11	2,955	D539L	295	4.32	0.34	868
C567	876	4.77	4.88	180	D539R	158	4.32	0.34	465
567568	875	4.82	4.88	179	D553L	411	5.05	1.21	340
509Q	244	4.08	0.11	2,218	D553R	367	5.05	1.21	303
C568	915	4.78	4.99	183	D554L	149	5.18	1.36	110
568569	911	4.92	4.99	183	D554R	261	5.18	1.36	192
509R	245	4.08	0.10	2,450	D557L	144	4.52	2.18	66
C569	920	4.90	5.09	181	D557R	610	4.52	2.18	280
569570	918	4.97	5.09	180	D558L	348	5.35	1.56	223
509O	100	4.05	0.04	2,500	D558R	263	5.35	1.56	169
509N	250	4.08	0.11	2,273	D559L	76	4.58	2.25	34
C564	347	4.07	0.15	2,313	D559R	116	4.60	2.25	52
564570	326	4.27	0.15	2,173	D560L	40	4.63	2.28	18
509S	431	4.13	0.19	2,268	D560R	86	4.63	2.28	38

TABLE 3-19 (continued)
100-year, 6-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
C570	1,044	4.87	5.43	192	D573L	53	5.60	5.18	10
CLEAR	2,387	5.17	30.43	78	D573R	179	5.62	5.18	35
B558R	263	5.35	1.56	169	D574L	685	6.00	6.09	112
558571	260	5.60	1.56	167	D574R	211	6.00	6.09	35
505A	341	4.15	0.18	1,894	D578L	234	5.52	5.18	45
C571	315	4.50	2.13	148	D578R	234	5.52	5.18	45
571572	311	4.65	2.13	146	TEMP1	371	4.17	0.49	757
505B	378	4.07	0.14	2,700	TEMP2	466	4.28	0.49	951
C572	429	4.37	2.28	188	WP504	162	4.67	0.26	623
500A	421	4.13	0.21	2,005	WP581	208	6.75	3.92	53
501502	365	4.73	0.21	1,738	501502	365	4.73	0.21	1,738
500B	325	4.22	0.20	1,625	502503	294	4.40	0.42	700
C502	491	4.22	0.42	1,169	502506	189	4.43	0.42	450
D502L	299	4.22	0.42	712	503508	356	4.90	0.54	659
D502R	192	4.22	0.42	457	504509	155	5.10	0.26	596
502506	189	4.43	0.42	450	506507	264	5.67	5.72	46
B534L	240	5.67	5.30	45	507508	273	4.67	5.93	46
534506	239	5.70	5.30	45	508511	271	5.28	6.88	39
C506	265	5.63	5.72	46	508517	249	5.27	6.88	36
506507	264	5.67	5.72	46	509510	361	4.33	0.49	737
500H	340	4.17	0.21	1,619	510511	272	4.35	0.49	555
C507	279	4.40	5.93	47	511512	492	5.03	7.49	66
507508	273	4.67	5.93	46	513512	201	4.38	0.10	2,010
B502L	299	4.22	0.42	712	514518	199	4.15	0.09	2,211
502503	294	4.40	0.42	700	515517	159	4.52	6.28	25
500C	248	4.12	0.12	2,067	515575	49	4.45	6.28	8
C503	395	4.35	0.54	731	517518	423	4.55	7.60	56
503508	356	4.90	0.54	659	518519	455	4.68	7.69	59
500I	644	4.17	0.41	1,571	520576	817	5.17	8.28	99
C508	528	4.52	6.88	77	521522	175	4.35	0.10	1,750
D508L	277	4.52	6.88	40	524526	871	4.72	0.65	1,340
D508R	251	4.52	6.88	36	525526	943	4.72	1.10	857
508517	249	5.27	6.88	36	526527	1562	4.93	1.88	831
B515L	166	4.27	6.28	26	527528	1764	5.02	2.60	678
515517	159	4.52	6.28	25	528529	2180	5.23	3.80	574
500L	292	4.13	0.16	1,825	530531	2238	5.47	4.97	450
C517	424	4.50	7.60	56	531532	1687	5.53	5.18	326
517518	423	4.55	7.60	56	531533	523	5.57	5.18	101

TABLE 3-19 (continued)
100-year, 6-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
500J	204	4.08	0.09	2,267	532538	866	5.83	5.18	167
514518	199	4.15	0.09	2,211	532580	339	5.68	5.18	65
C518	463	4.48	7.69	60	533579	754	5.60	5.18	146
518519	455	4.68	7.69	59	534506	239	5.70	5.30	45
500M	228	4.12	0.12	1,900	534535	550	5.95	5.30	104
C519	513	4.65	7.81	66	535515	156	6.12	6.09	26
C504	162	4.67	0.26	623	536545	696	6.42	6.52	107
504509	155	5.10	0.26	596	537538	237	4.63	0.91	260
500D	371	4.17	0.23	1,613	537577	735	4.55	0.91	808
TEMP1	371	4.17	0.49	757	538540	876	6.43	5.18	169
C509	371	4.17	0.49	757	539555	152	4.58	0.34	447
509510	361	4.33	0.49	737	539577	292	4.38	0.34	859
500E	219	4.10	0.11	1,991	540542	1282	5.03	7.28	176
C581	208	6.75	3.92	53	541543	205	6.45	6.15	33
581510	206	6.87	3.92	53	542543	1294	5.07	7.40	175
TEMP2	466	4.28	0.49	951	543545	1311	5.18	13.73	95
C510	466	4.28	0.49	951	545546	1581	5.27	20.47	77
D510L	190	4.28	0.49	388	549550	445	4.22	0.22	2,023
D510R	276	4.28	0.49	563	552553	626	5.12	0.57	1,098
510511	272	4.35	0.49	555	553554	408	5.20	1.21	337
B508L	277	4.52	6.88	40	553556	365	5.18	1.21	302
508511	271	5.28	6.88	39	554555	148	5.23	1.36	109
500F	647	4.20	0.44	1,470	555557	392	4.58	1.88	209
C511	509	4.52	7.49	68	556558	613	5.37	1.36	451
511512	492	5.03	7.49	66	557559	143	4.65	2.18	66
500K	219	4.12	0.10	2,190	557565	606	4.73	2.18	278
513512	201	4.38	0.10	2,010	558557	347	5.40	1.56	222
500G	349	4.13	0.20	1,745	558571	260	5.60	1.56	167
C512	579	4.95	7.79	74	559560	115	4.67	2.25	51
C520	818	5.10	8.28	99	559561	76	4.70	2.25	34
520576	817	5.17	8.28	99	560561	40	4.70	2.28	18
500O	182	4.13	0.10	1,820	560566	85	4.80	2.28	37
521522	175	4.35	0.10	1,750	561562	128	4.70	2.31	55
500P	201	4.10	0.08	2,513	562567	198	4.63	2.41	82
C522	307	4.23	0.18	1,706	564570	326	4.27	0.15	2,173
C576	875	5.12	8.47	103	565566	655	4.73	2.28	287
576523	874	5.15	8.47	103	566567	760	4.78	2.36	322
500N	228	4.17	0.11	2,073	567568	875	4.82	4.88	179

TABLE 3-19 (continued)
100-year, 6-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
C523	949	4.45	8.58	111	568569	911	4.92	4.99	183
501A	111	4.05	0.04	2,775	569570	918	4.97	5.09	180
501B	151	4.12	0.07	2,157	571572	311	4.65	2.13	146
CLEAR	1,358	4.63	17.00	80	573580	179	5.68	5.18	35
502B	139	4.12	0.05	2,780	574541	208	6.10	6.09	34
502C	100	4.15	0.05	2,000	574575	680	6.13	6.09	112
503A	458	4.12	0.22	2,082	575536	702	6.23	6.36	110
549550	445	4.22	0.22	2,023	576523	874	5.15	8.47	103
503C	278	4.18	0.12	2,317	577540	881	4.88	1.25	705
C550L	717	4.20	0.34	2,109	578573	232	5.60	5.18	45
503B	171	4.22	0.11	1,555	579534	803	5.67	5.18	155
C550	886	4.20	0.45	1,969	580535	511	6.08	5.18	99
504A	428	4.22	0.24	1,783	581510	206	6.87	3.92	53

TABLE 3-20
100-year, 24-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
WP504	193	12.60	0.26	742	500A	280	12.10	0.21	1,333
WP581	267	14.50	3.92	68	500B	227	12.17	0.20	1,135
CLEAR	278	12.93	4.18	67	500C	160	12.07	0.12	1,333
511A	704	12.17	0.65	1,083	500D	250	12.13	0.23	1,087
524526	638	12.70	0.65	982	500E	137	12.07	0.11	1,245
511B	792	12.50	1.10	720	500F	442	12.17	0.44	1,005
525526	788	12.60	1.10	716	500G	228	12.13	0.20	1,140
511D	140	12.20	0.13	1,077	500H	226	12.13	0.21	1,076
C526	1,472	12.63	1.88	783	500I	430	12.13	0.41	1,049
526527	1,432	12.87	1.88	762	500J	124	12.03	0.09	1,378
511E	430	12.43	0.57	754	500K	144	12.07	0.10	1,440
511F	225	12.07	0.15	1,500	500L	190	12.10	0.16	1,188
C527	1,709	12.83	2.60	657	500M	142	12.10	0.12	1,183
527528	1,686	12.93	2.60	648	500N	138	12.20	0.11	1,255
511C	747	12.57	1.20	623	500O	120	12.13	0.10	1,200
C528	2,257	12.83	3.80	594	500P	125	12.10	0.08	1,563
528529	2,188	13.10	3.80	576	501A	63	12.03	0.04	1,575
511H	312	12.17	0.31	1,006	501B	89	12.10	0.07	1,271
C529	2,211	13.10	4.11	538	502A	69	12.10	0.04	1,725
511G	768	12.27	0.87	883	502B	86	12.13	0.05	1,720
C530	2,387	13.07	4.97	480	502C	63	12.17	0.05	1,260
530531	2,337	13.33	4.97	470	503A	292	12.10	0.22	1,327
511I	236	12.07	0.21	1,124	503B	115	12.20	0.11	1,045
C531	2,337	13.33	5.18	451	503C	176	12.20	0.12	1,467
D531L	551	13.33	5.18	106	504A	290	12.20	0.24	1,208
D531R	1,779	13.33	5.18	343	505A	237	12.10	0.18	1,317
531532	1,769	13.40	5.18	342	505B	228	12.07	0.14	1,629
D532R	921	13.40	5.18	178	509A	498	12.37	0.57	874
D532L	848	13.40	5.18	164	509B	479	12.37	0.64	748
D532AL	494	13.40	5.18	95	509C	193	12.10	0.15	1,287
D532AR	353	13.40	5.18	68	509D	324	12.23	0.34	953
532580	350	13.57	5.18	68	509E	241	12.13	0.19	1,268
B532AL	494	13.40	5.18	95	509F	257	12.13	0.20	1,285
D578L	247	13.40	5.18	48	509G	134	12.10	0.09	1,489
D578R	247	13.40	5.18	48	509H	72	12.23	0.07	1,029
578573	244	13.47	5.18	47	509I	36	12.17	0.03	1,200
D573L	57	13.47	5.18	11	509J	106	12.20	0.10	1,060

TABLE 3-20 (continued)
100-year, 24-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
D573R	188	13.47	5.18	36	509K	36	12.17	0.03	1,200
573580	186	13.53	5.18	36	509L	125	12.07	0.08	1,563
C580	536	13.53	5.18	103	509M	101	12.20	0.10	1,010
580535	526	13.93	5.18	102	509N	151	12.10	0.11	1,373
B531L	551	13.33	5.18	106	509O	59	12.03	0.04	1,475
531533	544	13.43	5.18	105	509P	193	12.03	0.11	1,755
B578L	247	13.40	5.18	48	509Q	148	12.10	0.11	1,345
C533	791	13.40	5.18	153	509R	147	12.07	0.10	1,470
533579	788	13.47	5.18	152	509S	273	12.13	0.19	1,437
B573L	57	13.47	5.18	11	510A	806	12.30	0.91	886
C579	845	13.47	5.18	163	510B	374	12.23	0.36	1,039
579534	839	13.53	5.18	162	510C	675	12.40	0.85	794
511J	136	12.07	0.12	1,133	510D	75	12.17	0.06	1,250
C534	839	13.53	5.30	158	510E	195	12.23	0.18	1,083
D534L	251	13.53	5.30	47	510F	134	12.17	0.12	1,117
D534R	586	13.53	5.30	111	510G	208	12.17	0.18	1,156
534535	571	13.80	5.30	108	511A	704	12.17	0.65	1,083
511K	788	12.23	0.79	997	511B	792	12.50	1.10	720
C535	1,107	13.87	6.09	182	511C	747	12.57	1.20	623
D535R	941	13.87	6.09	155	511D	140	12.20	0.13	1,077
D535L	166	13.87	6.09	27	511E	430	12.43	0.57	754
535515	164	13.97	6.09	27	511F	225	12.07	0.15	1,500
511L	221	12.10	0.19	1,163	511G	768	12.27	0.87	883
C515	278	12.20	6.28	44	511H	312	12.17	0.31	1,006
D515L	223	12.20	6.28	36	511I	236	12.07	0.21	1,124
D515R	61	12.30	6.28	10	511J	136	12.07	0.12	1,133
515575	57	12.37	6.28	9	511K	788	12.23	0.79	997
511M	116	12.07	0.08	1,450	511L	221	12.10	0.19	1,163
B535R	941	13.87	6.09	155	511M	116	12.07	0.08	1,450
D574R	223	13.87	6.09	37	511N	85	12.10	0.07	1,214
D574L	717	13.87	6.09	118	511O	49	12.20	0.05	980
574575	710	14.00	6.09	117	511P	353	12.23	0.31	1,139
C575	741	14.00	6.36	117	511Q	106	12.13	0.09	1,178
575536	737	14.07	6.36	116	B502L	239	12.23	0.42	569
511Q	106	12.13	0.09	1,178	B508L	380	12.27	6.88	55
511N	85	12.10	0.07	1,214	B515L	223	12.20	6.28	36
C536	743	14.07	6.52	114	B531L	551	13.33	5.18	106

TABLE 3-20 (continued)
100-year, 24-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
536545	735	14.27	6.52	113	B532AL	494	13.40	5.18	95
511O	49	12.20	0.05	980	B532R	921	13.40	5.18	178
C545L	735	14.27	6.56	112	B534L	251	13.53	5.30	47
B532R	921	13.40	5.18	178	B535R	941	13.87	6.09	155
532538	901	13.70	5.18	174	B537R	631	12.30	0.91	693
510A	806	12.30	0.91	886	B539R	113	12.23	0.34	332
D537R	631	12.30	0.91	693	B553R	305	12.97	1.21	252
D537L	175	12.30	0.91	192	B554R	227	13.10	1.36	167
537538	165	12.57	0.91	181	B557L	131	12.40	2.18	60
510B	374	12.23	0.36	1,039	B558R	223	13.27	1.56	143
C538	930	13.70	5.18	180	B559L	70	12.47	2.25	31
538540	900	14.30	5.18	174	B560L	39	12.50	2.28	17
B537R	631	12.30	0.91	693	B573L	57	13.47	5.18	11
537577	619	12.43	0.91	680	B574R	223	13.87	6.09	37
509D	324	12.23	0.34	953	B578L	247	13.40	5.18	48
D539R	113	12.23	0.34	332	C502	406	12.23	0.42	967
D539L	211	12.23	0.34	621	C503	297	12.30	0.54	550
539577	208	12.30	0.34	612	C504	193	12.60	0.26	742
C577	812	12.40	1.25	650	C506	277	13.50	5.72	48
577540	772	12.80	1.25	618	C507	346	12.27	5.93	58
510C	675	12.40	0.85	794	C508	682	12.27	6.88	99
C540	1,415	12.87	7.28	194	C509	249	12.13	0.49	508
540542	1,407	12.93	7.28	193	C510	365	13.23	0.49	745
510F	134	12.17	0.12	1,117	C511	670	12.33	7.49	89
C542	1,430	12.93	7.40	193	C512	754	12.77	7.79	97
542543	1,424	12.97	7.40	192	C515	278	12.20	6.28	44
B574R	223	13.87	6.09	37	C517	517	12.40	7.60	68
574541	220	13.97	6.09	36	C518	550	12.37	7.69	72
510D	75	12.17	0.06	1,250	C519	606	12.50	7.81	78
C541	220	13.97	6.15	36	C520	1,007	13.03	8.28	122
541543	215	14.30	6.15	35	C522	209	12.20	0.18	1,161
510E	195	12.23	0.18	1,083	C523	1,108	12.37	8.58	129
C543	1,543	12.93	13.73	112	C526	1,472	12.63	1.88	783
543545	1,530	13.03	13.73	111	C527	1,709	12.83	2.60	657
510G	208	12.17	0.18	1,156	C528	2,257	12.83	3.80	594
C545R	1,562	13.03	13.91	112	C529	2,211	13.10	4.11	538
C545	1,996	12.93	20.47	98	C530	2,387	13.07	4.97	480

TABLE 3-20 (continued)
100-year, 24-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
545546	1,982	13.07	20.47	97	C531	2,337	13.33	5.18	451
511P	353	12.23	0.31	1,139	C533	791	13.40	5.18	153
502A	69	12.10	0.04	1,725	C534	839	13.53	5.30	158
C546	2,085	13.03	20.82	100	C535	1,107	13.87	6.09	182
509A	498	12.37	0.57	874	C536	743	14.07	6.52	114
552553	458	13.03	0.57	804	C538	930	13.70	5.18	180
509B	479	12.37	0.64	748	C540	1,415	12.87	7.28	194
C553	649	12.97	1.21	536	C541	220	13.97	6.15	36
D553R	305	12.97	1.21	252	C542	1,430	12.93	7.40	193
D553L	344	12.97	1.21	284	C543	1,543	12.93	13.73	112
553554	339	13.13	1.21	280	C545	1,996	12.93	20.47	98
509C	193	12.10	0.15	1,287	C545L	735	14.27	6.56	112
C554	347	13.10	1.36	255	C545R	1,562	13.03	13.91	112
D554R	227	13.10	1.36	167	C546	2,085	13.03	20.82	100
D554L	120	13.10	1.36	88	C550	570	12.20	0.45	1,267
554555	119	13.17	1.36	88	C550L	456	12.20	0.34	1,341
509E	241	12.13	0.19	1,268	C553	649	12.97	1.21	536
B539R	113	12.23	0.34	332	C554	347	13.10	1.36	255
539555	108	12.53	0.34	318	C555	387	12.30	1.88	206
C555	387	12.30	1.88	206	C556	528	13.10	1.36	388
555557	371	12.43	1.88	197	C557	722	12.40	2.18	331
B553R	305	12.97	1.21	252	C558	531	13.27	1.56	340
553556	301	13.10	1.21	249	C559	178	12.47	2.25	79
B554R	227	13.10	1.36	167	C560	121	12.50	2.28	53
C556	528	13.10	1.36	388	C561	122	12.53	2.31	53
556558	521	13.30	1.36	383	C562	189	12.37	2.41	78
509F	257	12.13	0.20	1,285	C564	209	12.07	0.15	1,393
C558	531	13.27	1.56	340	C565	637	12.57	2.28	279
D558R	223	13.27	1.56	143	C566	746	12.60	2.36	316
D558L	308	13.27	1.56	197	C567	958	12.63	4.88	196
558557	307	13.30	1.56	197	C568	1,005	12.67	4.99	201
509G	134	12.10	0.09	1,489	C569	1,008	12.77	5.09	198
C557	722	12.40	2.18	331	C570	1,139	12.80	5.43	210
D557L	131	12.40	2.18	60	C571	302	12.23	2.13	142
D557R	591	12.40	2.18	271	C572	422	12.27	2.28	185
557565	584	12.60	2.18	268	C575	741	14.00	6.36	117
509M	101	12.20	0.10	1,010	C576	1,063	13.03	8.47	126

TABLE 3-20 (continued)
100-year, 24-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
C565	637	12.57	2.28	279	C577	812	12.40	1.25	650
565566	635	12.63	2.28	279	C579	845	13.47	5.18	163
B557L	131	12.40	2.18	60	C580	536	13.53	5.18	103
557559	129	12.53	2.18	59	C581	267	14.50	3.92	68
509H	72	12.23	0.07	1,029	CLEAR	278	12.93	4.18	67
C559	178	12.47	2.25	79	CLEAR	3,216	12.97	30.43	106
D559L	70	12.47	2.25	31	CLEAR	1,772	12.40	17.00	104
D559R	108	12.47	2.25	48	D502L	239	12.23	0.42	569
559560	107	12.53	2.25	48	D502R	166	12.23	0.42	395
509I	36	12.17	0.03	1,200	D508L	380	12.27	6.88	55
C560	121	12.50	2.28	53	D508R	303	12.27	6.88	44
D560L	39	12.50	2.28	17	D510L	148	13.23	0.49	302
D560R	82	12.50	2.28	36	D510R	217	13.23	0.49	443
560566	80	12.67	2.28	35	D515L	223	12.20	6.28	36
509L	125	12.07	0.08	1,563	D515R	61	12.30	6.28	10
C566	746	12.60	2.36	316	D531L	551	13.33	5.18	106
566567	742	12.67	2.36	314	D531R	1,779	13.33	5.18	343
B559L	70	12.47	2.25	31	D532AL	494	13.40	5.18	95
559561	69	12.60	2.25	31	D532AR	353	13.40	5.18	68
B560L	39	12.50	2.28	17	D532L	848	13.40	5.18	164
560561	39	12.57	2.28	17	D532R	921	13.40	5.18	178
509K	36	12.17	0.03	1,200	D534L	251	13.53	5.30	47
C561	122	12.53	2.31	53	D534R	586	13.53	5.30	111
561562	121	12.57	2.31	52	D535L	166	13.87	6.09	27
509J	106	12.20	0.10	1,060	D535R	941	13.87	6.09	155
C562	189	12.37	2.41	78	D537L	175	12.30	0.91	192
562567	188	12.50	2.41	78	D537R	631	12.30	0.91	693
509P	193	12.03	0.11	1,755	D539L	211	12.23	0.34	621
C567	958	12.63	4.88	196	D539R	113	12.23	0.34	332
567568	955	12.67	4.88	196	D553L	344	12.97	1.21	284
509Q	148	12.10	0.11	1,345	D553R	305	12.97	1.21	252
C568	1,005	12.67	4.99	201	D554L	120	13.10	1.36	88
568569	993	12.80	4.99	199	D554R	227	13.10	1.36	167
509R	147	12.07	0.10	1,470	D557L	131	12.40	2.18	60
C569	1,008	12.77	5.09	198	D557R	591	12.40	2.18	271
569570	1,001	12.87	5.09	197	D558L	308	13.27	1.56	197
509O	59	12.03	0.04	1,475	D558R	223	13.27	1.56	143

TABLE 3-20 (continued)
100-year, 24-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID (1)	Peak Discharge in cfs (2)	Time to Peak in hours (3)	Drainage Area, in sq miles (4)	Unit Discharge in cfs/sm (5)	HEC-1 ID (6)	Peak Discharge in cfs (7)	Time to Peak in hours (8)	Drainage Area, in sq miles (9)	Unit Discharge in cfs/sm (10)
509N	151	12.10	0.11	1,373	D559L	70	12.47	2.25	31
C564	209	12.07	0.15	1,393	D559R	108	12.47	2.25	48
564570	195	12.27	0.15	1,300	D560L	39	12.50	2.28	17
509S	273	12.13	0.19	1,437	D560R	82	12.50	2.28	36
C570	1,139	12.80	5.43	210	D573L	57	13.47	5.18	11
CLEAR	3,216	12.97	30.43	106	D573R	188	13.47	5.18	36
B558R	223	13.27	1.56	143	D574L	717	13.87	6.09	118
558571	219	13.50	1.56	140	D574R	223	13.87	6.09	37
505A	237	12.10	0.18	1,317	D578L	247	13.40	5.18	48
C571	302	12.23	2.13	142	D578R	247	13.40	5.18	48
571572	294	12.40	2.13	138	TEMP1	249	12.13	0.49	508
505B	228	12.07	0.14	1,629	TEMP2	365	13.23	0.49	745
C572	422	12.27	2.28	185	WP504	193	12.60	0.26	742
500A	280	12.10	0.21	1,333	WP581	267	14.50	3.92	68
501502	240	12.57	0.21	1,143	501502	240	12.57	0.21	1,143
500B	227	12.17	0.20	1,135	502503	233	12.40	0.42	555
C502	406	12.23	0.42	967	502506	164	12.43	0.42	390
D502L	239	12.23	0.42	569	503508	271	12.83	0.54	502
D502R	166	12.23	0.42	395	504509	181	13.03	0.26	696
502506	164	12.43	0.42	390	506507	275	13.53	5.72	48
B534L	251	13.53	5.30	47	507508	324	12.50	5.93	55
534506	250	13.57	5.30	47	508511	357	12.67	6.88	52
C506	277	13.50	5.72	48	508517	291	12.70	6.88	42
506507	275	13.53	5.72	48	509510	236	12.27	0.49	482
500H	226	12.13	0.21	1,076	510511	215	13.30	0.49	439
C507	346	12.27	5.93	58	511512	647	12.87	7.49	86
507508	324	12.50	5.93	55	513512	130	12.33	0.10	1,300
B502L	239	12.23	0.42	569	514518	121	12.10	0.09	1,344
502503	233	12.40	0.42	555	515517	204	12.40	6.28	32
500C	160	12.07	0.12	1,333	515575	57	12.37	6.28	9
C503	297	12.30	0.54	550	517518	511	12.43	7.60	67
503508	271	12.83	0.54	502	518519	542	12.57	7.69	70
500I	430	12.13	0.41	1,049	520576	1,004	13.07	8.28	121
C508	682	12.27	6.88	99	521522	114	12.37	0.10	1,140
D508L	380	12.27	6.88	55	524526	638	12.70	0.65	982
D508R	303	12.27	6.88	44	525526	788	12.60	1.10	716
508517	291	12.70	6.88	42	526527	1,432	12.87	1.88	762

TABLE 3-20 (continued)
100-year, 24-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
B515L	223	12.20	6.28	36	527528	1,686	12.93	2.60	648
515517	204	12.40	6.28	32	528529	2,188	13.10	3.80	576
500L	190	12.10	0.16	1,188	530531	2,337	13.33	4.97	470
C517	517	12.40	7.60	68	531532	1,769	13.40	5.18	342
517518	511	12.43	7.60	67	531533	544	13.43	5.18	105
500J	124	12.03	0.09	1,378	532538	901	13.70	5.18	174
514518	121	12.10	0.09	1,344	532580	350	13.57	5.18	68
C518	550	12.37	7.69	72	533579	788	13.47	5.18	152
518519	542	12.57	7.69	70	534506	250	13.57	5.30	47
500M	142	12.10	0.12	1,183	534535	571	13.80	5.30	108
C519	606	12.50	7.81	78	535515	164	13.97	6.09	27
C504	193	12.60	0.26	742	536545	735	14.27	6.52	113
504509	181	13.03	0.26	696	537538	165	12.57	0.91	181
500D	250	12.13	0.23	1,087	537577	619	12.43	0.91	680
TEMP1	249	12.13	0.49	508	538540	900	14.30	5.18	174
C509	249	12.13	0.49	508	539555	108	12.53	0.34	318
509510	236	12.27	0.49	482	539577	208	12.30	0.34	612
500E	137	12.07	0.11	1,245	540542	1,407	12.93	7.28	193
C581	267	14.50	3.92	68	541543	215	14.30	6.15	35
581510	265	14.63	3.92	68	542543	1,424	12.97	7.40	192
TEMP2	365	13.23	0.49	745	543545	1,530	13.03	13.73	111
C510	365	13.23	0.49	745	545546	1,982	13.07	20.47	97
D510L	148	13.23	0.49	302	549550	283	12.23	0.22	1,286
D510R	217	13.23	0.49	443	552553	458	13.03	0.57	804
510511	215	13.30	0.49	439	553554	339	13.13	1.21	280
B508L	380	12.27	6.88	55	553556	301	13.10	1.21	249
508511	357	12.67	6.88	52	554555	119	13.17	1.36	88
500F	442	12.17	0.44	1,005	555557	371	12.43	1.88	197
C511	670	12.33	7.49	89	556558	521	13.30	1.36	383
511512	647	12.87	7.49	86	557559	129	12.53	2.18	59
500K	144	12.07	0.10	1,440	557565	584	12.60	2.18	268
513512	130	12.33	0.10	1,300	558557	307	13.30	1.56	197
500G	228	12.13	0.20	1,140	558571	219	13.50	1.56	140
C512	754	12.77	7.79	97	559560	107	12.53	2.25	48
C520	1,007	13.03	8.28	122	559561	69	12.60	2.25	31
520576	1,004	13.07	8.28	121	560561	39	12.57	2.28	17
500O	120	12.13	0.10	1,200	560566	80	12.67	2.28	35

TABLE 3-20 (continued)
100-year, 24-hour Storm Results, with Levee

Existing Condition In HEC-1 Run Order					Existing Condition In Numerical Order by Operation Type				
HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm	HEC-1 ID	Peak Discharge in cfs	Time to Peak in hours	Drainage Area, in sq miles	Unit Discharge in cfs/sm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
521522	114	12.37	0.10	1,140	561562	121	12.57	2.31	52
500P	125	12.10	0.08	1,563	562567	188	12.50	2.41	78
C522	209	12.20	0.18	1,161	564570	195	12.27	0.15	1,300
C576	1,063	13.03	8.47	126	565566	635	12.63	2.28	279
576523	1,061	13.07	8.47	125	566567	742	12.67	2.36	314
500N	138	12.20	0.11	1,255	567568	955	12.67	4.88	196
C523	1,108	12.37	8.58	129	568569	993	12.80	4.99	199
501A	63	12.03	0.04	1,575	569570	1,001	12.87	5.09	197
501B	89	12.10	0.07	1,271	571572	294	12.40	2.13	138
CLEAR	1,772	12.40	17.00	104	573580	186	13.53	5.18	36
502B	86	12.13	0.05	1,720	574541	220	13.97	6.09	36
502C	63	12.17	0.05	1,260	574575	710	14.00	6.09	117
503A	292	12.10	0.22	1,327	575536	737	14.07	6.36	116
549550	283	12.23	0.22	1,286	576523	1,061	13.07	8.47	125
503C	176	12.20	0.12	1,467	577540	772	12.80	1.25	618
C550L	456	12.20	0.34	1,341	578573	244	13.47	5.18	47
503B	115	12.20	0.11	1,045	579534	839	13.53	5.18	162
C550	570	12.20	0.45	1,267	580535	526	13.93	5.18	102
504A	290	12.20	0.24	1,208	581510	265	14.63	3.92	68

TABLE 3-21

Existing Condition

100-year Peak Discharges in Numerical Order by Operation Type, with Levee

HEC-1 ID (1)	Discharge, in cfs 6 (2)	24 (3)	Control (4)
500A	421	280	6-hour controls
500B	325	227	6-hour controls
500C	248	160	6-hour controls
500D	371	250	6-hour controls
500	219	137	6-hour controls
500F	647	442	6-hour controls
500G	349	228	6-hour controls
500H	340	226	6-hour controls
500I	644	430	6-hour controls
500J	204	124	6-hour controls
500K	219	144	6-hour controls
500L	292	190	6-hour controls
500M	228	142	6-hour controls
500N	228	138	6-hour controls
500O	182	120	6-hour controls
500P	201	125	6-hour controls
501A	111	63	6-hour controls
501B	151	89	6-hour controls
502A	113	69	6-hour controls
502B	139	86	6-hour controls
502C	100	63	6-hour controls
503A	458	292	6-hour controls
503B	171	115	6-hour controls
503C	278	176	6-hour controls
504A	428	290	6-hour controls
505A	341	237	6-hour controls
505B	378	228	6-hour controls
509A	674	498	6-hour controls
509B	638	479	6-hour controls
509C	279	193	6-hour controls
509D	453	324	6-hour controls
509	340	241	6-hour controls
509F	367	257	6-hour controls
509G	196	134	6-hour controls
509H	109	72	6-hour controls
509I	61	36	6-hour controls
509J	161	106	6-hour controls
509K	60	36	6-hour controls
509L	209	125	6-hour controls
509M	150	101	6-hour controls
509N	250	151	6-hour controls
509O	100	59	6-hour controls
509P	325	193	6-hour controls
509Q	244	148	6-hour controls
509R	245	147	6-hour controls
509S	431	273	6-hour controls
510A	994	806	6-hour controls
510B	518	374	6-hour controls
510C	850	675	6-hour controls
510D	126	75	6-hour controls
510	282	195	6-hour controls
510F	207	134	6-hour controls
510G	316	208	6-hour controls
511A	941	704	6-hour controls
511B	948	792	6-hour controls
511C	878	747	6-hour controls
511D	195	140	6-hour controls
511	579	430	6-hour controls
511F	340	225	6-hour controls
511G	961	768	6-hour controls
511H	458	312	6-hour controls
511I	382	236	6-hour controls
511J	238	136	6-hour controls
511K	1,001	788	6-hour controls
511L	336	221	6-hour controls
511M	182	116	6-hour controls
511N	132	85	6-hour controls
511O	78	49	6-hour controls
511P	493	353	6-hour controls
511Q	164	106	6-hour controls
B502L	299	239	6-hour controls
B508L	277	380	24-hour controls
B515L	166	223	24-hour controls
B531L	528	551	24-hour controls
B532AL	468	494	24-hour controls
B532R	877	921	24-hour controls

TABLE 3-21 (continued)

Existing Condition
100-year Peak Discharges in Numerical Order by Operation Type, with Levee

HEC-1 ID (1)	Discharge, in cfs 6 (2)	24 (3)	Control (4)	HEC-1 ID (1)	Discharge, in cfs 6 (2)	24 (3)	Control (4)
B534L	240	251	24-hour controls	C535	1,055	1,107	24-hour controls
B535R	896	941	24-hour controls	C536	703	743	24-hour controls
B537R	746	631	6-hour controls	C538	895	930	24-hour controls
B539R	158	113	6-hour controls	C540	1,288	1,415	24-hour controls
B553R	367	305	6-hour controls	C541	208	220	24-hour controls
B554R	261	227	6-hour controls	C542	1,300	1,430	24-hour controls
B557L	144	131	6-hour controls	C543	1,323	1,543	24-hour controls
B558R	263	223	6-hour controls	C545	1,592	1,996	24-hour controls
B559L	76	70	6-hour controls	C545L	695	735	24-hour controls
B560L	40	39	6-hour controls	C545R	1,336	1,562	24-hour controls
B573L	53	57	24-hour controls	C546	1,666	2,085	24-hour controls
B574R	211	223	24-hour controls	C550	886	570	6-hour controls
B578L	234	247	24-hour controls	C550L	717	456	6-hour controls
C502	491	406	6-hour controls	C553	779	649	6-hour controls
C503	395	297	6-hour controls	C554	410	347	6-hour controls
C504	162	193	24-hour controls	C555	394	387	6-hour controls
C506	265	277	24-hour controls	C556	618	528	6-hour controls
C507	279	346	24-hour controls	C557	755	722	6-hour controls
C508	528	682	24-hour controls	C558	612	531	6-hour controls
C509	371	249	6-hour controls	C559	192	178	6-hour controls
C510	466	365	6-hour controls	C560	127	121	6-hour controls
C511	509	670	24-hour controls	C561	128	122	6-hour controls
C512	579	754	24-hour controls	C562	199	189	6-hour controls
C515	214	278	24-hour controls	C564	347	209	6-hour controls
C517	424	517	24-hour controls	C565	657	637	6-hour controls
C518	463	550	24-hour controls	C566	762	746	6-hour controls
C519	513	606	24-hour controls	C567	876	958	24-hour controls
C520	818	1,007	24-hour controls	C568	915	1,005	24-hour controls
C522	307	209	6-hour controls	C569	920	1,008	24-hour controls
C523	949	1,108	24-hour controls	C570	1,044	1,139	24-hour controls
C526	1,594	1,472	6-hour controls	C571	315	302	6-hour controls
C527	1,780	1,709	6-hour controls	C572	429	422	6-hour controls
C528	2,229	2,257	24-hour controls	C575	705	741	24-hour controls
C529	2,175	2,211	24-hour controls	C576	875	1,063	24-hour controls
C530	2,274	2,387	24-hour controls	C577	908	812	6-hour controls
C531	2,232	2,337	24-hour controls	C579	807	845	24-hour controls
C533	757	791	24-hour controls	C580	518	536	24-hour controls
C534	800	839	24-hour controls	C581	208	267	24-hour controls

TABLE 3-21 (continued)

Existing Condition
100-year Peak Discharges in Numerical Order by Operation Type, with Levee

HEC-1	Discharge, in cfs		
ID	6	24	Control
(1)	(2)	(3)	(4)
CLEAR	240	278	24-hour controls
CLEAR	2,387	3,216	24-hour controls
CLEAR	1,358	1,772	24-hour controls
D502L	299	239	6-hour controls
D502R	192	166	6-hour controls
D508L	277	380	24-hour controls
D508R	251	303	24-hour controls
D510L	190	148	6-hour controls
D510R	276	217	6-hour controls
D515L	166	223	24-hour controls
D515R	49	61	24-hour controls
D531L	528	551	24-hour controls
D531R	1,694	1,779	24-hour controls
D532AL	468	494	24-hour controls
D532AR	341	353	24-hour controls
D532L	810	848	24-hour controls
D532R	877	921	24-hour controls
D534L	240	251	24-hour controls
D534R	560	586	24-hour controls
D535L	158	166	24-hour controls
D535R	896	941	24-hour controls
D537L	248	175	6-hour controls
D537R	746	631	6-hour controls
D539L	295	211	6-hour controls
D539R	158	113	6-hour controls
D553L	411	344	6-hour controls
D553R	367	305	6-hour controls
D554L	149	120	6-hour controls
D554R	261	227	6-hour controls
D557L	144	131	6-hour controls
D557R	610	591	6-hour controls
D558L	348	308	6-hour controls
D558R	263	223	6-hour controls
D559L	76	70	6-hour controls
D559R	116	108	6-hour controls
D560L	40	39	6-hour controls
D560R	86	82	6-hour controls
D573L	53	57	24-hour controls

HEC-1	Discharge, in cfs		
ID	6	24	Control
(1)	(2)	(3)	(4)
D573R	179	188	24-hour controls
D574L	685	717	24-hour controls
D574R	211	223	24-hour controls
D578L	234	247	24-hour controls
D578R	234	247	24-hour controls
TEMP1	371	249	6-hour controls
TEMP2	466	365	6-hour controls
WP504	162	193	24-hour controls
WP581	208	267	24-hour controls
501502	365	240	6-hour controls
502503	294	233	6-hour controls
502506	189	164	6-hour controls
503508	356	271	6-hour controls
504509	155	181	24-hour controls
506507	264	275	24-hour controls
507508	273	324	24-hour controls
508511	271	357	24-hour controls
508517	249	291	24-hour controls
509510	361	236	6-hour controls
510511	272	215	6-hour controls
511512	492	647	24-hour controls
513512	201	130	6-hour controls
514518	199	121	6-hour controls
515517	159	204	24-hour controls
515575	49	57	24-hour controls
517518	423	511	24-hour controls
518519	455	542	24-hour controls
520576	817	1,004	24-hour controls
521522	175	114	6-hour controls
524526	871	638	6-hour controls
525526	943	788	6-hour controls
526527	1,562	1,432	6-hour controls
527528	1,764	1,686	6-hour controls
528529	2,180	2,188	24-hour controls
530531	2,238	2,337	24-hour controls
531532	1,687	1,769	24-hour controls
531533	523	544	24-hour controls
532538	866	901	24-hour controls

TABLE 3-21 (continued)

Existing Condition
100-year Peak Discharges in Numerical Order by Operation Type, with Levee

HEC-1	Discharge, in cfs			HEC-1	Discharge, in cfs		
ID	6	24	Control	ID	6	24	Control
(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
532580	339	350	24-hour controls	558557	347	307	6-hour controls
533579	754	788	24-hour controls	558571	260	219	6-hour controls
534506	239	250	24-hour controls	559560	115	107	6-hour controls
534535	550	571	24-hour controls	559561	76	69	6-hour controls
535515	156	164	24-hour controls	560561	40	39	6-hour controls
536545	696	735	24-hour controls	560566	85	80	6-hour controls
537538	237	165	6-hour controls	561562	128	121	6-hour controls
537577	735	619	6-hour controls	562567	198	188	6-hour controls
538540	876	900	24-hour controls	564570	326	195	6-hour controls
539555	152	108	6-hour controls	565566	655	635	6-hour controls
539577	292	208	6-hour controls	566567	760	742	6-hour controls
540542	1,282	1,407	24-hour controls	567568	875	955	24-hour controls
541543	205	215	24-hour controls	568569	911	993	24-hour controls
542543	1,294	1,424	24-hour controls	569570	918	1,001	24-hour controls
543545	1,311	1,530	24-hour controls	571572	311	294	6-hour controls
545546	1,581	1,982	24-hour controls	573580	179	186	24-hour controls
549550	445	283	6-hour controls	574541	208	220	24-hour controls
552553	626	458	6-hour controls	574575	680	710	24-hour controls
553554	408	339	6-hour controls	575536	702	737	24-hour controls
553556	365	301	6-hour controls	576523	874	1,061	24-hour controls
554555	148	119	6-hour controls	577540	881	772	6-hour controls
555557	392	371	6-hour controls	578573	232	244	24-hour controls
556558	613	521	6-hour controls	579534	803	839	24-hour controls
557559	143	129	6-hour controls	580535	511	526	24-hour controls
557565	606	584	6-hour controls	581510	206	265	24-hour controls

TABLE 3-22

Summary of 100-year 6-hour and 24-hour Runoff Volumes with Levee

HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet	HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet
(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
500A	0.21	1.59	18	1.26	14	504A	0.24	2.11	27	1.85	24
500B	0.20	1.59	17	1.26	13	505A	0.18	1.74	17	1.42	14
500C	0.12	1.50	10	1.20	8	505B	0.14	2.39	18	2.24	17
500D	0.23	1.41	17	1.14	14	509A	0.57	1.84	56	1.57	48
500E	0.11	1.41	8	1.14	7	509B	0.64	1.51	52	1.23	42
500F	0.44	1.42	33	1.14	27	509C	0.15	1.70	14	1.38	11
500G	0.20	2.07	22	1.98	21	509D	0.34	1.64	30	1.31	24
500H	0.21	1.39	16	1.12	13	509E	0.19	1.81	18	1.49	15
500I	0.41	1.37	30	1.11	24	509F	0.20	1.73	18	1.41	15
500J	0.09	1.48	7	1.21	6	509G	0.09	1.78	9	1.46	7
500K	0.10	1.90	10	1.66	9	509H	0.07	1.81	7	1.49	6
500L	0.16	1.41	12	1.14	10	509I	0.03	1.60	3	1.28	2
500M	0.12	2.04	13	1.90	12	509J	0.10	1.87	10	1.61	9
500N	0.11	1.69	10	1.36	8	509K	0.03	1.75	3	1.42	2
500O	0.10	2.33	12	2.17	12	509L	0.08	2.25	10	2.07	9
500P	0.08	2.13	9	1.90	8	509M	0.10	1.67	9	1.36	7
501A	0.04	1.85	4	1.60	3	509N	0.11	2.31	14	2.28	13
501B	0.07	1.62	6	1.31	5	509O	0.04	2.70	6	3.02	6
502A	0.04	2.14	5	1.93	4	509P	0.11	2.50	15	2.50	15
502B	0.05	2.14	6	1.93	5	509Q	0.11	2.33	14	2.18	13
502C	0.05	2.14	6	1.93	5	509R	0.10	1.91	10	1.63	9
503A	0.22	2.44	29	2.35	28	509S	0.19	2.09	21	1.83	19
503B	0.11	2.21	13	2.02	12	510A	0.91	1.58	77	1.35	65
503C	0.12	2.05	13	1.78	11	510B	0.36	1.81	35	1.49	29

TABLE 3-22 (continued)

Summary of 100-year 6-hour and 24-hour Runoff Volumes with Levee

HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet	HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet
(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
510C	0.85	1.65	75	1.39	63	B515L	6.28	0.10	33	0.11	36
510D	0.06	1.76	6	1.40	4	B531L	5.18	0.29	81	0.31	85
510E	0.18	2.14	21	1.89	18	B532AL	5.18	0.24	67	0.26	71
510F	0.12	1.86	12	1.59	10	B532R	5.18	0.49	134	0.52	142
510G	0.18	1.98	19	1.79	17	B534L	5.30	0.13	36	0.14	39
511A	0.65	1.61	56	1.32	46	B535R	6.09	0.58	187	0.62	200
511B	1.10	1.72	101	1.56	91	B537R	0.91	1.33	65	1.16	56
511C	1.20	1.53	98	1.35	86	B539R	0.34	0.59	11	0.48	9
511D	0.13	1.76	12	1.44	10	B553R	1.21	0.74	48	0.67	43
511E	0.57	1.72	52	1.42	43	B554R	1.36	0.57	41	0.52	37
511F	0.15	1.72	14	1.40	11	B557L	2.18	0.11	13	0.10	11
511G	0.87	1.54	71	1.33	62	B558R	1.56	0.53	44	0.47	39
511H	0.31	1.41	23	1.14	19	B559L	2.25	0.06	8	0.06	7
511I	0.21	1.29	14	1.03	12	B560L	2.28	0.04	5	0.04	4
511J	0.12	1.24	8	0.98	6	B573L	5.18	0.02	5	0.02	5
511K	0.79	1.67	70	1.40	59	B574R	6.09	0.12	38	0.13	41
511L	0.19	1.41	14	1.14	12	B578L	5.18	0.12	33	0.13	35
511M	0.08	1.56	7	1.24	5	C502	0.42	1.59	36	1.26	28
511N	0.07	2.27	8	2.05	8	C503	0.54	0.98	28	0.75	22
511O	0.05	1.69	5	1.37	4	C504	0.26	1.17	16	1.20	17
511P	0.31	2.13	35	1.90	31	C506	5.72	0.16	49	0.17	52
511Q	0.09	2.39	11	2.26	11	C507	5.93	0.19	59	0.20	64
B502L	0.42	0.85	19	0.63	14	C508	6.88	0.25	92	0.29	106
B508L	6.88	0.11	40	0.14	50	C509	0.49	1.25	33	1.14	30

TABLE 3-22 (continued)

Summary of 100-year 6-hour and 24-hour Runoff Volumes with Levee

HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet	HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet
(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
C510	0.49	3.47	91	3.61	94	C543	13.73	0.42	310	0.48	354
C511	7.49	0.27	108	0.33	130	C545	20.47	0.40	439	0.48	528
C512	7.79	0.31	130	0.37	155	C545L	6.56	0.51	177	0.54	189
C515	6.28	0.12	42	0.14	46	C545R	13.91	0.43	320	0.49	366
C517	7.60	0.22	89	0.25	100	C546	20.82	0.42	467	0.50	560
C518	7.69	0.23	92	0.26	105	C550	0.45	2.27	55	2.10	50
C519	7.81	0.24	102	0.28	115	C550L	0.34	2.30	42	2.13	39
C520	8.28	0.48	210	0.56	249	C553	1.21	1.54	99	1.36	88
C522	0.18	2.23	21	2.01	19	C554	1.36	0.86	62	0.77	56
C523	8.58	0.51	234	0.60	274	C555	1.88	0.45	46	0.41	41
C526	1.88	1.56	157	1.46	146	C556	1.36	1.22	89	1.11	80
C527	2.60	1.50	207	1.44	200	C557	2.18	0.95	110	0.89	103
C528	3.80	1.39	282	1.40	284	C558	1.56	1.25	104	1.13	94
C529	4.11	1.33	291	1.35	295	C559	2.25	0.16	19	0.14	17
C530	4.97	1.28	338	1.34	356	C560	2.28	0.11	13	0.10	12
C531	5.18	1.24	342	1.31	361	C561	2.31	0.12	15	0.11	13
C533	5.18	0.41	113	0.43	119	C562	2.41	0.18	23	0.17	22
C534	5.30	0.43	121	0.46	129	C564	0.15	2.40	19	2.46	20
C535	6.09	0.68	220	0.72	235	C565	2.28	0.86	105	0.82	99
C536	6.52	0.51	176	0.54	187	C566	2.36	0.96	121	0.91	115
C538	5.18	0.61	169	0.65	178	C567	4.88	0.56	144	0.58	150
C540	7.28	0.72	280	0.78	301	C568	4.99	0.59	156	0.61	162
C541	6.15	0.13	41	0.14	45	C569	5.09	0.60	163	0.63	170
C542	7.40	0.73	288	0.79	310	C570	5.43	0.68	197	0.71	206

TABLE 3-22 (continued)

Summary of 100-year 6-hour and 24-hour Runoff Volumes with Levee

HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet	HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet
(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
C571	2.13	0.50	56	0.46	52	D532R	5.18	0.49	134	0.52	142
C572	2.28	0.60	73	0.57	69	D534L	5.30	0.13	36	0.14	39
C575	6.36	0.47	159	0.50	170	D534R	5.30	0.30	85	0.32	90
C576	8.47	0.50	228	0.59	267	D535L	6.09	0.10	33	0.11	35
C577	1.25	1.20	80	1.06	71	D535R	6.09	0.58	187	0.62	200
C579	5.18	0.42	117	0.45	124	D537L	0.91	0.25	12	0.18	9
C580	5.18	0.31	86	0.33	90	D537R	0.91	1.33	65	1.16	56
C581	3.92	0.25	51	0.29	60	D539L	0.34	1.04	19	0.83	15
CLEAR	4.18	0.30	68	0.34	76	D539R	0.34	0.59	11	0.48	9
CLEAR	30.43	0.40	641	0.50	803	D553L	1.21	0.79	51	0.70	45
CLEAR	17.00	0.37	334	0.45	412	D553R	1.21	0.74	48	0.67	43
D502L	0.42	0.85	19	0.63	14	D554L	1.36	0.29	21	0.25	18
D502R	0.42	0.74	16	0.63	14	D554R	1.36	0.57	41	0.52	37
D508L	6.88	0.11	40	0.14	50	D557L	2.18	0.11	13	0.10	11
D508R	6.88	0.14	52	0.16	57	D557R	2.18	0.84	97	0.79	92
D510L	0.49	1.38	36	1.44	38	D558L	1.56	0.72	60	0.66	55
D510R	0.49	2.08	54	2.17	57	D558R	1.56	0.53	44	0.47	39
D515L	6.28	0.10	33	0.11	36	D559L	2.25	0.06	8	0.06	7
D515R	6.28	0.03	9	0.03	10	D559R	2.25	0.09	11	0.08	10
D531L	5.18	0.29	81	0.31	85	D560L	2.28	0.04	5	0.04	4
D531R	5.18	0.94	261	1.00	275	D560R	2.28	0.07	8	0.06	7
D532AL	5.18	0.24	67	0.26	71	D573L	5.18	0.02	5	0.02	5
D532AR	5.18	0.21	58	0.22	61	D573R	5.18	0.10	28	0.11	30
D532L	5.18	0.45	125	0.48	132	D574L	6.09	0.46	149	0.49	159

TABLE 3-22 (continued)

Summary of 100-year 6-hour and 24-hour Runoff Volumes with Levee

HEC-1 ID (1)	Drainage Area sm (2)	100-year 6-hour Excess inches (3)	100-year 6-hour Volume acre-feet (4)	100-year 24-hour Excess inches (5)	100-year 24-hour Volume acre-feet (6)	HEC-1 ID (1)	Drainage Area sm (2)	100-year 6-hour Excess inches (3)	100-year 6-hour Volume acre-feet (4)	100-year 24-hour Excess inches (5)	100-year 24-hour Volume acre-feet (6)
D574R	6.09	0.12	38	0.13	41	518519	7.69	0.22	91	0.25	104
D578L	5.18	0.12	33	0.13	35	520576	8.28	0.48	210	0.56	249
D578R	5.18	0.12	33	0.13	35	521522	0.10	2.31	12	2.12	11
TEMP1	0.49	1.25	33	1.14	30	524526	0.65	1.61	56	1.32	46
TEMP2	0.49	3.47	91	3.61	94	525526	1.10	1.72	101	1.56	91
WP504	0.26	1.17	16	1.20	17	526527	1.88	1.56	156	1.46	146
WP581	3.92	0.25	51	0.29	60	527528	2.60	1.49	206	1.43	199
501502	0.21	1.59	18	1.26	14	528529	3.80	1.37	277	1.37	277
502503	0.42	0.84	19	0.62	14	530531	4.97	1.26	335	1.32	350
502506	0.42	0.73	16	0.62	14	531532	5.18	0.94	259	0.99	274
503508	0.54	0.97	28	0.74	21	531533	5.18	0.29	79	0.30	84
504509	0.26	1.11	15	1.14	16	532538	5.18	0.48	134	0.51	141
506507	5.72	0.16	49	0.17	52	532580	5.18	0.21	58	0.22	61
507508	5.93	0.18	58	0.20	63	533579	5.18	0.41	112	0.43	119
508511	6.88	0.11	40	0.13	49	534506	5.30	0.13	36	0.14	39
508517	6.88	0.14	51	0.15	56	534535	5.30	0.29	83	0.32	89
509510	0.49	1.24	32	1.13	29	535515	6.09	0.10	32	0.11	34
510511	0.49	2.07	54	2.15	56	536545	6.52	0.50	174	0.53	186
511512	7.49	0.27	106	0.32	128	537538	0.91	0.25	12	0.18	9
513512	0.10	1.81	10	1.44	8	537577	0.91	1.32	64	1.16	56
514518	0.09	1.47	7	1.18	6	538540	5.18	0.61	168	0.64	177
515517	6.28	0.10	32	0.11	36	539555	0.34	0.59	11	0.47	9
515575	6.28	0.03	9	0.03	9	539577	0.34	1.04	19	0.83	15
517518	7.60	0.22	88	0.25	99	540542	7.28	0.72	280	0.78	301

TABLE 3-22 (continued)

Summary of 100-year 6-hour and 24-hour Runoff Volumes with Levee

HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet	HEC-1 ID	Drainage Area sm	100-year 6-hour Excess inches	100-year 6-hour Volume acre-feet	100-year 24-hour Excess inches	100-year 24-hour Volume acre-feet
(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
541543	6.15	0.13	41	0.14	44	561562	2.31	0.12	15	0.11	13
542543	7.40	0.73	288	0.79	310	562567	2.41	0.18	23	0.17	22
543545	13.73	0.42	307	0.48	350	564570	0.15	2.38	19	2.41	19
545546	20.47	0.40	439	0.48	528	565566	2.28	0.86	104	0.81	99
549550	0.22	2.44	29	2.34	27	566567	2.36	0.96	121	0.91	115
552553	0.57	1.81	55	1.52	46	567568	4.88	0.56	144	0.58	150
553554	1.21	0.79	51	0.70	45	568569	4.99	0.58	155	0.61	162
553556	1.21	0.74	48	0.66	43	569570	5.09	0.60	163	0.62	169
554555	1.36	0.29	21	0.25	18	571572	2.13	0.49	56	0.46	52
555557	1.88	0.45	45	0.41	41	573580	5.18	0.10	28	0.11	30
556558	1.36	1.22	88	1.10	80	574541	6.09	0.12	37	0.12	40
557559	2.18	0.11	13	0.10	11	574575	6.09	0.45	147	0.48	156
557565	2.18	0.84	97	0.79	92	575536	6.36	0.47	159	0.50	170
558557	1.56	0.72	60	0.66	55	576523	8.47	0.50	228	0.59	267
558571	1.56	0.52	43	0.47	39	577540	1.25	1.19	79	1.05	70
559560	2.25	0.09	11	0.08	10	578573	5.18	0.12	33	0.13	35
559561	2.25	0.06	8	0.06	7	579534	5.18	0.42	117	0.45	123
560561	2.28	0.04	5	0.04	4	580535	5.18	0.31	86	0.33	90
560566	2.28	0.07	8	0.06	7	581510	3.92	0.24	51	0.28	59

TABLE 3-23

Existing Condition, 100-Year Peak Discharges
In Numerical Order By Operation Type
without Levee

HEC-1 ID (1)	Discharge, in cfs 6-hr (2)	24-hr (3)	Control (4)
510D	126	75	6-hour controls
510E	282	195	6-hour controls
510G	316	208	6-hour controls
511L	336	221	6-hour controls
511M	182	116	6-hour controls
511N	132	85	6-hour controls
511O	78	49	6-hour controls
511Q	164	106	6-hour controls
B535R	896	941	24-hour controls
B574R	211	223	24-hour controls
C515	214	278	24-hour controls
C535	1,055	1,107	24-hour controls
C536	272	319	24-hour controls
C541	208	220	24-hour controls
C542	1,300	1,430	24-hour controls
C543	1,615	1,891	24-hour controls
C545	1,611	2,010	24-hour controls
C545L	294	331	24-hour controls
C545R	1,634	1,914	24-hour controls
C546	1,688	2,104	24-hour controls
C575	111	157	24-hour controls
C582	884	925	24-hour controls
D515L	166	223	24-hour controls
D515R	49	61	24-hour controls
D535L	158	166	24-hour controls
D535R	896	941	24-hour controls
D574L	685	717	24-hour controls
D574R	211	223	24-hour controls
515575	49	57	24-hour controls
535515	156	164	24-hour controls
536545	266	301	24-hour controls
541582	207	218	24-hour controls
542543	1,294	1,424	24-hour controls
543545	1,609	1,876	24-hour controls
545546	1,598	1,996	24-hour controls
574541	208	220	24-hour controls
574582	681	711	24-hour controls
575536	109	148	24-hour controls
582543	879	917	24-hour controls

3.5.3 Comparison of Results with Previous Studies

Several studies have been done for the Rio Verde and Tonto Verde developments by the engineering firms that designed the subdivision improvements. The most current overall study of record for the Rio Verde development is Flood Plain Study of Rio Verde, Arizona, 20 May 1988, by Wiley & Associates, Inc. (Wiley) [26]. That study is based on the following:

1. The 5, 10, 25, 50 and 100-year storm.
2. The SCS Method Part I per Hydrologic Design for Highway Drainage in Arizona, March 1969, by the Arizona Department of Transportation (1969 ADOT Drainage Manual).

The most current overall study of record for the Tonto Verde development is Revised Master Drainage Plan Tonto Verde, May 1993, by Brooks, Hersey & Associates, Inc. (Brooks-Hersey) [4]. That study is based on the following:

1. The 100-year, 6-hour precipitation of 3.35 inches.
2. The 100-year, 24-hour precipitation of 4.39 inches.
3. Clark Unit Hydrograph.
4. Rainfall distributions per the Design Manual.
5. Green and Ampt rainfall loss equation.

The Wiley study is based on methodology that was not recommended for use by ADOT after March 1987. That study does not consider the distributary nature of the offsite watershed. The Brooks-Hersey study is more broad based than this study and does not adequately account for the distributary nature of the middle portion of the watershed of FEMA Washes 10 and 11. The results of the Wiley and Brooks-Hersey reports are compared with the results of this study in Table 3-24 for representative locations.

TABLE 3-24

Comparison of Peak Discharges from Previous Studies with Modeled Results for the 100-year, 24-Hour Storm

Upstream of Rio Verde
(upstream of Section 6)

HEC-1	Drainage Area, sm		Peak Discharge, cfs	
	This Study	Wiley	This Study	Wiley
(1)	(2)	(3)	(4)	(5)
C542	7.40	4.34	1,430	1,116
C565	2.28	0.97	637	286
C567	4.88	1.10	958	308
C568	4.99	2.29	1,005	615

Upstream of Tonto Verde
(upstream of Section 31)

HEC-1	Drainage Area, sm		Peak Discharge, cfs	
	This Study	Brooks-Hersey	This Study	Brooks-Hersey
(1)	(2)	(3)	(4)	(5)
C511	7.49	1.04	670	300
C517	7.60	6.29	517	993
C531	5.18	5.26	2,337	4,359
C541	6.15	0.11	220	127
C542	7.40	7.86	1,430	3,207
C575	6.36	5.83	741	1,622

The results of the Wiley study do not compare well with the results of this study. The drainage areas are smaller in the Wiley study, which appears to result from lack of attention to the distributary flow areas. The peak discharges are also significantly less than this study. Those differences are attributable to the discrepancies in drainage area and to the improper methodology. There is no reason to doubt the results of this study based on the comparisons with the Wiley study.

The results of the Brooks-Hersey study also do not compare well with the results of this study. The drainage areas differ, apparently from insufficient detail in analyzing the distributary flow areas. The peak discharges differ because of drainage area and methodology. The differences resulting from drainage area discrepancies are obvious, but the differences caused by methodology are not immediately apparent. Those differences are best understood by comparing the results of the two studies at concentration point C531. Refer to Exhibit D, sheet 2. The drainage area above C531 corresponds to drainage basin M in the Brooks-Hersey study. The watershed area estimates are essentially the same; 5.18 square miles for this study versus 5.26 square miles for the Brooks-Hersey study. The 100-year, 24-hour peak discharges are significantly different ; 2,337 cfs for this study versus 4,359 cfs for Brooks-Hersey. The rainfall excess estimates are virtually the same; 1.31 inches for this study versus 1.46 inches for Brooks-Hersey. The difference in rainfall excess is due to selection of initial abstraction; 0.34 inches for this study versus 0.15 inches for Brooks-Hersey. Runoff volume is not the cause of the difference in peak discharge. The difference in peak discharge results from the choice of unit hydrograph and the T_c estimate.

The drainage area contributing to C531 is divided into nine (9) subbasins for the purposes of this study. The same watershed was modeled as a single basin in the Brooks-Hersey study. There are no significant flow diversions upstream of C531 which affect peak discharges at that location. The Clark Unit Hydrograph was used for the Brooks-Hersey study, and a T_c of 1.096 hours was estimated for basin M. An independent check of T_c was made using parameters estimated from Exhibit D ($L = 6.06$ miles, $S = 107$ feet/mile and $K_b = 0.06$). That estimate is 1.454 hours and the duration of the most intense portion of rainfall excess is estimated to be less than 1 hour.

Use of the Clark Unit Hydrograph for the non-urbanized portions of the study area is not appropriate because the duration of the most intense portion of rainfall excess is less than T_c for the majority of that area. The watershed upstream of C531 was modeled in this using the Phoenix Mountain S-Graph for that reason. Refer to Section 3.2.2.1. The subbasin input data for Brooks-Hersey basin M was modified appropriately to use that S-Graph. The Brooks-Hersey HEC-1 model was re-run and the resulting peak discharge was 2,531 cfs which is much closer to the results of this study (2,337 cfs). Most of the peak discharges from the Brooks-Hersey study listed in Table 3-24 are downstream of

C531 and therefore are strongly influenced by that peak discharge. There is no reason to doubt the results of this study based on the comparison with the results of the Brooks-Hersey study, because the methodology used for the Brooks-Hersey study was inappropriate for this watershed.

3.5.4 Discussion of Results

The modeled results appear reasonable based on the discussion in Section 3.3 of confidence checks. The final results are lower than those presented in previous studies, but the modeled results are based on more reasonable input parameters and a more detailed level of study. The confidence checks were done at, or upstream of, the natural flow diversion locations. This was necessary in order to make valid comparisons.

Hydrographs are plotted at key locations on the watershed for the purpose of visually inspecting the modeled results. Those hydrographs are included as Figures 3-8 through 3-16. Each hydrograph is discussed as follows:

Figure 3-8: That hydrograph is for C504 for a 100-year, 24-hour storm. The hydrograph represents flow entering the study area from the Rio Verde North study area. The hydrograph was furnished by Wood, Patel & Associates.

Figures 3-9 and 3-10:

Both hydrographs are for C510. Figure 3-9 is for the 100-year, 6-hour storm and Figure 3-10 is for the 100-year, 24-hour storm. C510 is located on Rio Verde Drive downstream of C504. Those hydrographs represent the total flow at C510 before a flow split occurs which diverts runoff from the Rio Verde South study area into the Rio Verde North study area. Note the multiple peak discharges, separated by a least 1 hour.

Figures 3-11 and 3-12:

Both hydrographs are for C535. Figure 3-11 is for the 100-year, 6-hour storm and Figure 3-12 is for the 100-year, 24-hour storm. C535 is located at the downstream end of subbasin 511K and is a major flow split location on FEMA Wash 11 at the Limit of Detailed Study. Note the multiple peak discharges, separated by about 1.5 hours.

Figure 3-13: Figure 3-13 is the 100-year, 24-hour (controlling) hydrograph at C536 which is the FEMA Wash 11 crossing of Forest Road just upstream of the confluence with FEMA Wash 10. Note the multiple peak discharges, separated by about 1.5 hours.

Figure 3-14: Figure 3-14 is the 100-year, 6-hour (controlling) hydrograph at C537. Point C537 is located at the downstream end of subbasin 510A and is typical of the single basins in the upper portion of the watershed. Point C537 is a key flow split location.

Figure 3-15: Figure 3-15 is the 100-year, 24-hour (controlling) hydrograph at C568 which is the FEMA Wash 9 crossing of Forest Road.

Figure 3-16: Figure 3-16 is the 100-year, 24-hour (controlling) hydrograph at C581. Hydrograph C581 is upstream of C510 and represents flow entering the study area from the Rio Verde North study area. The hydrograph was furnished by Wood, Patel & Associates. Note the multiple peak discharges separated a little more than 1 hour.

It is apparent that hydrologic routing is very important to the accuracy of this model. The timing of peak discharges is important because of the long narrow subbasins. The routing parameters were carefully selected in order to provide a reasonable representation of the complex hydraulics of the study watershed. The examination of the modeled hydrographs yields no reason to doubt the validity of the model.

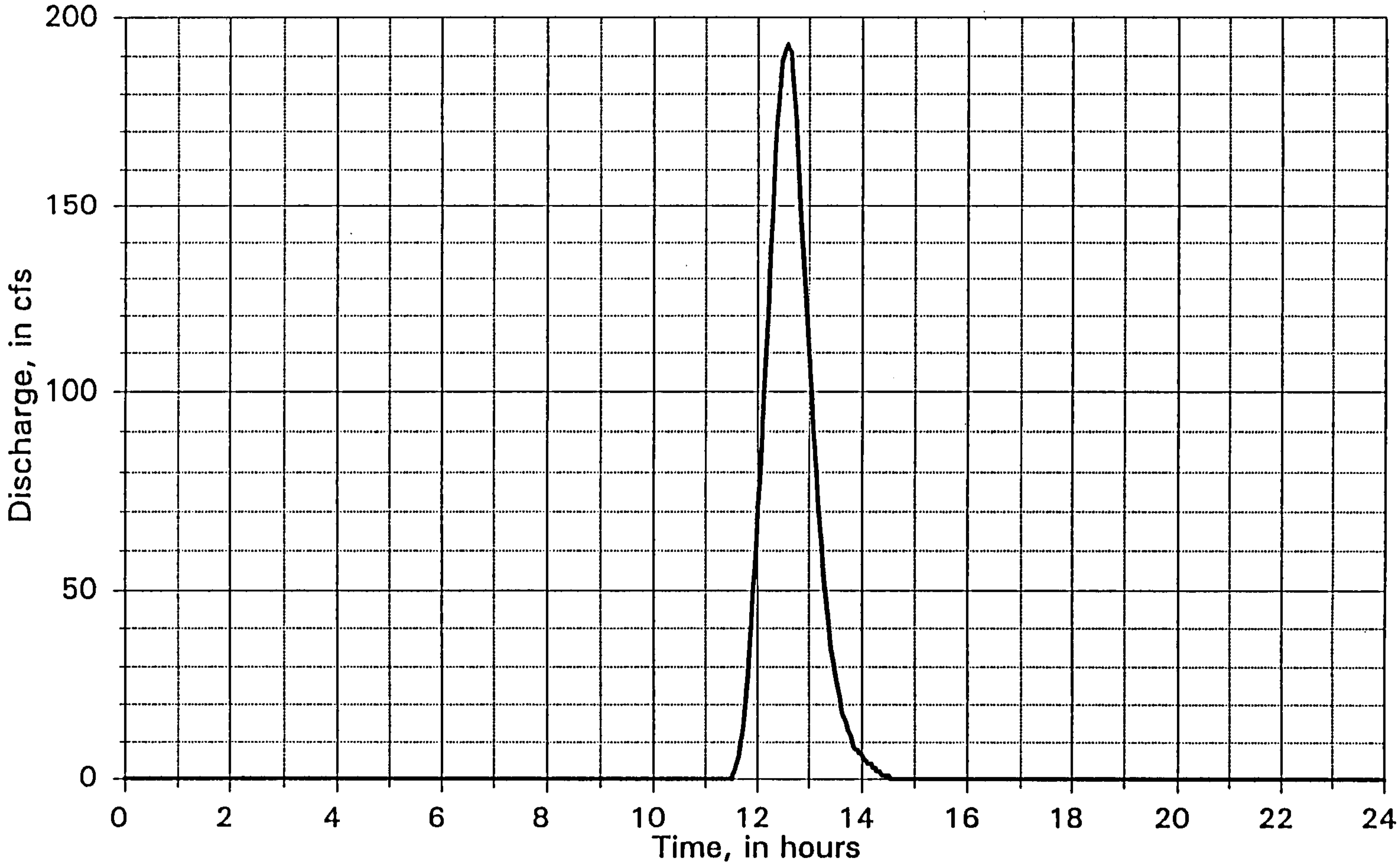


FIGURE 3-8

Hydrograph at C504 for a 100-year, 24-hour Storm

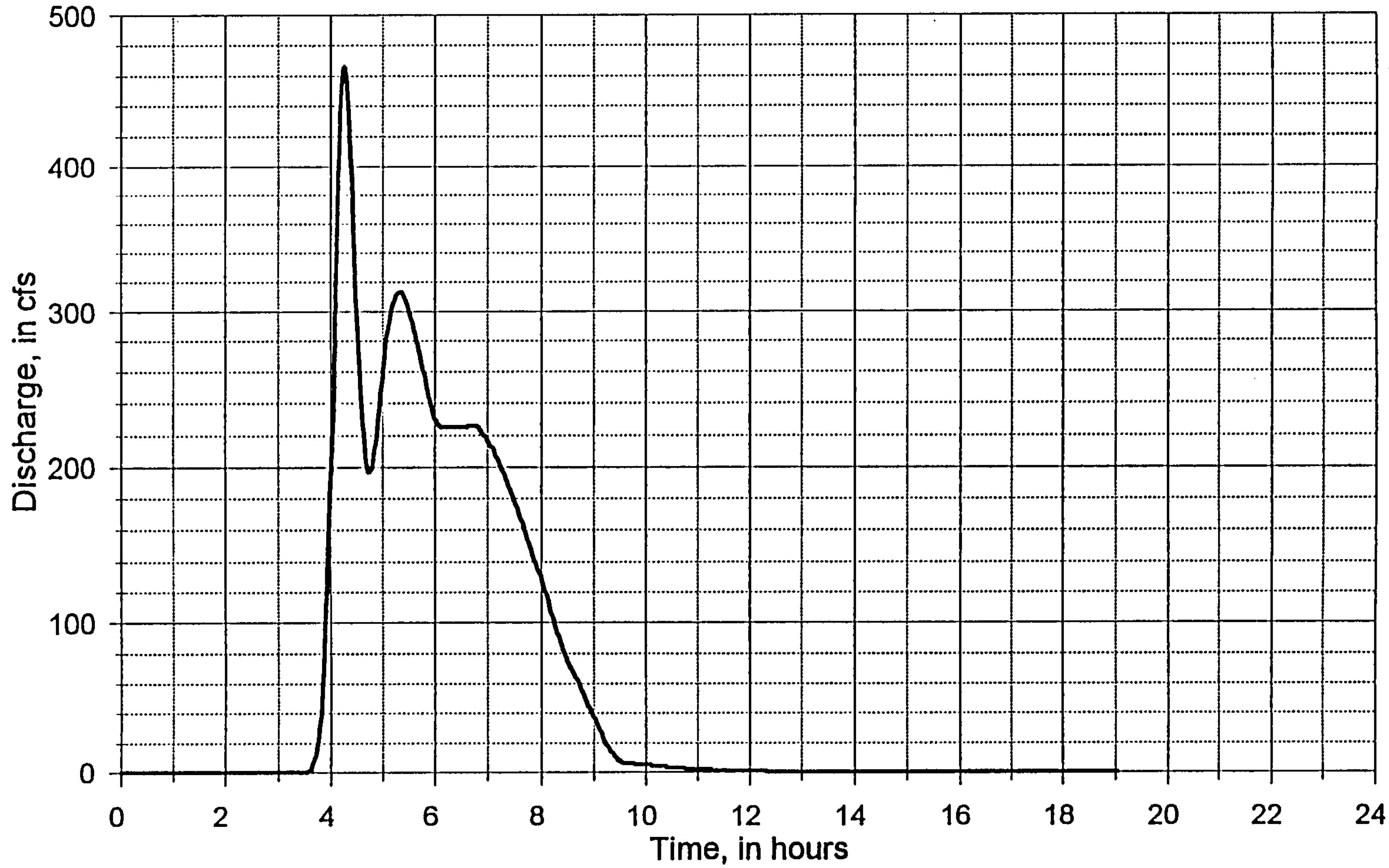


FIGURE 3-9

Hydrograph at C510 for a 100-year, 6-hour Storm

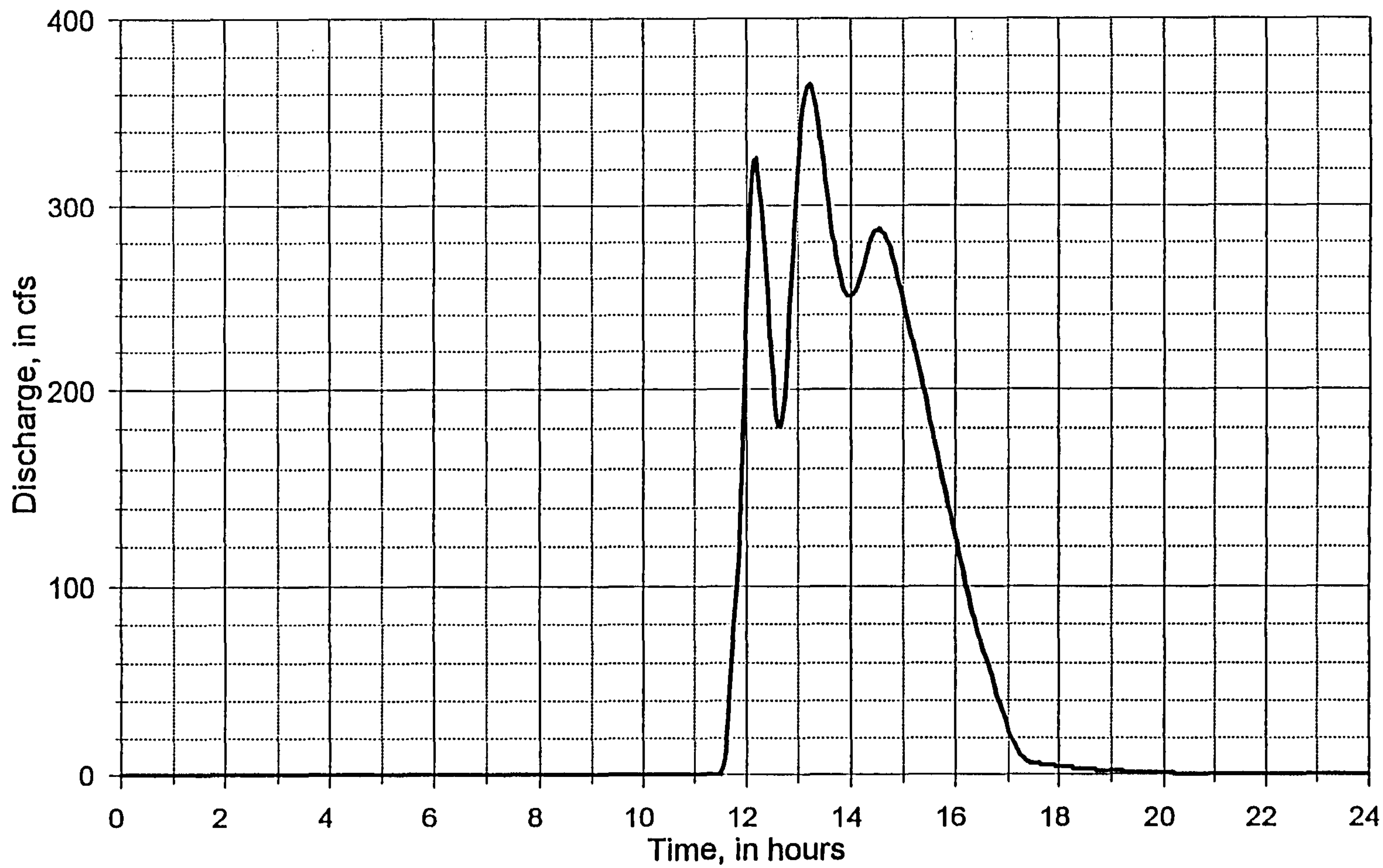


FIGURE 3-10

Hydrograph at C510 for a 100-year, 24-hour Storm

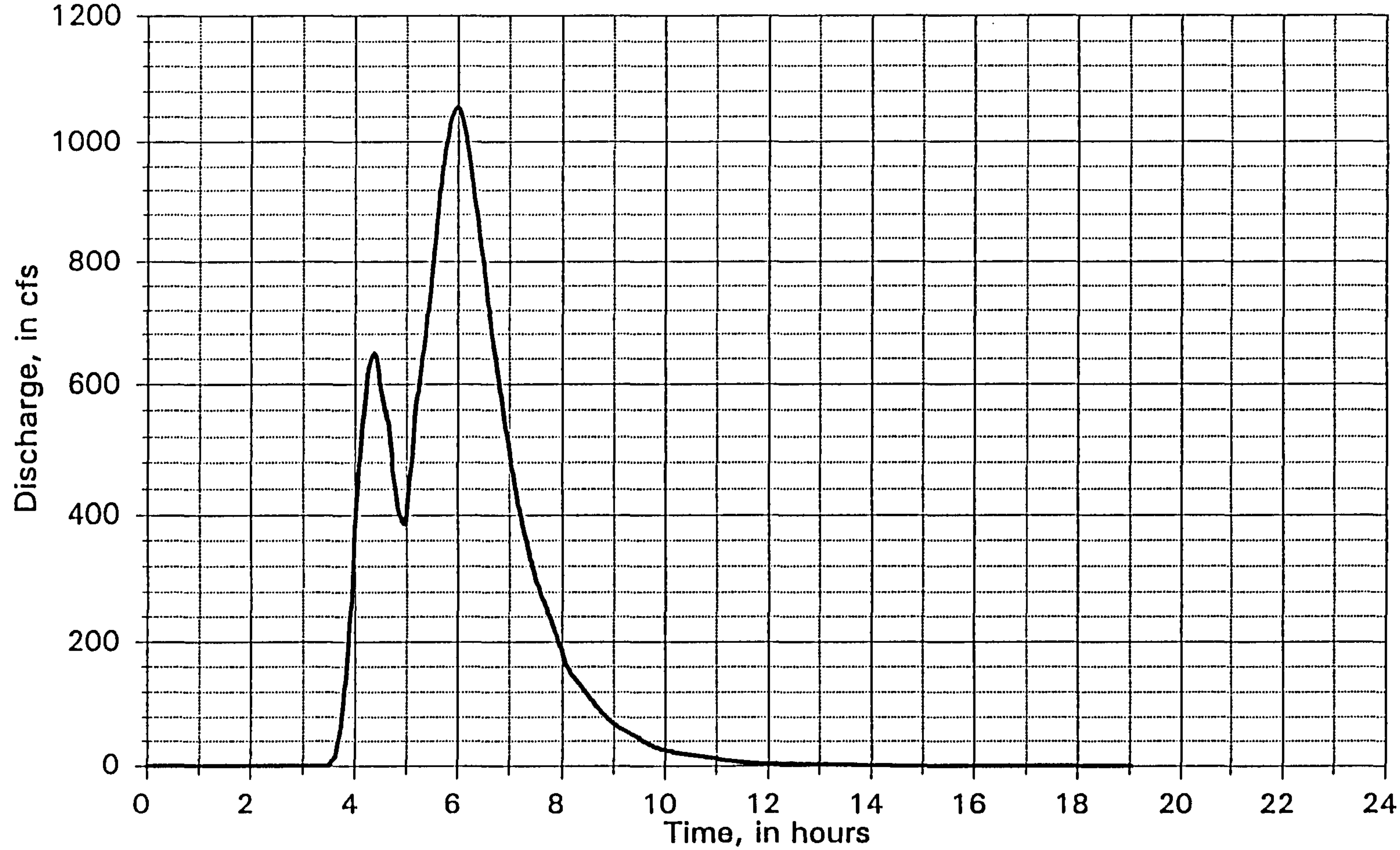


FIGURE 3-11

Hydrograph at C535 for a 100-year, 6-hour Storm

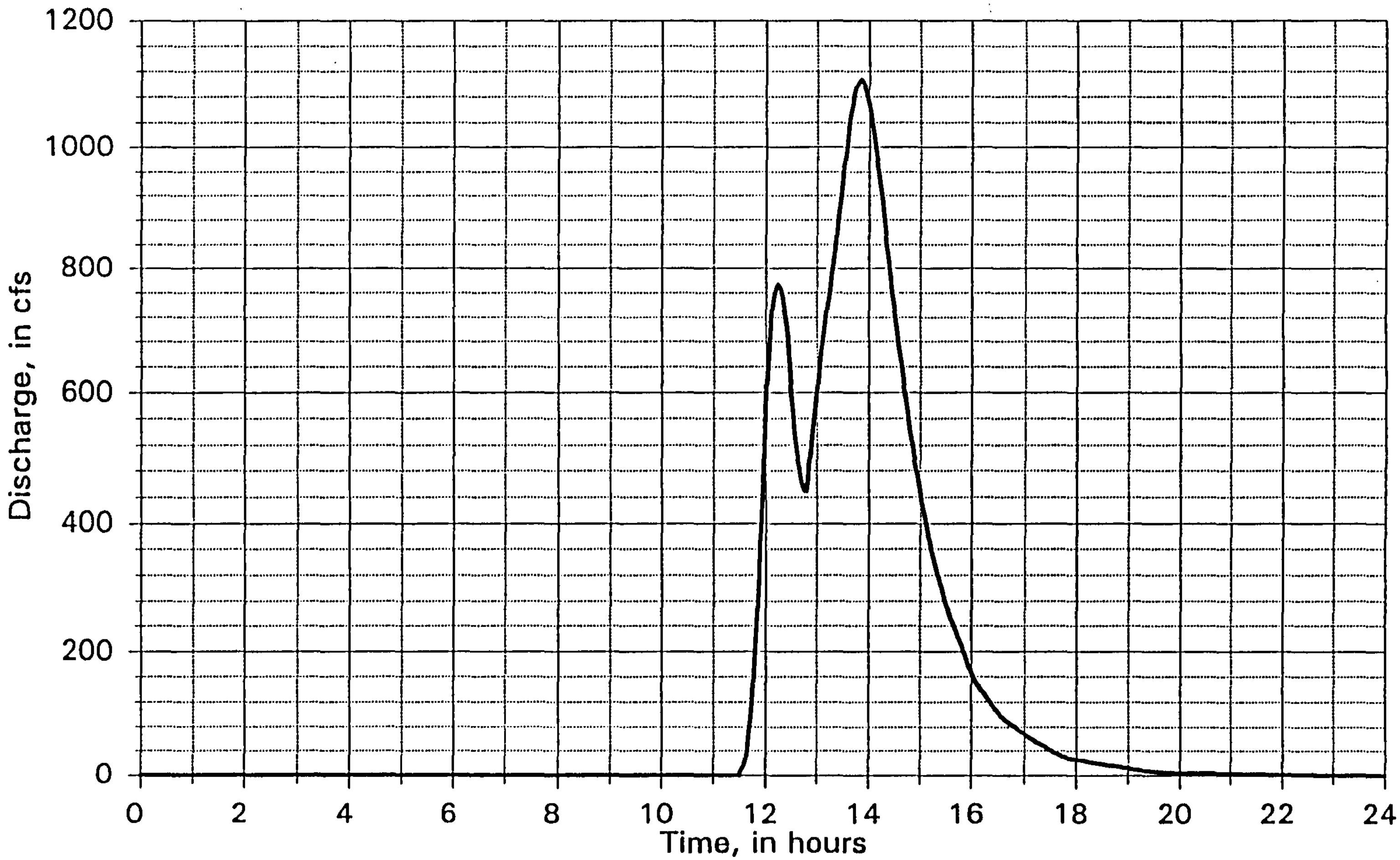


FIGURE 3-12

Hydrograph at C535 for a 100-year, 24-hour Storm

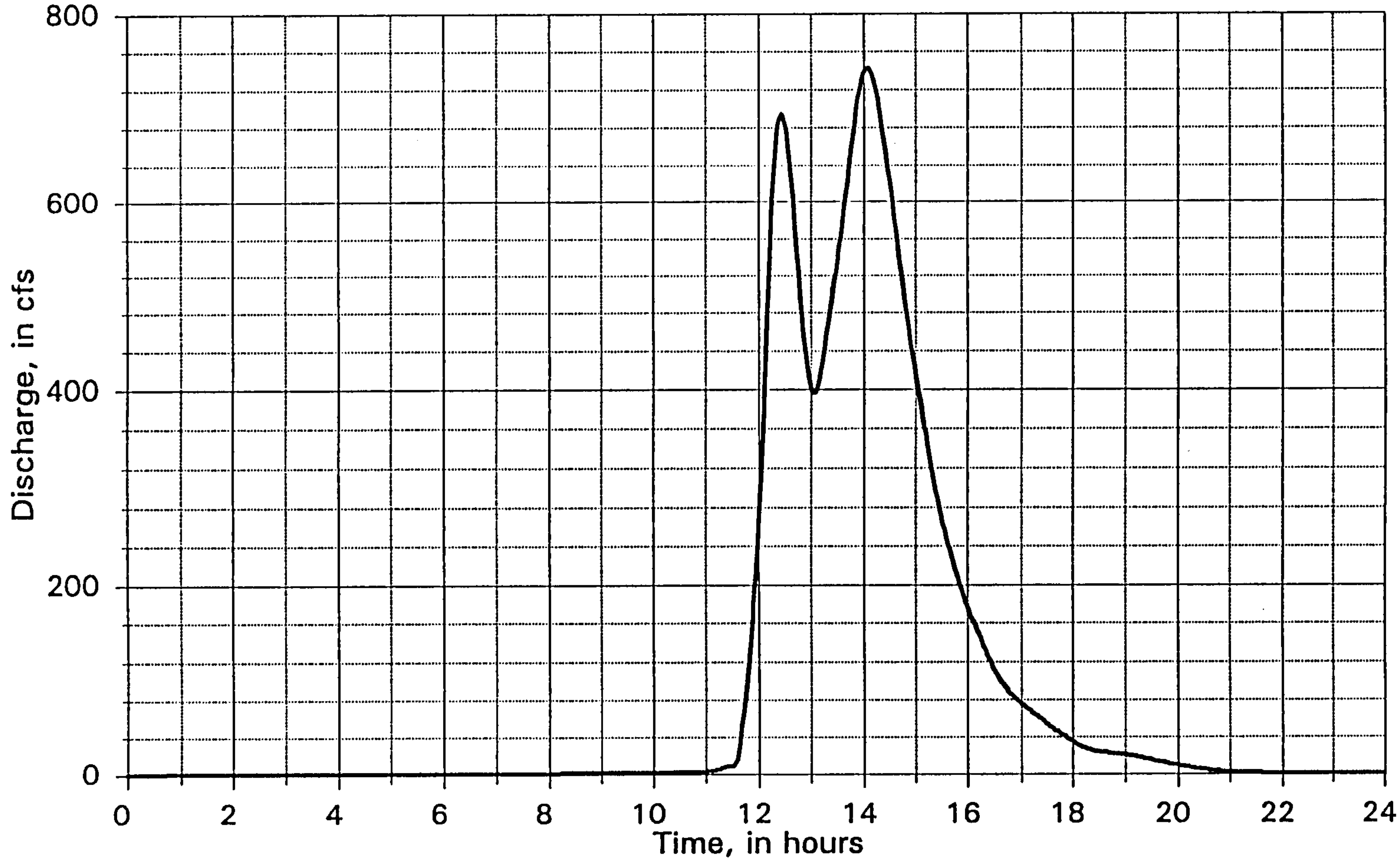


FIGURE 3-13

Hydrograph at C536 for a 100-Year, 24-Hour Storm

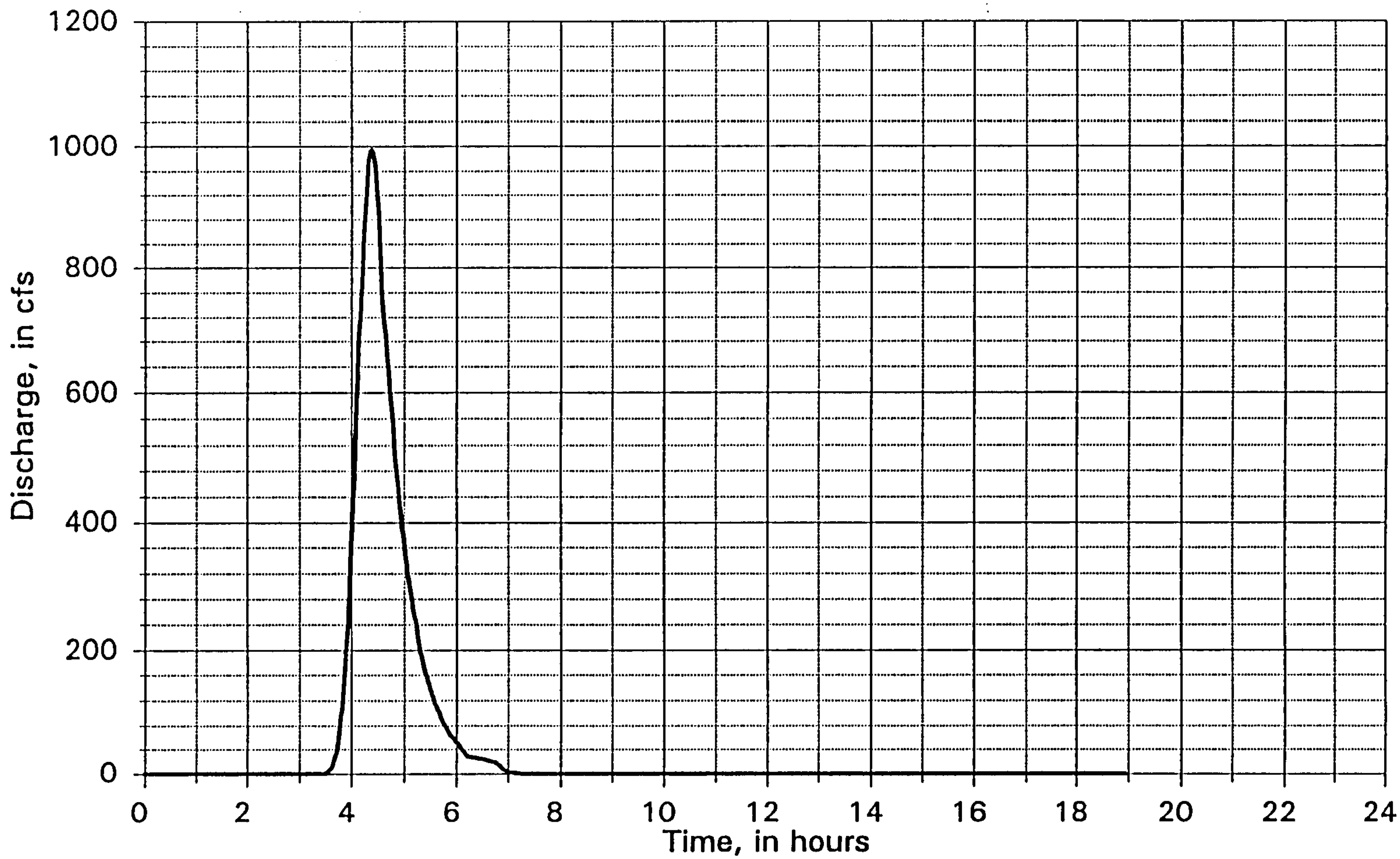


FIGURE 3-14

Hydrograph at C537 (510A) for a 100-year, 6-hour Storm

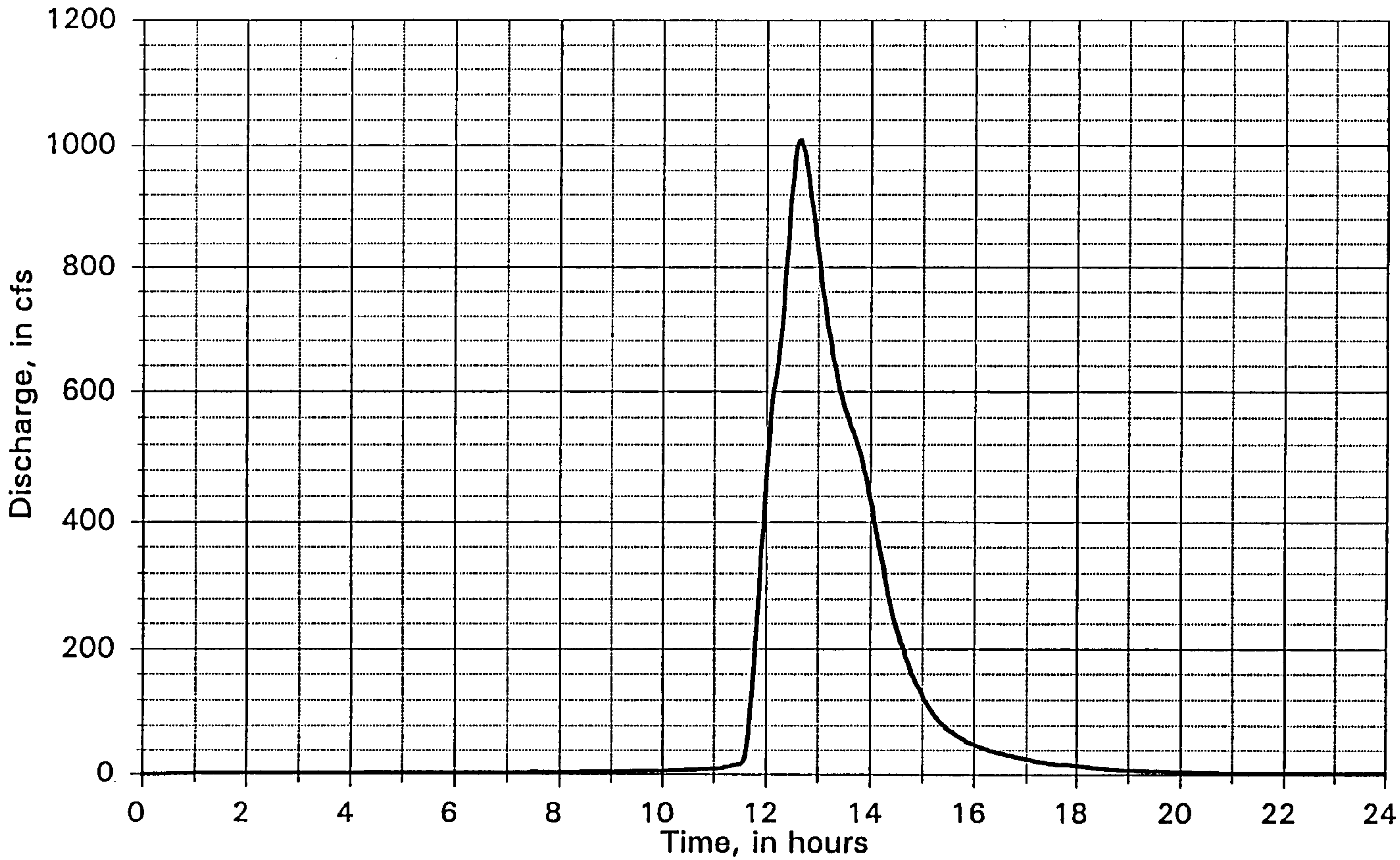


FIGURE 3-15

Hydrograph at C568 for a 100-year, 24-hour Storm

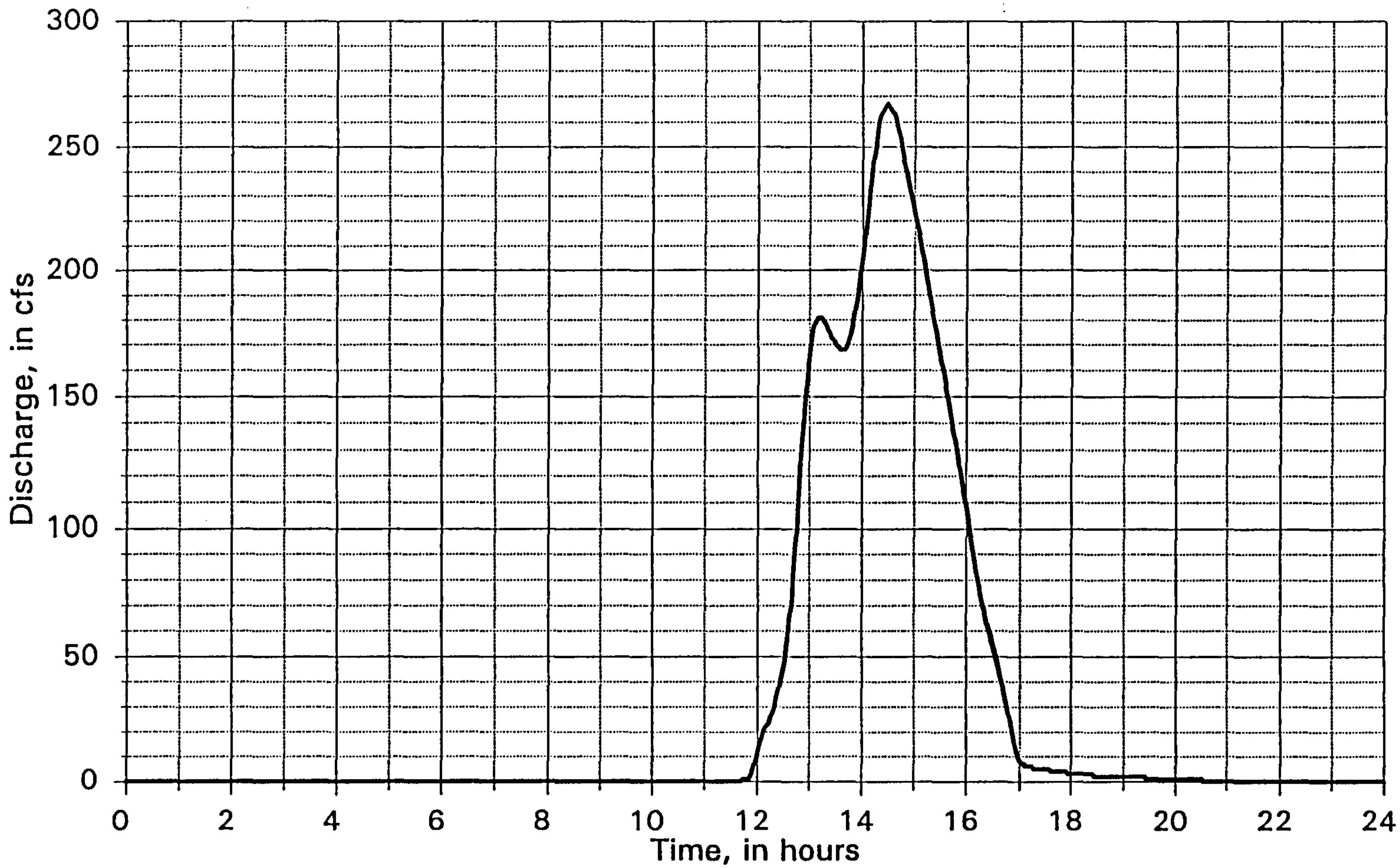


FIGURE 3-16

Hydrograph at C581 for a 100-year, 24-hour Storm

3.5.5 Applicability of Hydrologic Models for Other Uses

The HEC-1 models have been developed for the existing condition 6-hour and 24-hour storms as a part of this study. The specific purpose in preparing the existing condition models is for floodplain delineation and flood insurance purposes. A secondary purpose is for use by the District for evaluating development projects proposed on the watershed. The watershed was modeled in more detail for that reason. The key assumptions upon which this study is based were made with both purposes in mind. Therefore, if the models are used for other purposes, such as for design of drainage improvements, the following should be considered:

1. The time of concentration and routing parameters may not be appropriate for other storm frequencies.

2. The flow splits (diversions) that are modeled as an existing condition may need to be reevaluated, or different assumptions made regarding the percentage of flow in the branches downstream of the split. This could particularly be true for a design condition.

3. The percent impervious (RTIMP) for the watershed under consideration should be verified and updated to reflect development that has occurred since the time of this study. This study is based on the assumption that the Tonto Verde development is completely built-out, according to plans on record to date.

3.6 Final Modeling Results on Diskette

The diskette containing the HEC-1 input files is located at the back of Book 1 of 2 following Section 7.

SECTION 4: HYDRAULIC ANALYSIS

The entire contents of Study Documentation Section 4 are found in "Rio Verde South Floodplain Delineation Study, Technical Data Notebook, Hydraulics".

SECTION 5: EROSION/SEDIMENT TRANSPORT ANALYSIS

Not part of this report.

SECTION 6: REFERENCE MATERIALS

6.1 Other Published Flood Studies

There are no other significant published flood studies of record. Refer to Section 6.6.

6.2 Previous FEMA Studies

There is a previous approximate level study done for FEMA Washes 9, 10 and 11.

6.3 Other Applicable Studies

Refer to Sections 6.5 and 6.6.

6.4 Published and Unpublished Historical Flood Information

There is no significant historical flood information of record for this watershed.

6.5 Bibliography

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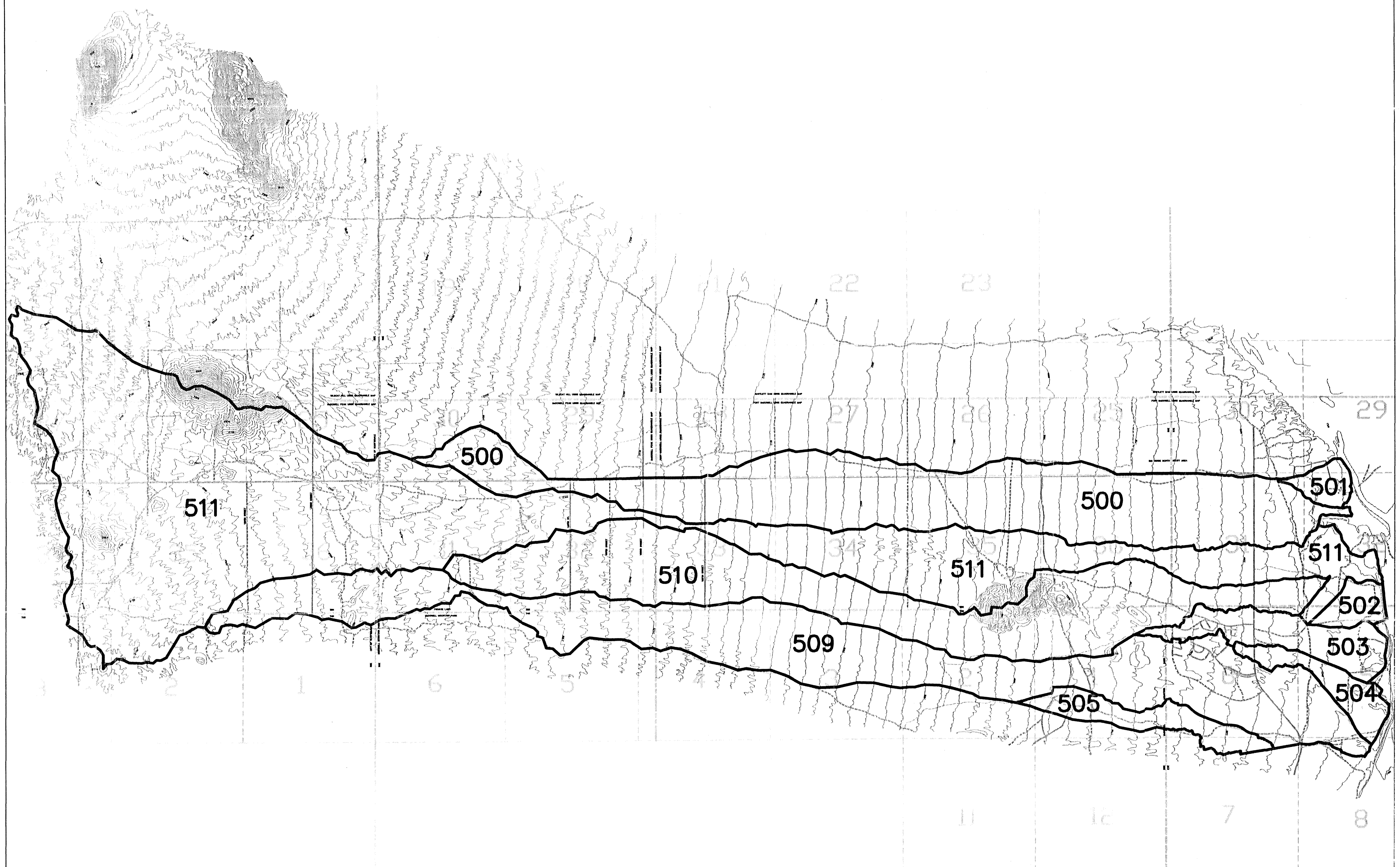
SECTION 7: CROSS-REFERENCE AND LABELING INFORMATION

Not part of this report.

[illegible]



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

NOTES

LEGEND

Basin Identifier	501
Drainage Basin Boundary	
Section Line	
Township and Range Line	
Basin Identifier	29

2000 0' 2000 4000

SCALE: 1"= 2000'

HYDROLOGY EXHIBIT "A"

DRAINAGE BASIN MAP

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 1

Dwg. Name: \P\RIOVERDE\ACAD\NEW-RIO.dwg
Date: REV. DEC. 7, 1994 09:00am

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY
FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

NOTES

LEGEND

- 500B Subbasin Identifier
- Drainage Basin Boundary
- Drainage Subbasin Boundary
- Soil Map Unit Boundary
- 33 Soil Map Unit Identifier per SOIL SURVEY OF AGUILA-CAREFREE AREA, PARTS OF MARICOPA AND PINAL COUNTIES, ARIZONA, U.S.D.A. - S.C.S., APRIL 1986

N

1000 0' 1000 2000
SCALE: 1"= 1000'

HYDROLOGY EXHIBIT "B"
DRAINAGE SUB-BASIN SOILS MAP

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94
SUBMITTED BY: DATE:		

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 1

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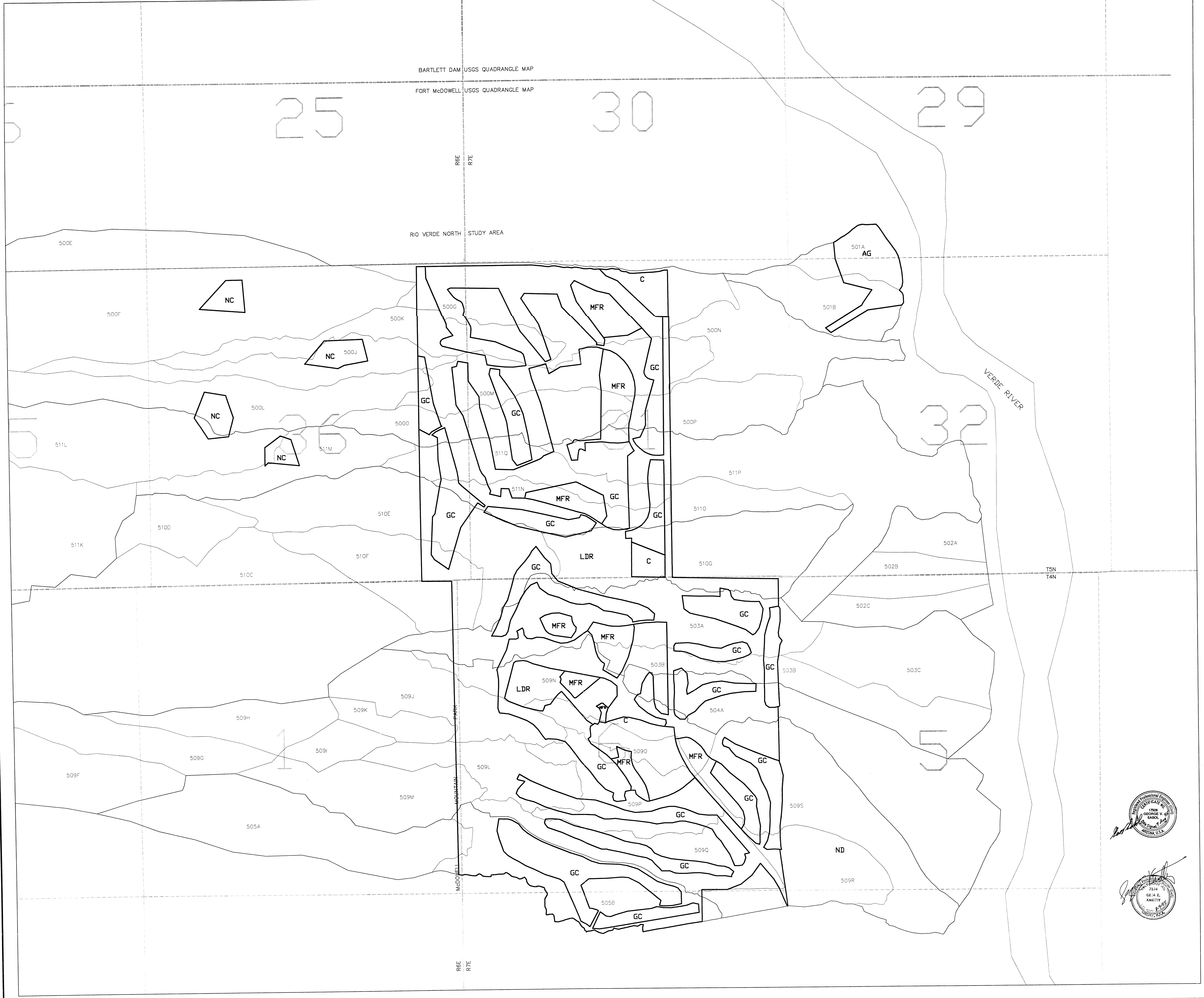


THE TOPOGRAPHY ON THIS MAP IS BASED ON USGS QUADRANGLE MAPS, AS NOTED ON EACH SHEET.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

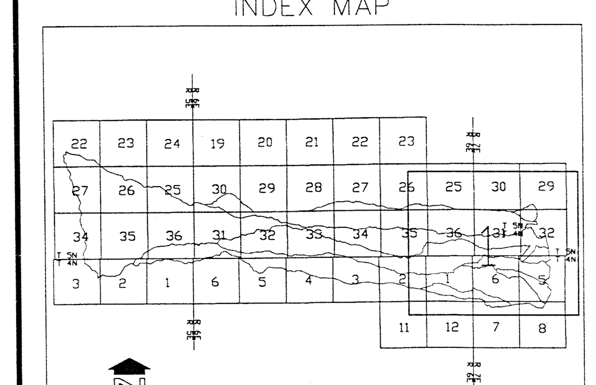
F.C.D. CONTRACT NO. 93-07

NOTES

LEGEND

Subbasin Identifier	500B
Drainage Basin Boundary	
Drainage Subbasin Boundary	
Land-Use Boundary	
AG	Agricultural
C	Commercial
NC	Non-Contributing
ND	Natural Desert
GC	Golf Course
LDR	Low-Density Residential
MFR	Multi-Family Residential

INDEX MAP



NOT TO SCALE

500 0' 500 1000

SCALE: 1"= 500'

HYDROLOGY EXHIBIT "C" LAND USE MAP

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 1

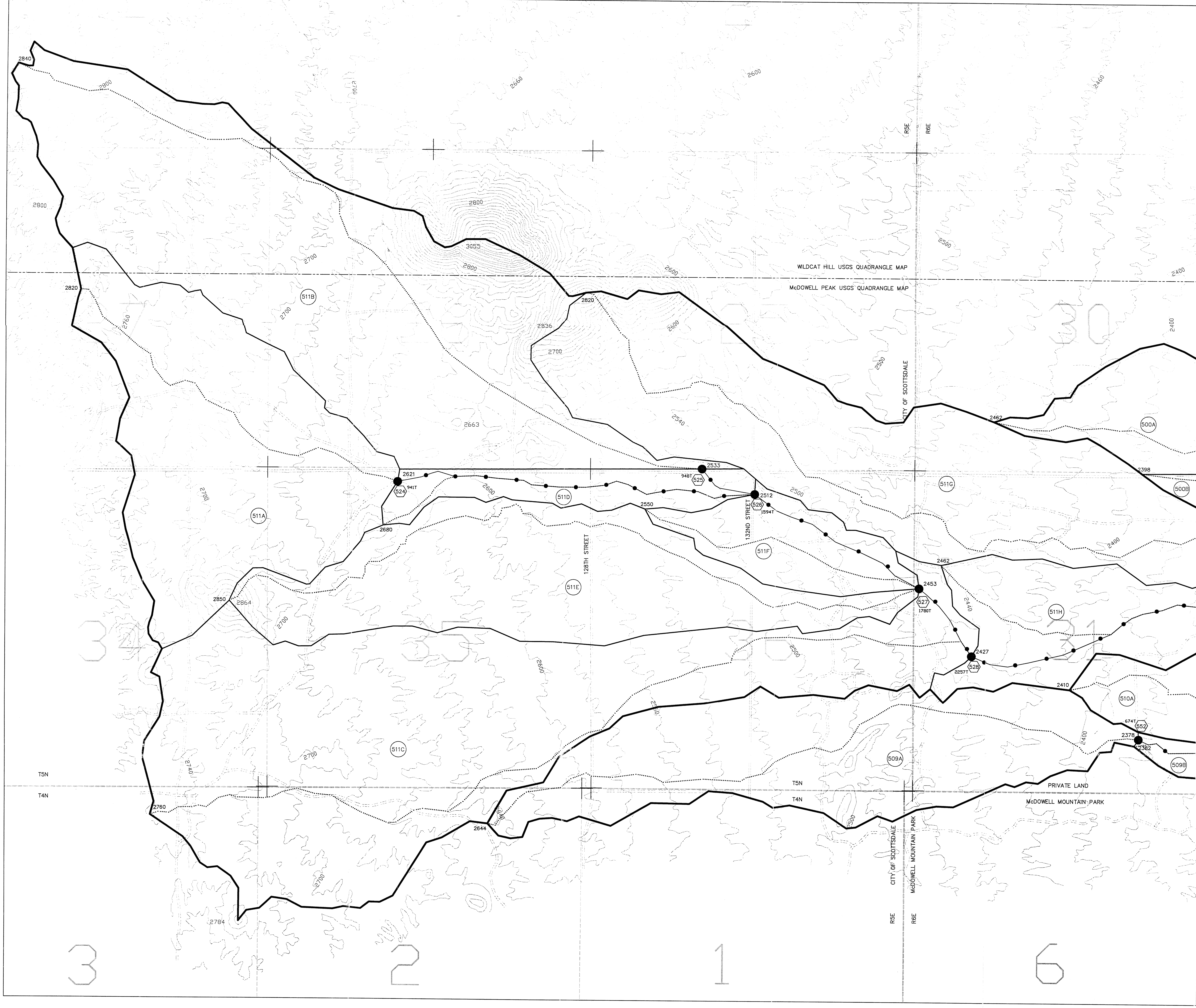
Dwg. Name: \P\RIOVERDE\ACAD\RIO500.dwg
Date: REV. DEC. 7, 1994 09:00am

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07



NOTES

1. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

LEGEND

Subbasin Identifier	500B
Subbasin Concentration Point	
Intermediate Concentration Point	
Concentration Point Number (Peak discharge is 1594 cfs)	1594T 526
Flow Split Conc. Point Number (Peak discharge 682 cfs; 380 cfs RT, & 303 cfs LT)	682T 380LT 303RT 508
Elevation (at concentration point or top of Tc path)	1598.6
Drainage Basin Boundary	
Drainage Subbasin Boundary	
Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)	
Time of Concentration Flow Path	
Section Line	
Township and Range Line	
USGS Quadrangle Map Boundary	

INDEX MAP

NOT TO SCALE

SCALE: 1"= 500'

HYDROLOGY EXHIBIT "D"

WATERSHED MAP OF ENTIRE STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 3

Dwg. Name: \P\RIOVERDE\ACAD\NEW-RIO.dwg

Date: REV. NOV. 17, 1994 09:00am

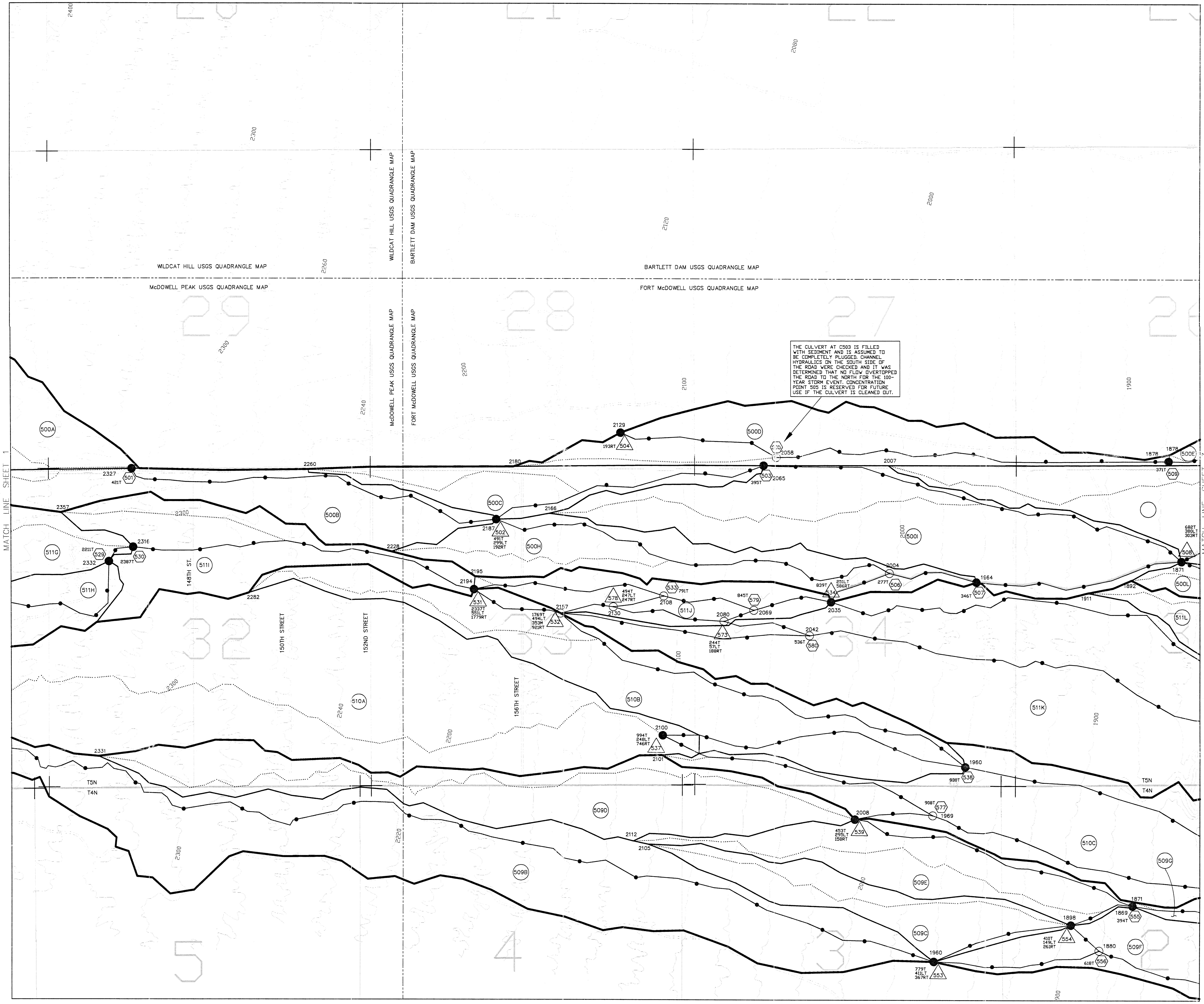
THE TOPOGRAPHY ON THIS MAP IS BASED ON USGS QUADRANGLE MAPS, AS NOTED ON EACH SHEET.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07



NOTES

1. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

LEGEND

- Subbasin Identifier
- Subbasin Concentration Point
- Intermediate Concentration Point
- Concentration Point Number (Peak discharge is 1594 cfs.)
- Flow Split Conc. Point Number (Peak discharge 682 cfs; 380 cfs RT, & 303 cfs LT)
- Elevation (at concentration point or top of Tc path)
- Drainage Basin Boundary
- Drainage Subbasin Boundary
- Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)
- Time of Concentration Flow Path
- Section Line
- Township and Range Line
- USGS Quadrangle Map Boundary

INDEX MAP

NOT TO SCALE

SCALE: 1"= 500'

HYDROLOGY EXHIBIT "D"

WATERSHED MAP OF ENTIRE STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.
in association with
George V. Sabol Consulting Engineers, Inc.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

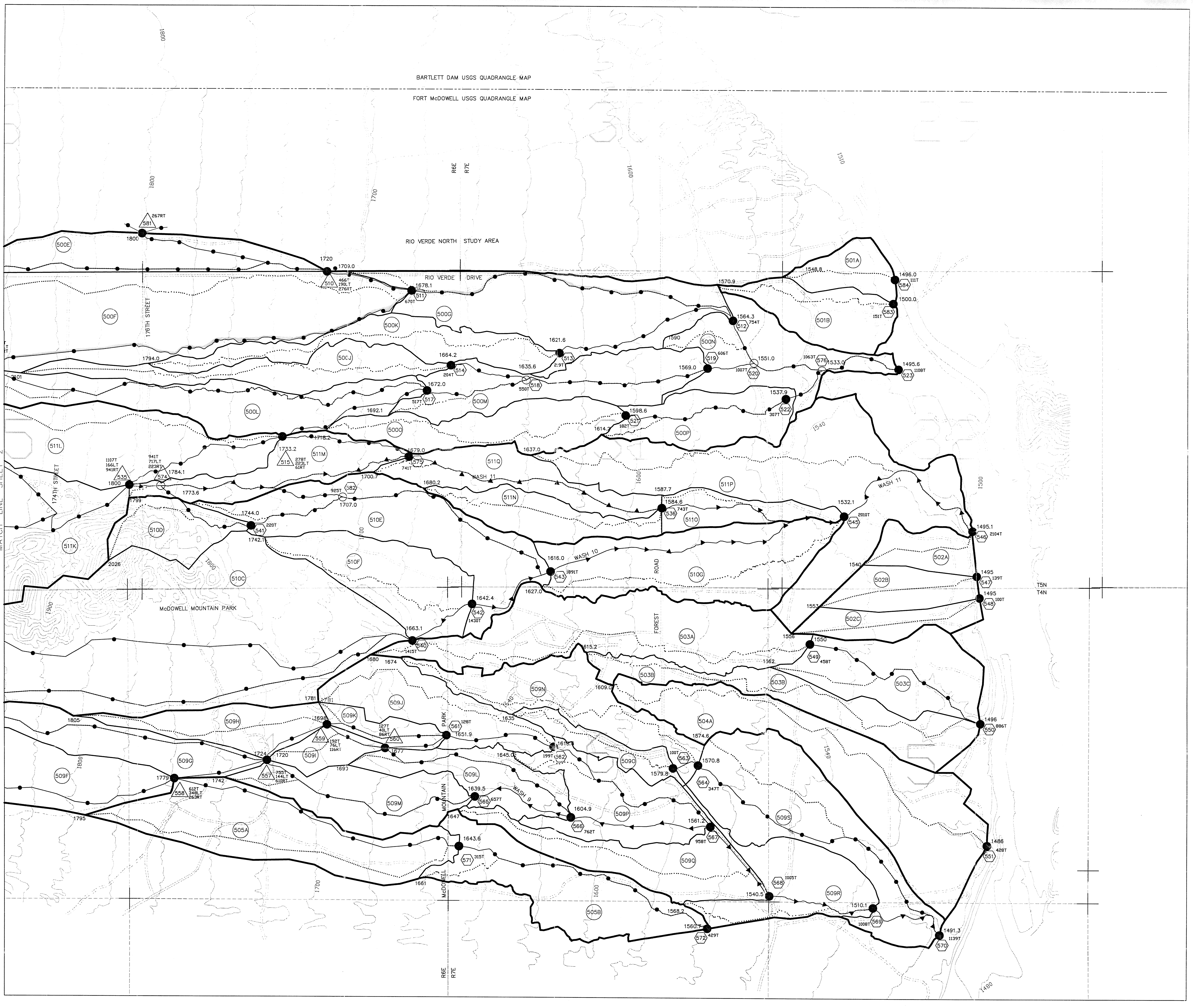
APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 2 OF 3

Dwg. Name: \P\RIOVERDE\ACAD\RIO500.dwg
Date: REV. AUG 10, 1995 8:00 am

THE TOPOGRAPHY ON THIS MAP IS BASED ON USGS QUADRANGLE MAPS, AS NOTED ON EACH SHEET.



THE TOPOGRAPHY ON THIS MAP IS BASED ON USGS QUADRANGLE MAPS, AS NOTED ON EACH SHEET.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

NOTES

1. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

LEGEND

Subbasin Identifier	500B
Subbasin Concentration Point	●
Intermediate Concentration Point	○
Concentration Point Number (Peak discharge is 1594 cfs)	1594T 526
Flow Split Conc. Point Number (Peak discharge 682 cfs, 380 cfs RT, & 303 cfs LT)	682T 380LT 303RT 508
Elevation (at concentration point or top of Tc path)	1598.6
Drainage Basin Boundary	
Drainage Subbasin Boundary	
Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)	
Time of Concentration Flow Path	
Section Line	
Township and Range Line	
USGS Quadrangle Map Boundary	

INDEX MAP

NOT TO SCALE

SCALE: 1" = 500'

HYDROLOGY EXHIBIT "D"

WATERSHED MAP OF ENTIRE STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE	
DESIGN	F.C.D.M.C.	1993	FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
DESIGN CHK.	TRL	6/94	RECOMMENDED BY: DATE
PLANS	BKE	7/94	APPROVED BY: DATE
PLANS CHK.	TRL	7/94	CHIEF ENGINEER AND GENERAL MANAGER
SUBMITTED BY:		DATE	SHEET 3 OF 3

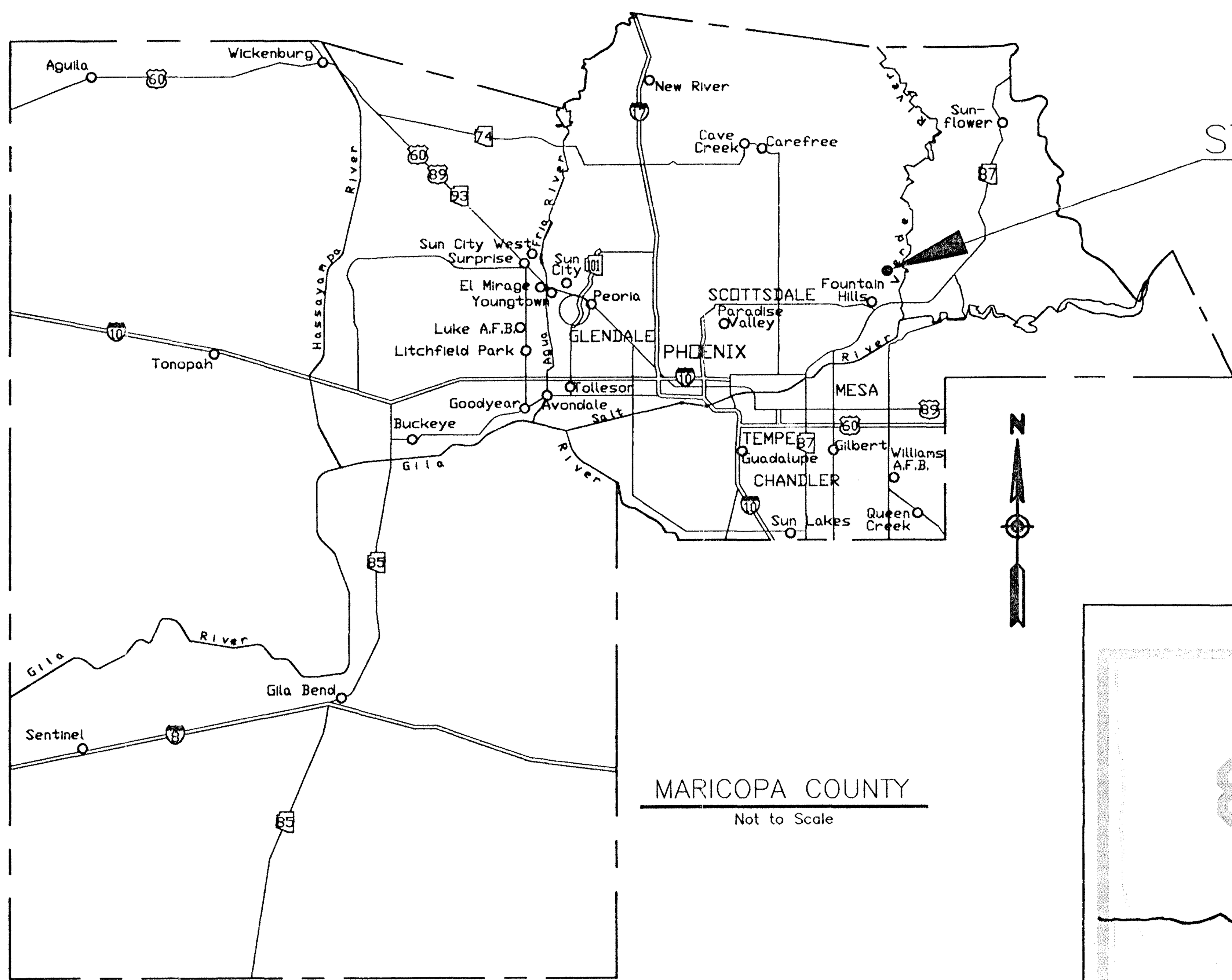
Dwg. Name: \P\RIOVERDE\ACAD\NEW-RIO.dwg
Date: REV. NOV. 17, 1994 09:00am

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RIO VERDE SOUTH

Flood Delineation Study

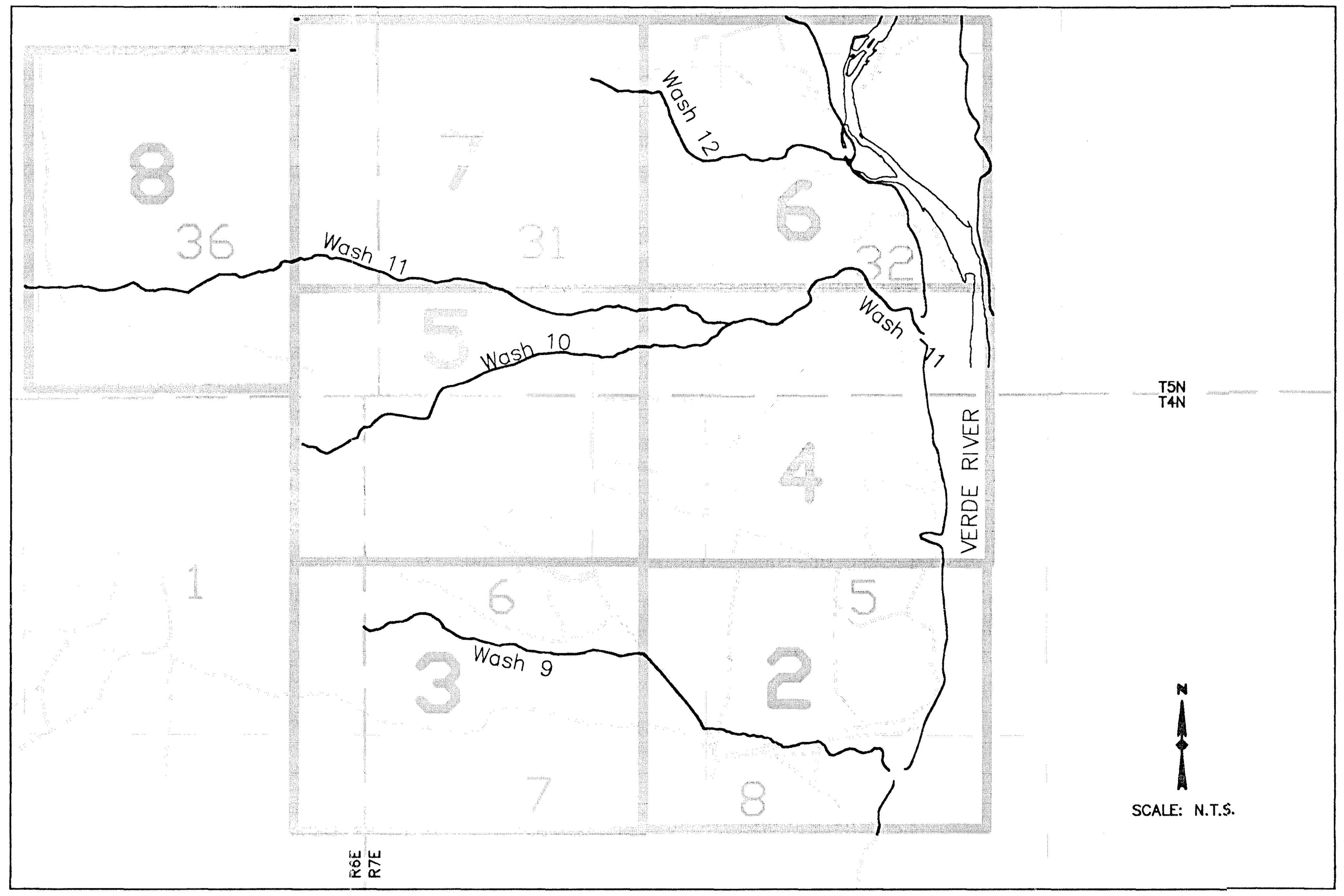
FCD 93-07



LOCATION MAP

DATUM

HORIZONTAL: North American Datum of 1983
VERTICAL: National Geodetic Vertical Datum of 1929



STUDY AREA MAP
AND SHEET INDEX

AERIAL MAPPING

Aerial Mapping Company, Inc.
3141 W. Clarendon Avenue
Phoenix, Arizona 85017 (602) 263-5728

Flight Date: December 22, 1993
Contour Interval: 2 Feet

GROUND CONTROL

Burgess & Niple, Inc.
5025 E. Washington Street
Phoenix, Arizona 85034 (602) 244-8100

ADDITIONAL SURVEY

Alcocer Land Surveyors
3501 N. 16th Street, Suite C
Phoenix, Arizona 85016 (602) 263-7846

HYDROLOGY

George V. Sabol Consulting Engineers, Inc.
7950 E. Acoma Drive, Suite 211
Scottsdale, Arizona 85260-6962 (602) 483-3368

HYDRAULICS

McLaughlin Kmetty Engineers, Ltd.
3501 N. 16th Street
Phoenix, Arizona 85016 (602) 248-7702

LEGEND

Section Line

Section Label — 31

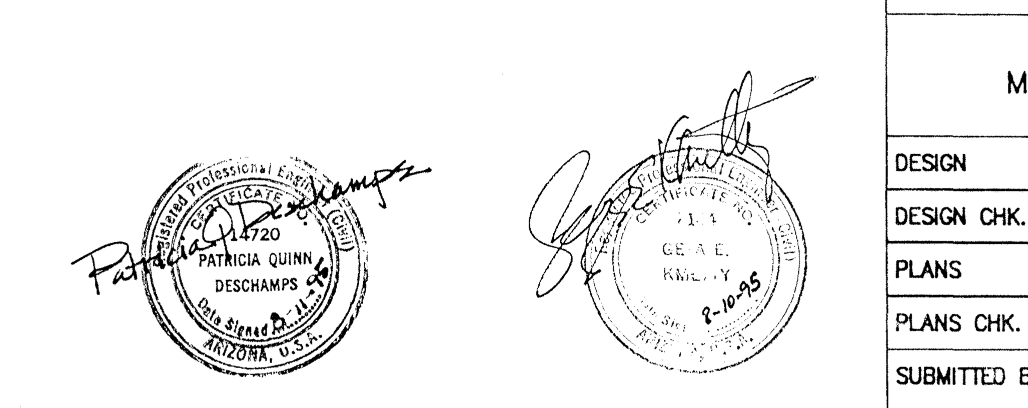
Sheet Limits

Sheet Number — 8

Study Wash

SHEET INDEX

Sheet 2-8 Hydrology Exhibit E
Watershed Map of Detailed Study Area



HYDROLOGY EXHIBIT "E"
COVER SHEET

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	FEB	9/94
DESIGN CHK.	CLJ	9/94
PLANS	PJK,RLP	8/95
PLANS CHK.	FEB	8/95

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

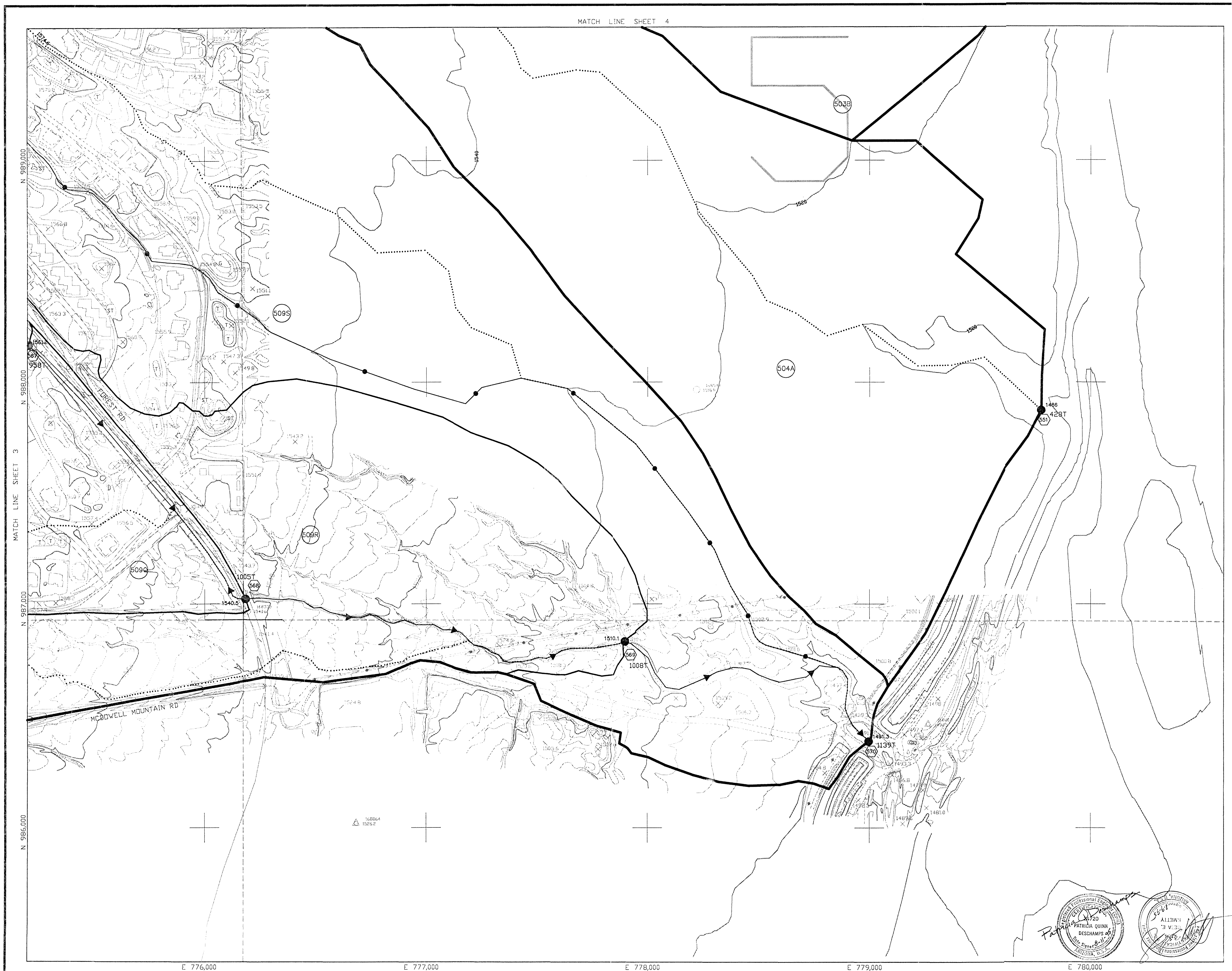
RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 1 OF 8

Dwg. Name: \P\89407003\ACAD\RVEXECVR.dwg
Date: REV. AUG. 10, 1995 10:20 am



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

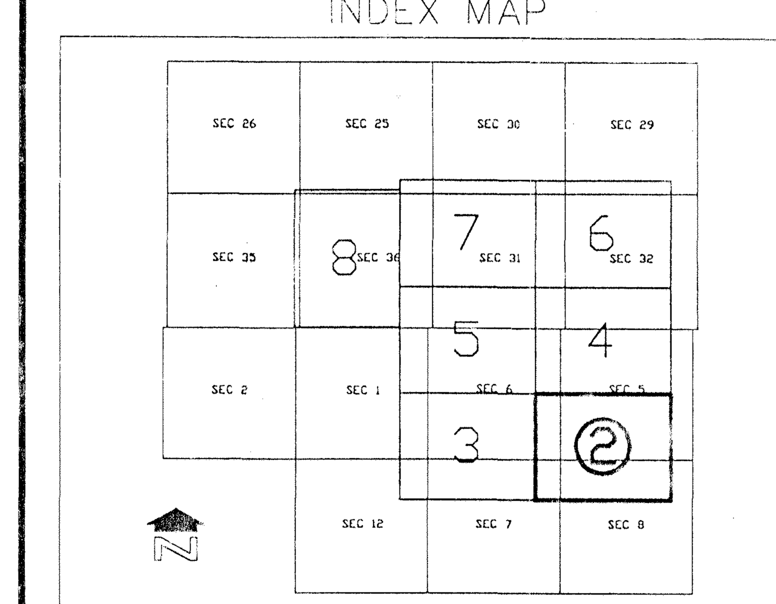
NOTES

1. Sheet No. 1 was intentionally omitted HYDROLOGY EXHIBIT "E".
2. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

LEGEND

Legend item	Symbol
Subbasin Identifier	500P
Subbasin Concentration Point	●
Intermediate Concentration Point	○
Concentration Point Number Peak discharge is 1430 cfs.	1430T 542
Flow Split Conc. Point Number Peak discharge 941 cfs; 223 cfs RT, & 717 cfs LT	941T 717LT 223RT 574
Elevation (at concentration point or top of Tc path)	1598.6
Drainage Basin Boundary	
Drainage Subbasin Boundary	
Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)	
Time of Concentration Flow Path	
Section Line	
Township and Range Line	
USGS Quadrangle Map Boundary	

INDEX MAP



200 0' 200 400

SCALE: 1"= 200'

HYDROLOGY EXHIBIT "E"

WATERSHED MAP OF DETAILED STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

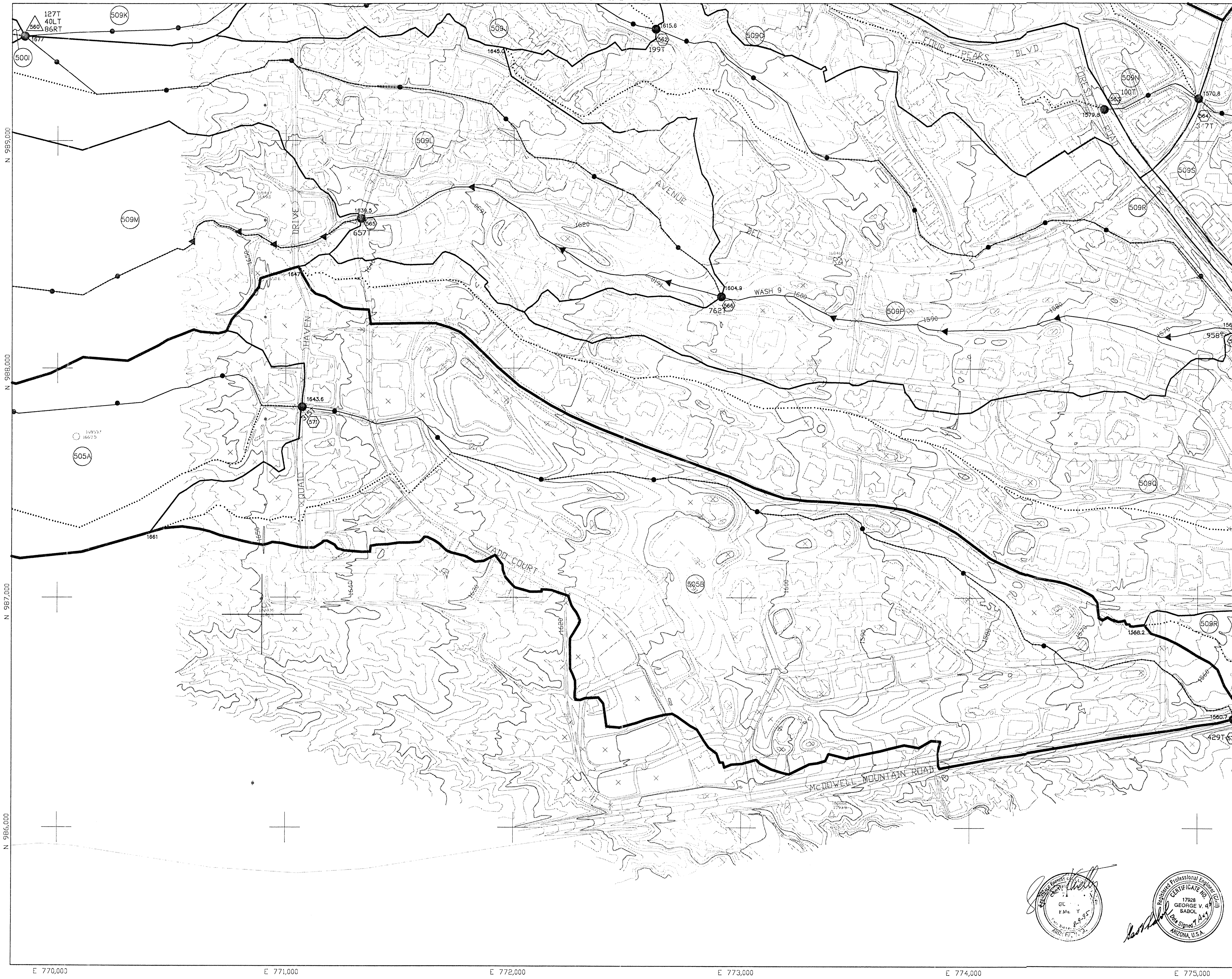
SHEET 2 OF 8

Dwg. Name: \P\RIOVRDE\ACAD\NEW-RIO.dwg
Date: REV. NOV. 17, 1994 09:00am

AERIAL MAPPING COMPANY, INC.
SURVEYING AND PHOTOGRAMMETRY
FLIGHT DATE: 12-22-1993

THIS MAP WAS PREPARED BY PHOTOGRAMMETRIC METHODS TO NATIONAL MAP ACCURACY STANDARDS 1"= 200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY DATA PROVIDED BY BURGESS & NIPLE.

MATCH LINE SHEET 5



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

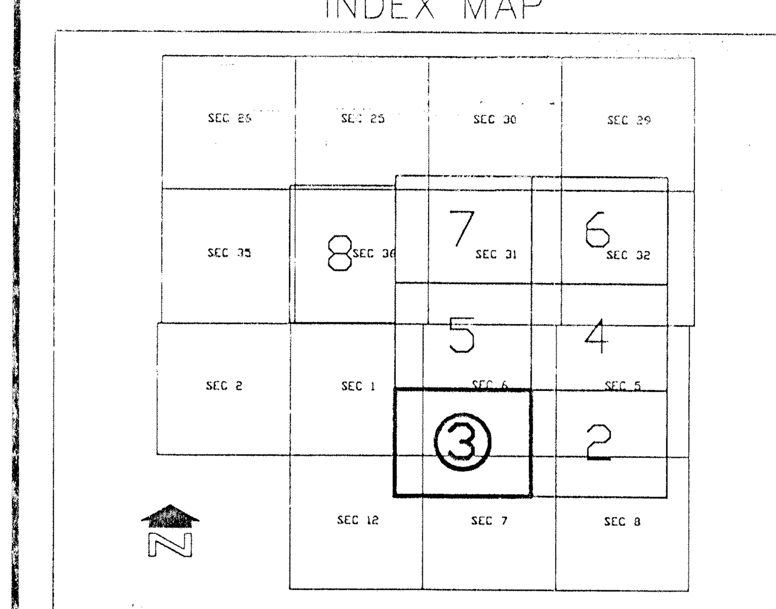
NOTES

1. Sheet No. 1 was intentionally omitted HYDROLOGY EXHIBIT "E".
2. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

LEGEND

Item	Symbol
Subbasin Identifier	500P
Subbasin Concentration Point	●
Intermediate Concentration Point	○
Concentration Point Number (Peak discharge is 1430 cfs.)	1430T 542
Flow Split Conc. Point Number (Peak discharge 941 cfs; 223 cfs RT, & 717 cfs LT)	941T 717LT 223RT 574
Elevation (at concentration point or top of Tc path)	1598.6
Drainage Basin Boundary	
Drainage Subbasin Boundary	
Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)	
Time of Concentration Flow Path	
Section Line	
Township and Range Line	
USGS Quadrangle Map Boundary	

INDEX MAP



200 0' 200 400

SCALE: 1"= 200'

HYDROLOGY EXHIBIT "E"

WATERSHED MAP OF DETAILED STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE	
DESIGN	F.C.D.M.C.	1993	FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
DESIGN CHK.	TRL	6/94	RECOMMENDED BY: DATE
PLANS	BKE	7/94	APPROVED BY: DATE
PLANS CHK.	TRL	7/94	CHIEF ENGINEER AND GENERAL MANAGER
SUBMITTED BY:		DATE:	SHEET 3 of 8

Dwg. Name: \P\RIOVERDE\CAD\NEW-RIO.dwg
Date: REV. NOV. 17, 1994 09:00am

AERIAL MAPPING COMPANY, INC.
SURVEYING AND PHOTOGRAMMETRY
FLIGHT DATE: 12-22-1993

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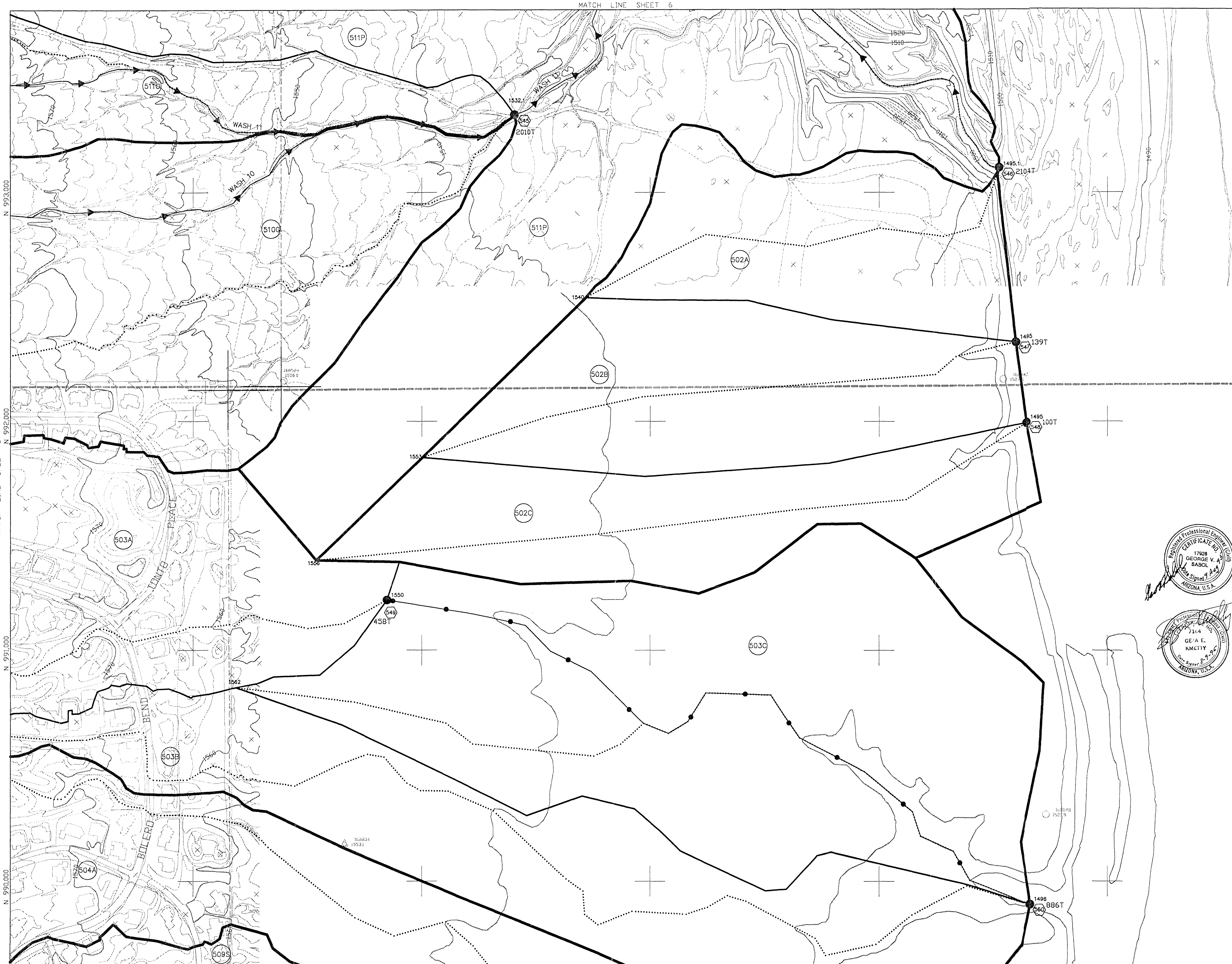
1"= 200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY
DATA PROVIDED BY BURGESS & NIPLE.

MATCH LINE SHEET 6



MATCH LINE SHEET 5

MATCH LINE SHEET 2

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

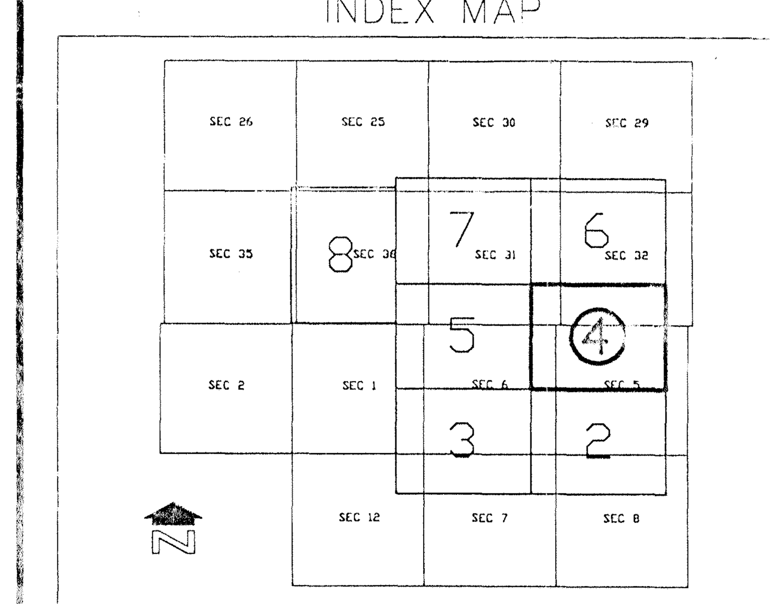
NOTES

1. Sheet No. 1 was intentionally omitted HYDROLOGY EXHIBIT "E".
2. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

LEGEND

- Subbasin Identifier (500P)
- Subbasin Concentration Point
- Intermediate Concentration Point
- Concentration Point Number — Peak discharge is 1430 cfs. (1430T, 142)
- Flow Split Conc. Point Number — Peak discharge 941 cfs; 223 cfs RT, & 717 cfs LT (941T, 717LT, 223RT, 57A)
- Elevation (at concentration point or top of Tc path)
- Drainage Basin Boundary
- Drainage Subbasin Boundary
- Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)
- Time of Concentration Flow Path
- Section Line
- Township and Range Line
- USGS Quadrangle Map Boundary

INDEX MAP



200 0' 200 400

SCALE: 1"= 200'

HYDROLOGY EXHIBIT "E"

WATERSHED MAP OF DETAILED STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE	
DESIGN	F.C.D.M.C.	1993	FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
DESIGN CHK.	TRL	6/94	RECOMMENDED BY: DATE
PLANS	BKE	7/94	APPROVED BY: DATE
PLANS CHK.	TRL	7/94	CHIEF ENGINEER AND GENERAL MANAGER
SUBMITTED BY:		DATE:	SHEET 4 OF 8

Dwg. Name: \P\RIOVERDE\ACAD\NEW-RIO.dwg
Date: REV. NOV. 17, 1994 09:00am

AERIAL MAPPING COMPANY, INC.
SURVEYING AND PHOTOGRAMMETRY
FLIGHT DATE: 12-22-1993

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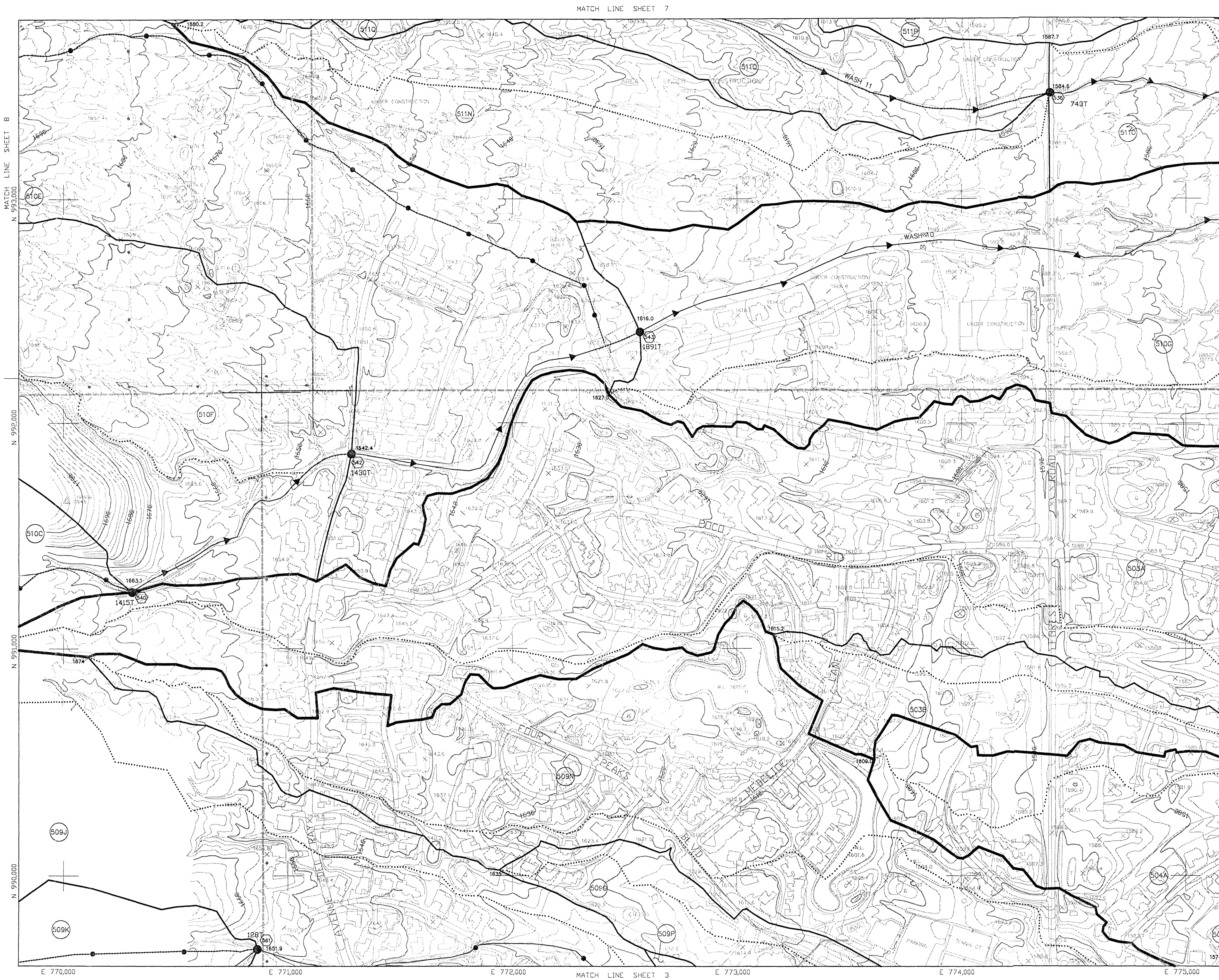
1"= 200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY
DATA PROVIDED BY BURGESS & NIPLE



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

NOTES

1. Sheet No. 1 was intentionally omitted HYDROLOGY EXHIBIT "E".
2. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

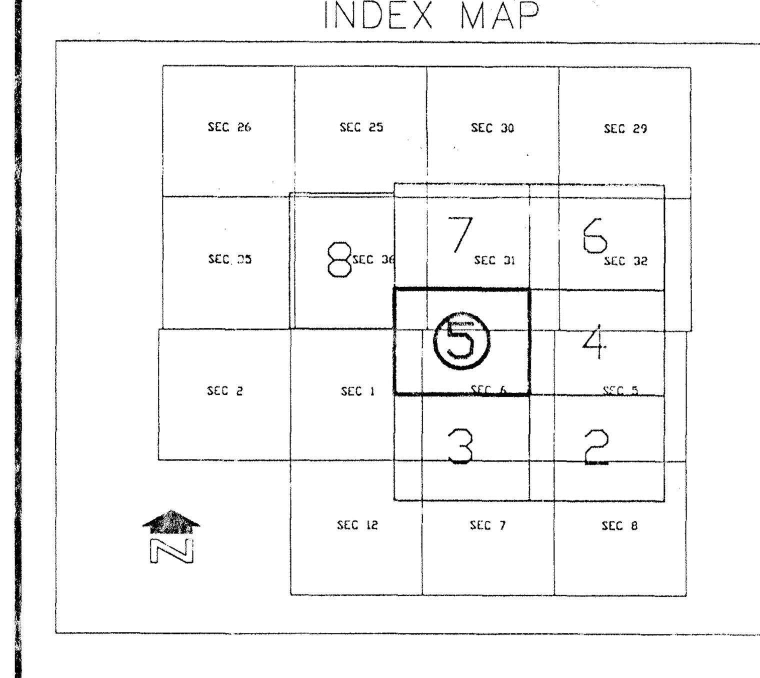
[Registered Professional Engineer (Civil) seal: CERTIFICATE NO. 17928, GEORGE V. SABOL, ARIZONA, U.S.A.; signed]

[Registered Professional Engineer (Civil) seal: 7184, GEZA E. KMETTY, ARIZONA, U.S.A.; signed]

LEGEND

- Subbasin Identifier
- Subbasin Concentration Point
- Intermediate Concentration Point
- Concentration Point Number — 1430T (542) — Peak discharge is 1430 cfs.
- Flow Split Conc. Point Number — 941T 717LT 223RT (574) — Peak discharge 941 cfs, 223 cfs RT, & 717 cfs LT
- Elevation (at concentration point or top of Tc path)
- Drainage Basin Boundary
- Drainage Subbasin Boundary
- Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)
- Time of Concentration Flow Path
- Section Line
- Township and Range Line
- USGS Quadrangle Map Boundary

INDEX MAP



N

200 0' 200 400

SCALE: 1"= 200'

HYDROLOGY EXHIBIT "E"

WATERSHED MAP OF DETAILED STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94

SUBMITTED BY: DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 5 OF 8

Dwg. Name: \P\RIOVERDE\ACAD\NEW-RIO.dwg
Date: REV. NOV. 17, 1994 09:00am

AERIAL MAPPING COMPANY, INC.
SURVEYING AND PHOTOGRAMMETRY
FLIGHT DATE: 12-22-1993

THIS MAP WAS PREPARED BY PHOTOGRAMMETRIC METHODS TO NATIONAL MAP ACCURACY STANDARDS 1"= 200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY DATA PROVIDED BY BURGESS & NIPLE.

AERIAL MAPPING COMPANY, INC.
SURVEYING AND PHOTOGRAMMETRY
FLIGHT DATE: 12-22-1993

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1"= 200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY
DATA PROVIDED BY BURGESS & NIPLE

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

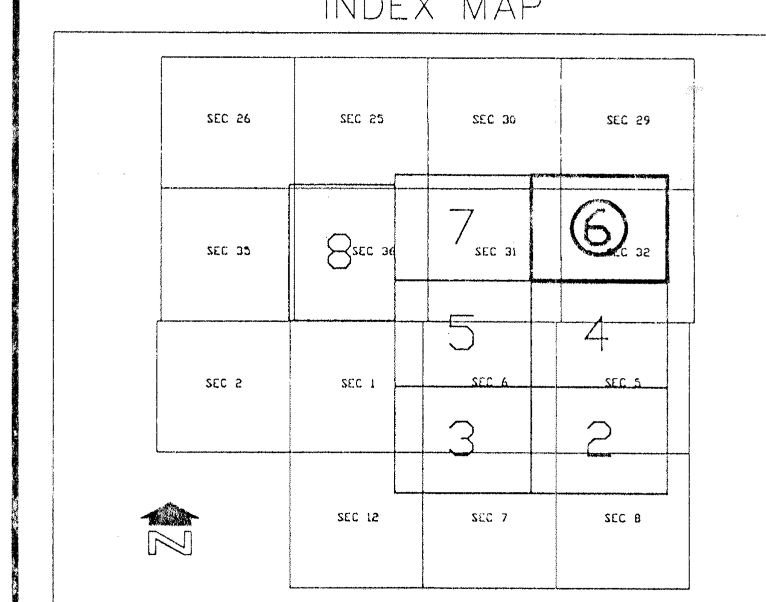
NOTES

1. Sheet No. 1 was intentionally omitted HYDROLOGY EXHIBIT "E".
2. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

LEGEND

Subbasin Identifier	100P
Subbasin Concentration Point	●
Intermediate Concentration Point	○
Concentration Point Number (Peak discharge is 1430 cfs.)	1430T 542
Flow Split Conc. Point Number (Peak discharge 941 cfs; 223 cfs RT, & 717 cfs LT)	941T 717LT 223RT 574
Elevation (at concentration point or top of Tc path)	1598.6
Drainage Basin Boundary	
Drainage Subbasin Boundary	
Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)	
Time of Concentration Flow Path	
Section Line	
Township and Range Line	
USGS Quadrangle Map Boundary	

INDEX MAP



200 0' 200 400
SCALE: 1"= 200'

HYDROLOGY EXHIBIT "E"

WATERSHED MAP OF DETAILED STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SUBMITTED BY: DATE:

SHEET 6 OF 8

Dwg. Name: P:\RIOVERDE\ACAD\NEW-RIO.dwg
Date: REV. NOV. 17, 1994 09:00am

MAPPING COMPANY, INC.
ING AND PHOTOGRAMMETRY
DATE: 12-22-1993

THIS MAP WAS PREPARED BY PHOTOGRAMMETRIC METHODS TO NATIONAL MAP ACCURACY STANDARDS
1"= 200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY
DATA PROVIDED BY BURGESS & NIPLE.

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

NOTES

1. Sheet No. 1 was intentionally omitted HYDROLOGY EXHIBIT "E".
2. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.

LEGEND

- Subbasin Identifier (500P)
- Subbasin Concentration Point
- Intermediate Concentration Point
- Concentration Point Number 1430T (542) — Peak discharge is 1430 cfs.
- Flow Split Conc. Point Number 941T 717LT 223RT (574) — Peak discharge 941 cfs; 223 cfs RT, & 717 cfs LT
- Elevation (at concentration point or top of Tc path)
- Drainage Basin Boundary
- Drainage Subbasin Boundary
- Hydrograph Flood Routing Path (Triangles denote a Hec-2 study reach)
- Time of Concentration Flow Path
- Section Line
- Township and Range Line
- USGS Quadrangle Map Boundary

INDEX MAP

SCALE: 1"= 200'

HYDROLOGY EXHIBIT "E"

WATERSHED MAP OF DETAILED STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

	BY	DATE
DESIGN	F.C.D.M.C.	1993
DESIGN CHK.	TRL	6/94
PLANS	BKE	7/94
PLANS CHK.	TRL	7/94
SUBMITTED BY:		DATE:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

RECOMMENDED BY: DATE

APPROVED BY: DATE

CHIEF ENGINEER AND GENERAL MANAGER

SHEET 7 OF 8

Dwg. Name: \P\RIOVERDE\ACAD\NEW-RIO.dwg
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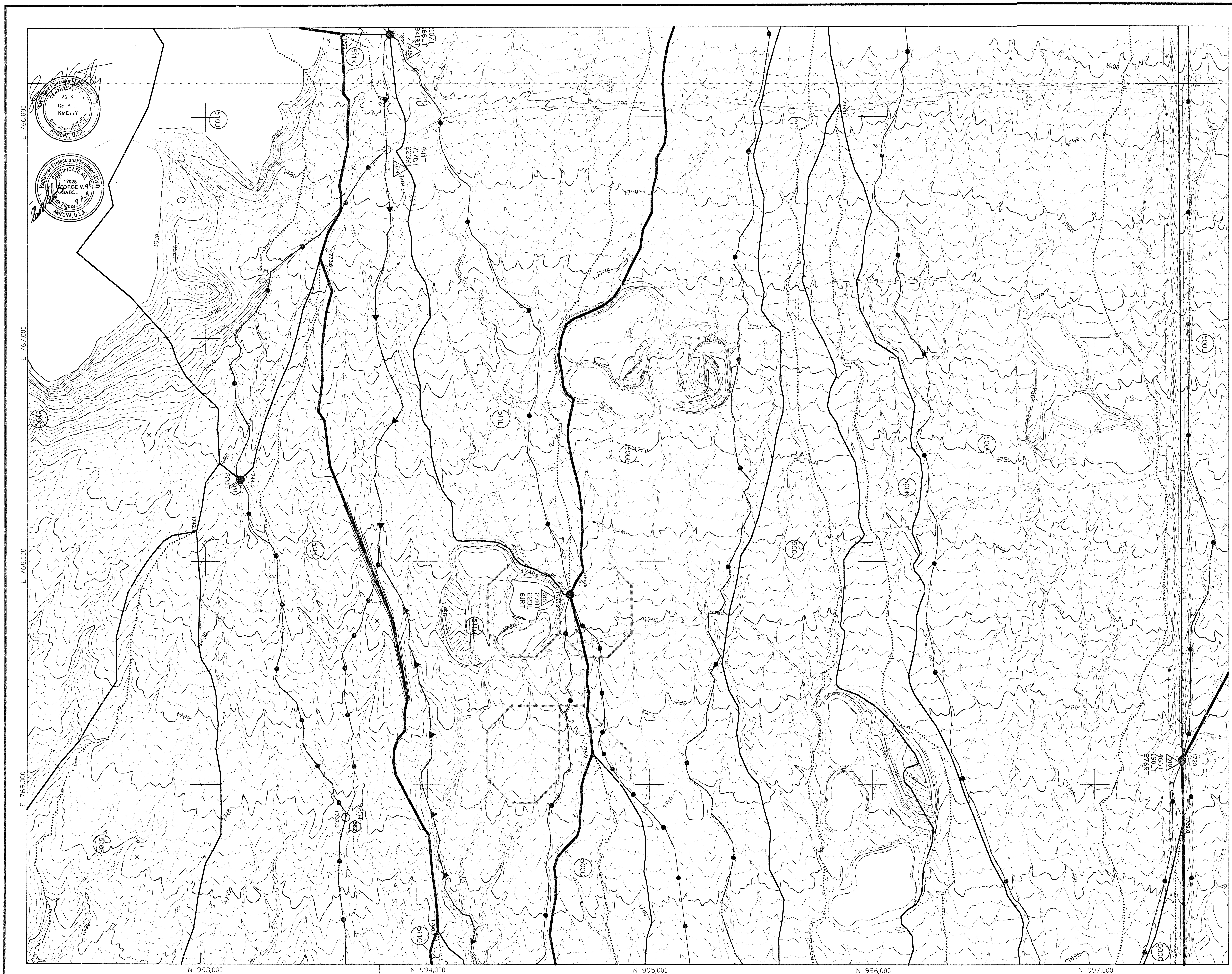


FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD DELINEATION STUDY OF

RIO VERDE SOUTH

F.C.D. CONTRACT NO. 93-07

NOTES

1. Sheet No. 1 was intentionally omitted HYDROLOGY EXHIBIT "E"
2. Flowrates are the 100-yr, 6-hr or 24-hr storm, whichever is greater.
3. Solid contours are "as-built" per mappping prepared by Brooks, Hersey and Associates, Inc. Dated __________, Job No. 519-01fp.

LEGEND

Subbasin Identifier (500P)

Subbasin Concentration Point

Intermediate Concentration Point

Concentration Point Number 1430T
Peak discharge is 1430 cfs.

Flow Split Conc. Point Number 941T 717LT 223RT
Peak discharge 941 cfs; 223 cfs RT, & 717 cfs LT

Elevation 1598.6
(at concentration point or top of Tc path)

Drainage Basin Boundary

Drainage Subbasin Boundary

Hydrograph Flood Routing Path
(Triangles denote a Hec-2 study reach)

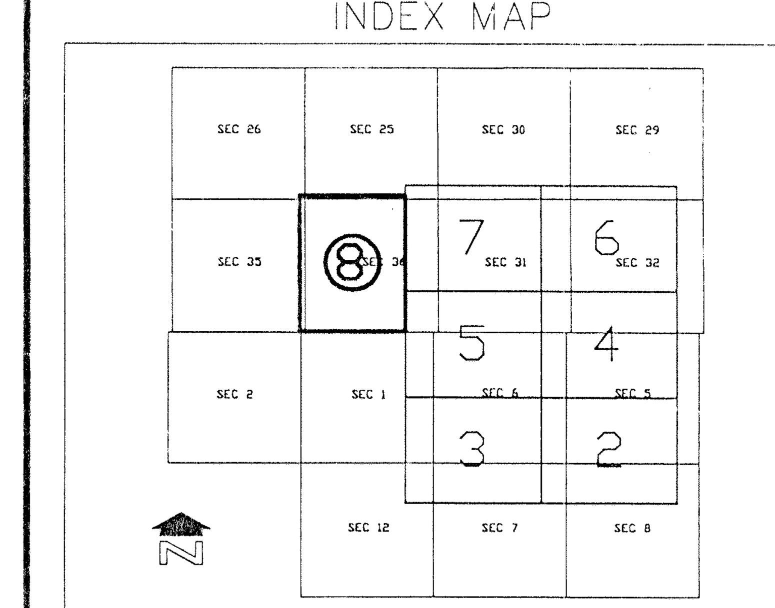
Time of Concentration Flow Path

Section Line

Township and Range Line

USGS Quadrangle Map Boundary

INDEX MAP



N

200 0' 200 400

SCALE: 1"= 200'

HYDROLOGY EXHIBIT "E"

WATERSHED MAP OF DETAILED STUDY AREA

McLAUGHLIN KMETTY ENGINEERS, LTD.

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DESIGN	F.C.D.M.C.	1993	FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
DESIGN CHK.	TRL	6/94	RECOMMENDED BY: DATE
PLANS	BKE	7/94	APPROVED BY: DATE
PLANS CHK.	TRL	7/94	CHIEF ENGINEER AND GENERAL MANAGER
SUBMITTED BY: DATE:			SHEET 8 OF 8

Dwg. Name: \RIVERDE\ACAD\NEW-RIO.dwg
Date: REV. NOV. 17, 1994 09:00am

AERIAL MAPPING COMPANY, INC.
SURVEYING AND PHOTOGRAMMETRY
FLIGHT DATE: 12-22-1993

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1"= 200' HORIZONTAL SCALE AND 2' CONTOUR INTERVALS AND BASED ON GROUND CONTROL SURVEY
DATA PROVIDED BY BURGESS & NIPLE.