Table D1.8 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 2 of the Carrizo-Wilcox Aquifer for counties within the study area

Livestock

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	47	92	97	97	97	97	97	97
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	1	1	1	1	1	1	1	1
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	2	2	2	2	2	2	2	2
Camp	12	12	32	32	32	32	32	32
Cass	13	32	5	5	5	5	5	5
Cherokee	1	115	163	163	163	163	163	163
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	-	-	-	-	-	-	-	-
Freestone	12	9	15	15	15	15	15	15
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	9	3	1	2	2	2	2	2
Henderson	24	38	28	28	28	28	28	28
Hopkins	-	-	-	-	-	-	-	-
Houston	2	3	2	2	2	2	2	2
Leon	86	130	432	432	432	432	432	432
Limestone	-	-	-	-	-	-	-	-
Madison	2	2	205	205	205	205	205	205
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	2	8	8	8	8	8	8
Morris	5	7	-	-	-	-	-	-
Nacogdoches	139	112	151	151	139	145	141	150
Natchitoches, LA	17	-	6	6	6	6	6	6
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	-	-	-	-	-	-
Rusk	11	9	9	10	10	10	10	10
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	3	3	5	5	5	5	5	5
Shelby	-	-	-	-	-	-	-	-
Smith	12	14	35	35	35	35	35	35
Titus	2	3	5	5	5	5	5	5
Trinity	-	-	-	-	-	-	-	-
Upshur	2	4	9	9	9	9	9	9
Van Zandt	2	2	1	1	1	1	1	1
Wood	14	19	14	14	14	14	14	14
Total	418	614	1,226	1,228	1,216	1,222	1,218	1,227

Table D1.8 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 2 of the Carrizo-Wilcox Aquifer for counties within the study area

Irrigation

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	-	1	7	7	7	7	7	7
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	-	-	-	-	-	-	-	-
Camp	-	3	4	4	4	4	4	4
Cass	-	-	-	-	-	-	-	-
Cherokee	4	9	9	1	1	1	1	1
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	-	-	-	-	-	-	-	-
Freestone	-	-	-	-	-	-	-	-
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	-	-	-	-	-	-	-	-
Henderson	-	-	-	-	-	-	-	-
Hopkins	-	-	-	-	-	-	-	-
Houston	-	-	7	7	6	6	7	7
Leon	-	-	-	-	-	-	-	-
Limestone	-	-	-	-	-	-	-	-
Madison	1	1	-	-	-	-	-	-
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	21	36	36	36	36	36	36
Morris	-	-	-	-	-	-	-	-
Nacogdoches	-	10	74	74	74	74	74	74
Natchitoches, LA	23	32	37	37	37	37	37	37
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	-	-	-	-	-	-
Rusk	-	-	-	-	-	-	-	-
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	-	-	-	-	-	-	-	-
Smith	1	-	2	2	2	2	2	2
Titus	-	-	-	-	-	-	-	-
Trinity	-	-	-	-	-	-	-	-
Upshur	-	-	-	-	-	-	-	-
Van Zandt	-	-	-	-	-	-	-	-
Wood	-	1	2	2	2	2	2	2
Total	29	78	178	170	169	169	170	170

Table D1.9
Rate of groundwater withdrawal (acre-feet per year) from flow layer 3 of the Carrizo-Wilcox Aquifer for counties within the study area

Municipal and Industrial*

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	421	515	323	319	314	311	308	305
Angelina	5,592	5,786	3,257	2,185	2,224	2,553	2,711	3,047
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	53	27	-	-	-	-	-	-
Camp	-	-	-	-	-	-	-	-
Cass	-	-	-	-	-	-	-	-
Cherokee	1,920	1,712	970	620	649	746	782	862
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	-	-	-	-	-	-	-	-
Freestone	-	-	-	-	-	-	-	-
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	331	340	351	366	394	429
Harrison	89	119	27	36	36	36	36	36
Henderson	102	116	156	160	163	164	161	163
Hopkins	-	-	-	-	-	-	-	-
Houston	281	-	687	648	653	659	663	665
Leon	61	73	1,392	1,031	526	410	364	369
Limestone	-	-	-	-	-	-	-	-
Madison	66	150	1,163	1,119	1,086	1,052	1,002	959
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	-	-	-	-	-	-	-
Morris	242	26	-	-	-	-	-	-
Nacogdoches	4,360	4,708	1,420	1,262	1,391	1,570	1,781	2,057
Natchitoches, LA	-	-	-	-	-	-	-	-
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	-	-	-	-	-	-
Rusk	111	114	-	-	-	-	-	-
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	18	1	9	10	10	11	11	12
Shelby	-	-	-	-	-	-	-	-
Smith	347	83	14	14	14	14	14	14
Titus	-	-	-	-	-	-	-	-
Trinity	-	-	-	-	-	-	-	-
Upshur	490	388	287	298	296	309	326	340
Van Zandt	-	-	-	-	-	-	-	-
Wood	1,037	704	388	406	438	472	498	541
Total	15,190	14,522	10,424	8,448	8,151	8,673	9,051	9,799

*industrial includes manufacturing, mining, and power generation

Table D1.9 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 3 of the Carrizo-Wilcox Aquifer for counties within the study area

County – Other (Non-reported Domestic)

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	256	456	684	700	707	717	715	731
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	16	11	10	10	11	12	13	15
Camp	160	183	206	277	282	288	291	293
Cass	179	199	45	46	47	48	52	53
Cherokee	213	267	383	124	135	144	152	159
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	23	25	2	2	2	3	4	4
Freestone	-	-	-	-	-	-	-	-
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	414	591	325	324	350	352	364	363
Henderson	213	376	286	291	291	188	183	291
Hopkins	-	-	-	-	-	-	-	-
Houston	13	15	6	6	6	6	6	6
Leon	202	342	239	257	277	297	319	345
Limestone	-	-	-	-	-	-	-	-
Madison	1	1	-	-	-	-	-	-
Marion	113	115	68	70	71	73	74	74
Miller, AR	-	-	-	-	-	-	-	-
Morris	59	73	9	9	9	9	8	8
Nacogdoches	615	814	786	794	808	819	817	820
Natchitoches, LA	1	2	3	3	4	4	4	5
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	2	51	48	45	44	44	44
Rusk	384	476	469	437	468	507	511	540
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	127	159	77	76	75	75	75	75
Shelby	1	1	-	-	-	-	-	-
Smith	811	1,164	1,461	1,506	1,644	1,810	1,992	2,185
Titus	60	76	47	69	72	82	87	89
Trinity	-	-	-	-	-	-	-	-
Upshur	364	371	311	332	332	335	327	327
Van Zandt	82	144	130	136	168	166	168	168
Wood	230	299	284	312	326	349	365	401
Total	4,537	6,162	5,882	5,829	6,130	6,328	6,571	6,996

Table D1.9 (*Continued...*)

Rate of groundwater withdrawal (acre-feet per year) from flow layer 3 of the Carrizo-Wilcox Aquifer for counties within the study area

Livestock

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	36	46	74	74	74	74	74	74
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	1	1	1	1	1	1	1	1
Camp	31	31	83	83	83	83	83	83
Cass	31	72	13	13	13	13	13	13
Cherokee	-	25	35	35	35	35	35	35
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	3	4	4	4	4	4	4	-
Freestone	43	31	54	54	54	54	54	54
Gregg	10	8	56	56	56	56	56	56
Grimes	-	-	-	-	-	-	-	-
Harrison	37	12	103	119	134	151	169	186
Henderson	17	28	18	18	18	18	18	18
Hopkins	-	-	-	-	-	-	-	-
Houston	1	1	1	1	1	1	1	1
Leon	132	191	539	539	539	539	539	539
Limestone	-	-	-	-	-	-	-	-
Madison	-	1	39	39	39	39	39	39
Marion	2	2	3	3	3	3	3	3
Miller, AR	-	10	45	45	45	45	45	45
Morris	3	4	-	-	-	-	-	-
Nacogdoches	112	90	122	122	112	117	114	121
Natchitoches, LA	10	4	4	4	4	4	4	4
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	11	11	54	54	54	54	54	54
Rusk	-	-	-	-	-	-	-	-
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	31	33	29	29	30	30	31	31
Shelby	-	-	-	-	-	-	-	-
Smith	17	19	48	48	48	48	48	48
Titus	11	12	22	22	22	22	22	22
Trinity	-	-	-	-	-	-	-	-
Upshur	-	-	-	-	-	-	-	-
Van Zandt	-	-	-	-	-	-	-	-
Wood	-	-	-	-	-	-	-	-
Total	539	636	1,347	1,363	1,369	1,391	1,407	1,427

Table D1.9 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 3 of the Carrizo-Wilcox Aquifer for counties within the study area

Irrigation

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	-	4	17	17	17	17	17	17
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	22	1	14	14	14	14	14	14
Camp	-	16	20	20	20	20	20	20
Cass	-	-	-	-	-	-	-	-
Cherokee	11	23	833	49	49	49	49	49
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	-	-	1	1	1	1	1	1
Freestone	-	-	-	-	-	-	-	-
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	-	4	7	7	7	7	7	7
Henderson	-	-	-	-	-	-	-	-
Hopkins	-	-	-	-	-	-	-	-
Houston	-	-	10	10	10	10	10	10
Leon	-	-	-	-	-	-	-	-
Limestone	-	-	-	-	-	-	-	-
Madison	1	2	-	-	-	-	-	-
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	515	886	886	886	886	886	886
Morris	-	-	-	-	-	-	-	-
Nacogdoches	-	57	423	423	423	423	423	423
Natchitoches, LA	17	24	28	28	28	28	28	28
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	150	146	145	141	137	133
Rusk	-	1	4	4	4	4	4	4
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	8	8	8	8	8	8
Shelby	-	-	-	-	-	-	-	-
Smith	3	1	10	10	10	10	10	10
Titus	-	-	-	-	-	-	-	-
Trinity	-	-	-	-	-	-	-	-
Upshur	-	1	-	-	-	-	-	-
Van Zandt	-	-	-	-	-	-	-	-
Wood	-	46	46	46	46	46	46	46
Total	54	695	2,457	1,669	1,668	1,664	1,660	1,656

Table D1.10
Rate of groundwater withdrawal (acre-feet per year) from flow layer 4 of the Carrizo-Wilcox Aquifer for counties within the study area

Municipal and Industrial*

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	344	173	461	378	298	264	238	228
Angelina	601	649	12,237	11,841	10,698	11,298	11,992	13,208
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	196	148	235	243	258	282	314	354
Camp	236	259	35	35	36	37	39	41
Cass	166	154	185	479	174	170	165	162
Cherokee	2,842	2,771	2,171	1,841	1,816	1,830	1,892	2,023
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	-	-	-	-	-	-	-	-
Freestone	-	-	-	-	-	-	-	-
Gregg	449	214	269	274	281	290	299	309
Grimes	-	-	-	-	-	-	-	-
Harrison	87	83	80	107	107	107	107	107
Henderson	69	170	151	152	148	149	150	155
Hopkins	-	-	-	-	-	-	-	-
Houston	-	-	-	-	-	-	-	-
Leon	644	888	1,475	1,482	1,489	1,562	1,628	1,723
Limestone	-	-	-	-	-	-	-	-
Madison	4	10	-	-	-	-	-	-
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	-	-	-	-	-	-	-
Morris	221	6,412	-	-	-	-	-	-
Nacogdoches	308	358	1,073	967	1,048	1,169	1,311	1,497
Natchitoches, LA	-	113	233	246	265	288	317	350
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	42	51	61	72	84	98
Rusk	774	944	1,032	758	676	684	692	710
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	100	95	18	19	20	22	22	23
Shelby	23	52	-	-	-	-	-	-
Smith	3,927	2,364	4,444	4,934	5,272	5,256	5,660	4,267
Titus	-	-	-	-	-	-	-	-
Trinity	-	-	-	-	-	-	-	-
Upshur	486	493	370	395	399	416	450	480
Van Zandt	-	-	511	560	605	663	715	782
Wood	1,206	532	1,010	1,081	1,205	1,323	1,450	1,611
Total	12,683	16,882	26,032	25,843	24,856	25,882	27,525	28,128

*industrial includes manufacturing, mining, and power generation

Table D1.10 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 4 of the Carrizo-Wilcox Aquifer for counties within the study area

County – Other (Non-reported Domestic)

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	612	1,043	1,570	1,607	1,625	1,646	1,641	1,678
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	1	3	-	-	-	-	-	-
Caddo, LA	53	36	33	34	36	39	44	50
Camp	390	540	610	821	836	853	862	867
Cass	272	319	73	74	74	75	78	78
Cherokee	180	199	286	93	101	107	113	119
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	75	93	8	9	9	10	13	13
Freestone	269	339	344	329	308	301	304	303
Gregg	1,288	1,273	615	751	747	794	833	866
Grimes	-	-	-	-	-	-	-	-
Harrison	440	637	386	384	423	428	437	436
Henderson	556	832	712	719	719	715	708	718
Hopkins	42	45	31	40	39	43	48	52
Houston	2	2	1	1	1	1	1	1
Leon	242	372	267	287	308	331	355	384
Limestone	14	28	68	69	71	76	81	87
Madison	-	-	-	-	-	-	-	-
Marion	243	232	137	140	144	146	148	149
Miller, AR	-	1	1	1	1	1	1	1
Morris	221	255	23	23	22	22	21	20
Nacogdoches	348	435	420	424	431	437	436	438
Natchitoches, LA	29	70	95	100	108	118	129	143
Navarro	-	-	-	-	-	-	-	-
Panola	18	19	9	9	9	8	8	8
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	4	9	202	190	177	172	172	172
Rusk	2,153	2,626	2,474	2,165	2,320	2,509	2,545	2,673
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	143	147	46	46	45	45	45	45
Shelby	913	1,000	540	571	556	163	561	575
Smith	365	468	576	598	649	709	774	845
Titus	210	292	183	270	284	322	340	351
Trinity	-	-	-	-	-	-	-	-
Upshur	303	397	348	370	370	372	30	360
Van Zandt	352	530	447	476	616	592	598	600
Wood	232	348	400	440	459	491	514	565
Total	9,970	12,590	10,905	11,041	11,488	11,526	11,840	12,597

Table D1.10 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 4 of the Carrizo-Wilcox Aquifer for counties within the study area

Livestock

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	36	41	74	74	74	74	74	74
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	2	2	2	2	2	2	2	2
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	8	8	8	8	8	8	8	8
Camp	49	49	131	131	131	131	131	131
Cass	21	40	18	18	18	18	18	18
Cherokee	1	52	73	73	73	3	73	73
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	44	66	62	62	62	62	62	62
Freestone	141	99	165	165	165	165	165	165
Gregg	33	28	188	188	188	188	188	188
Grimes	-	-	-	-	-	-	-	-
Harrison	59	21	87	96	104	114	124	134
Henderson	63	99	71	71	71	71	71	71
Hopkins	3	4	2	2	2	2	2	2
Houston	-	-	-	-	-	-	-	-
Leon	135	180	403	403	403	403	403	403
Limestone	4	5	49	49	49	49	49	49
Madison	-	-	-	-	-	-	-	-
Marion	14	14	16	16	16	16	16	16
Miller, AR	-	6	27	27	27	27	27	27
Morris	10	14	3	3	3	3	3	3
Nacogdoches	123	99	134	134	123	128	125	133
Natchitoches, LA	142	-	53	53	53	53	53	53
Navarro	-	-	-	-	-	-	-	-
Panola	1	1	2	2	2	2	2	2
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	181	178	905	905	905	905	905	905
Rusk	349	295	288	292	296	292	297	295
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	23	25	22	22	22	23	23	23
Shelby	284	298	738	900	670	823	1,003	1,223
Smith	27	31	55	55	55	55	55	55
Titus	62	71	126	126	126	126	126	126
Trinity	-	-	-	-	-	-	-	-
Upshur	18	49	125	125	125	125	125	125
Van Zandt	152	185	63	63	63	63	63	63
Wood	27	36	22	22	22	22	22	22
Total	2,012	1,996	3,912	4,087	3,858	3,953	4,215	4,451

Table D1.10 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 4 of the Carrizo-Wilcox Aquifer for counties within the study area

Irrigation

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	-	12	68	68	68	68	68	68
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	9	3	6	6	6	6	6	6
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	335	3	188	188	188	188	188	188
Camp	-	31	38	38	38	38	38	38
Cass	-	-	-	-	-	-	-	-
Cherokee	10	17	6	-	-	-	-	-
De Soto, LA	-	-	-	-	-	-	-	-
Franklin	-	1	5	5	5	5	5	5
Freestone	-	10	1	1	1	1	1	1
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	-	3	6	6	6	6	6	6
Henderson	23	5	-	-	-	-	-	-
Hopkins	-	-	-	-	-	-	-	-
Houston	-	-	10	10	10	10	10	10
Leon	-	-	-	-	-	-	-	-
Limestone	-	-	-	-	-	-	-	-
Madison	-	-	-	-	-	-	-	-
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	1,115	1,917	1,917	1,917	1,917	1,917	1,917
Morris	-	-	-	-	-	-	-	-
Nacogdoches	-	66	495	495	495	495	495	495
Natchitoches, LA	118	167	193	193	193	193	193	193
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	13	13	6,628	6,469	6,407	6,223	6,045	5,872
Rusk	-	19	55	55	55	55	55	55
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	55	55	55	55	55	55
Shelby	-	8	11	11	12	15	18	21
Smith	19	5	55	55	55	55	55	55
Titus	-	-	-	-	-	-	-	-
Trinity	-	-	-	-	-	-	-	-
Upshur	-	-	-	-	-	-	-	-
Van Zandt	-	-	-	-	-	-	-	-
Wood	-	91	75	75	75	75	75	75
Total	527	1,569	9,812	9,647	9,586	9,405	9,230	9,060

Table D1.11
Rate of groundwater withdrawal (acre-feet per year) from flow layer 5 of the Carrizo-Wilcox Aquifer for counties within the study area

Municipal and Industrial*

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	192	-	130	139	146	152	165	176
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	23	26	25	25	25	25	25	25
Caddo, LA	943	1,030	1,115	1,149	1,219	1,324	1,465	1,641
Camp	469	514	273	271	274	279	286	294
Cass	1,070	1,033	46	45	44	42	41	41
Cherokee	3	4	60	13	14	15	16	18
De Soto, LA	422	835	96	96	96	96	96	96
Franklin	459	401	1,479	1,384	1,338	1,278	1,297	1,359
Freestone	101	809	179	204	204	199	199	200
Gregg	317	150	382	352	337	335	335	334
Grimes	-	-	-	-	-	-	-	-
Harrison	313	265	52	47	45	39	42	43
Henderson	542	486	324	303	299	308	319	339
Hopkins	78	76	-	-	-	-	-	-
Houston	-	-	-	-	-	-	-	-
Leon	-	-	-	-	-	-	-	-
Limestone	-	646	6,200	6,889	6,889	6,889	6,889	6,889
Madison	-	-	-	-	-	-	-	-
Marion	-	-	91	63	50	44	40	54
Miller, AR	-	4,248	9	10	11	11	12	13
Morris	477	291	409	412	401	395	383	379
Nacogdoches	275	271	256	259	262	284	301	316
Natchitoches, LA	-	-	-	-	-	-	-	-
Navarro	-	-	-	-	-	-	-	-
Panola	1,007	1,691	357	331	291	401	402	399
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	-	-	-	-	-	-
Rusk	2,887	2,850	3,086	2,789	2,450	2,241	2,144	2,092
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	427	369	305	304	303	311	317	328
Smith	1,057	634	2,239	2,460	2,627	2,639	2,807	2,208
Titus	135	213	1,876	1,771	1,735	1,722	1,724	1,735
Trinity	-	-	-	-	-	-	-	-
Upshur	39	38	6	7	6	7	7	7
Van Zandt	1,213	643	569	611	648	699	741	800
Wood	-	-	-	-	-	-	-	-
Total	12,449	17,523	19,564	19,934	19,714	19,735	20,053	19,786

*industrial includes manufacturing, mining, and power generation

Table D1.11 (*Continued...*)

Rate of groundwater withdrawal (acre-feet per year) from flow layer 5 of the Carrizo-Wilcox Aquifer for counties within the study area

County – Other (Non-reported Domestic)

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	11	11	15	15	16	16	16	16
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	47	40	38	41	44	46	48	50
Bowie	963	1,141	76	76	76	76	76	76
Caddo, LA	1,556	1,324	1,222	1,262	1,344	1,468	1,633	1,841
Camp	-	-	-	-	-	-	-	-
Cass	16	26	6	6	6	6	6	6
Cherokee	-	33	48	15	16	17	18	19
De Soto, LA	659	201	-	-	-	-	-	-
Franklin	74	130	11	12	12	13	18	18
Freestone	205	274	253	242	226	221	223	222
Gregg	110	128	62	75	75	79	83	87
Grimes	-	-	-	-	-	-	-	-
Harrison	1,074	1,405	933	933	1,034	1,053	1,065	1,062
Henderson	371	490	469	470	470	469	468	470
Hopkins	245	342	521	641	640	672	734	768
Houston	-	-	-	-	-	-	-	-
Leon	-	-	-	-	-	-	-	-
Limestone	72	121	297	300	311	332	355	383
Madison	-	-	-	-	-	-	-	-
Marion	74	90	53	55	56	57	58	58
Miller, AR	11	12	12	13	14	14	15	16
Morris	49	51	-	-	-	-	-	-
Nacogdoches	44	51	49	50	51	52	51	52
Natchitoches, LA	3	6	8	8	9	10	10	12
Navarro	10	16	-	-	-	-	-	-
Panola	1,621	1,951	945	926	896	858	858	858
Rains	238	366	368	389	408	276	293	311
Red River, LA	9	7	9	9	10	11	12	14
Robertson	14	24	534	503	469	455	456	455
Rusk	183	238	212	166	178	193	197	205
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	856	943	501	522	509	515	513	526
Smith	13	19	22	23	25	27	29	32
Titus	608	726	316	466	490	556	587	605
Trinity	-	-	-	-	-	-	-	-
Upshur	38	52	49	52	52	52	52	52
Van Zandt	733	1,051	637	739	1,290	1,059	1,073	1,082
Wood	311	520	642	705	735	786	824	905
Total	10,218	11,789	8,308	8,714	9,462	9,389	9,771	10,201

Table D1.11 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 5 of the Carrizo-Wilcox Aquifer for counties within the study area

Livestock

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	5	5	9	9	9	9	9	9
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	11	11	12	12	12	12	12	12
Bowie	96	107	542	580	580	580	580	580
Caddo, LA	37	36	39	39	39	39	39	39
Camp	8	8	22	22	22	22	22	22
Cass	4	5	5	5	5	5	5	5
Cherokee	-	-	-	-	-	-	-	-
De Soto, LA	192	3	111	111	111	111	111	111
Franklin	121	183	179	179	179	179	179	179
Freestone	76	54	75	75	75	75	75	75
Gregg	4	4	21	21	21	21	21	21
Grimes	-	-	-	-	-	-	-	-
Harrison	46	20	340	362	386	410	436	463
Henderson	76	120	90	90	90	90	90	90
Hopkins	334	541	269	269	269	269	269	269
Houston	-	-	-	-	-	-	-	-
Leon	-	-	-	-	-	-	-	-
Limestone	35	38	422	422	422	422	422	422
Madison	-	-	-	-	-	-	-	-
Marion	6	6	7	7	7	7	7	7
Miller, AR	13	61	61	61	61	61	61	61
Morris	49	53	181	181	181	181	181	181
Nacogdoches	39	32	45	45	41	43	42	44
Natchitoches, LA	60	-	22	22	22	22	22	22
Navarro	-	-	-	-	-	-	-	-
Panola	439	530	703	703	703	703	703	703
Rains	59	99	-	-	-	-	-	-
Red River, LA	10	8	10	10	10	10	10	10
Robertson	149	16	745	745	745	745	745	745
Rusk	171	155	149	151	153	150	154	150
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	457	479	1,170	1,427	1,030	1,264	1,541	1,878
Smith	-	-	-	-	-	-	-	-
Titus	246	290	506	506	506	506	506	506
Trinity	-	-	-	-	-	-	-	-
Upshur	8	20	51	51	51	51	51	51
Van Zandt	186	225	51	52	61	71	85	93
Wood	57	79	59	59	59	59	59	59
Total	2,994	3,188	5,896	6,216	5,850	6,117	6,437	6,807

Table D1.11 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 5 of the Carrizo-Wilcox Aquifer for counties within the study area

Irrigation

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	1	4	25	25	25	25	25	25
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	49	16	30	30	30	30	30	30
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	853	15	482	482	482	482	482	482
Camp	-	5	6	6	6	6	6	6
Cass	-	-	-	-	-	-	-	-
Cherokee	-	-	-	-	-	-	-	-
De Soto, LA	17	14	19	19	19	19	19	19
Franklin	-	-	6	6	6	6	6	6
Freestone	-	6	2	2	2	2	2	2
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	-	39	16	16	16	16	16	16
Henderson	42	9	-	-	-	-	-	-
Hopkins	-	-	-	-	-	-	-	-
Houston	-	-	-	-	-	-	-	-
Leon	-	-	-	-	-	-	-	-
Limestone	-	-	-	-	-	-	-	-
Madison	-	-	-	-	-	-	-	-
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	2,415	4,152	4,152	4,152	4,152	4,152	4,152
Morris	-	-	-	-	-	-	-	-
Nacogdoches	-	6	41	41	41	41	41	41
Natchitoches, LA	74	106	125	125	125	125	125	125
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	4	61	155	155	155	155	155	155
Robertson	10	10	5,171	5,047	4,998	4,855	4,716	4,581
Rusk	-	6	17	17	17	17	17	17
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	-	3	8	9	10	12	15	18
Smith	3	-	-	3	3	3	3	3
Titus	-	-	-	-	-	-	-	-
Trinity	-	-	-	-	-	-	-	-
Upshur	-	-	-	-	-	-	-	-
Van Zandt	-	-	220	220	220	220	220	220
Wood	-	23	3	3	3	3	3	3
Total	1,053	2,738	10,478	10,358	10,310	10,169	10,033	9,901

Table D1.12
Rate of groundwater withdrawal (acre-feet per year) from flow layer 6 of the Carrizo-Wilcox Aquifer for counties within the study area

Municipal and Industrial*

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	61	81	4	5	5	6	6	7
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	95	57	74	74	75	77	81	86
Caddo, LA	92	116	4	4	4	5	5	6
Camp	-	-	-	-	-	-	-	-
Cass	645	656	202	340	335	330	325	309
Cherokee	-	-	-	-	-	-	-	-
De Soto, LA	587	316	-	-	-	-	-	-
Franklin	-	-	3	3	3	3	3	3
Freestone	982	1,021	1,169	1,212	1,269	1,324	1,346	1,371
Gregg	-	-	356	372	387	409	432	459
Grimes	-	-	-	-	-	-	-	-
Harrison	366	298	331	435	482	512	516	532
Henderson	606	667	927	666	665	672	676	693
Hopkins	134	88	102	108	112	119	126	134
Houston	-	-	-	-	-	-	-	-
Leon	-	-	-	-	-	-	-	-
Limestone	-	-	-	-	-	-	-	-
Madison	-	-	-	-	-	-	-	-
Marion	2	-	-	-	-	-	-	-
Miller, AR	-	-	-	-	-	-	-	-
Morris	-	-	-	-	-	-	-	-
Nacogdoches	-	-	-	-	-	-	-	-
Natchitoches, LA	-	-	-	-	-	-	-	-
Navarro	-	-	-	-	-	-	-	-
Panola	138	127	1,438	1,185	937	1,757	1,782	1,755
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	-	-	-	-	-	-
Rusk	74	4	995	895	794	760	756	760
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	16	24	153	149	146	146	147	151
Smith	-	-	-	-	-	-	-	-
Titus	-	-	-	-	-	-	-	-
Trinity	-	-	-	-	-	-	-	-
Upshur	-	-	-	-	-	-	-	-
Van Zandt	738	723	1,451	1,412	1,362	1,455	1,564	1,639
Wood	-	-	1,128	1,128	1,128	1,128	1,128	1,128
Total	4,536	4,178	8,337	7,988	7,704	8,703	8,893	9,033

*industrial includes manufacturing, mining, and power generation

Table D1.12 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 6 of the Carrizo-Wilcox Aquifer for counties within the study area

County – Other (Non-reported Domestic)

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	2	2	3	3	3	3	3	3
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	557	646	43	43	43	43	43	43
Caddo, LA	548	488	449	464	494	540	601	677
Camp	-	-	-	-	-	-	-	-
Cass	-	-	-	-	-	-	-	-
Cherokee	-	-	-	-	-	-	-	-
De Soto, LA	24	9	-	-	-	-	-	-
Franklin	135	167	4	5	5	5	7	7
Freestone	328	480	485	464	435	424	428	427
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	-	-	-	-	-	-	-	-
Henderson	569	860	872	872	872	872	872	872
Hopkins	141	183	548	645	641	648	675	682
Houston	-	-	-	-	-	-	-	-
Leon	-	-	-	-	-	-	-	-
Limestone	175	263	631	638	662	706	754	813
Madison	-	-	-	-	-	-	-	-
Marion	-	-	-	-	-	-	-	-
Miller, AR	2	4	4	5	5	5	6	6
Morris	-	1	-	-	-	-	-	-
Nacogdoches	-	-	-	-	-	-	-	-
Natchitoches, LA	-	-	-	-	-	-	-	-
Navarro	42	84	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	-	-	-	-	-	-
Rusk	-	-	-	-	-	-	-	-
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	5	5	3	3	3	3	3	3
Smith	-	-	-	-	-	-	-	-
Titus	79	103	1	1	1	2	2	2
Trinity	-	-	-	-	-	-	-	-
Upshur	-	-	-	-	-	-	-	-
Van Zandt	630	967	231	286	589	448	454	459
Wood	-	-	-	-	-	-	-	-
Total	3,237	4,262	3,274	3,429	3,753	3,699	3,848	3,994

Table D1.12 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 6 of the Carrizo-Wilcox Aquifer for counties within the study area

Livestock

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	1	1	2	2	2	2	2	2
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	-	-	-	-	-	-	-	-
Bowie	189	211	107	1,147	1,147	1,147	1,147	1,147
Caddo, LA	3	3	3	3	3	3	3	3
Camp	-	-	-	-	-	-	-	-
Cass	-	-	-	-	-	-	-	-
Cherokee	-	-	-	-	-	-	-	-
De Soto, LA	2	-	1	1	1	1	1	1
Franklin	172	261	268	268	268	268	268	268
Freestone	204	148	224	224	224	224	224	224
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	40	16	66	70	74	78	82	87
Henderson	166	263	203	203	203	203	203	203
Hopkins	1,155	1,699	339	339	339	339	339	339
Houston	-	-	-	-	-	-	-	-
Leon	-	-	-	-	-	-	-	-
Limestone	68	76	810	810	810	810	810	810
Madison	-	-	-	-	-	-	-	-
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	1	7	7	7	7	7	7
Morris	4	4	16	16	16	16	16	16
Nacogdoches	-	-	-	-	-	-	-	-
Natchitoches, LA	-	-	-	-	-	-	-	-
Navarro	15	15	12	12	12	12	12	12
Panola	263	319	423	423	423	423	423	423
Rains	90	153	-	-	-	-	-	-
Red River, LA	-	-	-	-	-	-	-	-
Robertson	-	-	-	-	-	-	-	-
Rusk	-	-	-	-	-	-	-	-
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	-	-	-	-	-	-	-	-
Smith	-	-	-	-	-	-	-	-
Titus	29	35	59	59	59	59	59	59
Trinity	-	-	-	-	-	-	-	-
Upshur	-	-	-	-	-	-	-	-
Van Zandt	270	327	49	60	122	188	281	330
Wood	1	2	1	1	1	1	1	1
Total	2,672	3,534	2,590	3,645	3,711	3,781	3,878	3,932

Table D1.12 (*Continued...*)
Rate of groundwater withdrawal (acre-feet per year) from flow layer 6 of the Carrizo-Wilcox Aquifer for counties within the study area

Irrigation

County	1980	1990	2000	2010	2020	2030	2040	2050
Anderson	-	-	7	7	7	7	7	7
Angelina	-	-	-	-	-	-	-	-
Bienville, LA	-	-	-	-	-	-	-	-
Bossier, LA	9	2	5	5	5	5	5	5
Bowie	-	-	-	-	-	-	-	-
Caddo, LA	287	7	163	163	163	163	163	163
Camp	-	5	7	7	7	7	7	7
Cass	-	-	-	-	-	-	-	-
Cherokee	-	-	-	-	-	-	-	-
De Soto, LA	2	2	4	4	4	4	4	4
Franklin	-	-	-	-	-	-	-	-
Freestone	-	8	3	3	3	3	3	3
Gregg	-	-	-	-	-	-	-	-
Grimes	-	-	-	-	-	-	-	-
Harrison	-	4	1	1	1	1	1	1
Henderson	32	7	-	-	-	-	-	-
Hopkins	-	-	-	-	-	-	-	-
Houston	-	-	-	-	-	-	-	-
Leon	-	-	-	-	-	-	-	-
Limestone	-	-	-	-	-	-	-	-
Madison	-	-	-	-	-	-	-	-
Marion	-	-	-	-	-	-	-	-
Miller, AR	-	6	10	10	10	10	10	10
Morris	-	-	-	-	-	-	-	-
Nacogdoches	-	-	1	1	1	1	1	1
Natchitoches, LA	-	-	-	-	-	-	-	-
Navarro	-	-	-	-	-	-	-	-
Panola	-	-	-	-	-	-	-	-
Rains	-	-	-	-	-	-	-	-
Red River, LA	1	23	59	59	59	59	59	59
Robertson	-	-	-	-	-	-	-	-
Rusk	-	-	-	-	-	-	-	-
Sabine, LA	-	-	-	-	-	-	-	-
Sabine, TX	-	-	-	-	-	-	-	-
San Augustine	-	-	-	-	-	-	-	-
Shelby	-	-	-	-	-	-	-	-
Smith	-	-	-	-	-	-	-	-
Titus	-	-	-	-	-	-	-	-
Trinity	-	-	-	-	-	-	-	-
Upshur	-	-	-	-	-	-	-	-
Van Zandt	-	-	-	-	-	-	-	-
Wood	-	-	-	-	-	-	-	-
Total	331	64	260	260	260	260	260	260

APPENDIX D2

Post Plots of Groundwater Withdrawal Estimates for the Carrizo-Wilcox for 1980, 1990, 2000, 2010, 2020, 2030, 2040, and 2050

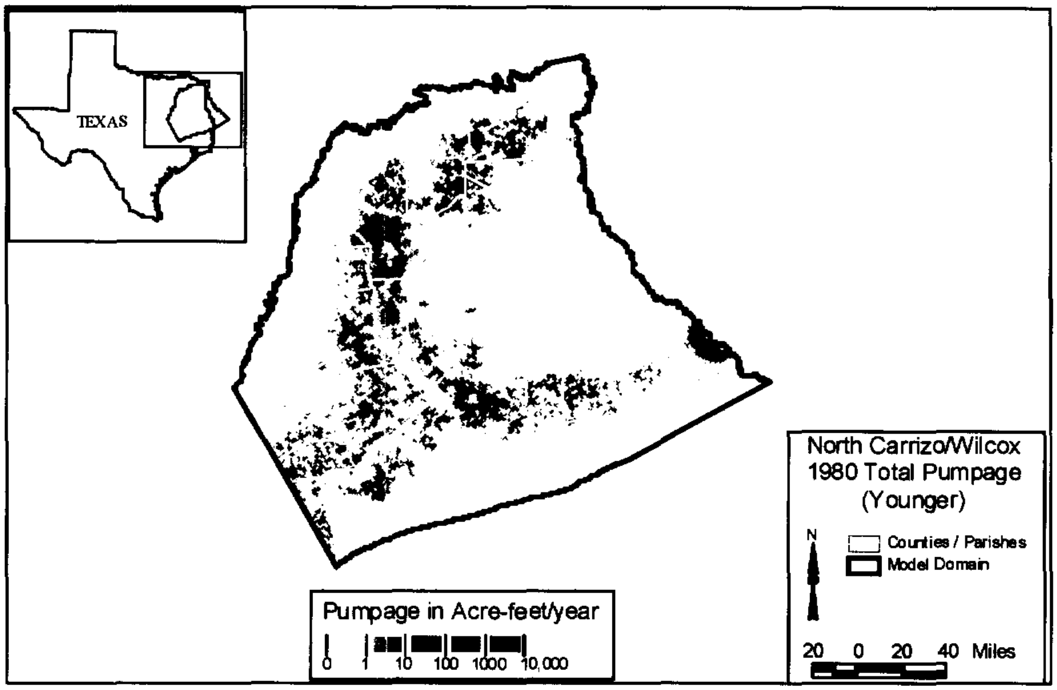


Figure D.2.1 Younger (Layer 1) Pumpage, 1980 (AFY)

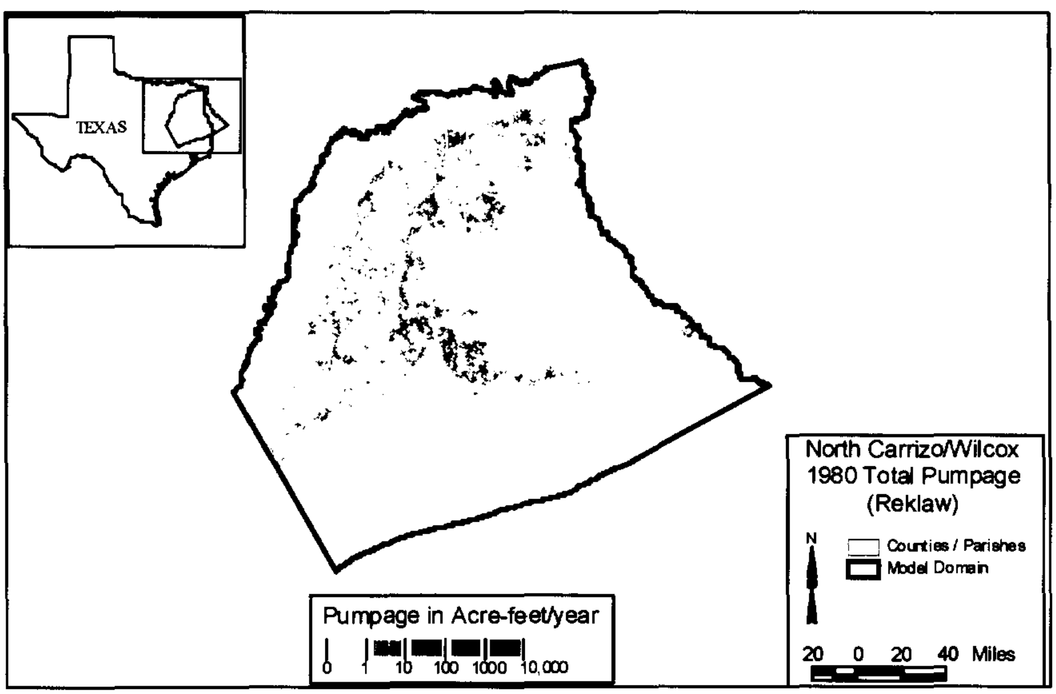


Figure D.2.2 Reklaw (Layer 2) Pumpage, 1980 (AFY)

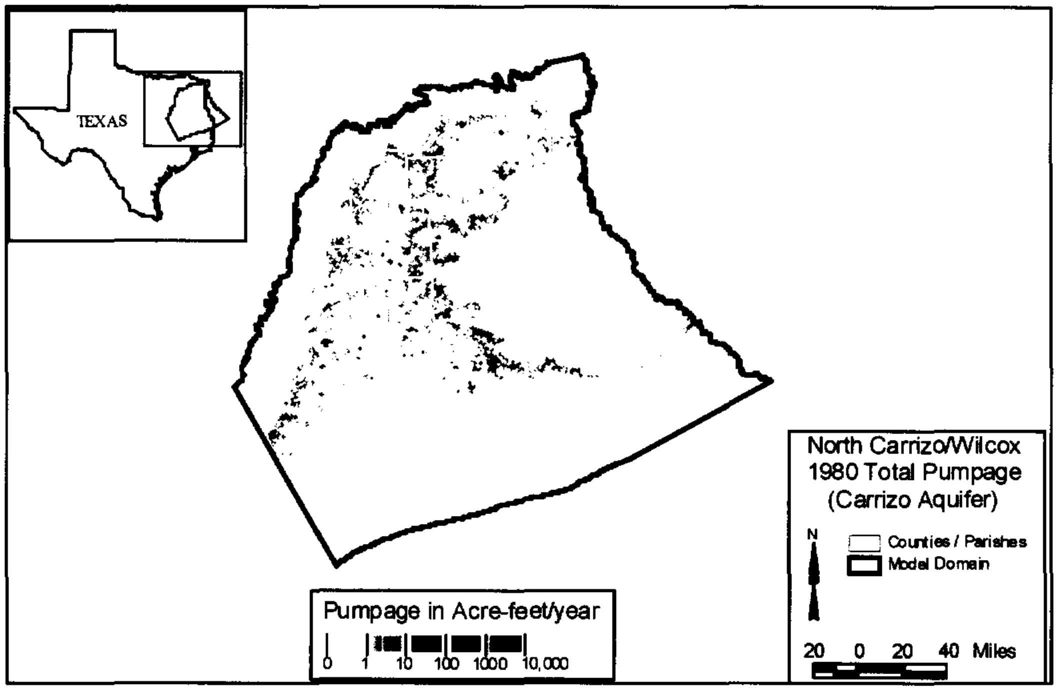


Figure D.2.3 Carrizo (Layer 3) Pumpage, 1980 (AFY)

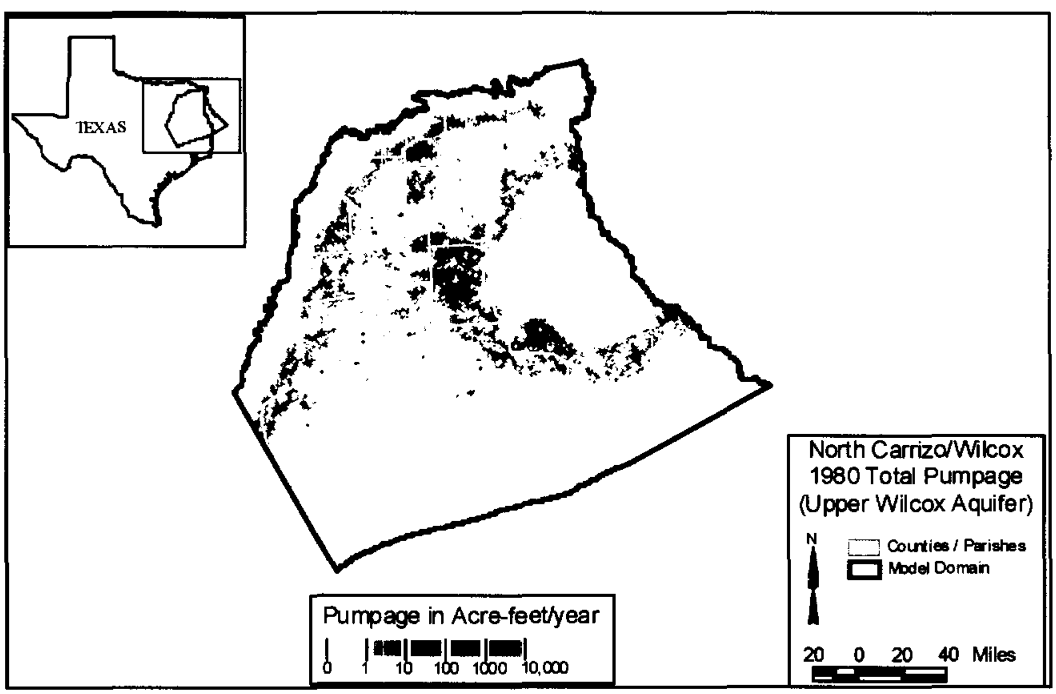


Figure D.2.4 Upper Wilcox (Layer 4) Pumpage, 1980 (AFY)

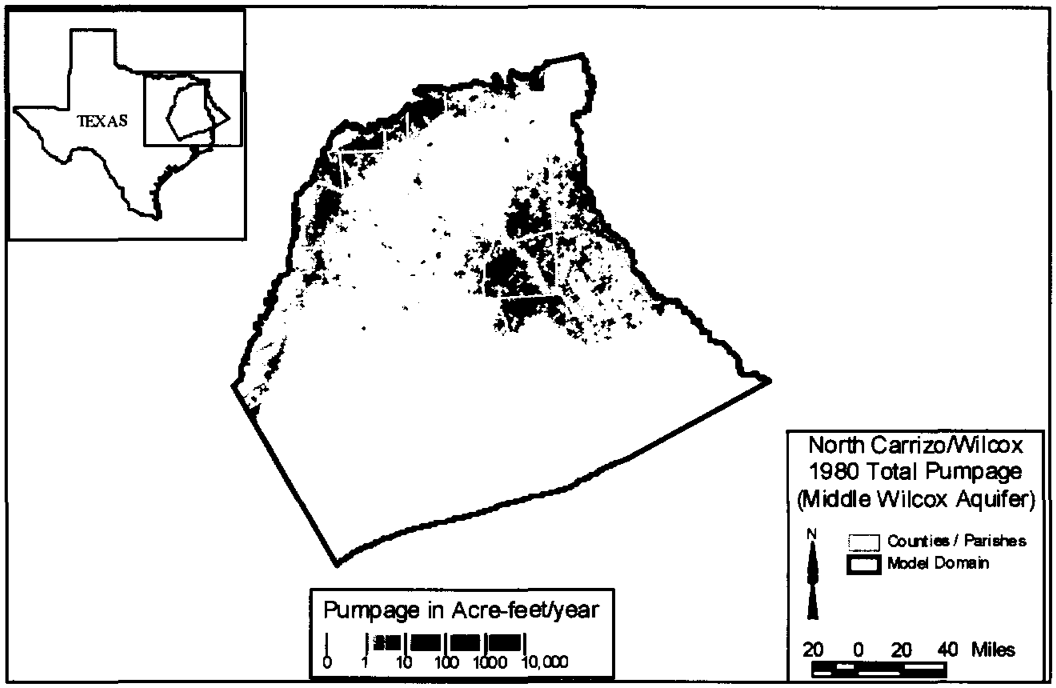


Figure D.2.5 Middle Wilcox (Layer 5) Pumpage, 1980 (AFY)

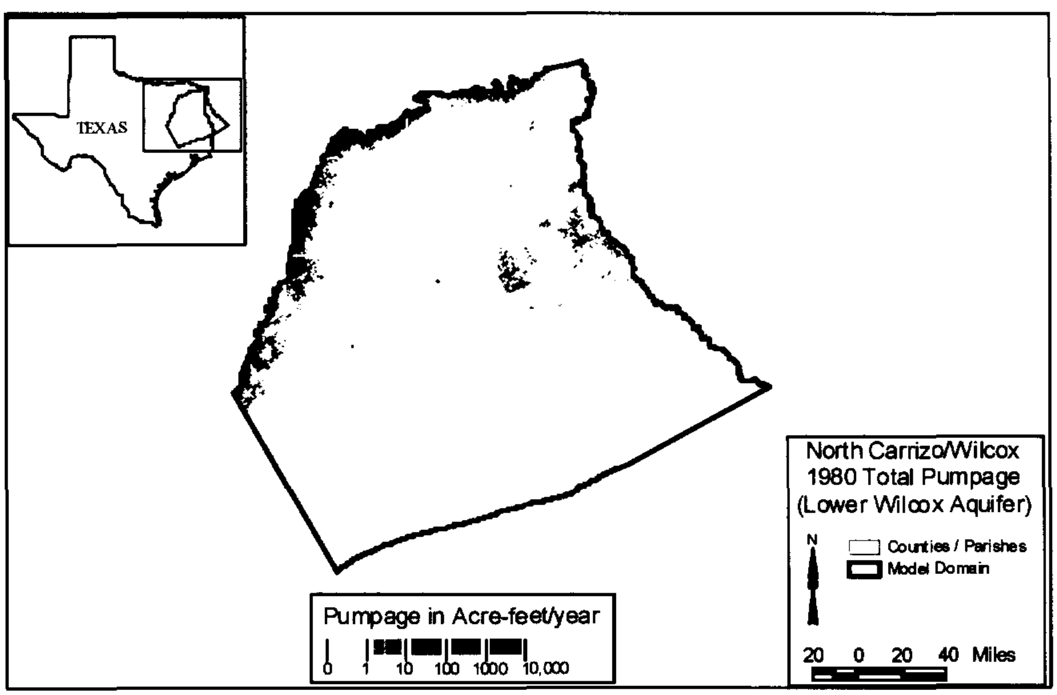


Figure D.2.6 Lower Wilcox (Layer 6) Pumpage, 1980 (AFY)

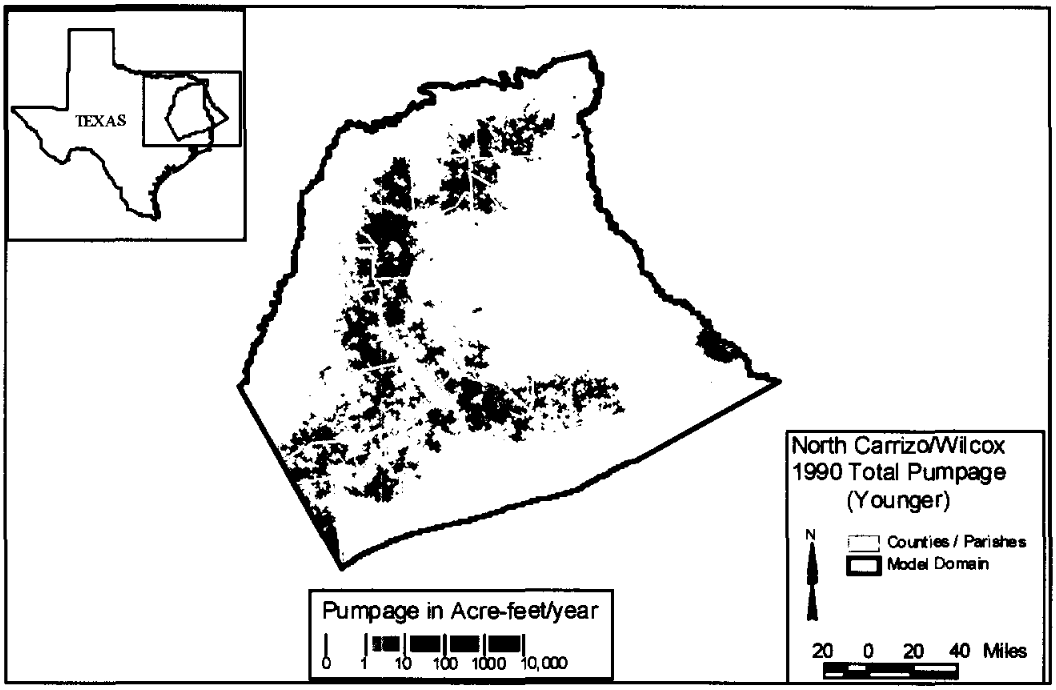


Figure D.2.7 Younger (Layer 1) Pumpage, 1990 (AFY)

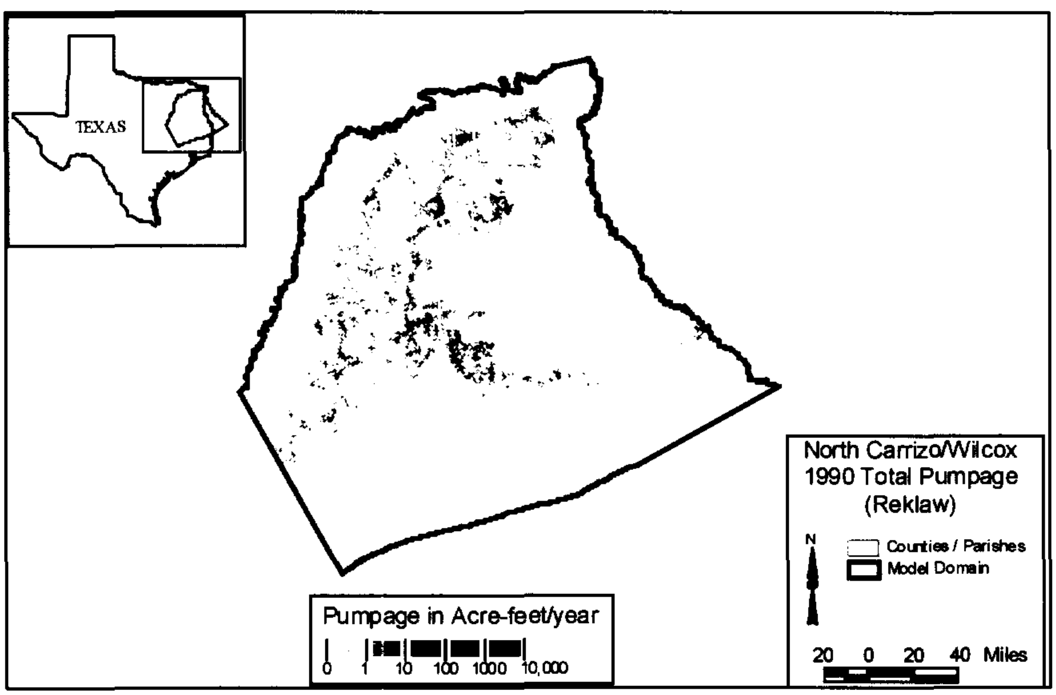


Figure D.2.8 Reklaw (Layer 2) Pumpage, 1990 (AFY)

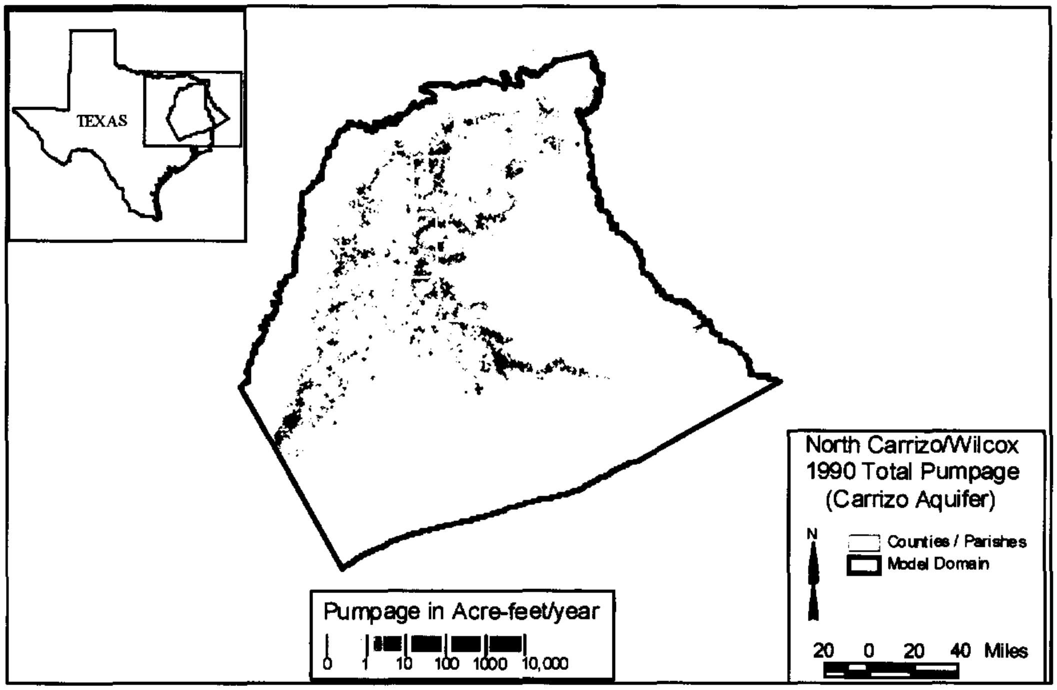


Figure D.2.9 Carrizo (Layer 3) Pumpage, 1990 (AFY)

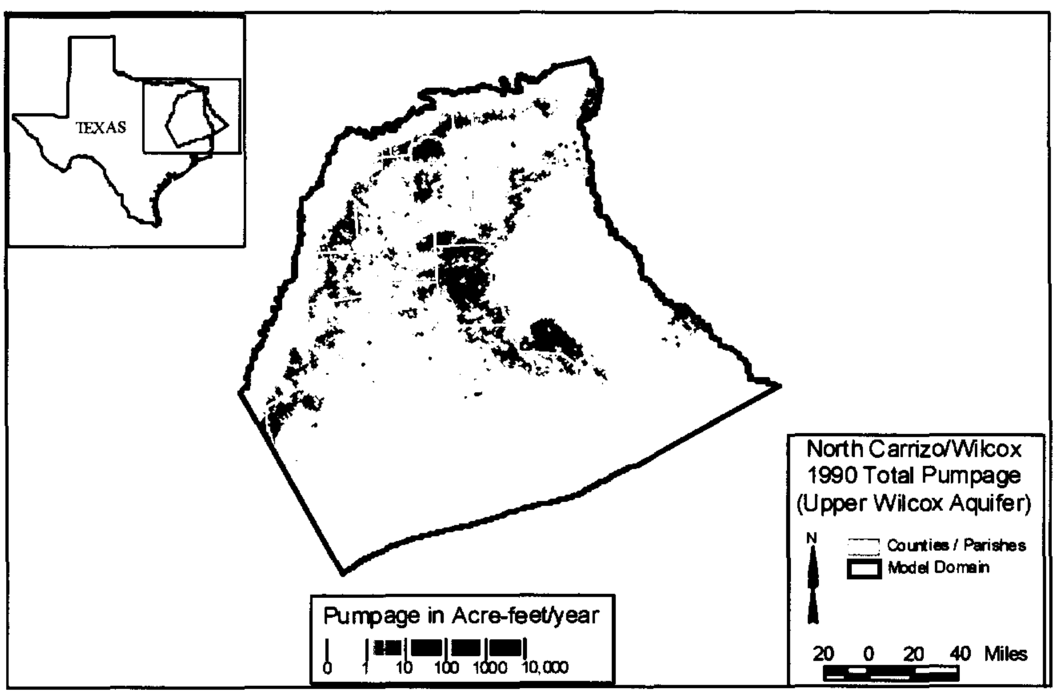


Figure D.2.10 Upper Wilcox (Layer 4) Pumpage, 1990 (AFY)

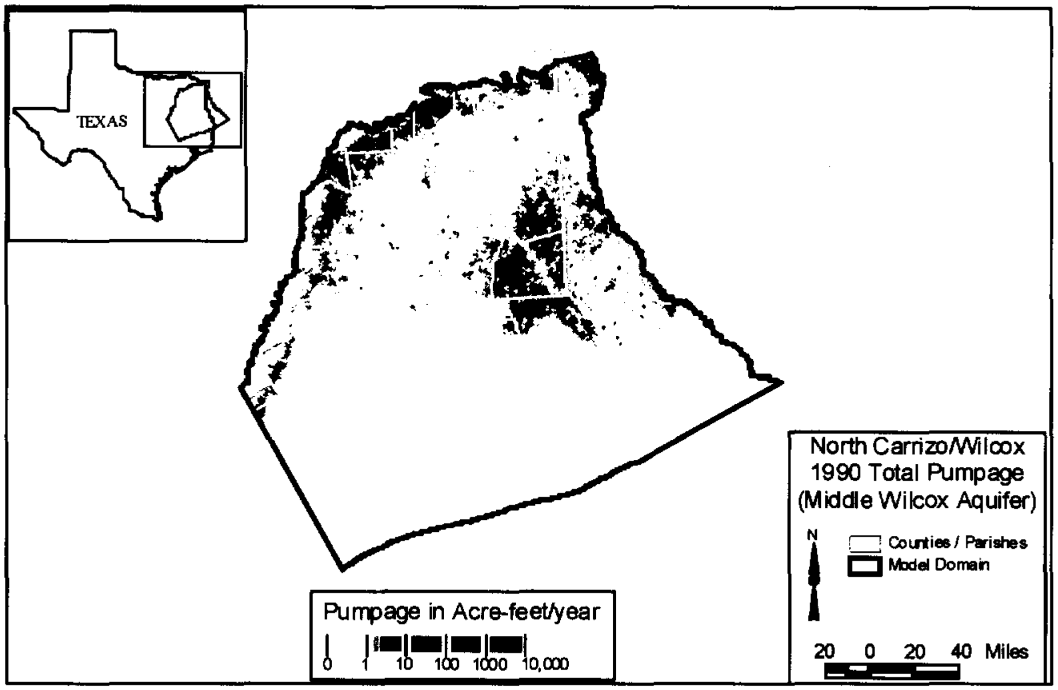


Figure D.2.11 Middle Wilcox (Layer 5) Pumpage, 1990 (AFY)

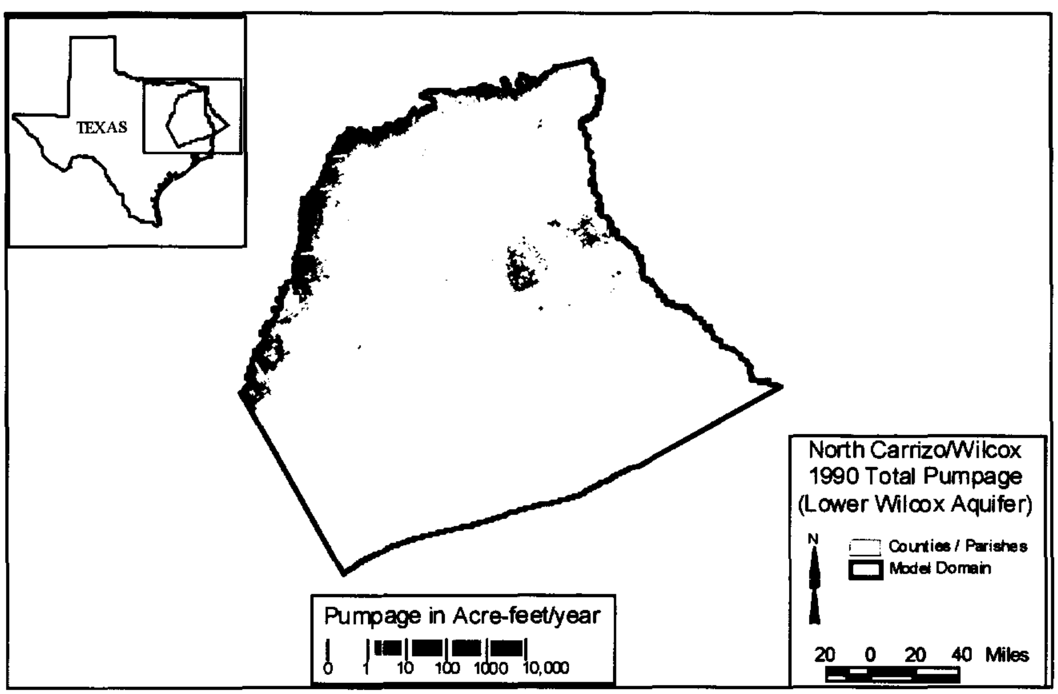


Figure D.2.12 Lower Wilcox (Layer 6) Pumpage, 1990 (AFY)

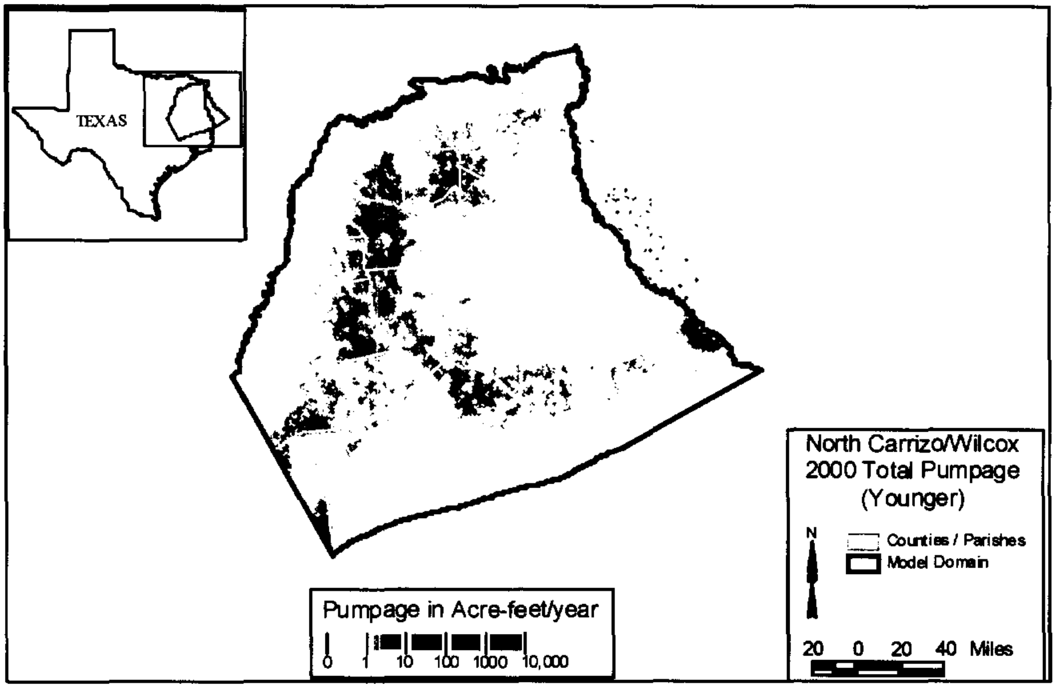


Figure D.2.13 Younger (Layer 1) Pumpage, 2000 (AFY)

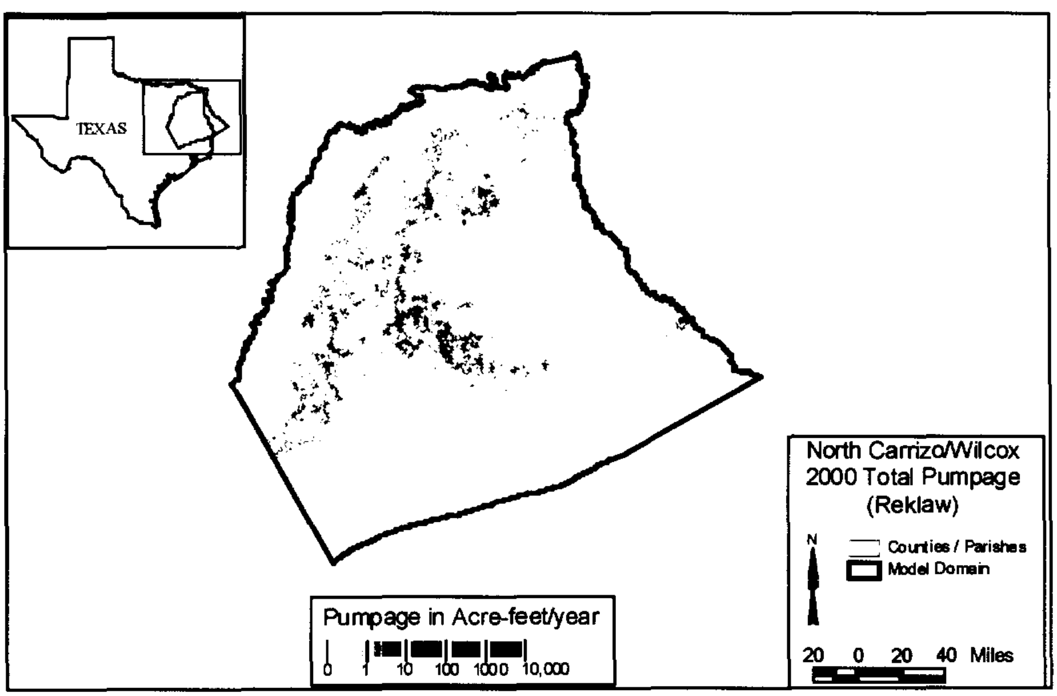


Figure D.2.14 Reklaw (Layer 2) Pumpage, 2000 (AFY)

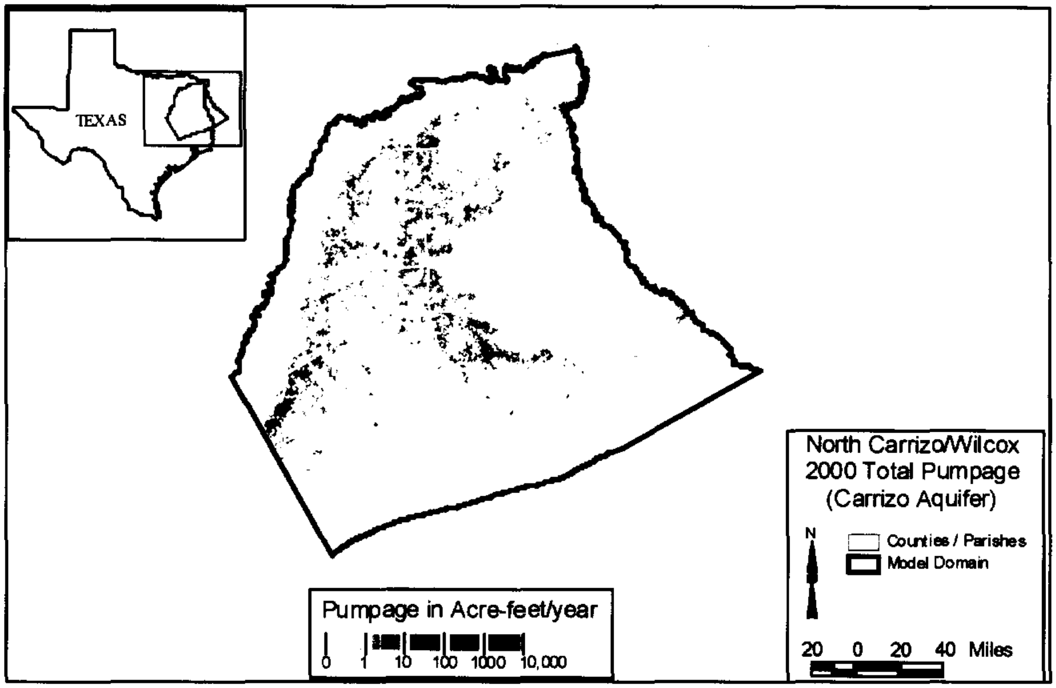


Figure D.2.15 Carrizo (Layer 3) Pumpage, 2000 (AFY)

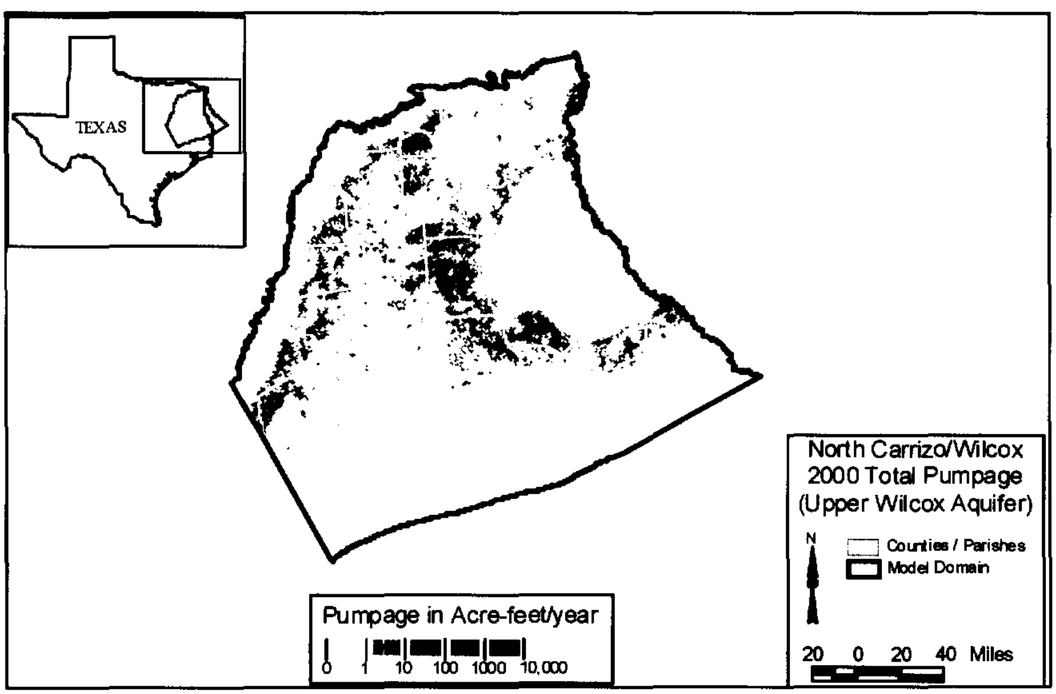


Figure D.2.16 Upper Wilcox (Layer 4) Pumpage, 2000 (AFY)

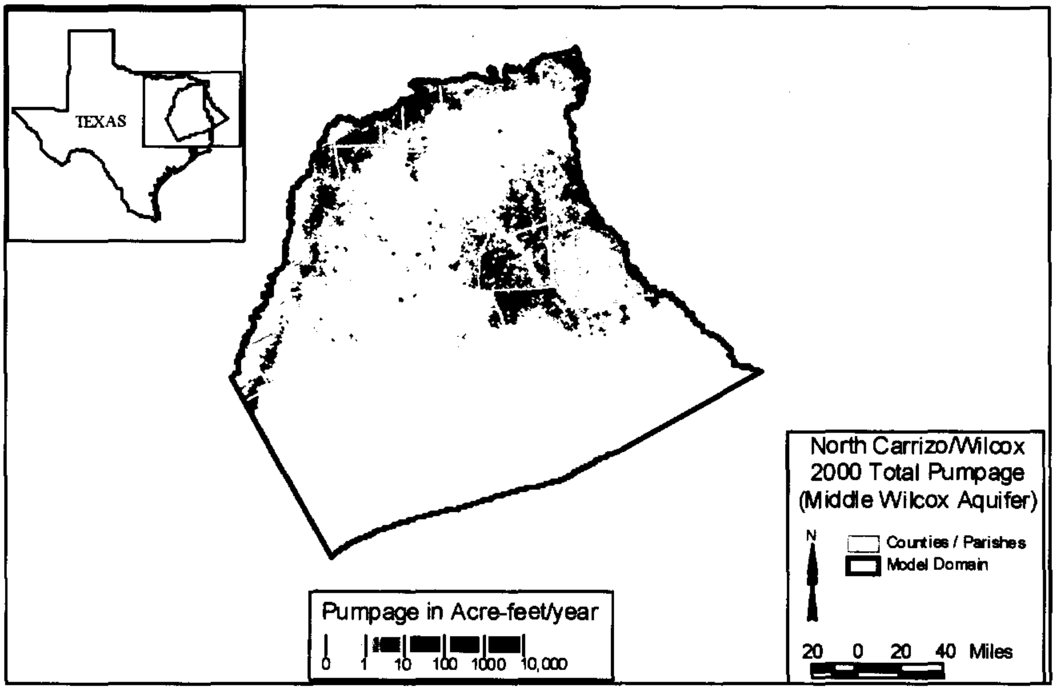


Figure D.2.17 Middle Wilcox (Layer 5) Pumpage, 2000 (AFY)

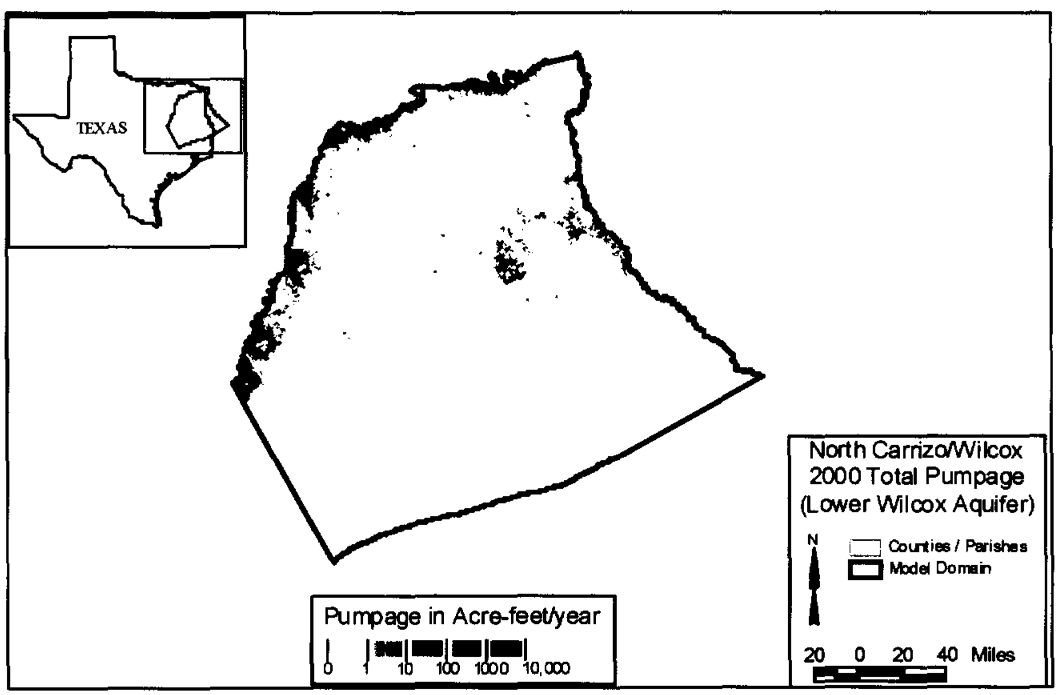


Figure D.2.18 Lower Wilcox (Layer 6) Pumpage, 2000 (AFY)

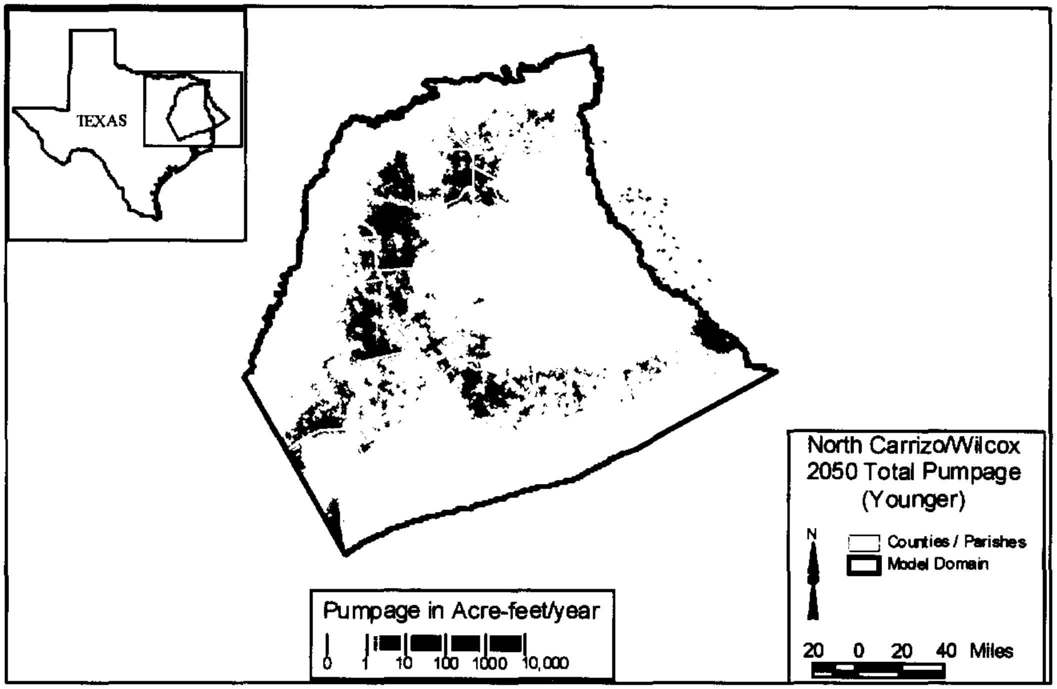


Figure D.2.19 Younger (Layer 1) Pumpage, 2000 (AFY)

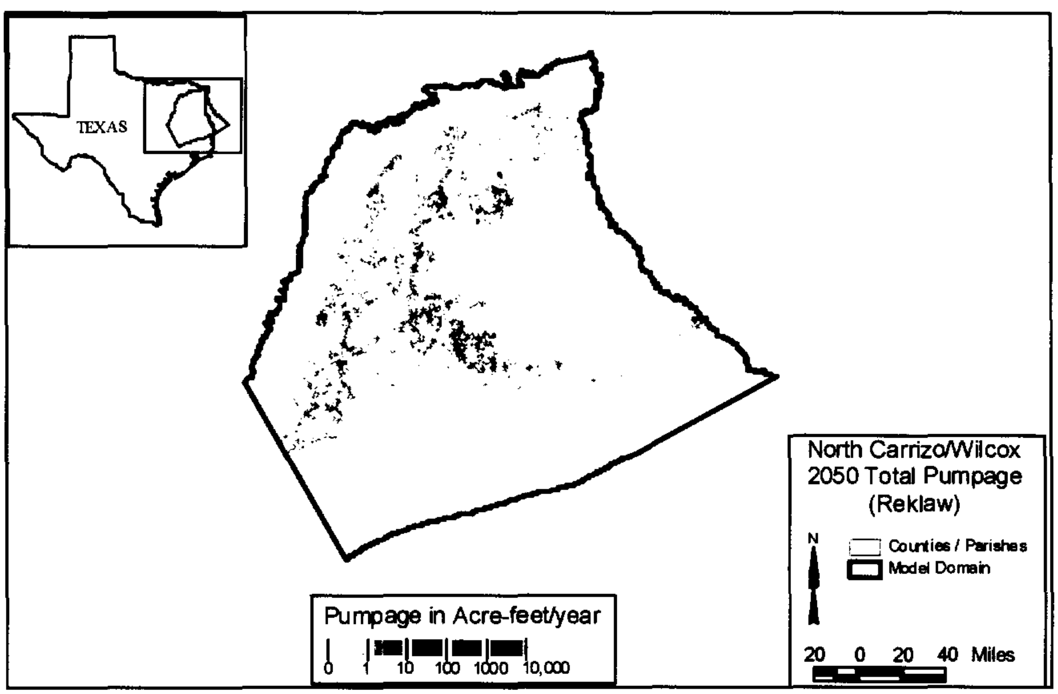


Figure D.2.20 Reklaw (Layer 2) Pumpage, 2050 (AFY)

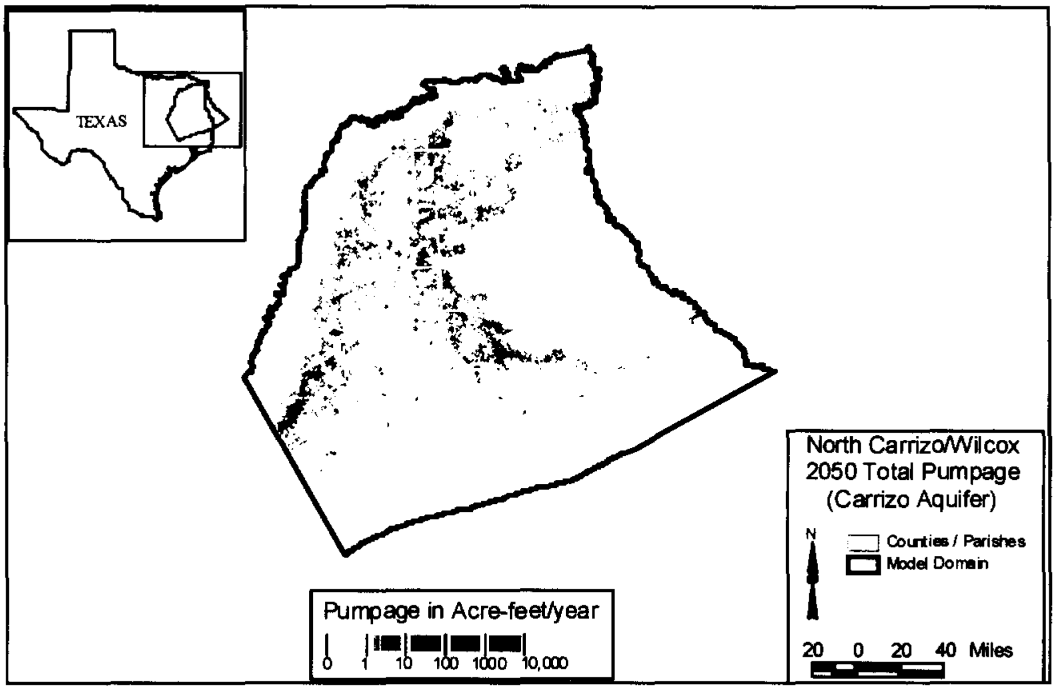


Figure D.2.21 Carrizo (Layer 3) Pumpage, 2050 (AFY)

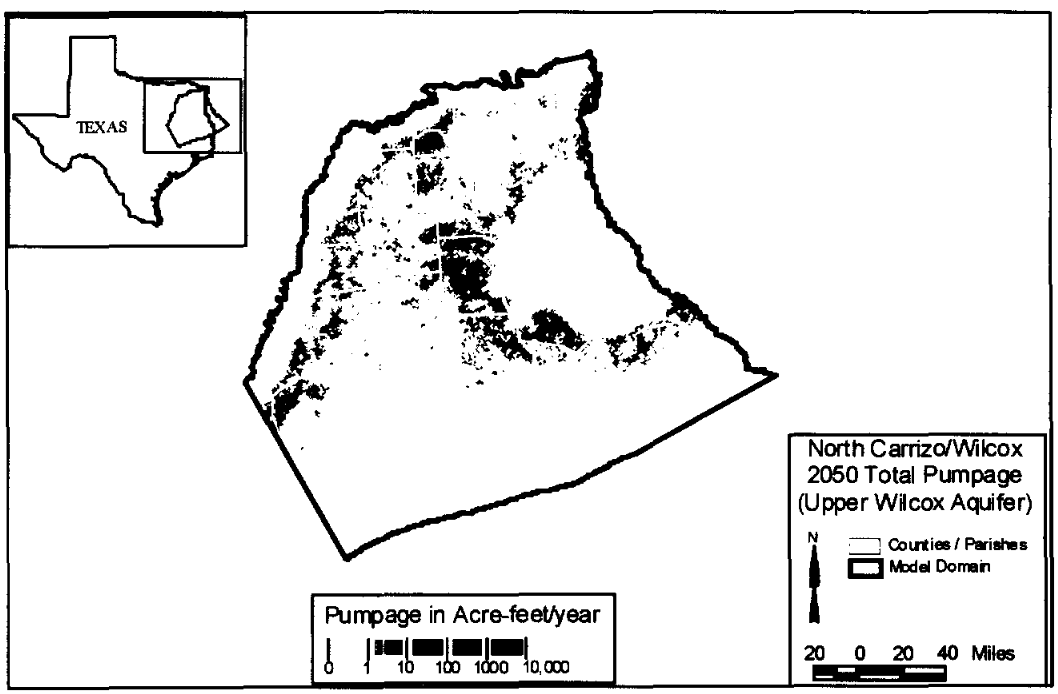


Figure D.2.22 Upper Wilcox (Layer 4) Pumpage, 2050 (AFY)

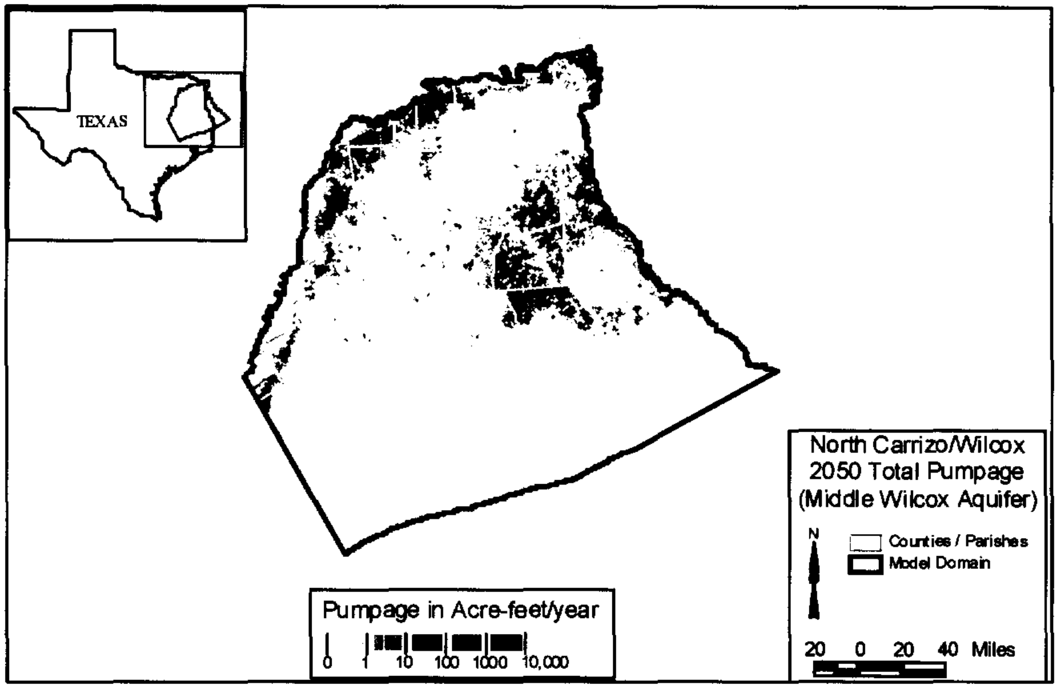


Figure D.2.23 Middle Wilcox (Layer 5) Pumpage, 2050 (AFY)

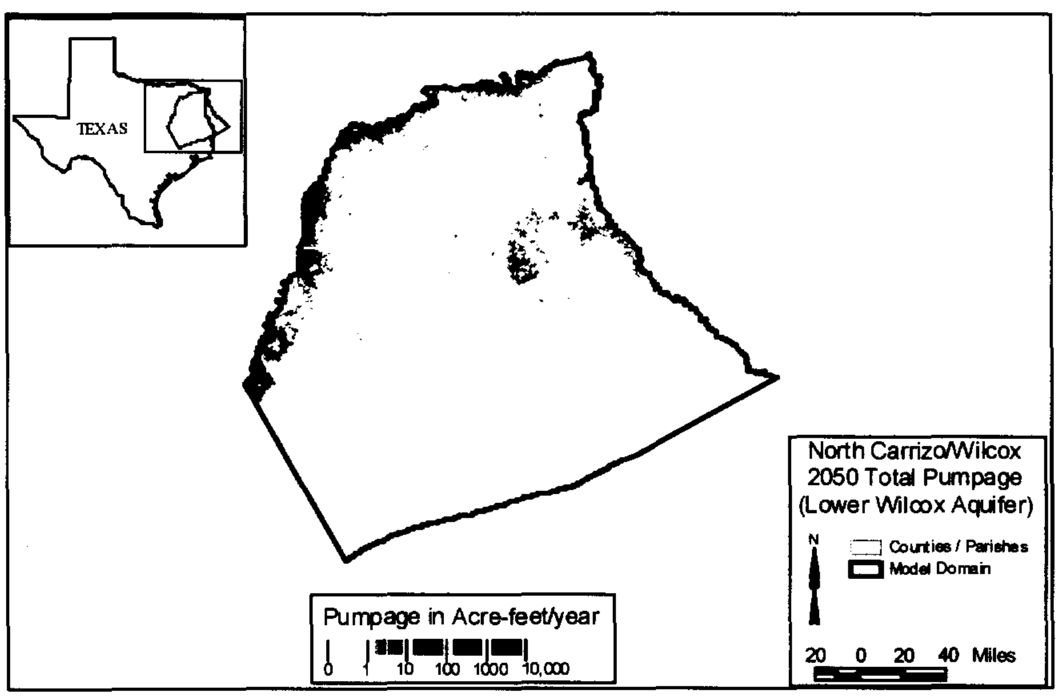
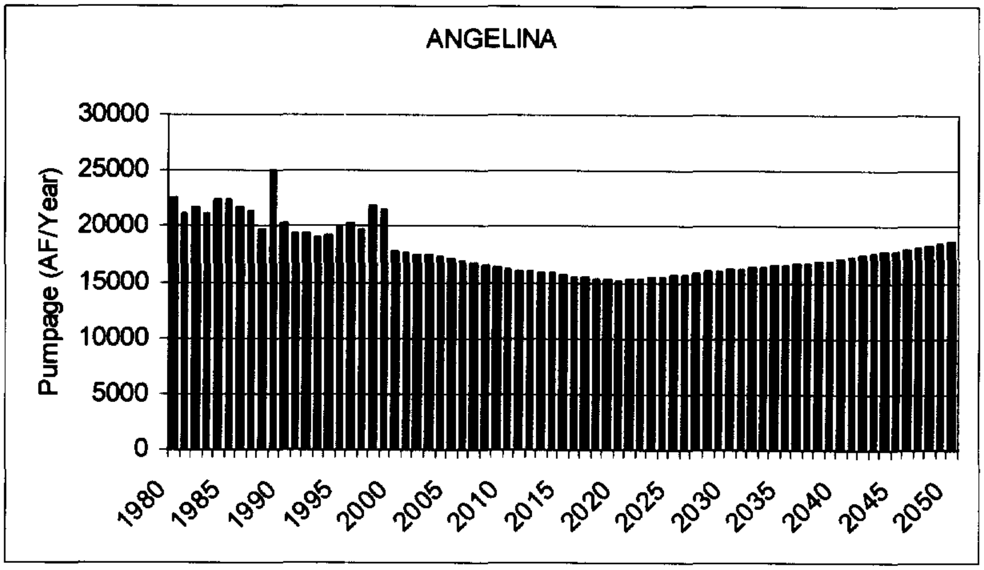
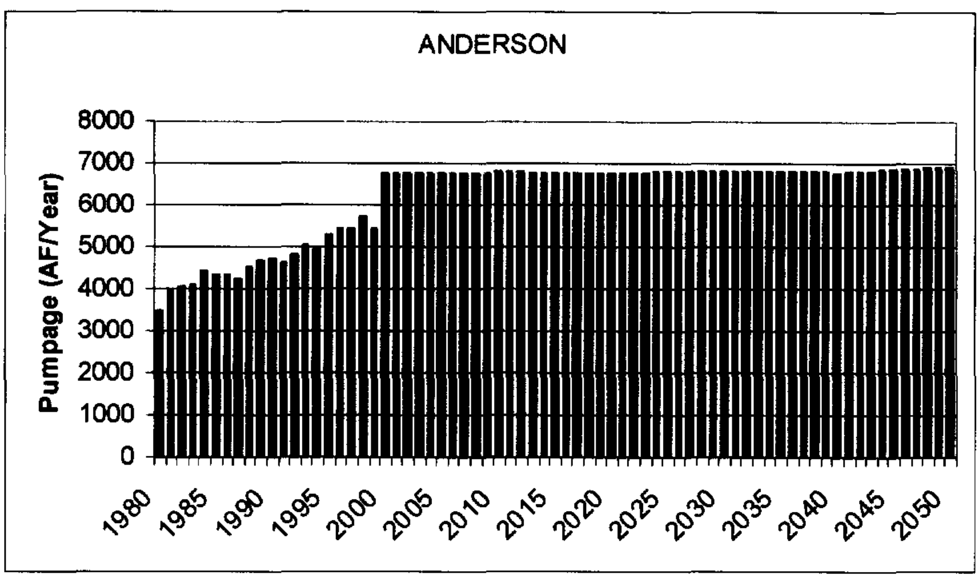


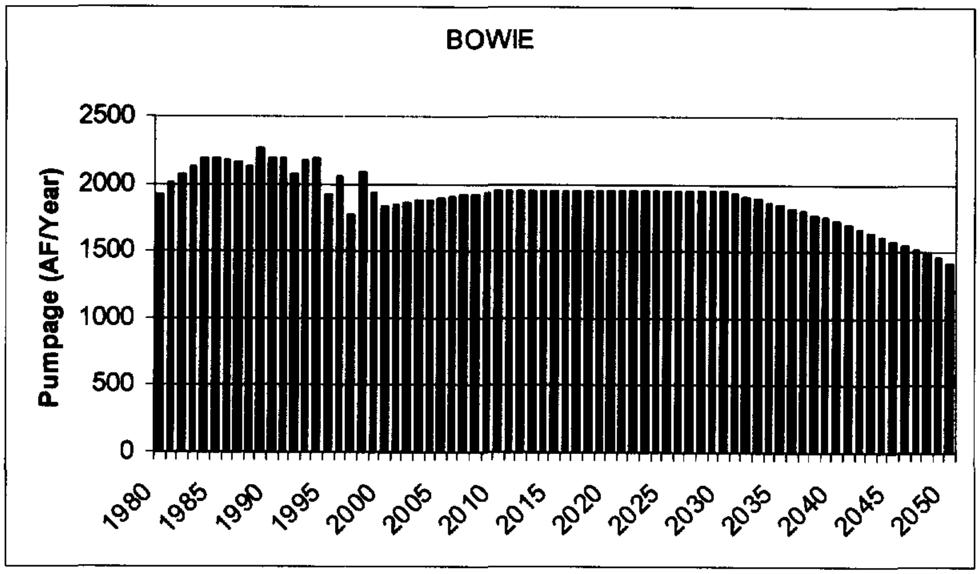
Figure D.2.24 Lower Wilcox (Layer 6) Pumpage, 2050 (AFY)

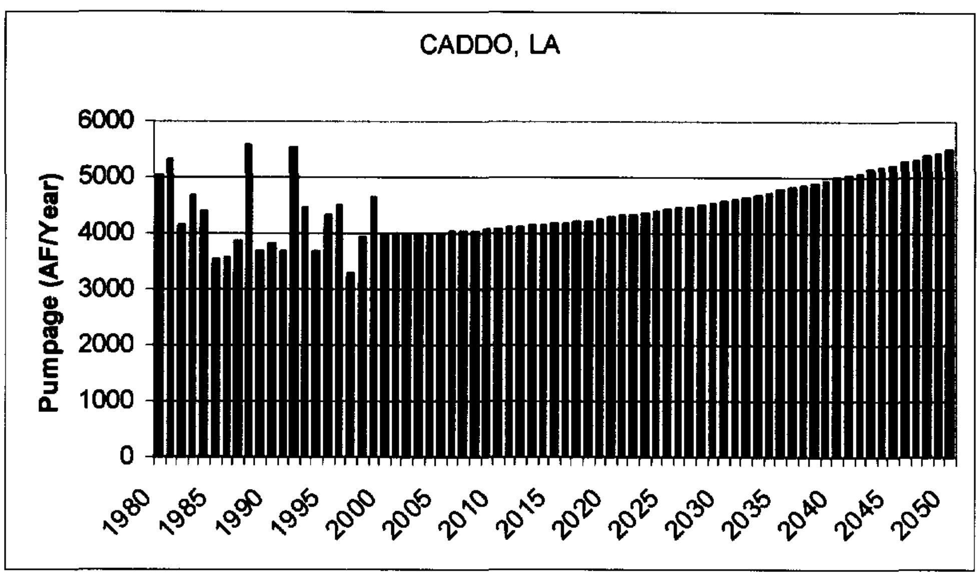
APPENDIX D3

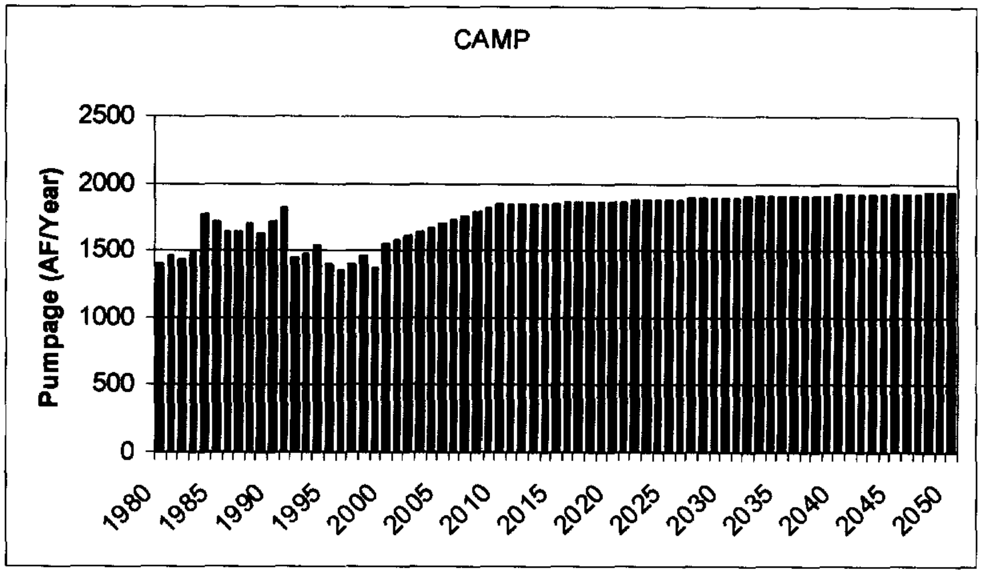
Carrizo-Wilcox Groundwater Withdrawal Distributions by County

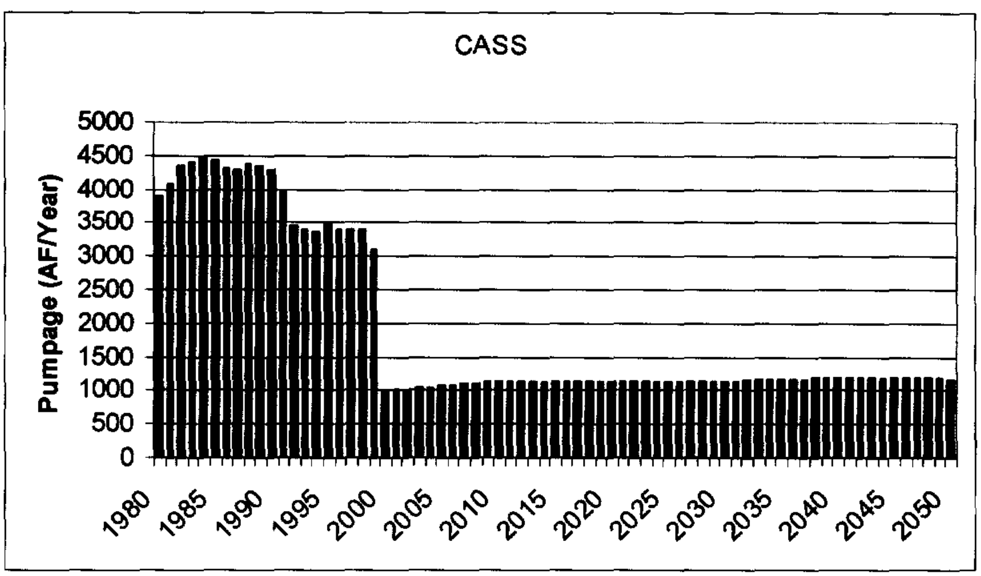

ANGELINA
Pumpage (AF/Year)
30000
25000
20000
15000
10000
5000
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

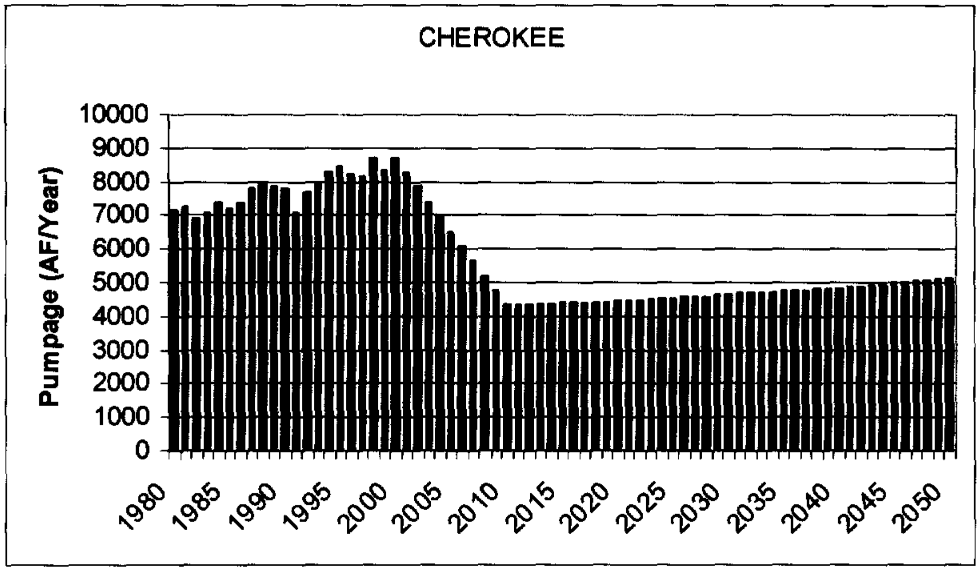

ANDERSON
Pumpage (AF/Year)
8000
7000
6000
5000
4000
3000
2000
1000
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

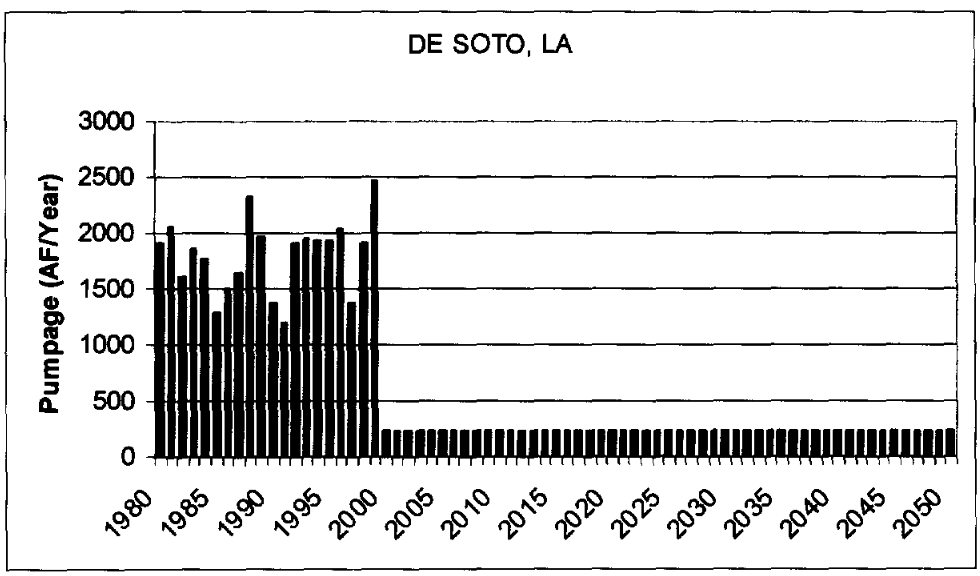

BOWIE
Pumpage (AF/Year)
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

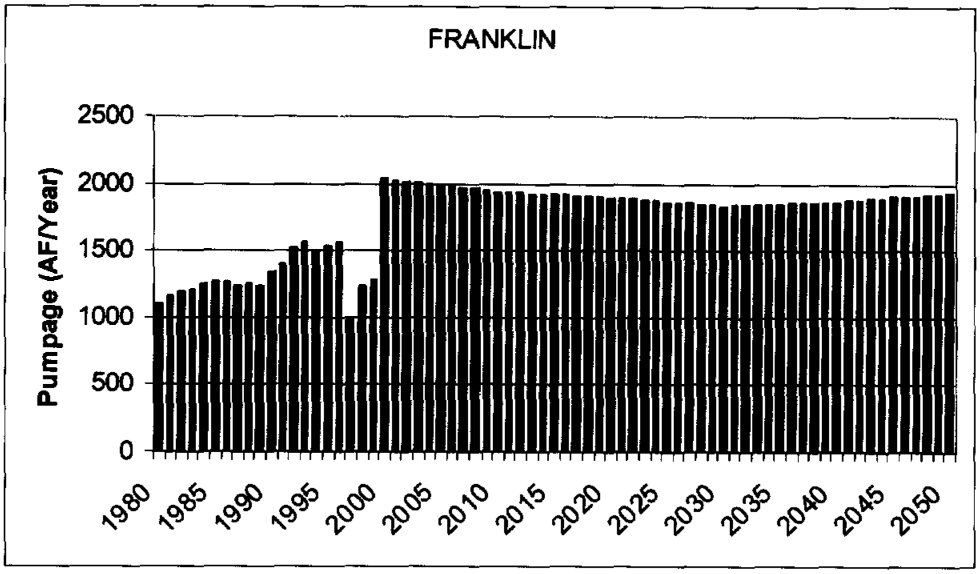

CADDO, LA
Pumpage (AF/Year)
6000
5000
4000
3000
2000
1000
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

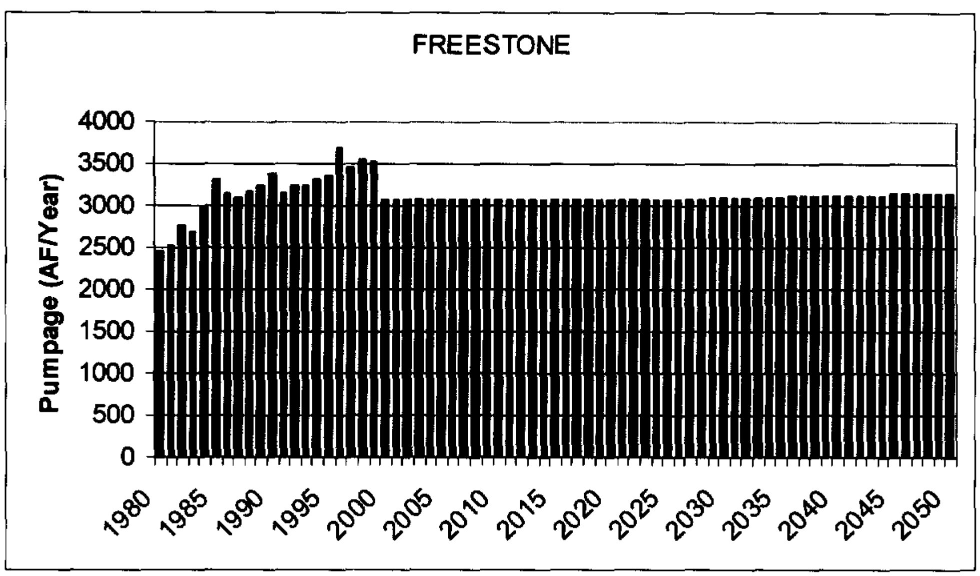

CAMP
Pumpage (AF/Year)
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

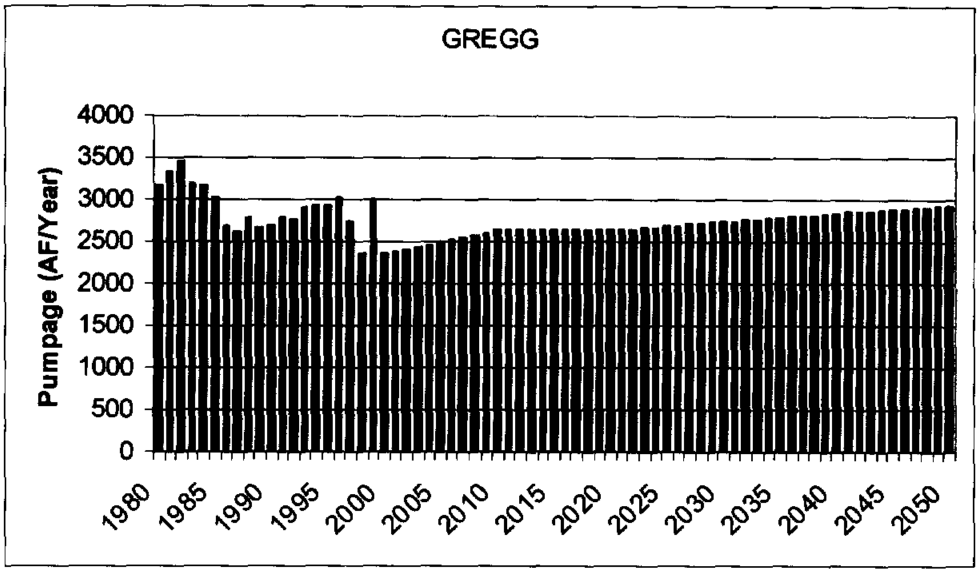

CASS
Pumpage (AF/Year)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

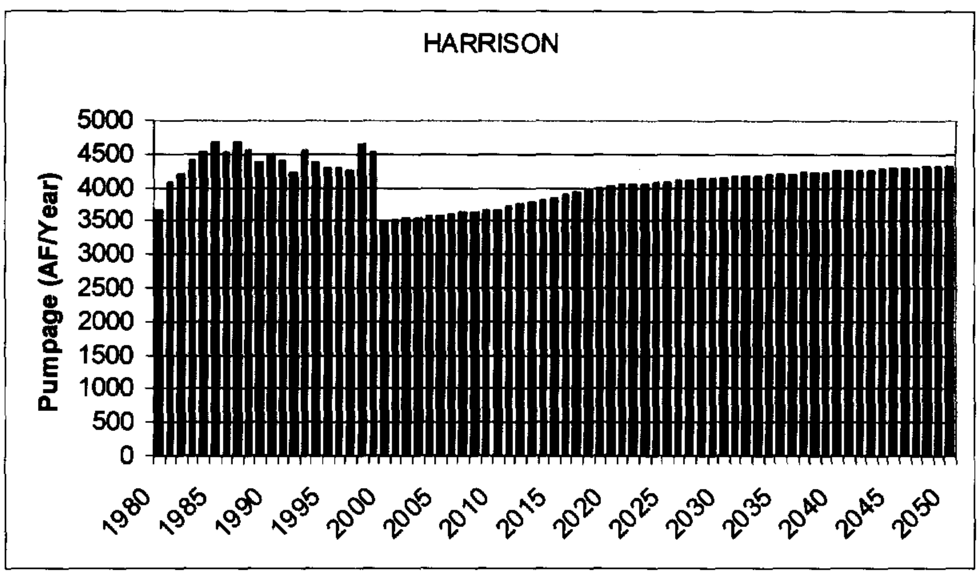

CHEROKEE
Pumpage (AF/Year)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

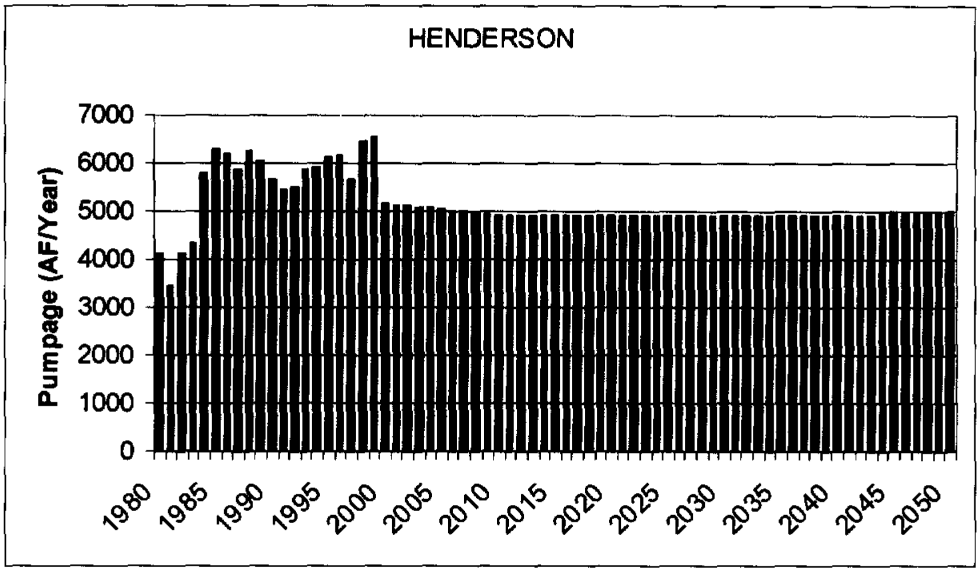

DE SOTO, LA
Pumpage (AF/Year)
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

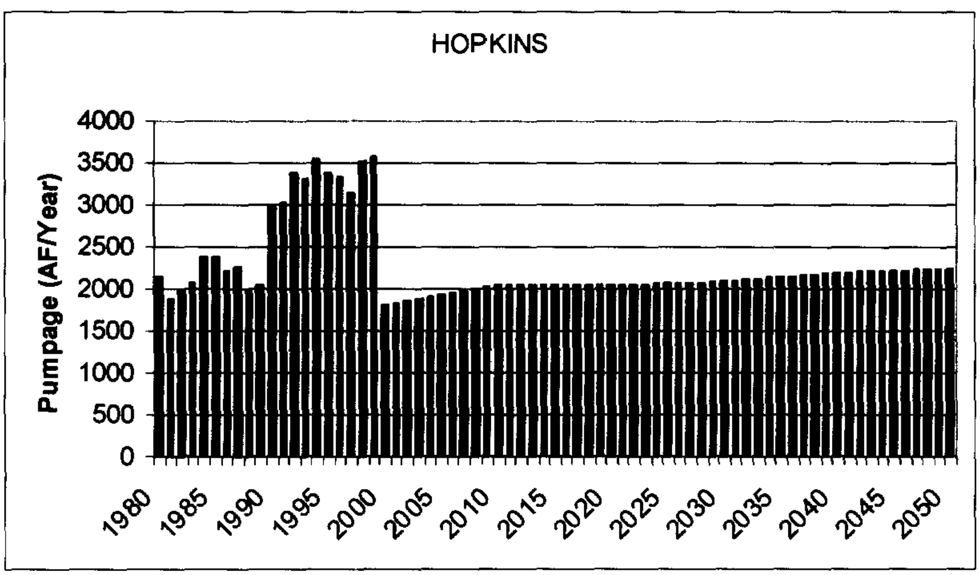

FRANKLIN
Pumpage (AF/Year)
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

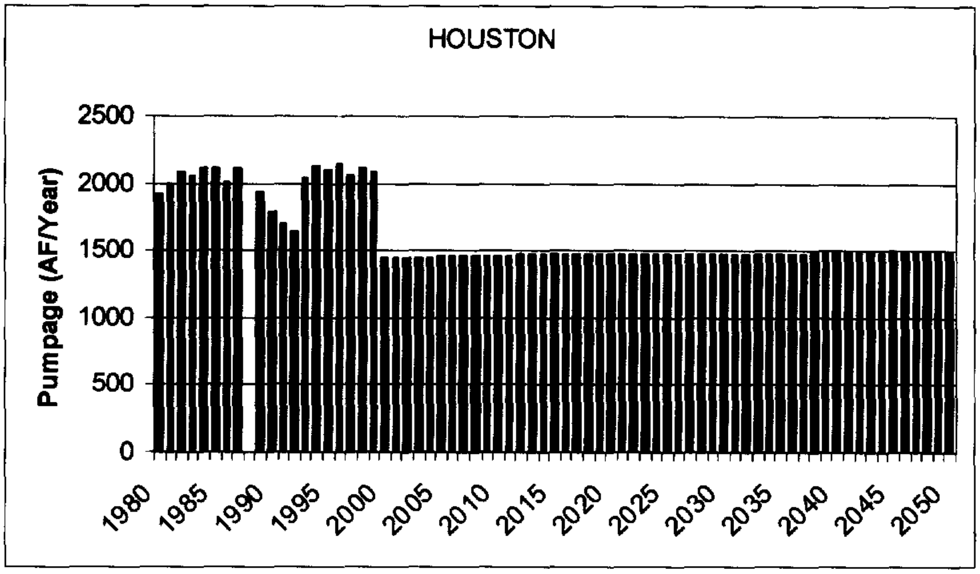

FREESTONE
Pumpage (AF/Year)
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

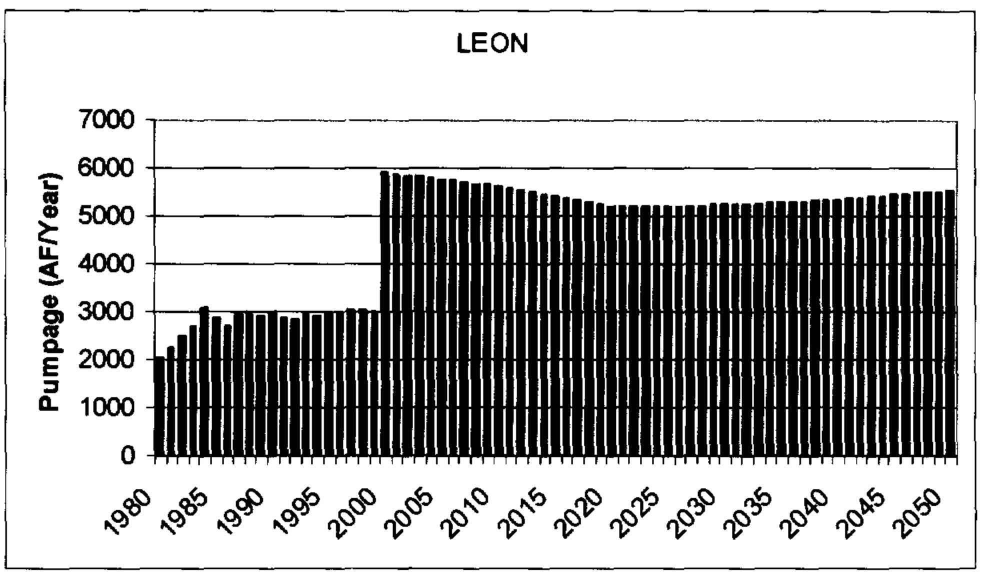

GREGG
Pumpage (AF/Year)
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

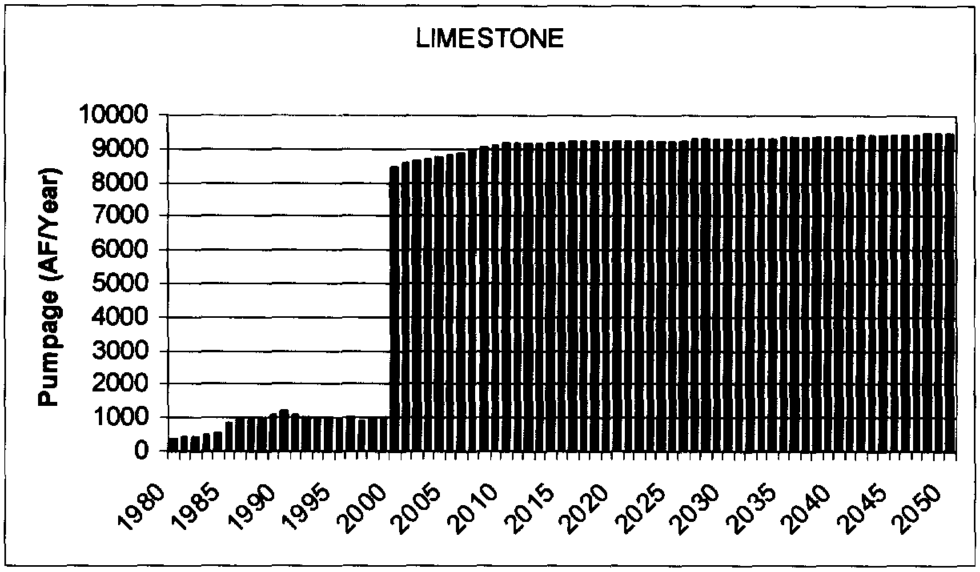

HARRISON
Pumpage (AF/Year)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050


HENDERSON
Pumpage (AF/Year)
7000
6000
5000
4000
3000
2000
1000
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050


HOPKINS
Pumpage (AF/Year)
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050


HOUSTON
2500
2000
1500
1000
500
0
Pumpage (AF/Year)
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050


LEON
7000
6000
5000
4000
3000
2000
1000
0
Pumpage (AF/Year)
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050


LIMESTONE
Pumpage (AF/Year)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
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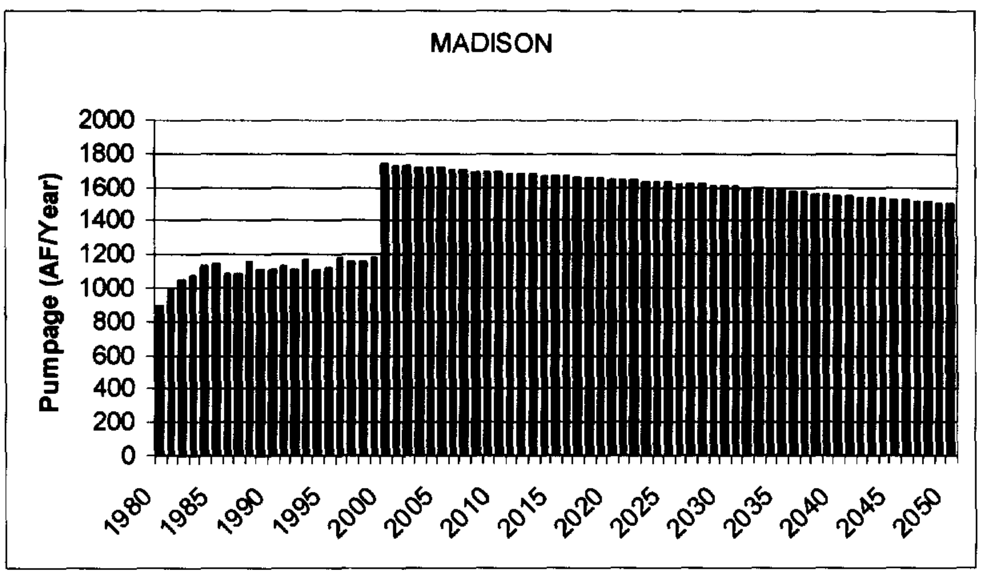
2045
2050


MADISON
Pumpage (AF/Year)
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1800
1600
1400
1200
1000
800
600
400
200
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
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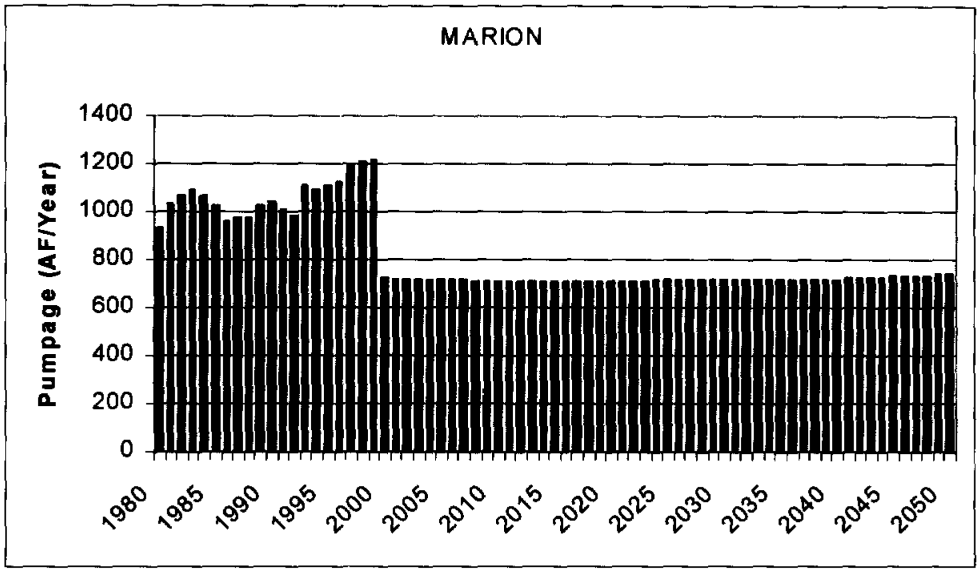
2035
2040
2045
2050


MARION
Pumpage (AF/Year)
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1200
1000
800
600
400
200
0
1980
1985
1990
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2020
2025
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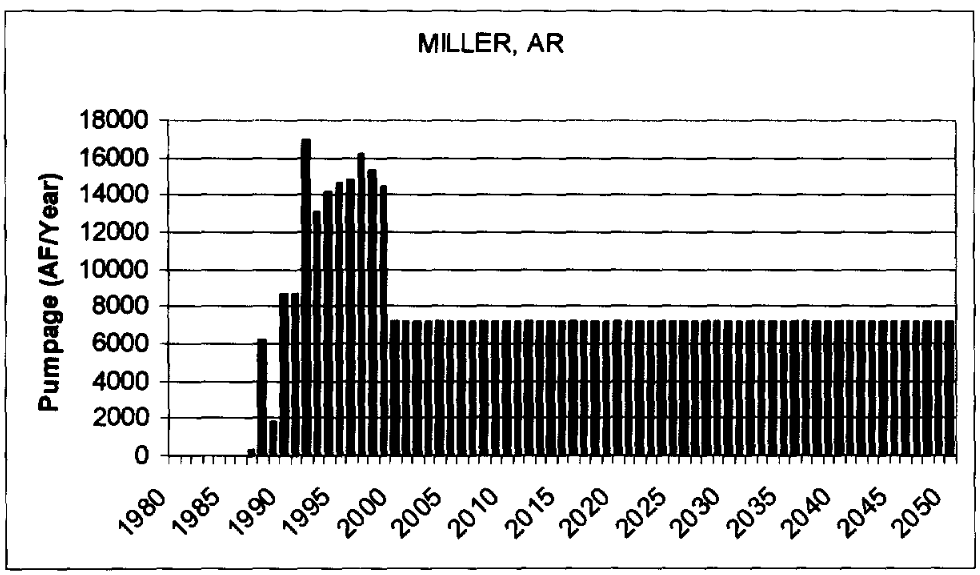
2035
2040
2045
2050


MILLER, AR
Pumpage (AF/Year)
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16000
14000
12000
10000
8000
6000
4000
2000
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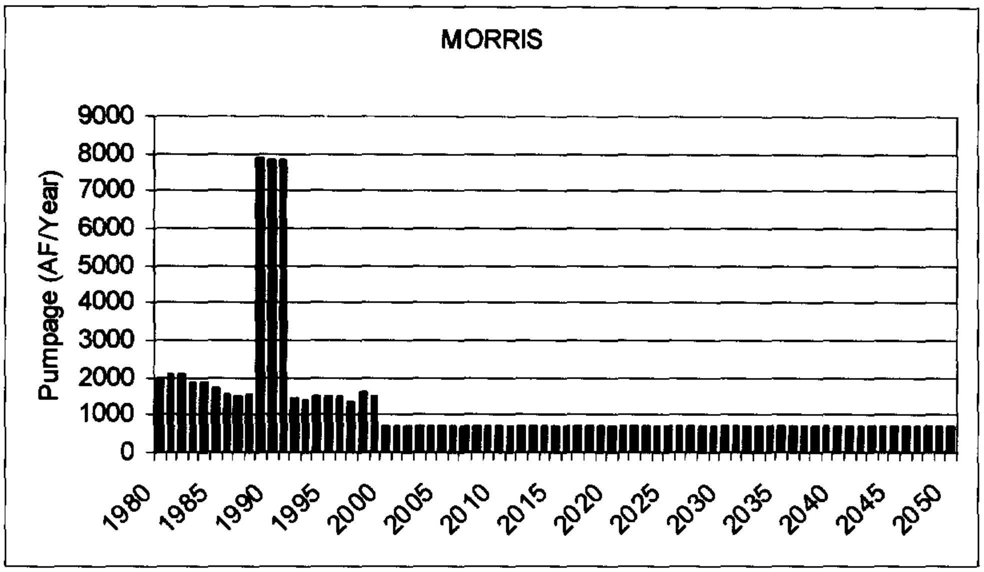
MORRIS
Pumpage (AF/Year)
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7000
6000
5000
4000
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2000
1000
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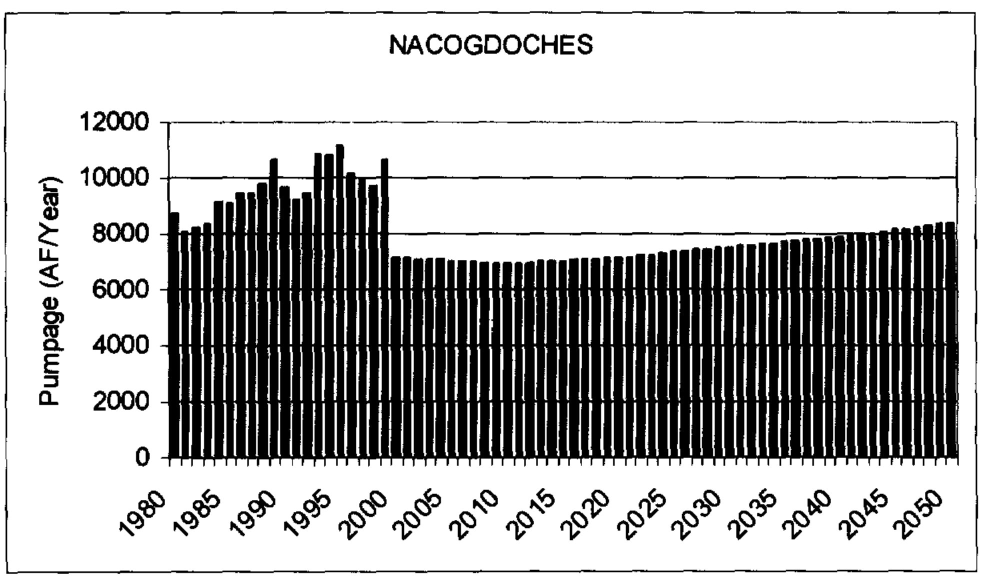
NACOGDOCHES
Pumpage (AF/Year)
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10000
8000
6000
4000
2000
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2015
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2025
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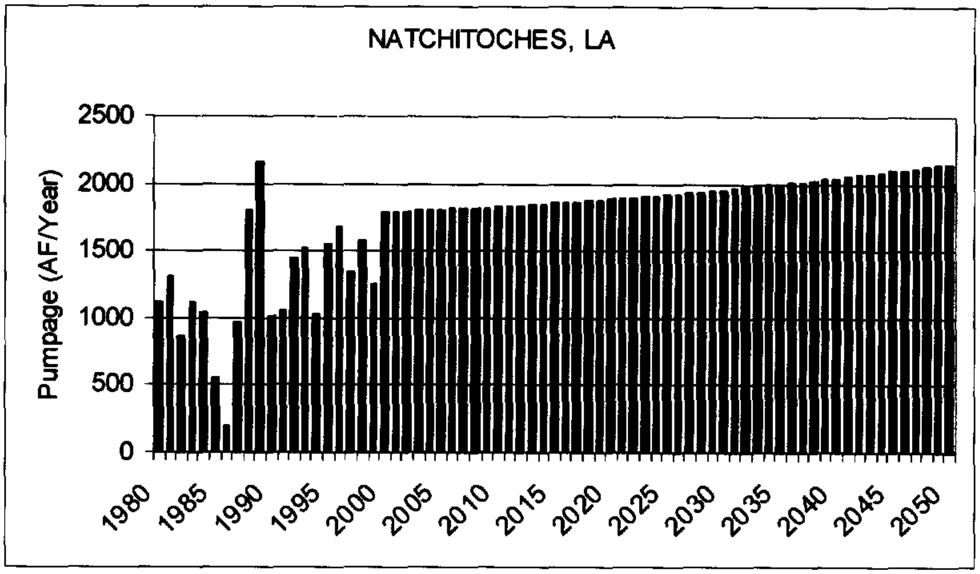
NATCHITOCHES, LA
Pumpage (AF/Year)
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2000
1500
1000
500
0
1980
1985
1990
1995
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2010
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2020
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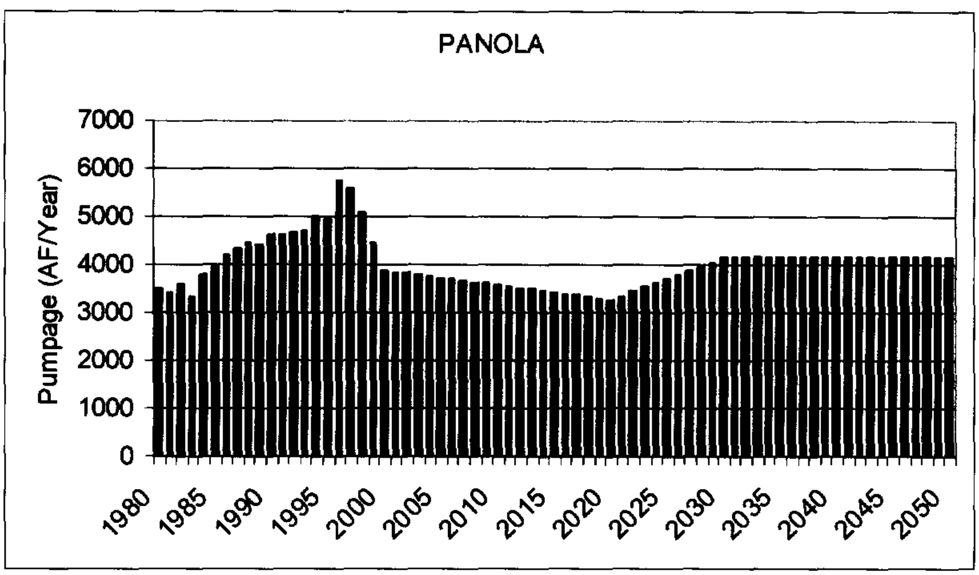
PANOLA
Pumpage (AF/Year)
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6000
5000
4000
3000
2000
1000
0
1980
1985
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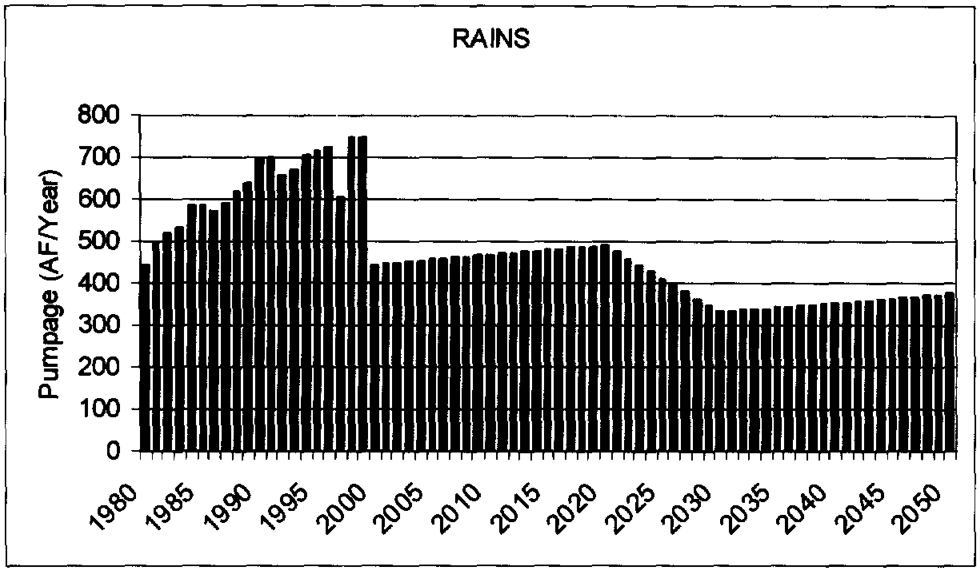
RAINS
Pumpage (AF/Year)
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700
600
500
400
300
200
100
0
1980
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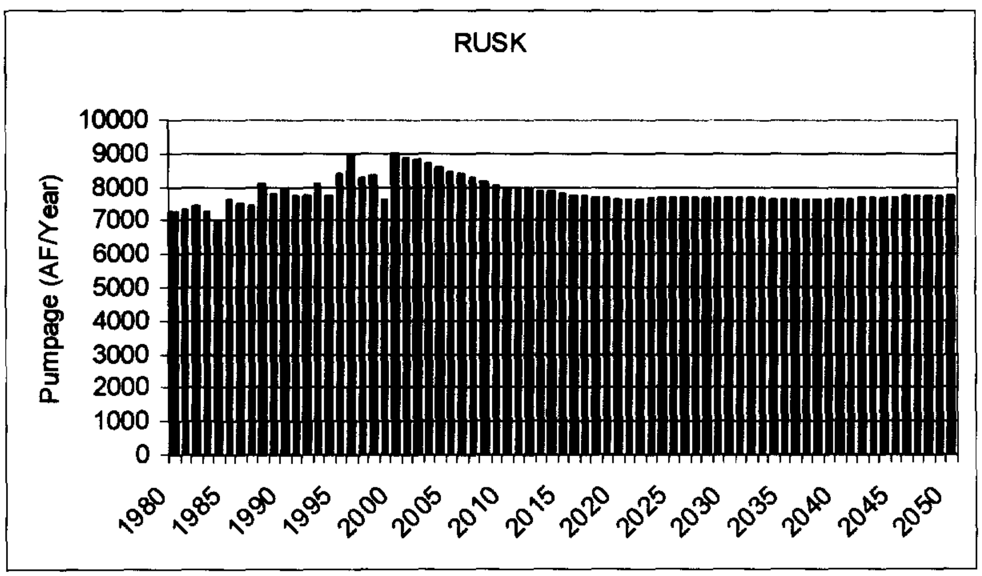
RUSK
Pumpage (AF/Year)
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9000
8000
7000
6000
5000
4000
3000
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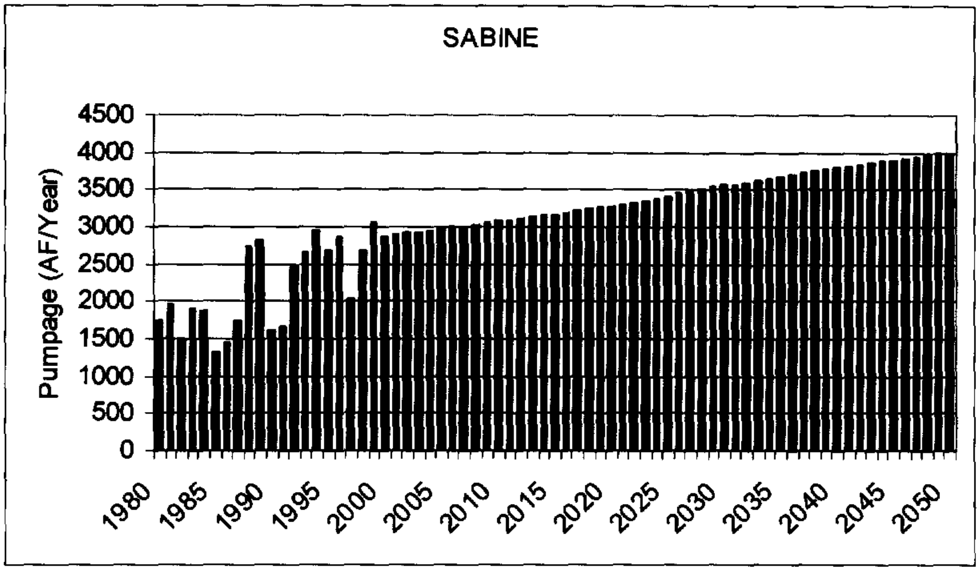
SABINE
Pumpage (AF/Year)
4500
4000
3500
3000
2500
2000
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1000
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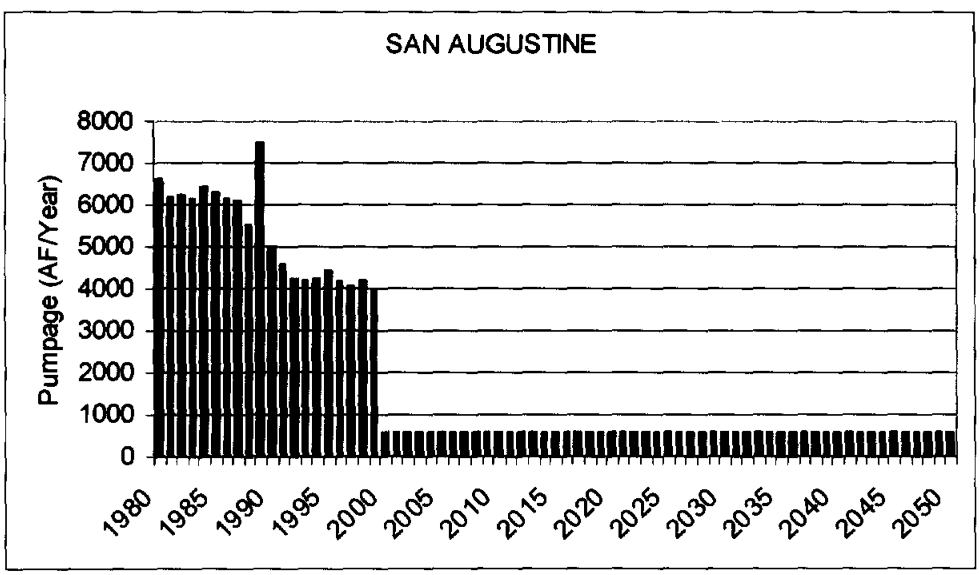
SAN AUGUSTINE
Pumpage (AF/Year)
8000
7000
6000
5000
4000
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0
1980
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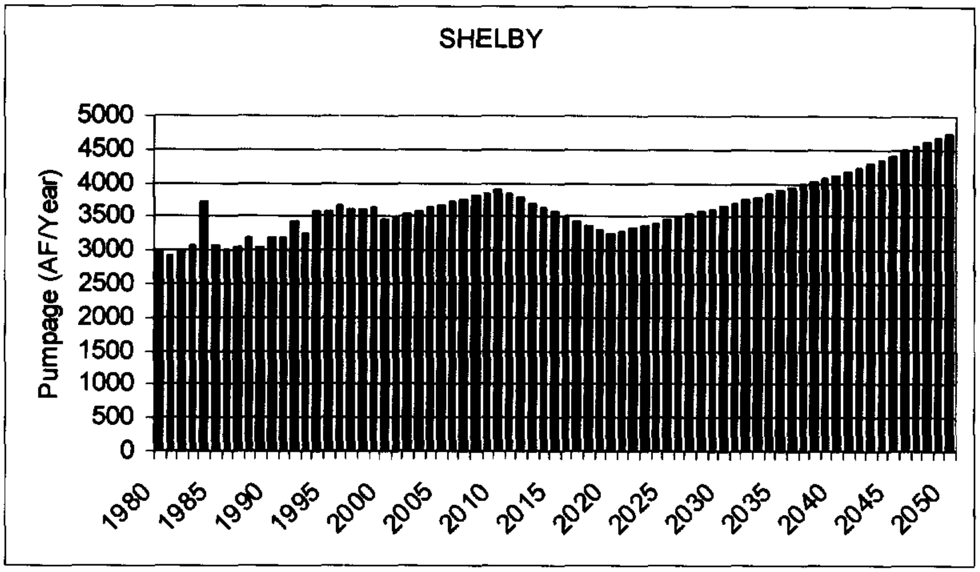
SHELBY
Pumpage (AF/Year)
5000
4500
4000
3500
3000
2500
2000
1500
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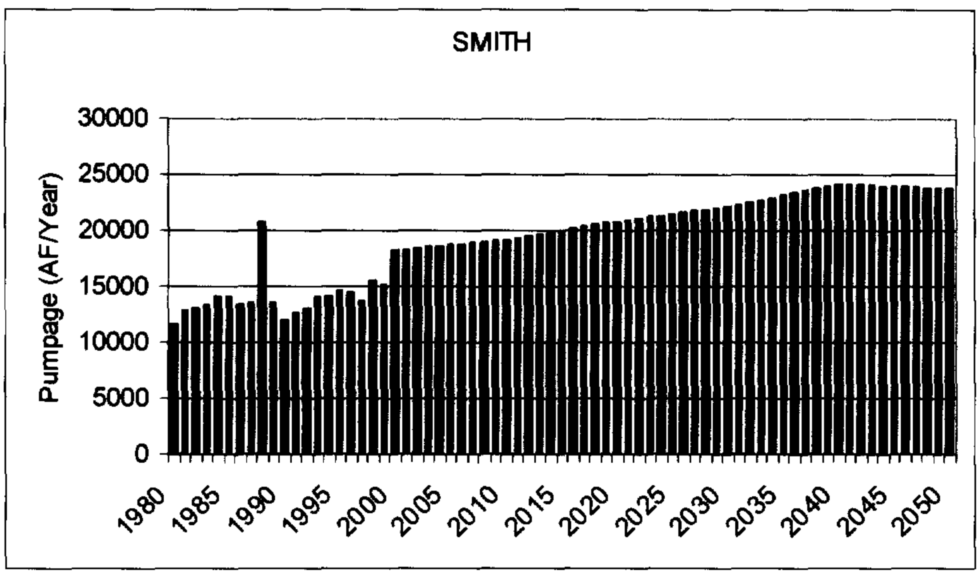
SMITH
Pumpage (AF/Year)
30000
25000
20000
15000
10000
5000
0
1980
1985
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1995
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2025
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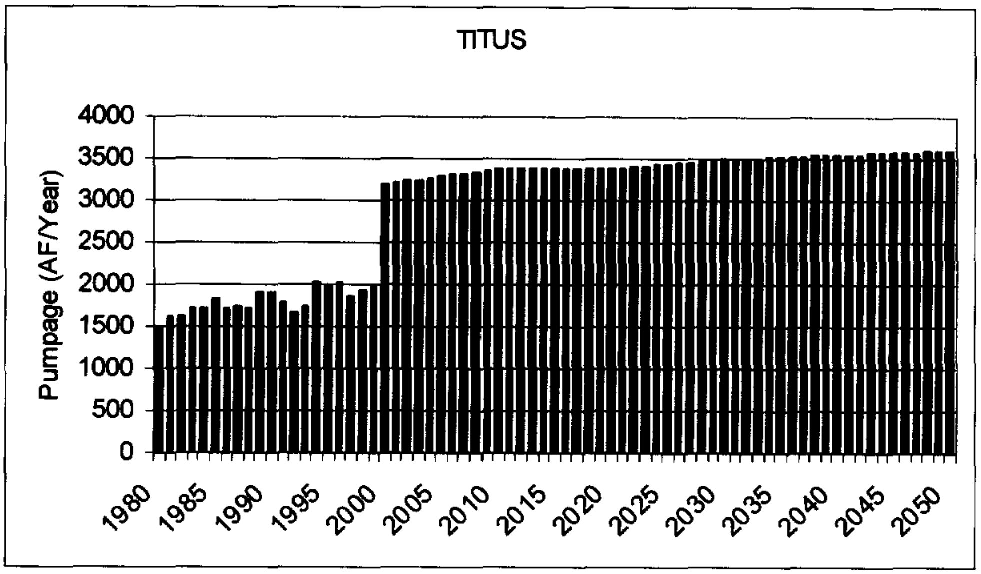
TITUS
Pumpage (AF/Year)
4000
3500
3000
2500
2000
1500
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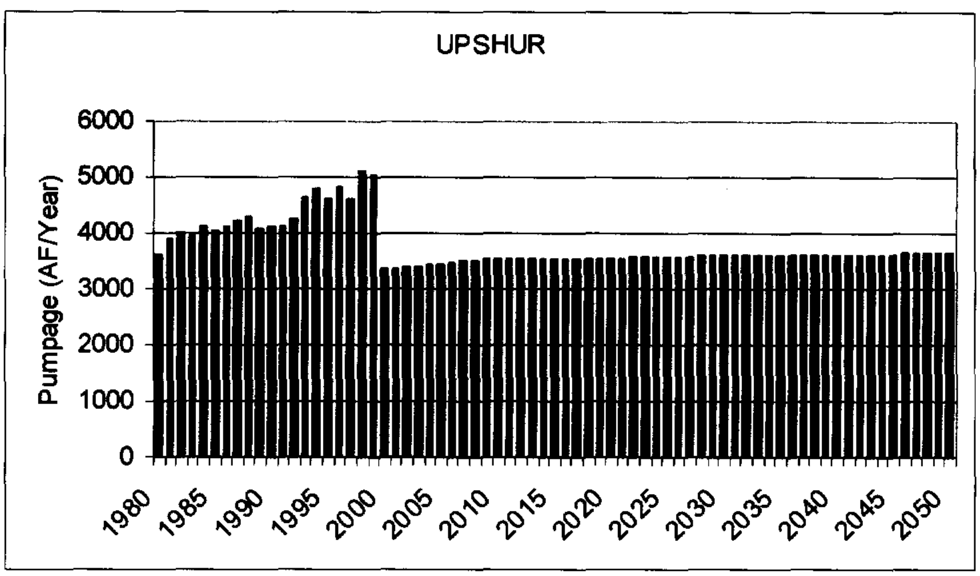
UPSHUR
Pumpage (AF/Year)
6000
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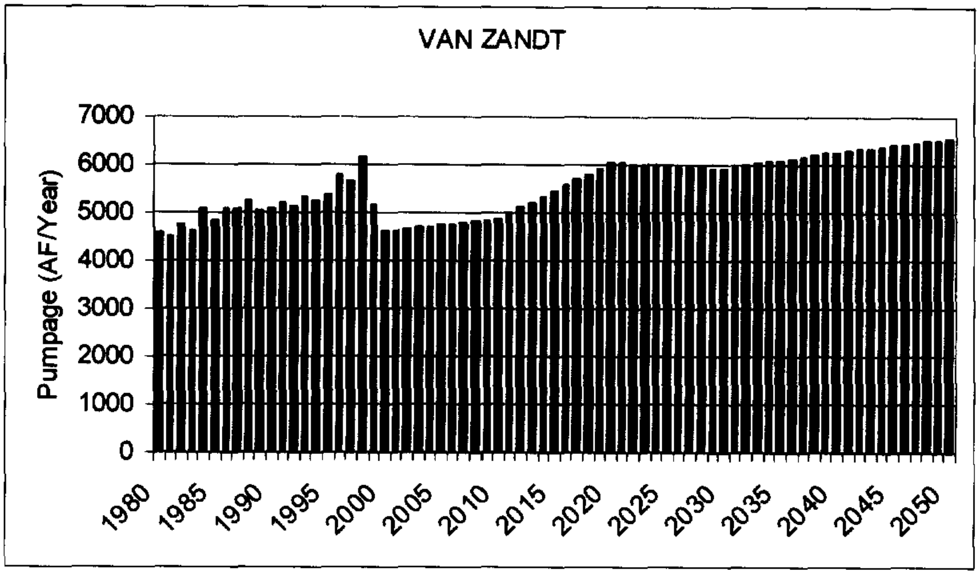
VAN ZANDT
Pumpage (AF/Year)
7000
6000
5000
4000
3000
2000
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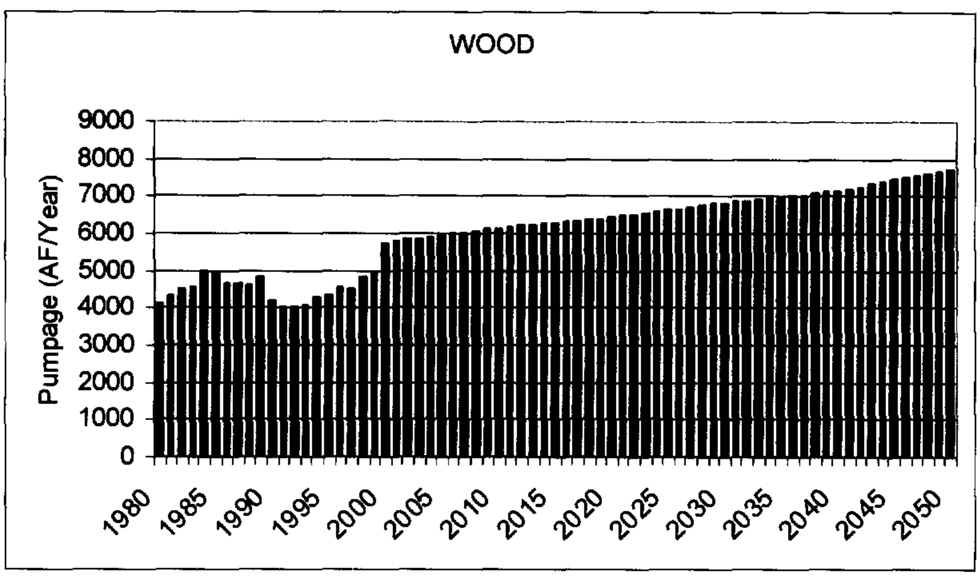
WOOD
Pumpage (AF/Year)
9000
8000
7000
6000
5000
4000
3000
2000
1000
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1980
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APPENDIX E

Using SWAT with MODFLOW in a Decoupled Environment

Appendix E
Using SWAT with MODFLOW in a Decoupled Environment

Background:

Our goal is to use the recharge/evapotranspiration estimates from a SWAT simulation to estimate recharge/evapotranspiration inputs to a MODFLOW simulation. We do not want to do any iteration and are not allowed real-time updating between the two.

The following is a general description of how these physical processes are implemented in the two models.

Recharge/Evapotranspiration in MODFLOW:

In MODFLOW, recharge is input in length/time units. This rate of water is added directly to the uppermost active layer during each stress period. The rate can be varied spatially for each grid block, and temporally for each stress period.

In MODFLOW, evapotranspiration removes water directly from the uppermost saturated layer. When the water table is at or above a specified elevation (called the "ET surface"), water is removed at the specified maximum rate. If the water table is below the ET surface, but above a specified extinction depth, then water is removed at a rate that decreases linearly from a maximum at the ET surface to zero at the extinction depth. Below the extinction depth, no water is removed. Figure E.1 illustrates this approach.

Recharge/Evapotranspiration in SWAT:

In SWAT, basically

Change in Soil Water = Infiltration - Evapotranspiration - Recharge

where

Infiltration = Precipitation - Runoff

A running soil water balance is calculated during the simulation. Precipitation is separated into infiltration and runoff using the SCS Curve Number method. Evapotranspiration requires more complex calculations. The following is a summary of how evapotranspiration is calculated in SWAT (skipping some of the minor details):

First, a potential (or more correctly, "reference") evapotranspiration (Figure E.2), $E_{t,0}$, is calculated, typically using some flavor of the Penman approach. This reference evapotranspiration is that which would occur for some reference grass with no soil water limitation. Three separate steps are required to estimate an actual evapotranspiration (Figure E.3) from this potential evapotranspiration.

Step 1: Account for vegetative differences -- since not all vegetation is reference grass, differences in growing cycles, size, and water use are accounted for by correlating the maximum daily transpiration with the leaf area index (LAI) of the plant, i.e.

$$E_{t,max} = \frac{(LAI)(E_{t,0})}{3.0} \qquad 0<\text{LAI}<3.0$$

$$E_{t,max} = E_{t,0} \qquad \text{LAI} > 3.0$$

The LAI changes with plant type, growth cycle, growing conditions, etc.

Step 2: Account for decreasing potential with increasing root zone depth -- root density is assumed to be greatest near the soil surface, and decreases with depth. With default SWAT parameters, about 50% of the water uptake occurs in the top 6% of the root zone.

Step 3: Account for soil water limitation -- plants cannot remove water from the soil if the soil water content is at the plant wilting point. So the $E_{t,max}$ that is calculated in Step 1 has to be limited by soil water.

Without writing down all of the equations, we just note that

$$E_{t,actual} = f(E_{t,max}, depth, soil\ moisture)$$

Note that this explanation applies to the unsaturated zone only. SWAT does allow for calculation of groundwater transpiration (called "revap" in SWAT). However, SWAT has a very crude implementation of groundwater modeling, so the relative height of the water table is unlikely to be consistent. Therefore, we do not calculate groundwater evapotranspiration in SWAT.

The Approach

So if we apply the recharge from SWAT directly MODFLOW, we neglect groundwater transpiration. The greatest error will occur when SWAT is predicting dry soil conditions and MODFLOW is predicting a near-surface water table (i.e. within the root zone). When these conditions occur, SWAT will underpredict actual ET.

What we will do to rectify this is to apply the "unused" ET (that is, the difference between maximum ET and actual ET) as ET in MODFLOW. In MODFLOW, we set

Recharge = Recharge from SWAT

$ET = (E_{t,max} - E_{t,actual})$ from SWAT

The four main scenarios are discussed below:

Scenario 1: Infiltration > Evapotranspiration, water table below extinction depth

This scenario should be fine, with no MODFLOW ET (since the water table is below the extinction depth), but with recharge being estimated by SWAT. The SWAT estimate does not include groundwater ET of course, but with the water table below the extinction depth, there should be no groundwater ET.

Scenario 2: Infiltration > Evapotranspiration, water table above extinction depth

In this scenario, MODFLOW starts to draw water from the water table based on the difference between the maximum transpiration and the actual transpiration estimated by SWAT. However, the MODFLOW ET shouldn't have much impact in this case because with infiltration occurring, soil moisture should be high, $E_{t,actual}$ will be similar to $E_{t,max}$, and the difference will be near zero.

Scenario 3: Infiltration < Evapotranspiration, water table below extinction depth

In this scenario, there will be no recharge, and MODFLOW will have shut down ET.

Scenario 4: Infiltration < Evapotranspiration, water table above extinction depth

In this scenario, SWAT will have set recharge to zero, and will not remove water from the soil profile below the wilting point. SWAT will not account for the fact that the groundwater evapotranspiration should be occurring. However, the ET in MODFLOW will be pulling water off of the water table at a rate near $E_{t,max}$, (since $E_{t,actual}$ will be small due to low soil moisture) which is a good estimate for this situation.

Figure E.4 shows an example of preliminary SWAT results from a deciduous forest area for the year 1975 in the northern model region. Note that actual evapotranspiration is primarily due to soil evaporation in the winter months. In the spring and summer, transpiration begins to dominate the ET, and when soil water is high, actual transpiration is similar to maximum potential transpiration. Note that in late summer, the precipitation is inconsistent and soil water is decreasing, so the difference between maximum and actual transpiration is significant on some days.

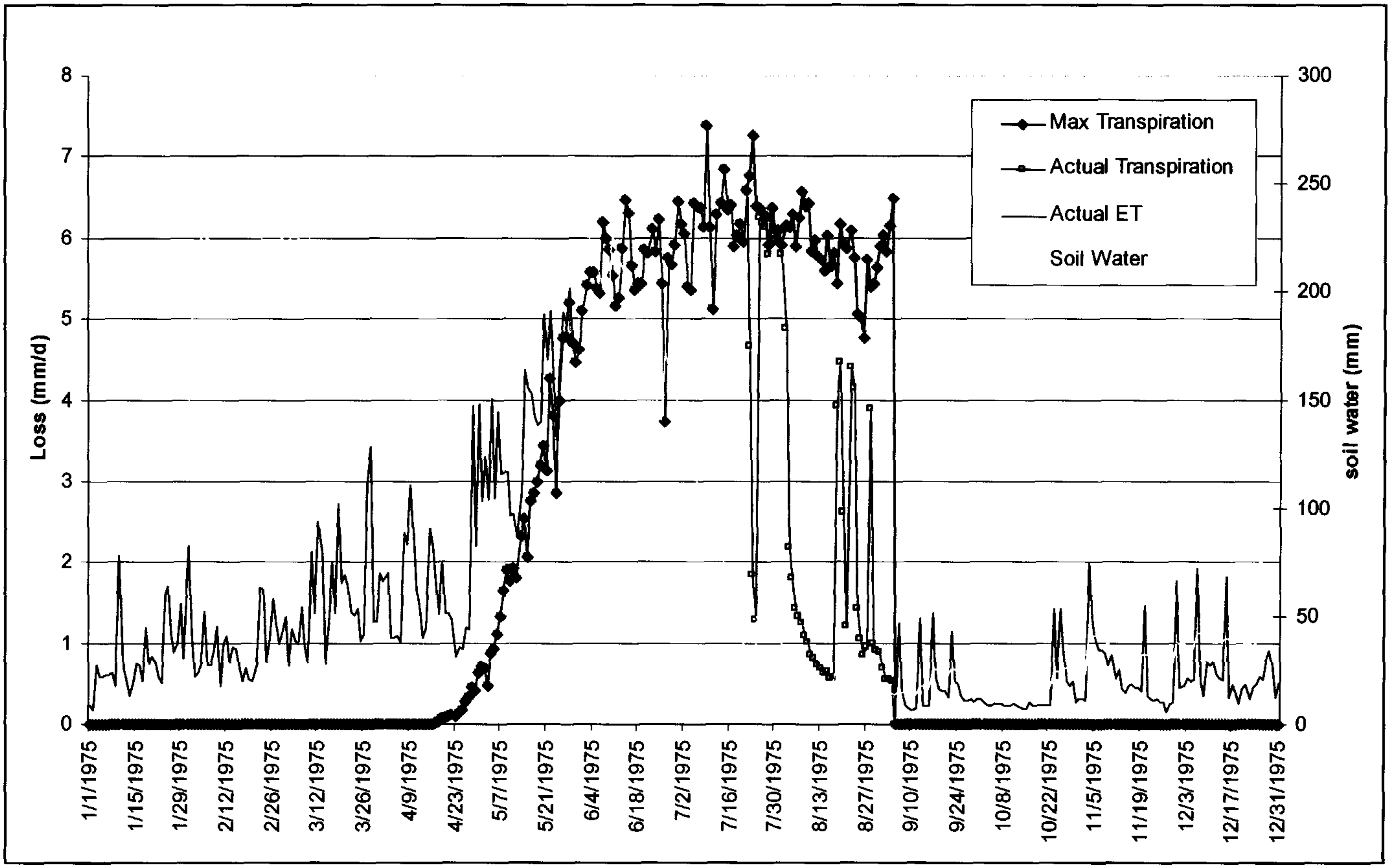

Figure E.1 Example SWAT results

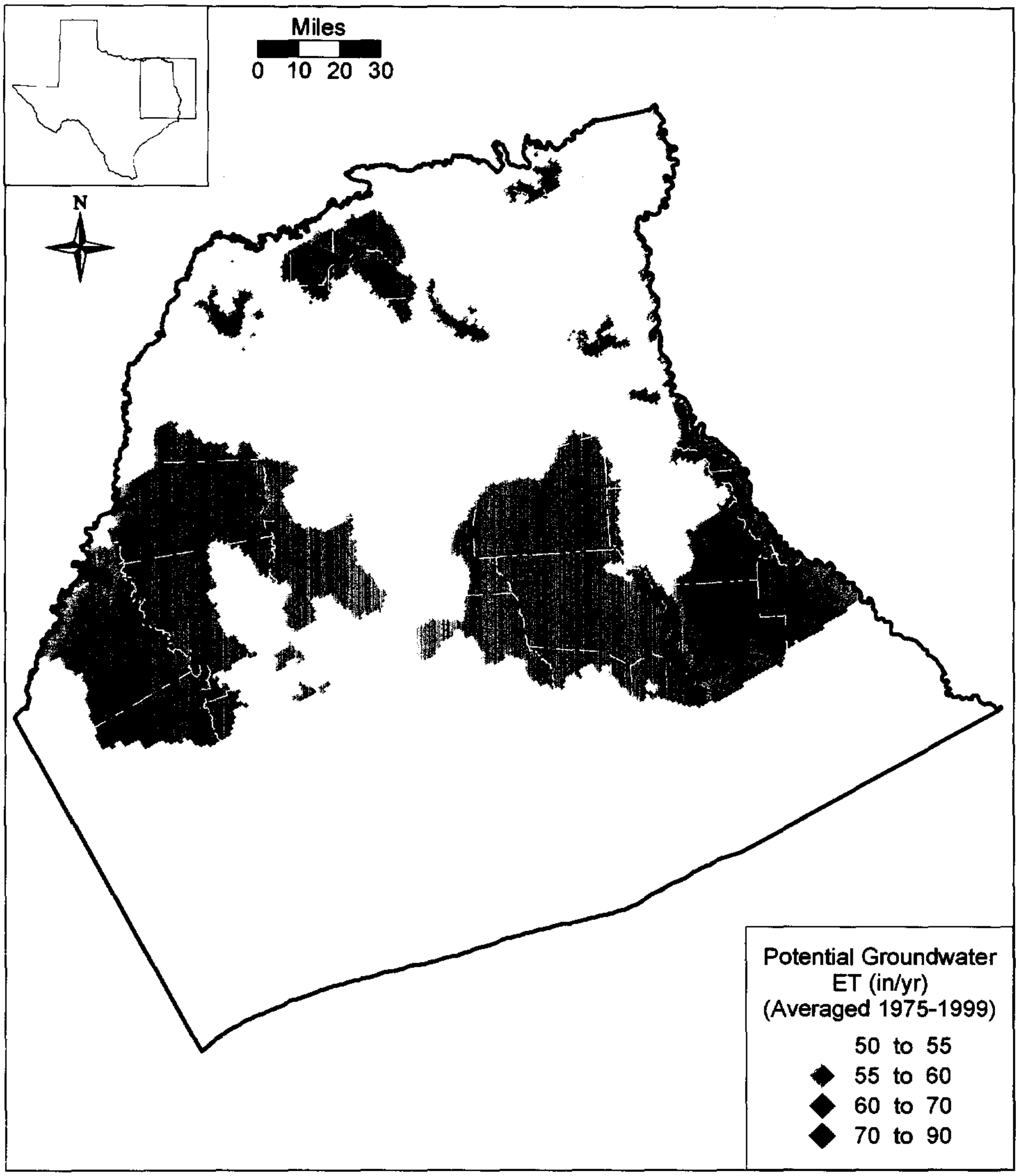

Figure E.2 Potential ET averaged over 1975 – 1999.

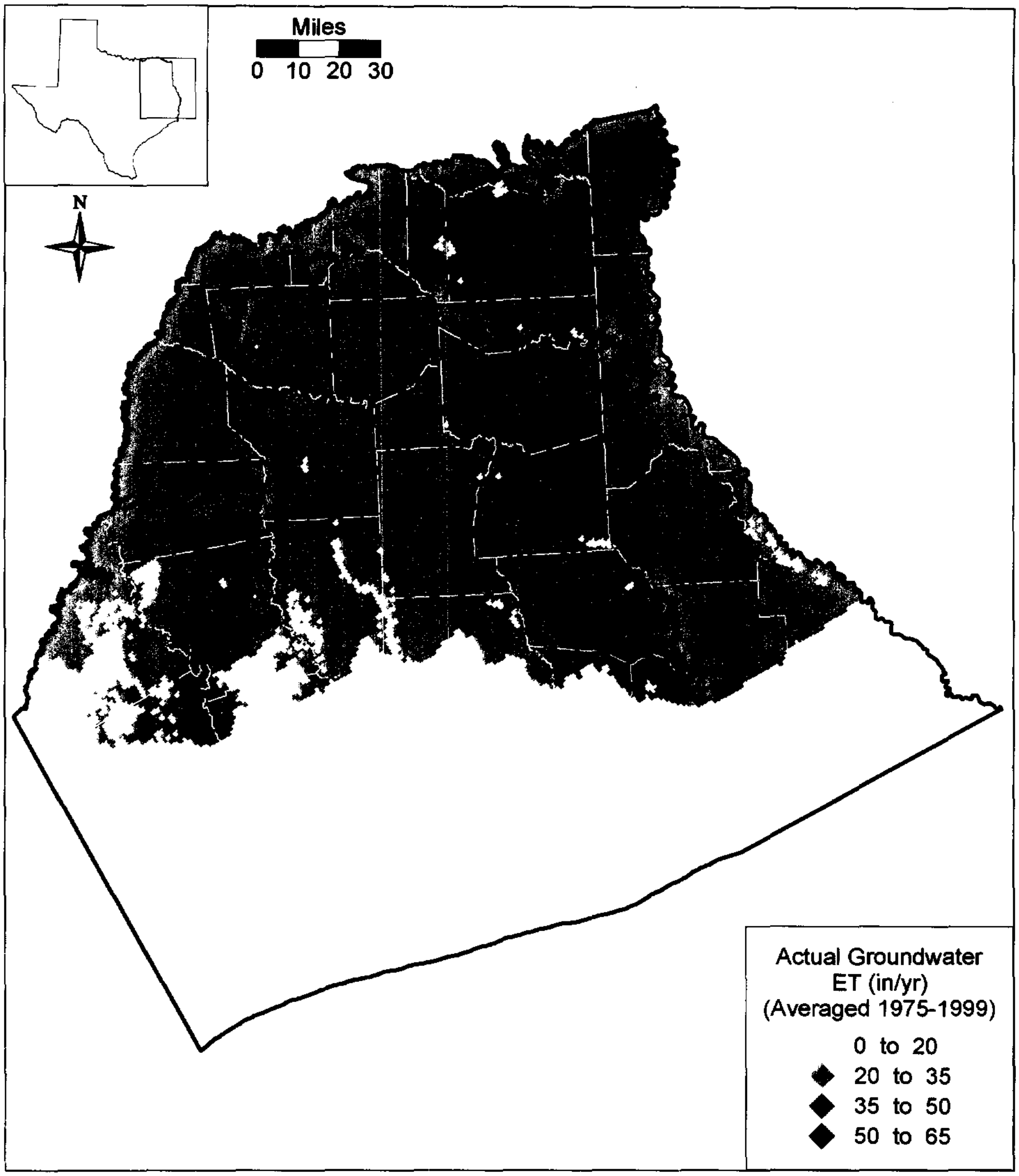

Figure E.3 Actual ET (vadose zone) averaged over 1975 – 1999.

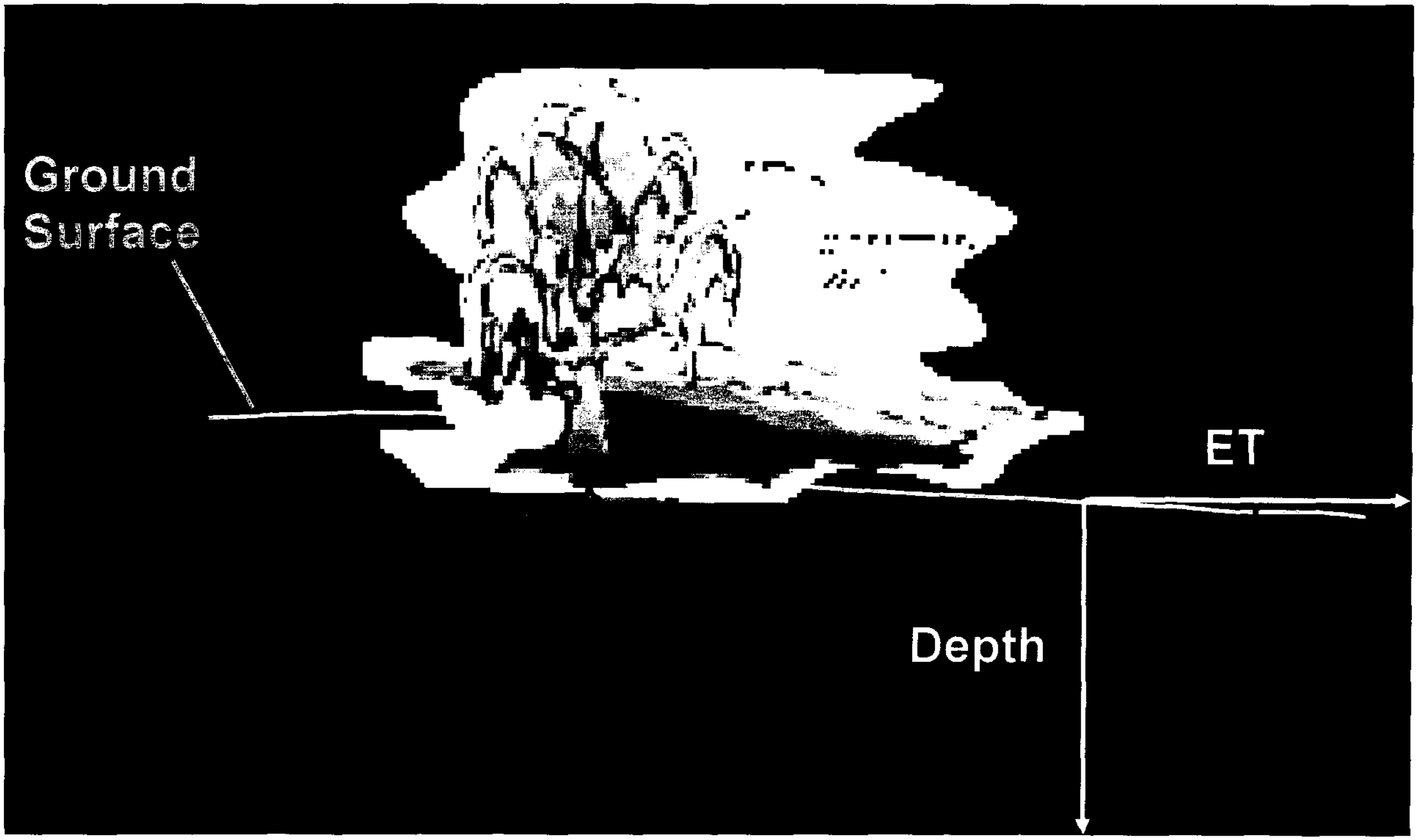

Figure E.4 MODFLOW approach to groundwater evapotranspiration

APPENDIX F
Water Quality

Appendix F

Water Quality

Groundwater in the northern Carrizo-Wilcox aquifer was evaluated for its quality as a drinking water supply, for irrigation of crops, and for industrial purposes, by comparing the measured chemical and physical properties of the water to screening levels. Water quality measurements were retrieved for the entire available historical record, from about 1920 through 2001, from databases maintained by the Texas Water Development Board, the U.S. Geological Survey, and the Texas Commission on Environmental Quality's Public Water System. The percentages of wells in the aquifer with one or more measurements exceeding individual screening levels are illustrated in Table F.1. Table F.2 indicates the percentage of wells in the northern Carrizo-Wilcox aquifer from each county that exceeded at least one screening level for drinking water, irrigation, or industrial uses.

Concentration levels of selected constituents were evaluated for well data from the identified databases. They are presented in Figures F.1 through F.7 for nitrate nitrogen, lead, iron, sodium hazard, total dissolved solids, hardness, and silica, respectively. Each column in the figures reflects the highest observed measurement in a single well. The height of the column, and its color, represent the magnitude of the concentration. A general discussion of drinking, irrigation, and industrial water quality within the northern Carrizo-Wilcox GAM area is presented below.

Drinking Water Quality - Screening levels for drinking water supply are based on the maximum contaminant levels (MCLs) established in National Primary Drinking Water Regulations and National Secondary Drinking Water Regulations. National Primary Drinking Water Regulations are legally enforceable standards that apply to public water systems to protect human health from contaminants in drinking water. National Secondary Drinking Water Regulations are non-enforceable guidelines for drinking water contaminants that may cause aesthetic effects (taste, color, odor, foaming), cosmetic effects (skin or tooth discoloration), and technical effects (e.g., corrosivity, expensive water treatment, plumbing fixture staining, scaling, and sediment).

Total dissolved solids (TDS) is a measure of water saltiness, the sum of concentrations of all dissolved ions (such as sodium, calcium, magnesium, potassium, chloride, sulfate, carbonates) plus silica. Some dissolved solids, such as calcium, give water a pleasant taste, but most, including chloride and sulfate, make water taste salty, bitter, or metallic. Dissolved solids can also increase its corrosiveness. TDS levels have exceeded secondary MCLs, the maximum contaminant level of National Secondary Drinking Water Regulations, in almost 30% of the wells in the northern Carrizo-Wilcox aquifer.

Elevated levels of iron and manganese adversely impact water quality in approximately 20% of the wells in the northern Carrizo-Wilcox aquifer. Water containing iron in excess of 0.3 mg/L and manganese in excess of 0.05 mg/L may cause reddish-brown or blackish-gray stains on laundry, utensils, and plumbing fixtures, as well as color, taste and odor problems.

High concentrations of nitrate nitrogen can cause serious illness in infants younger than 6 months old. Nitrate nitrogen levels that exceed the primary MCL of 10 mg/L were detected in about 6% of the wells.

Fluoride is a naturally-occurring element found in most rocks. At very low concentrations, fluoride is a beneficial nutrient. At a concentration of 1 mg/L, fluoride helps to prevent dental cavities. However, at concentrations above 2 mg/L, fluoride can stain children's teeth. At concentrations above 4 mg/L, fluoride can cause a type of bone disease.

Overall, approximately 6% of the wells in the northern Carrizo-Wilcox aquifer are deemed to have unsuitable drinking water quality for health reasons, and approximately 40% of the wells have water that may be unpalatable for drinking, cause stains to teeth, plumbing fixtures, and laundry, or cause scaling or corrosion in plumbing without prior treatment.

Irrigation Water Quality - The utility of groundwater for crop irrigation was evaluated based on the concentrations of boron, chloride, and total dissolved solids, as well as the salinity hazard, the sodium hazard, and the sodium absorption ratio. Various soils and plants differ in their tolerance of salts. This tolerance is also affected by the abundance of rainfall and frequency of irrigation. In the absence of consensus standards for water quality for irrigation, we attempted to identify thresholds that would be unsuitable for long-term use on most types of plants and soils.

Boron may cause toxicity to many plants at levels above 2 mg/L (van der Leeden et al., 1990). Most crops cannot tolerate chloride levels above 1000 mg/L for an extended period of time (Tanji, 1990). Salinity, as measured by total dissolved solids (TDS) or electrical conductivity, can also be toxic to plants by making plants unable to take up water. James et al. (1982) consider TDS levels above 2100 unsuitable for most irrigation. The salinity hazard classification system of the U.S. Salinity Laboratory (1954) indicates that waters with electrical conductivity over 750 micromhos present a high salinity hazard, and those with electrical conductivity over 2250 micromhos present a very high salinity hazard. Irrigation water containing large amounts of sodium cause a breakdown in the physical structure of soil such that movement of water through the soil is restricted. The sodium absorption ratio (SAR) is an indication of the sodium hazard to soils. An SAR of greater than 18 is generally considered unsuitable for continuous use in irrigation, but the sodium hazard depends on both the SAR and water salinity. The sodium hazard was calculated based on the classification system developed by the U.S. Salinity Laboratory (1954).

Overall, approximately 23% of the wells in the northern Carrizo-Wilcox aquifer are deemed to have unsuitable water quality for irrigation of many types of crops.

Industrial Water Quality - The quality of water for most industrial purposes is indicated by the content of dissolved solids, as well as its corrosivity and tendency to form scale and sediment in boilers and cooling systems. Some constituents responsible for scaling are hardness (calcium and magnesium), silica, and iron. Water temperature and pH also have a direct effect on how quickly and severely these constituents cause scaling or corrosion. pH values below 6.5 may enhance corrosion, while pH values above 8.5 will contribute to scaling and sediment. Waters with a silica concentration of 40 mg/L or higher are considered unsuitable for use in most steam boilers. Waters with a hardness of 180 mg/L (as calcium carbonate) or higher are considered very hard, and are unsuitable for many industrial purposes because water softening becomes uneconomical.

Overall, approximately 38% of the wells in the northern Carrizo-Wilcox aquifer are deemed to have unsuitable water quality for many industrial purposes without substantial pre-treatment, such as water softening.

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Shafer, G.H. 1968. Ground-water Resources of Nueces and San Patricio Counties, Texas. Report 73. Texas Water Development Board, Austin, Texas

Tanji, K.K. 1990. Agricultural Salinity Assessment and Management. American Society of Civil Engineers. Manuals and Reports on Engineering Practice Number 71.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and Improvement of Saline and Alkali Soils. U.S. Department of Agriculture, Agricultural. Handbook 60.

Van der Leeden, F., F.L. Troise, and D.K. Todd. 1990. The Water Encyclopedia. Lewis Publishers.

Table F.1 Occurrence and levels of some commonly-measured groundwater quality constituents in the northern Carrizo-Wilcox aquifer.

Constituent	Number Of Wells	Screening Level (Mg/L)	Type	Percent Of Wells Exceeding Screening Level*
Nitrate Nitrogen	2502	10	1° MCL	6.2%
Lead	388	0.015	1° MCL	2.1%
Beryllium	255	0.004	1° MCL	0.8%
Alpha Activity, pCi/L	245	15	1° MCL	0.8%
Cadmium	385	0.005	1° MCL	0.8%
Beta Activity, pCi/L	246	50	1° MCL	0.4%
Fluoride	2681	4	1° MCL	0.3%
Barium	391	2	1° MCL	0.3%
Selenium	432	0.05	1° MCL	0.2%
Arsenic	392	0.01	1° MCL	0.0%
Copper	387	1.3	1° MCL	0.0%
Antimony	256	0.006	1° MCL	0.0%
Chromium	390	0.1	1° MCL	0.0%
Mercury	237	0.002	1° MCL	0.0%
Nitrite Nitrogen	241	1	1° MCL	0.0%
Thallium	210	0.002	1° MCL	0.0%
Total Dissolved Solids	2977	500	2° MCL	29%
Iron	961	0.3	2° MCL	19%
Manganese	575	0.05	2° MCL	18%
Chloride	3225	250	2° MCL	8.5%
Fluoride	2681	2	2° MCL	2.6%
Sulfate	3065	250	2° MCL	2.4%
Aluminum	286	0.2	2° MCL	2.4%
Zinc	387	5	2° MCL	0.0%
Copper	387	1.0	2° MCL	0.0%
Silver	254	0.1	2° MCL	0.0%
Salinity Hazard	2464	Very High (Sp. Cond. >2250)	Irrigation	3.2%
		High Or Very High (Sp. Cond. > 750)	Irrigation	35%
Sodium (Alkali) Hazard	2858	Very High (SAR>26)	Irrigation	24%
		High Or Very High (SAR>18)	Irrigation	33%
Boron	425	2	Irrigation	1.9%
Total Dissolved Solids	2977	2100	Irrigation	1.4%
Chloride	3225	1000	Irrigation	1.0%
PH	2512	<6.5 OR >8.5	Industrial	30%
Hardness	3312	180	Industrial	11%
Silica	2241	40	Industrial	10%

* percentage of wells with one or more measurements of the parameter that exceeded the screening level.

Table F.2 County-level water quality in the northern Carrizo-Wilcox aquifer.

		% of Wells Exceeding One or More Screening Levels				
County Name	RWPG	Wells Sampled	1° MCL	2° MCL	Irrigation	Industrial
Anderson	I	119	3.5%	40%	39%	37%
Angelina	I	46	0.0%	91%	91%	89%
Bowie	D	28	19%	39%	11%	68%
Brazos	G	17	6.3%	47%	88%	25%
Caddo (LA)		219	2.3%	30%	4.1%	12%
Camp	D	43	9.5%	16%	9.5%	17%
Cass	D	101	14%	33%	17%	30%
Cherokee	I	105	5.3%	47%	52%	47%
De Soto (LA)		139	2.8%	64%	24%	37%
Franklin	D	43	27%	33%	4.8%	40%
Freestone	C	236	7.5%	33%	9.7%	52%
Gregg	D	75	1.5%	51%	76%	32%
Harrison	D	166	4.2%	30%	18%	27%
Henderson	C/I	209	6.3%	28%	5.3%	31%
Hopkins	D	28	18%	57%	7.1%	64%
Houston	I	25	0.0%	32%	72%	28%
Leon	H	44	0.0%	32%	16%	26%
Limestone	G	73	1.4%	45%	5.7%	43%
Madison	H	6	0.0%	33%	80%	40%
Marion	D	31	0.0%	57%	61%	32%
Miller (AR)		1	0.0%	100%	0.0%	100%
Morris	D	54	21%	18%	11%	22%
Nacogdoches	I	160	4.0%	46%	19%	46%
Natchitoches (LA)		82	1.5%	57%	23%	37%
Navarro	C	13	50%	50%	10%	92%
Panola	I	92	1.1%	48%	36%	64%
Rains	D	26	24%	58%	12%	54%
Red River (LA)		57	0.0%	53%	8.8%	22%
Robertson	G	157	4.7%	25%	18%	42%
Rusk	I	126	4.1%	66%	52%	66%
Sabine	I	32	17%	46%	38%	19%
Sabine (LA)		70	3.4%	76%	30%	36%
San Augustine	I	62	23%	29%	17%	16%
Shelby	I	97	5.2%	59%	54%	62%
Smith	D/I	170	0.6%	36%	20%	33%
Titus	D	75	26%	26%	8.5%	28%
Upshur	D	74	2.9%	45%	24%	36%
Van Zandt	D	150	5.1%	23%	6.9%	27%
Wood	D	117	4.8%	34%	14%	31%
All		3368	6.2%	41%	23%	38%

Figure F.1 Maximum observed nitrate nitrogen levels.

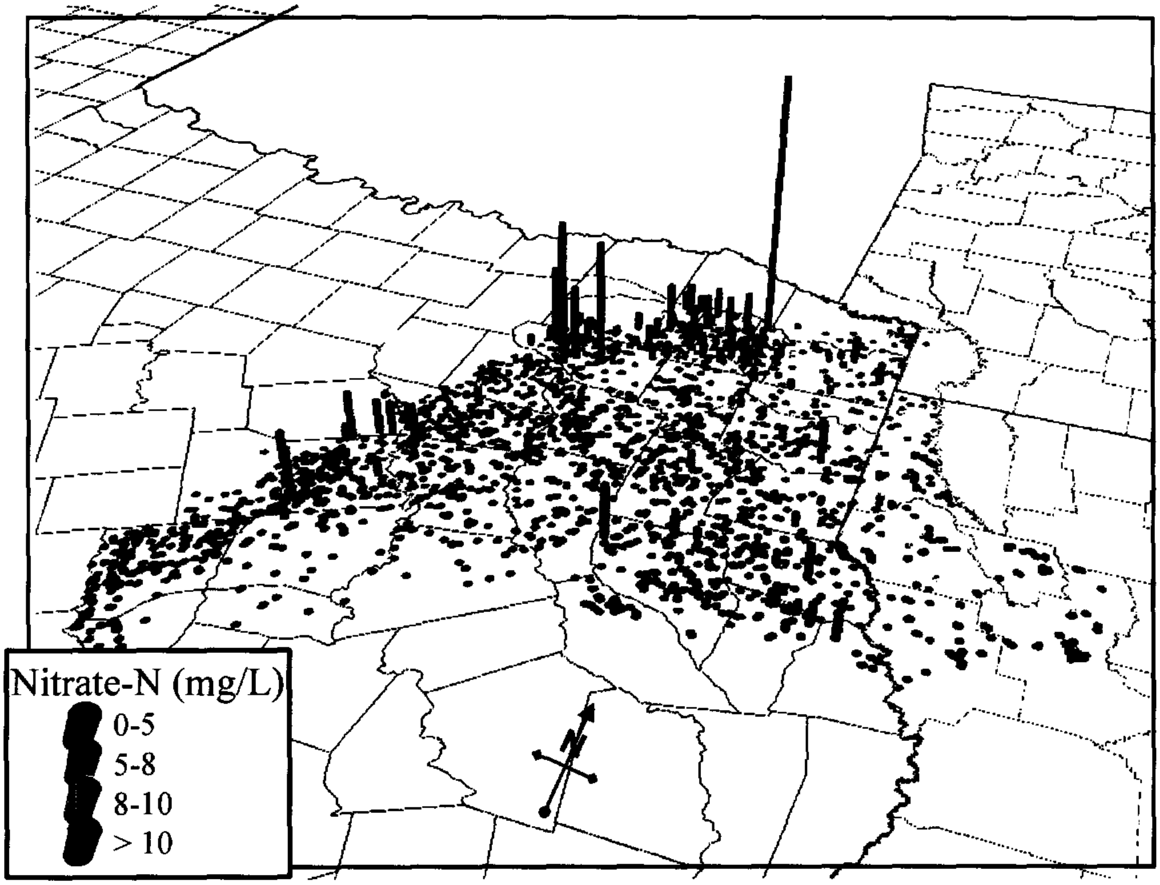


Figure F.2 Maximum observed lead levels.

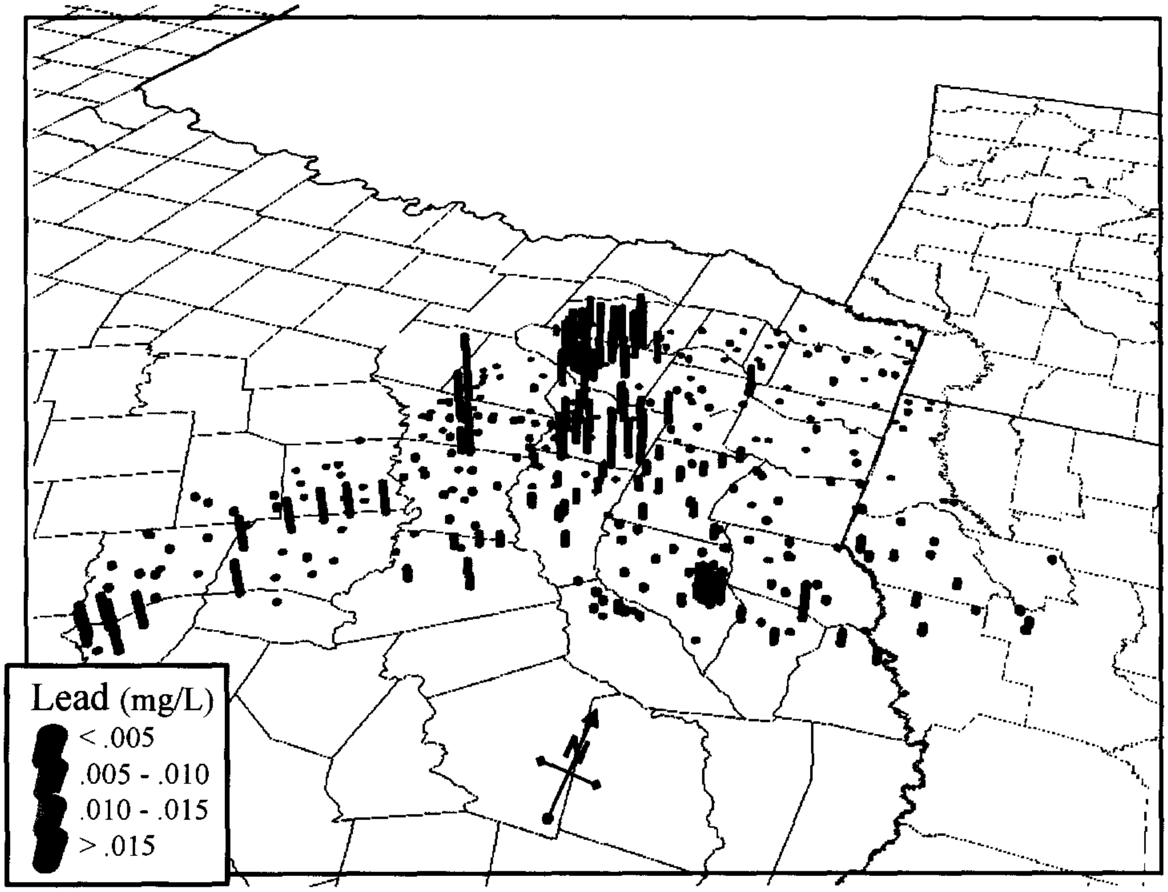


Figure F.3 Maximum observed iron levels.

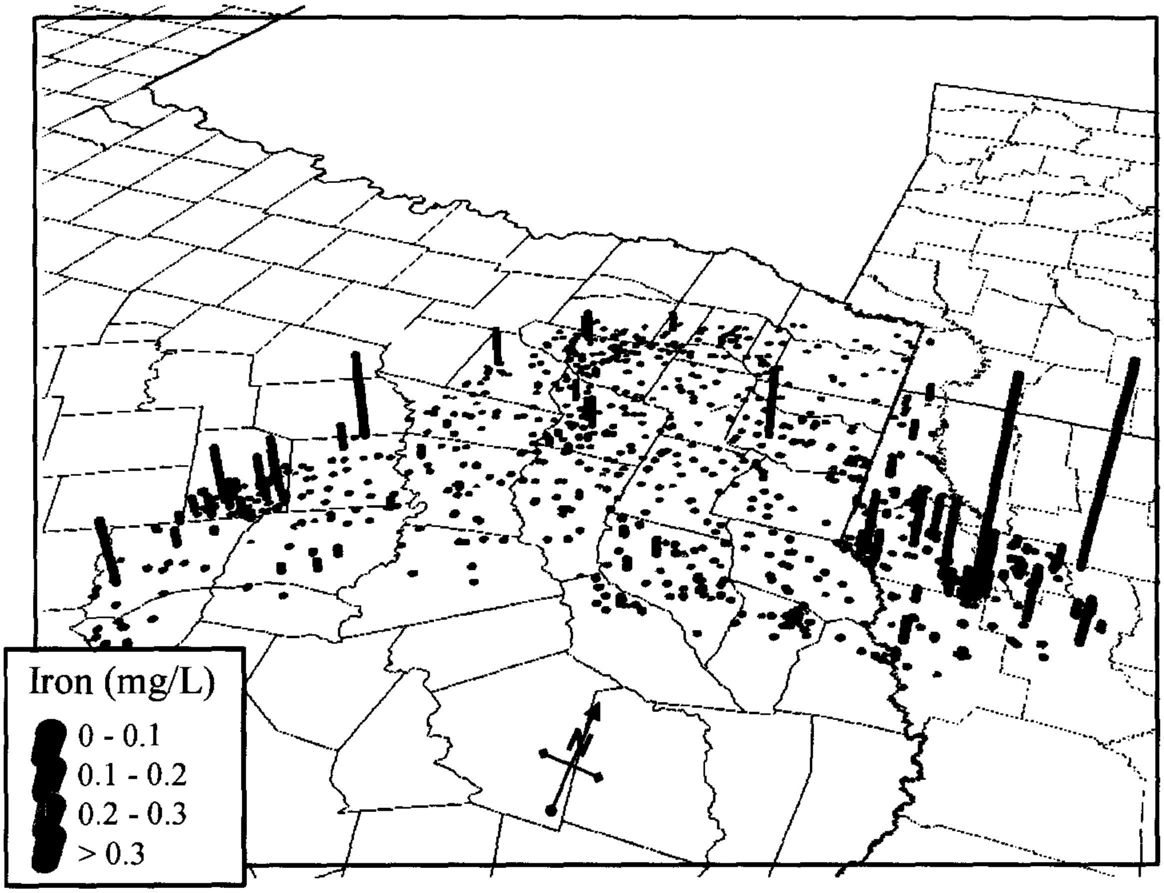


Figure F.4 Maximum observed sodium hazard levels.

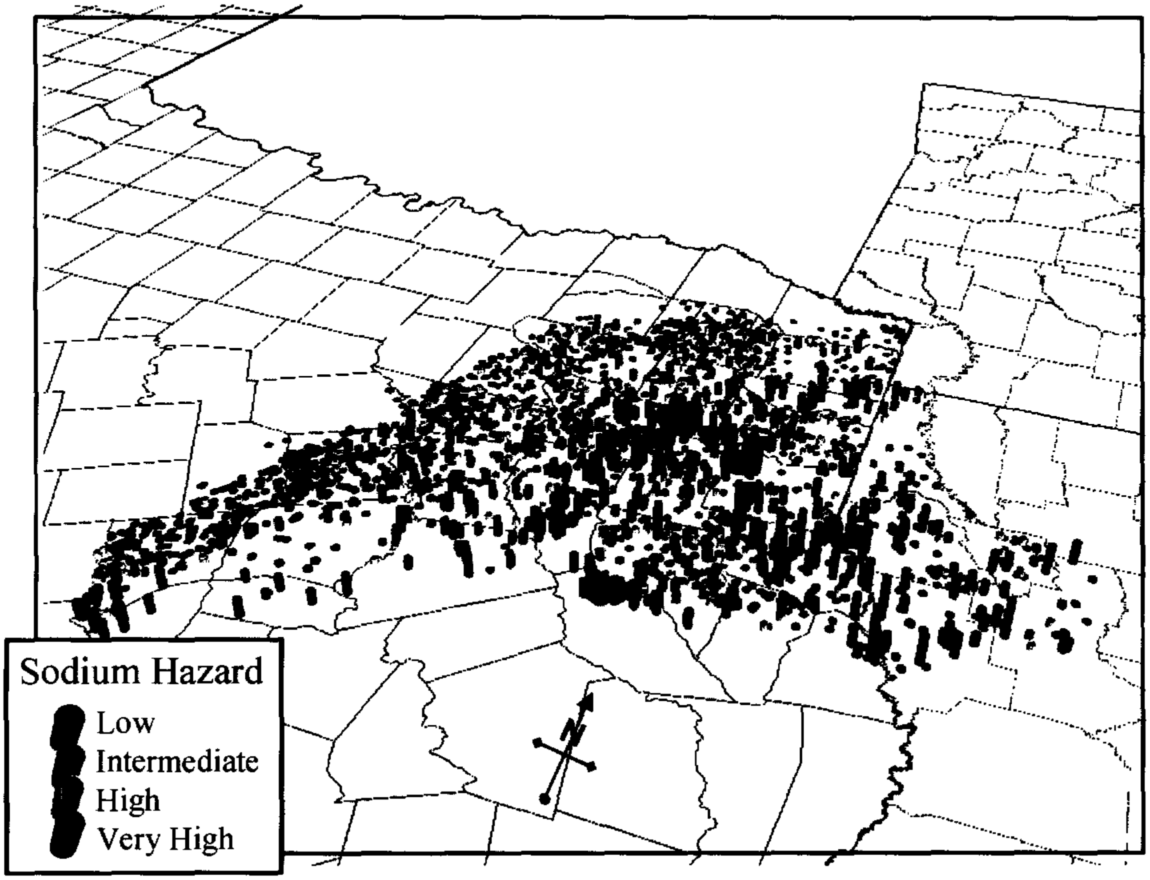


Figure F.5 Maximum observed total dissolved solids (TDS) levels.

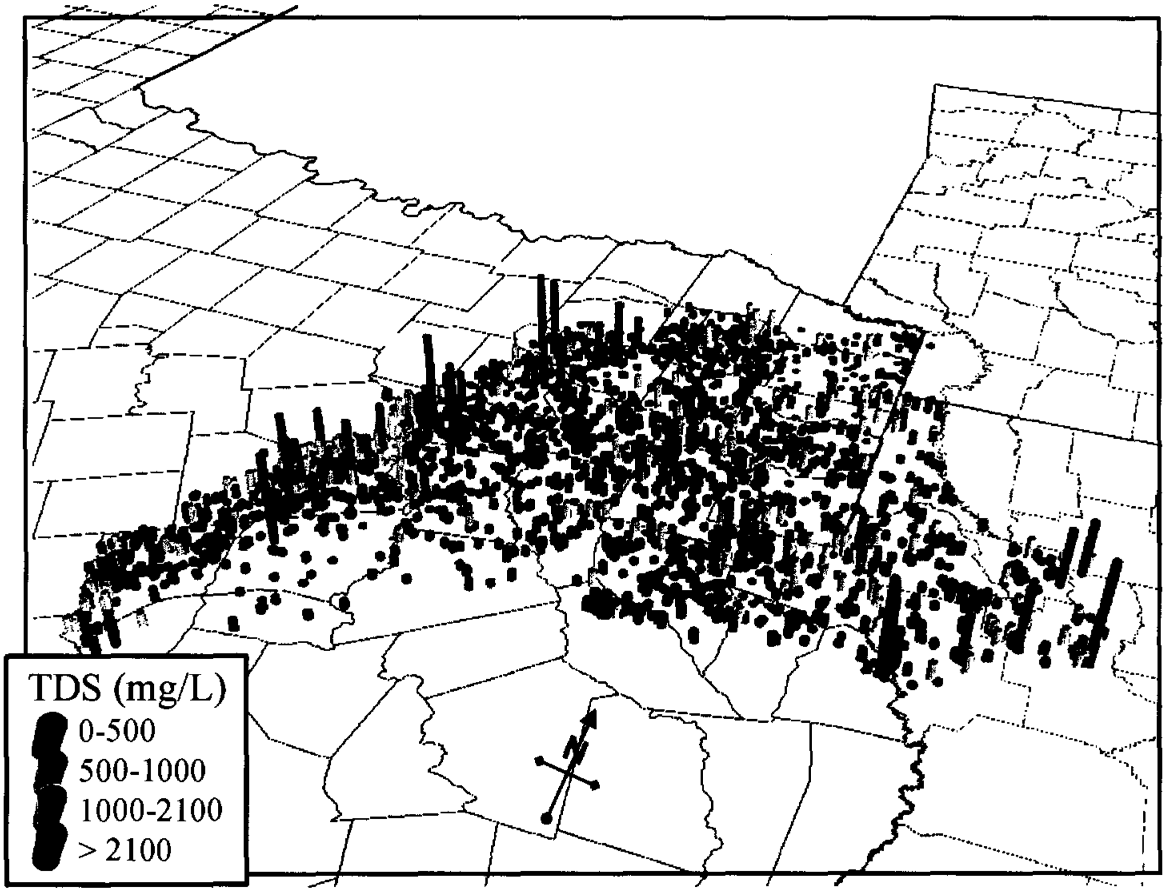


Figure F.6 Maximum observed hardness levels.

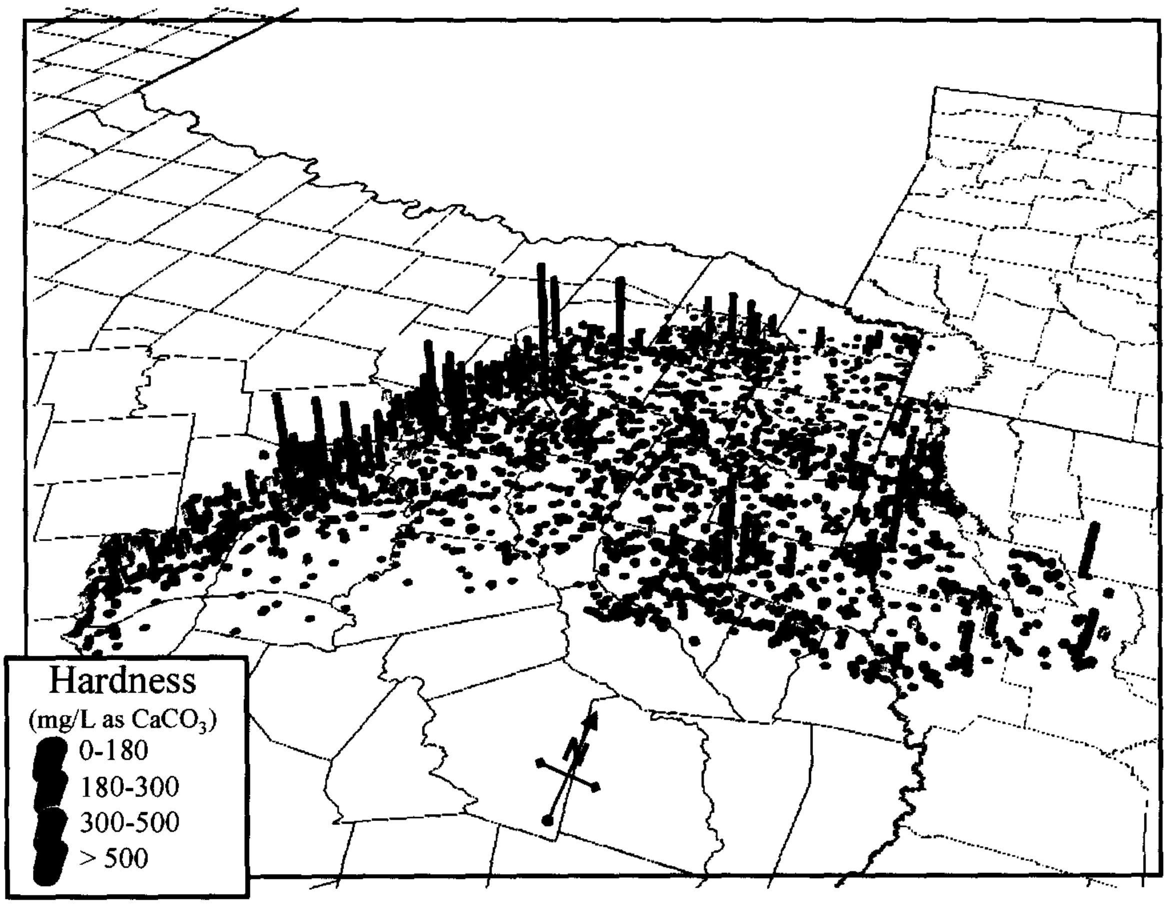
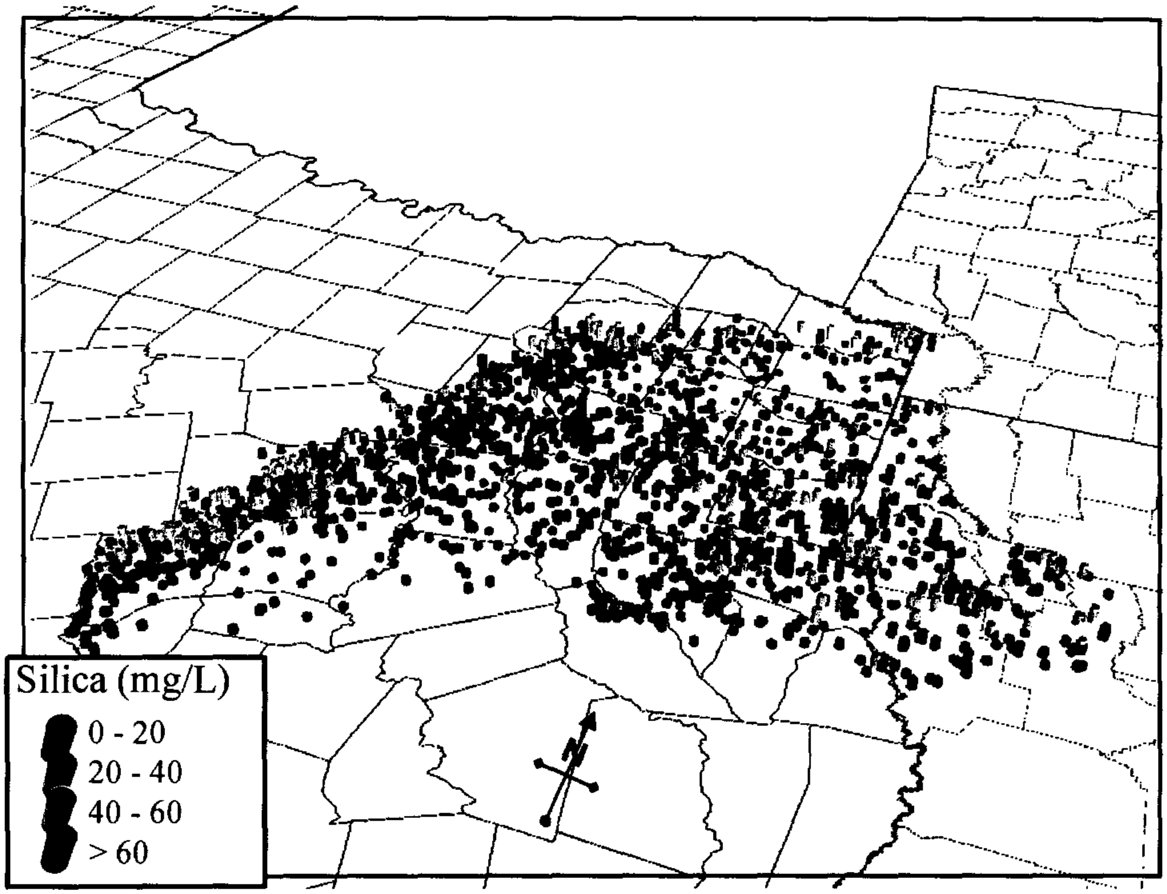


Figure F.7 Maximum observed silica levels.



APPENDIX G

Draft report Comments and Responses

Appendix G

Responses to Texas Water Development Board Comments on the September 2002 Draft Report

TEXAS WATER DEVELOPMENT BOARD
Review of the Draft Final Report: Contract No. 2001-483-377
" Groundwater Availability Model for the Northern Carrizo-Wilcox Aquifer"

ADMINISTRATIVE AND TECHNICAL COMMENTS ON DRAFT REPORT

(Note: The Para Lines referred to below are the line numbers in the paragraph of the section and not the line number from the top of the page.)

General Comments:

1. Please consider using higher resolution graphics. Many of the graphics are pixelated.
   Completed.

2. Please include an authorship list.
   Completed.

3. Please include the following figures:
   - representative stream flow hydrographs for the major streams in the study area
     Completed. See Figure 9.2.3.
   - spring-flow hydrographs, if available
     None were available.
   - map of rural population density
     Completed. See Figure 4.7.1.
   - map of estimated recharge rates, factors or coefficients.
     Calibrated recharge rates for the steady-state model are shown in Figure 8.1.6. Calibrated recharge rates for the transient model averaged over 1980-1999 are shown in Figure 9.2.20.

Table of Contents:

1. Page i, Section 4.4.3: Change number of subsection to 4.4.4.
   Completed.
2. Page i, Section 4.4.4: Change number of subsection to 4.4.5.
   Completed.
3. Page ii, Section 8.1.2: Change number of subsection to 8.1.3.
   Completed.
4. Page ii, Section 8.1.3: Change number of subsection to 8.1.4.
   Completed.

Abstract:

1. Please add a short summary of the main findings of the study including the predictions for the next 50 years. The limitations of the study, and areas that need improving for similar future studies, should be listed.
   Completed.

Section 1: Introduction

1. Section 1.0, Page 1-3: Please add information on Region D's water needs and supply plans, similar to that of Region I.
   Completed.

Section 2: Study Area

1. Section 2.2, Page 2-14, Para 3, Para Line 4: Reference Mexia-Talco fault zone to a figure.
   Reference to the Mexia-Talco fault zone was removed from this sentence since this section is not dealing with structure. The Mexia-Talco fault zone is shown on Figure 4.2.1 under Section 4.2, Structure.
2. Section 2.2, Page 2-18, Para 6, Para Line 5: Are the lower and upper Wilcox formations formal stratigraphic units? If they are, please capitalize lower and upper.
   This division is informal; upper and lower will not be capitalized.
3. Section 2.2, Page 2-21, Para 7, Para Line 7: Please correct the spelling of "Fischer and McGowan". The correct spelling is Fisher and McGowen.
   Completed.
5. Section 2.2, Page 2-21, Para 7, Para Line 18: Please correct the spelling of McGowan. The correct spelling is McGowen.
   Completed.

Section 3: Previous Investigations

1. Section 3.0, Page 3-1, Para 3, Para Line 2: "Oakwood Dome". Please describe the general location of this feature or show on a map.
   Completed.
2. Section 3.0, Page 3-4, Para 8, Para Line 5: Please add "Formation" at the end of "Newby".
   Completed.
3. Section 3.0, Page 3-4, Para 8, Para Line 7: Please verify year "1985". It is cited as "1988" in Table 3.1.
   Completed.

Section 4: Hydrogeologic Setting

1. Section 4.0: Hydrogeologic Setting. Please include a sub-section on the water-quality work done for the project.
   Completed. Added as Section 4.8.
2. Section 4.2, Page 4-13, Para 4, Para Line 10: Please delete "certain", and give examples (with locations) of where the Reklaw is relatively thin.
   Deleted sentence. False points were added in areas where data were sparse and kriging created artifacts.

3. Section 4.2, Page 4-21, Para 5, Para Line 10: Please show the Trinity River on the maps if it is being used extensively as a reference feature.
   Completed. The Trinity River is shown and labeled on Figures 2.2 and 2.13.
4. Section 4.2, Page 4-21, Para 5, Para Lines 12, 13: The observation "indicating a more east-west trend in the deeper section." is not clear. Please clarify.
   Deleted "indicating a more east-west trend in the deeper section."
5. Section 4.3, Page 4-21, Para 1, Para Lines 2 and 7: Please correct the reference to Mace et al. Cited as "2000a" in References.
   Completed.
6. Section 4.3, Page 4-22, Para 3, Para Line 2: Please correct the reference to Mace et al. Cited as "2000a" in References.
   Completed.
7. Section 4.3.1, Page 4-23, Para 2, Para Line 3: Please clarify that the aquifer code is the TWDB aquifer code.
   This section was rewritten to clarify the methodology used for processing the hydraulic conductivity database. TWDB is included with "aquifer code" where it is mentioned in the new text.
8. Section 4.3.1, Page 4-23, Para 2, Para Line 5: Is it 4,108 or 5,108 (1,680 + 3,430 - 2)? Please check all other numbers accordingly, later in the paragraph.
   This section was rewritten to clarify the methodology used for processing the hydraulic conductivity database.
9. Section 4.3.2, Page 4-25, Para 2, Para Line 1: Please correct the reference to Mace et al. Cited as "2000a" in References.
   This section was rewritten to clarify the methodology used for processing the hydraulic conductivity database. The citation is no longer included in this section.
10. Section 4.3.2, Page 4-25, Para 2, Para Line 6: Please explain what CDF stands for.
    This section was rewritten to clarify the methodology used for processing the hydraulic conductivity database. CDF is defined.
11. Section 4.3.3: Spatial Distribution of Hydraulic Property Data. Please explain how K was kriged. The distribution does not look like a simple-kriged distribution.
    Log hydraulic conductivities were kriged in Surfer 7.02 using ordinary kriging.
12. Section 4.3.3: Spatial Distribution of Hydraulic Property Data. Please include a discussion on horizontal anisotropy.
    Completed.
13. Section 4.3.3, Page 4-27, Para 4, Para Lines 6, 7: Please check the accuracy of the statement that the Carrizo sand decreases in thickness southward. On page 4-21 it is stated that the thickness of the unit increases to the southeast.
    These sentences were rewritten. The Carrizo thickens significantly only to the southwest.
14. Section 4.3.4, Page 4-38, Para 5, Para Line 2: McGown and Fisher (1976) is not in the Reference list. Is it Fisher and McGowen (1976)?
    Completed.
15. Section 4.4.3, Page 4-55, Para 3, Para Line12, 13: Possible contradiction to the statement that flow is upward. Earlier in the para, on line 5, it states that flow is downward.
    The last two sentences of this paragraph have been removed to eliminate this inconsistency.
16. Section 4.4.3, Page 4-58, Para 2, Para Line 6: Please clarify if all water levels were used if they met "any" criterion or "all" criteria.
    Completed; water levels were used if any of the criteria were met.
17. Section 4.5, Page 4-86: Recharge. Please discuss possible temporal variations in recharge.
    Completed.

18. Section 4.5, Page 4-87, Para 2, Para Lines 7, 8: Please explain why the Wilcox Group has good potential for recharge.
    Completed.
19. Section 4.5, Page 4-87, Para 3, Para Line 7: Atascosa County is not in the study area. Please mention this.
    Completed.
20. Section 4.6, Page 4-93, Para 4: Table 4.6.2 shows springs in the study area. Have these springs been assigned as drains in the model? If so, what are the simulated discharges at these springs?
    As noted in Section 6.3.3, springs with significant flow rates were in or very near modeled stream segments and were, therefore, not included as drains.
21. Section 4.6, Page 4-93, Para 4, Para Line 4: Please clarify if the spring survey was a field survey or a literature survey.
    Completed; it was a literature survey.

Section 5: Conceptual Model of Groundwater Flow in the Aquifer

1. No comments.

Section 6: Model Design

1. Section 6.3.4, Page 6-9, Para 4, Lines 8, 9: "This rooting depth is passed through to MODFLOW as the extinction depth required by the MODFLOW recharge package." Do the authors mean MODFLOW ET package?
   Completed; "Recharge package" was changed to "ET package".
2. Section 6.3.2, Page 6-5, Para 1, Para Line 7: Please check reference of "Williamson et al. (1989). Is cited as "Williamson et al., 1990" in the References section.
   Completed.
3. Section 6.3.3, Page 6-6, Para 3, Para Line 8: Lowercase "Alluvium".
   Completed.
4. Section 6.4.1, Page 6-10, Para 2, Para Line 3: Please check and correct the year in "Gutjahr et al., 1967". It is cited as 1978 in the References section.
   Completed.
5. Section 6.4.1, Page 6-11, Para 3, Para Line 2: Correct the reference to Mace et al. Cited as "2000a" in References.
   Completed.
6. Section 6.4.1, Page 6-13, Para 8, Para Line10: Please explain why a percent sand study was not done for the Queen City Sand.
   Completed. Because the Queen City Formation was not in the scope of the Carrizo-Wilcox GAM and because it was added to act as a boundary condition for the Carrizo-Wilcox GAM, we did not consider a detailed study of the Queen City Formation necessary.
7. Section 6.4.2, Page 6-14, Para 2, Para Line 3: Please correct the typo "Mace at al (200)." Should be "Mace et al. (2000a)".
   Completed.

Section 7: Modeling Approach

1. Section 7.2, Page 7-5, Para 3, Para Line 3: Please check and correct the reference of "(Williamson et al., 1989)". It is cited as "1990" in the References section
   Completed.

Section 8: Steady-State Model

1. Section 8.1.2, Page 8-1: Please include maps showing extinction depth and final ET rate (ET max). Please also append the potential ET map and actual ET map obtained from the SWAT in Appendix E. SWAT model (into one or more CDs) used to estimate recharge and ET should also be submitted.
   Maps showing steady-state ET extinction depth and calibrated ET max were added as Figures 8.1.7 and 8.1.8. Maps showing average potential ET and average actual ET in SWAT were included as Figures E.2 and E.3 in Appendix E. The SWAT data is included on CD.
2. Section 8.1.2, Page 8-1, Para 1, Para Line 7: Please explain why spatial Kh distribution for Layer 1 was considered preliminary.
   Because the Queen City Formation (Layer 1) was not in the scope of the Carrizo-Wilcox GAM and because it was added to act as a boundary condition for the Carrizo-Wilcox GAM, we did not consider a detailed study of the Queen City Formation necessary.
3. Section 8.1.2, Page 8-2, Para 4, Para Line 4: Reference to "Figure 8.1.4" is incorrect. Please change to "Figure 8.1.5."
   Completed.
4. Section 8.1.3, Page 8-3, Para 1, Para Line 4: Please check and correct the reference of "(Williamson et al., 1989)". It is cited as "1990" in the References section.
   Completed.
5. Section 8.2, Page 8-12: Simulation Results. Please include MAE and ME along with RMS.
   Completed. ME and MAE were added to Table 8.2.1.
6. Section 8.2.1, Page 8-14, Para 8, Lines 2, 3: Please include actual values to replace the XXX and YYYs.
   Completed.
7. Section 8.2.2, Page 8-14: Streams. Please include an assessment of how well the simulated stream baseflow matches the measured streamflow.
   Completed. Simulated stream baseflow was compared to available gain/loss estimates.
8. Section 8.2.2, Page 8-14, Para 1, Para Line 3: Please clarify if "These are" are losses.
   Completed.
9. Section 8.3, Page 8-28, Para 1: Please renumber the equations. Should be "8.3.1, 8.3.2 and 8.3.3", and change in the text where applicable.
   Completed.

Section 9: Transient Model

1. Section 9.1, Page 9-1, Para 3, Para Line 3: Specific storage value is not in the same units as that in 6.4.2. Please correct.
   Completed.
2. Section 9.1, Page 9-2, Para 3, Para Line 4: Please correct the reference to Mace et al. Cited as "2000a" in References.
   Completed.
3. Section 9.2, Page 9-4: Simulation Results. Please include MAE and ME along with RMS.
   Completed. ME and MAE were added to Table 9.2.1.
4. Section 9.2.1, Page 9-4, Para 1, Para Line 5: Please explain why a hydraulic head contour map was not produced for the Queen City.
   Because the Queen City Formation was not in the scope of the Carrizo-Wilcox GAM and because it was added to act as a boundary condition for the Carrizo-Wilcox GAM, we did not consider a detailed study of the Queen City Formation necessary.

5. Section 9.2.3, Page 9-8, Para 1, Para Line 8: Please change “Figure 9.2.5” to “Figure 9.2.25”.
   Completed.
6. Section 9.3, Page 9-44, Para 6, Para Line 3: Please change “Figures 9.3.9” to “Figure 9.3.9”.
   Completed.

Section 10: Model Predictive Simulations

1. No comments.

Section 11: Limitations of the Model

1. Section 11.1, Page 11-2, Para 3, Para Line 6: Please explain why the pumping data must be considered uncertain, or reference another section if it has been discussed there.
   Completed. An expanded discussion has been added to Section 11.
2. Section 11.2, Page 11-3, Para 2, Para Line 5: Please explain why this is not considered a significant limitation of the model.
   Completed.
3. Section 11.2, Page 11-4, Para 4, Para Line 9: Please explain when and where the adjustments have to be examined in more detail.
   We examined the problem that MODFLOW encountered when ET approached or exceeded recharge under steady-state conditions and determined that the problem is probably inherent to MODFLOW in cases where depth to groundwater is shallow.

Section 12: Future Improvements

1. Section 12.1, Page 12-1, Para 4, Para Line 6: Please explain the kind of monitoring required.
   Completed.
2. General: Are any pumping-data improvements necessary?
   Completed.

Section 13: Conclusions

1. Section 13.0, Page 13-1, Para 1, Para Line 6: Please change “Queen City Clay Formation” to “Queen City Sand”
   Completed.
2. General: Please expand the discussion of the predictive results with at least some specific highlights of the results and areas.
   Completed.
3. General: Please mention the regional scale of the model.
   Completed.

Section 14: Acknowledgements

1. No comments.

Section 15: References

1. Page 15-1: Alexander and White, 1966 should appear before Anders, 1967.
   Completed.
2. Page 15-4: Grubb, 1997 should appear before Guevara and Garcia, 1972.
   Completed.
3. Page 15-7: Page and May, 1964 should appear before Page, Newcome and Graeff, 1963.
   Completed.

Figures:

Section 1: Introduction

1. No comments.

Section 2: Study Area

1. Figure 2.2, Page 2-3: Please simplify the map. Include only large streams. Keep only major roadways.
   Completed.
2. Figure 2.3, Page 2-4: Please change the title to "Areal extent of the major aquifers in the study area." The figure also shows the downdip part of the aquifer in Texas.
   Completed.
3. Figure 2.5, Page 2-7: Please add the Lake Country Groundwater Conservation District (Wood County) to the map. The district is yet to be confirmed. Also, the following districts were confirmed at the 11/05/02 elections: Bluebonnet GCD, Brazos Valley GCD and the Mid-East Texas GCD.
   Completed.
4. Figure 2.6, Page 2-8: Please enlarge map. Remove the subtitle in the legend box and simplify scale. Lakes in legend box are not shown on the map.
   Completed.
5. Figure 2.7, Page 2-9: Label large towns for reference?
   Completed.
6. Figure 2.8, Page 2-11: Please correct the title to "Average pan evaporation rate, in inches per year, in the study area." Describe in the legend what the grid blocks are.
   Completed.
7. Figure 2.9, Page 2-12: Please add a number to the precipitation gage symbol in the legend box to match the map. In the title, change "available for" to "in".
   Completed.
8. Figure 2.10, Page 2-13: Oregon Climate Services is not listed in the References. Please list.
   Completed. See page 2-11.
9. Figure 2.11a, Page 2-15: Ellis County is not within or close to the study area. Is this graph appropriate?
   Since this figure was designed to show regional trends in precipitation, we feel that showing the gage in Ellis County is appropriate.

10. Figure 2.12, Page 2-17: Please label the Trinity River on the map since it is referred to in the text and used to describe the stratigraphy. In the table below the map, add River to Trinity at both locations. In the stratigraphy table, correct the spelling of Quarternary (should be Quaternary). In legend box, add A and A' to the cross section line and change "trace" to "line". Show Sabine Uplift, East Texas Basin, Houston Embayment and Mexia-Talia Fault on the map?
    The structural features were not added because they made the figure too confusing. Structural features are shown on Figure 4.2.1. All other comments completed.
11. Figure 2.13, Page 2-19: Please correct the spellings of "Claibourne" and "Recklaw". Should be "Claiborne" and "Reklaw", respectively. Also, please add a comma after "Kaiser et al."
    Completed.
12. Figure 2.14, Page 2-20: The cross-sections are hard to read. Can they be enlarged? Also, in the title, please add that the cross-section lines are shown in Figure 2.12.
    Completed.

Section 3: Previous Investigations

1. Figure 3.1, Page 3-3: In the title, please add "Carrizo-Wilcox" after "Northern". Check the references to Harden and Associates and Thorkildsen. They are listed as 2001, and Thorkildsen et al., 1989, respectively, in the Reference section.
   Completed. The Thorkildsen reference was corrected to Thorkildsen and Price. The Harden and Associates reference was corrected in Section 15.

Section 4: Hydrogeologic Setting

1. Figure 4.1.1, Page 4-3: Please correct the spellings of "Claibourne" and "Recklaw" to "Claiborne" and "Reklaw", respectively.
   Completed.
2. Figure 4.2.1, Page 4-4: Please add an explanation for the arrows (e.g., regional dip of the geological units) in the legend.
   Completed.
3. Figure 4.2.2 to 4.2.8, Pages 4-6 to 4-12: On all the maps, please note the contour interval used. Also, give complete reference (e.g., with year) for all sources of data listed under "Data Sources". Remove any outcrop symbols in the legend box not shown on the map. On Figure 4.2.8, add a space between "map" and "of" in the title.
   Completed. Contour interval was added to the figure titles. Complete references for all data sources are included in Table 4.2.1.
4. Figures 4.2.9 to 4.2.15, Pages 4-14 to 4-20: On all the maps, please note the contour interval used. On Figure 4.2.15, correct the title by removing "younger" and lowercasing "Formation."
   Completed. Contour interval was added to the figure titles.
5. Figure 4.3.1, Page 4-26: What is CDF? Please spell out. Also, use smaller font for the horizontal axis.
   Completed.
6. Figure 4.3.2, Page 4-28: Please use smaller font for the horizontal axis.
   Completed.

7. Figures 4.3.3 to 4.3.7, Pages 4-29 to 4-34: Please use comma separators for the numbers in the variograms.
   Because these are insets, they will be left as is.
8. Figure 4.3.8, Page 4-37: Please label the figures as (a) and (b) and reference them as such in the title, instead of "top" and "bottom". Also in the title, change "maximum sand thickness of the upper Wilcox and hydraulic conductivity (Log K)" to "maximum sand thickness and hydraulic conductivity (Log K) of the upper Wilcox."
   Completed.
9. Figure 4.3.9, Page 4-39: Please add contour interval used. Check reference of "Fisher and McGowen, 1976". It is listed as "1967" in the References section.
   Completed. Contour interval was added to the figure title.
10. Figure 4.4.1, Page 4-42: Please correct the spelling of "seperate" at both locations.
   Completed.
11. Figure 4.4.2, Page 4-44: Please change the title. It only mentions the Carrizo Sand and the Wilcox Group, but the map shows other aquifers.
   Completed.
12. Figure 4.4.6, Page 4-54: Please add comma separators to numbers on the axes.
   Completed.
13. Figure 4.4.7, Page 4-56: Why is data for the Cypress aquifer included in the map?
   The Cypress aquifer is discussed on page 4-41 and is included here for completeness.
14. Figure 4.4.8, Page 4-57: Please add comma separators to numbers on the axes. Again, explain why data for the Cypress aquifer is included?
   Completed. The Cypress aquifer is discussed on page 4-41 and is included here for completeness.
15. Figures 4.4.9a to 4.4.9e, Pages 4-59 to 4-63: Please add contour interval to all maps in this series and the unit of elevation, in the legend.
   Completed.
16. Figures 4.4.10a to 4.4.10d, Pages 4-65 to 4-68: Please add contour interval to all maps in this series and the unit of elevation, in the legend.
   Completed.
17. Figures 4.4.11a to 4.4.11d, Pages 4-69 to 4-72: Please add contour interval to all maps in this series and the unit of elevation, in the legend.
   Completed.
18. Figures 4.4.16a to 4.4.19b, Pages 4-78 to 4-85: Please add contour interval to all maps in this series and the unit of elevation, in the legend. Also, make a note that (-) values mean decline and (+) values mean rise.
   Completed.
19. Figure 4.5.1, Page 4-90: Please make a note that reservoir numbers are listed in Table 4.5.2 and the reservoir characteristics described there.
   Completed.
20. Figure 4.6.1, Page 4-94: Please check reference year of Slade, Bentley and Michaud. It is listed as 2002 in the References section, and in the figure title. Make a note in the legend that the survey numbers are listed in Table 4.6.1, and details are provided in this table.
   Completed.

21. Figure 4.6.2, Page 4-96: Please make a note in the legend that the spring numbers are listed in Table 4.6.2 and details about the springs are provided in this table.
    Completed.
22. Figures 4.7.1 to 4.7.6, Pages 4-107 to 4-109: Please remove the subtitles in the legend box. Change the title to read "XXXX (Layer Y) pumpage (AFY), 1990."
    Completed.

Section 5: Conceptual Model of Groundwater Flow in the Aquifer

1. Figure 5.1, Page 5-5: In the cross-section, correct Es to Esb. Please show offsets on the faults.
   Completed.

Section 6: Model Design

1. Figure 6.2.1, Page 6-15: Please redesign the map to make the county names legible. Are rivers and lakes necessary on this map?
   Completed.
2. Figure 6.3.1 to 6.3.6, Pages 6-16 to 6-21: Please include a box to show active cells in the legend.
   Inactive cells are shown in the legend. All other cells are active.

Section 7: Modeling Approach

1. No comments.

Section 8: Steady-State Model

1. Figures 8.1.1 to 8.1.4, Pages 8-6 to 8-9: Please use either Kh in the title and legend box, or horizontal hydraulic conductivity in both places.
   Completed.
2. Figure 8.1.5, Page 8-10: Please explain what Kh and Kv stand for.
   Completed.
3. Figures 8.2.1a to 8.2.5, Pages 8-18 to 8-26: In the legend box explain that the symbols are residuals and the blue lines hydraulic head contours. Provide contour intervals and units of measurements. Also, in Figure 8.2.1a, delete "and" in the title between "residuals" and "for".
   Completed.
4. Figure 8.2.6, Page 8-27: Use comma separators for numbers.
   Completed.
5. Figures 8.3.1 to 8.3.10, Pages 8-31 to 8-35: Explain what Kv, Kh, and K stand for wherever applicable on these figures. Please assign negative signs to all fraction values left of 0. Please also include +/- 10 % in these sensitivity plots.
   The sensitivity titles in the legends of these figures have been included in the text with each sensitivity definition in Section 8.3. There was not enough room on the figures to fully define Kv, Kh, and K on each figure. The sensitivities are listed as positive fractions instead of +/- percent so that the values on the figures correlate to the equations listed in the text. The sensitivities at 0.9 and 1.1 are at +/- 10%.

Section 9: Transient Model

1. Figures 9.2.1 to 9.2.5, Pages 9-11 to 9-15: Please provide units of measurement and contour intervals on all maps. Relocate numbers that overlie each other.
   Completed.
2. Figures 9.2.6 to 9.2.9, Pages 9-16 to 9-19: Please provide units of measurement and contour intervals on all maps. Relocate numbers that overlie each other. Explain what (-) and (+) values mean.
   Completed. Explanation of positive/negative residuals is included in the text.
3. Figures 9.2.12 to 9.2.15, Pages 9-22 to 9-25: Please provide units of measurement and contour intervals on all maps. Relocate numbers that overlie each other.
   Completed.
4. Figures 9.2.16a to 9.2.19, Pages 9-26 to 9-36: Please indicate (either in map title or legend) points/lines that are simulated heads and points/lines that are measured heads.
   Completed.
5. Figure 9.2.23, Page 9-40: Please redesign the graphs so that two different data sets are visible.
   Completed.
6. Figure 9.2.24, Page 9-41: Correct the reference of Slade et al. in both figure and title. Should be Slade et al., 2002.
   Completed.
7. Figures 9.3.1 to 9.3.10, Pages 9-46 to 9-50: Please explain what Kv, Kh and K denote in these figures. Assign negative signs to all fraction values left of 0. Please also include +/- 10 % in these sensitivity plots.
   The sensitivity titles in the legends of these figures have been included in the text with each sensitivity definition in Section 9.3. There was not enough room on the figures to fully define Kv, Kh, and K on each figure. The sensitivities are listed as positive fractions instead of +/- percent so that the values on the figures correlate to the equations listed in the text. The sensitivities for +/- 10% were not performed because the sensitivities are almost linear and additional sensitivities at +/- 10% would not add significant additional information to the plots. Since these sensitivities can be estimated from the +/- 25% sensitivities presented, the TWDB has agreed that the additional runs are not needed.

Section 10: Model Predictive Simulations

1. Figure 10.1.1, Page 10-5: Years 1952 and 1956 have been repeated on the horizontal axis. Change to 1953 and 1957, respectively.
   Completed.
2. Figures 10.2.1 to 10.2.18, Pages 10-11 to 10-28: Identify each figure on a 2-figure page with (a) and (b) and change title accordingly (delete “top” and “bottom” in the title). Add contour intervals to all figures.
   Completed. Contour interval was not included since the contour intervals are variable on the difference plots. Contour lines are labeled and scale bars are included for each figure.

Section 11: Limitations of the Model

1. No comments.

Section 12: Future Improvements

1. No comments.

Section 13: Conclusions

1. No comments.

Section 14: Acknowledgements

1. No comments.

Section 15: References

1. No comments.

Tables:

Section 1: Introduction

1. No comments.

Section 2: Study Area

1. No comments.

Section 3: Previous Investigations

1. Table 3.1, Page 3-1: Please check the reference for Thorkildsen (1991). It is not listed in the References. Also, check and correct reference for R.W. Harden and Associates (2000) which is listed as (2001) in the References section.
   The reference for Thorkildsen (1991) was corrected in Table 3.1. The reference for Harden and Associates was corrected in the Section 15.

Section 4: Hydrogeologic Setting

1. Table 4.2.1, Page 4-5: Please check and correct the reference for Wilson and Hosman (1987) at both locations. It is cited as (1988) in the References section.
   Completed.
2. Table 4.3.1, Page 4-24: Please explain in note what K and T denote.
   Completed.
3. Table 4.3.2, Page 4-41: Please check and correct references for Thorkildsen, and Harden and Associates.
   The reference for Thorkildsen et al. was corrected in Table 4.3.2. The reference for Harden and Associates was corrected in the Section 15.

4. Table 4.4.1, Page 4-52: Duessen (1914) is not listed in the References section.
   This reference was added to Section 15.
5. Table 4.5.1, Page 4-88: Please check and correct the following references: Harden and Associates (2000) and Thorkildsen et al. (1989). Also, the following two are not in the References section: Thompson (1972) and Guyton and Associates (1998).
   The references for Harden (2000), Thorkildsen et al. (1991), and Guyton & Assoc. and HDR (1998) were corrected in Table 4.5.1. The reference for Thompson (1972) was was added to Section 15.
6. Table 4.5.2, Page 4-91: Is there no information available for Clear Lake, Eastman Lakes, and Trinidad Lake?
   There was no information available for these lakes. This was so noted in the table.
7. Table 4.6.2, Pages 4-97 to 4-100: Please change Gunnar Brune, 1975 and 1981, to Brune, 1975 and 1981 everywhere in the table.
   Completed.

Section 5: Conceptual Model of Groundwater Flow in the Aquifer

1. No comments.

Section 6: Model Design

1. No comments.

Section 7: Modeling Approach

1. No comments.

Section 8: Steady-State Model

1. Table 8.1.1, Page 8-5: Table shows horizontal hydraulic conductivity and anisotropy ratio. Please insert a column to show calibrated vertical hydraulic conductivity that was used to calculate the anisotropy ratio.
   Completed.
2. Table 8.2.1, Page 8-16: Please add a note that RMS = Root Mean Square.
   Completed.

Section 9: Transient Model

1. Table 9.2.1, Page 9-9: Please add a note that RMS = Root Mean Square.
   Completed.
2. Table 9.2.2, Page 9-10: Please expand "Reser." and "Rech." in the column headings. It is unclear what they denote.
   Completed.

Section 10: Model Predictive Simulations

1. Table 10.3.1, Page 10-35: Please change title to "Water Budget (AFY) for Predictive Simulations." Also, explain in note what 2050* is (i.e., how is it different from 2050).
   Completed.

Section 11: Limitations of the Model

1. No comments.

Section 12: Future Improvements

1. No comments.

Section 13: Conclusions

1. No comments.

Section 14: Acknowledgements

1. No comments.

Section 15: References

1. No comments.

Appendices:

General Comment:

1. Please include in the appendix all of the transient plots comparing simulated to measured for the model. The reader should also be able to identify where these plots spatially relate to.
In Figures 9.2.16 to 9.2.19 there are 55 hydrographs shown with location information. We selected these hydrographs to be representative of the regional heads within the model and thus of the full set of hydrographs used for calibration and verification over the model region. The scatterplots shown in Figures 9.2.10 and 9.2.11 contain all target values for the calibration and verification periods. During discussions with the TWDB it was agreed that the 55 hydrographs presented are sufficient to represent the entire dataset. All hydrograph data is included in the data model.

Appendix A: Brief Summary of the development of the Carrizo-Wilcox Aquifer in Each County and List of Reviewed Reports

1. Please change "William F Guyton & Associations (1970)" to "William F. Guyton & Associates (1970)" everywhere that it is used in this appendix.
Completed.
2. Page A-25: Newcome et al. Please add "1963" to the reference.
Completed.

Appendix B: Standard Operating Procedures (SOPs) for Processing Historical Pumpage Data TWDB Groundwater Availability Modeling (GAM) Projects

1. No comments.

Appendix C: Standard Operating Procedures (SOPs) for Processing Predictive Pumpage Data TWDB Groundwater Availability Modeling (GAM) Projects

1. No comments.

Appendix D1: Tabulated Groundwater Withdrawal Estimates for the Carrizo-Wilcox for 1980, 1990, 2000, 2010, 2020, 2030, 2040 and 2050

1. No comments.

Appendix D2: Post Plots of Groundwater Withdrawal Estimates for the Carrizo-Wilcox for 1980, 1990, 2000, 2010, 2020, 2030, 2040 and 2050

1. No comments.

Appendix D3: Carrizo-Wilcox Groundwater Withdrawal Distributions by County

1. No comments.

Appendix E: Using SWAT with MODFLOW in a Decoupled Environment

1. No comments.

Stakeholder Comment:

1. First, when we did our first water plan for Region I, we had planned to use the TWDB's in house GAM for the Carrizo-Wilcox. Unfortunately the numbers were so large, indicating that we had a lot more ground water in the Carrizo and associated aquifers than our water users had be led to believe existed. So we did not use the GAM in our first plan. Of particular concern is the Nacogdoches Lufkin area where the level of the aquifer has dropped significantly over time due to pretty heavy pumping yet the model didn't seem (if I remember correctly) to show this. Your new model (the one you showed today) does seem to show this, but only after you went back in and changed some of the parameters (the Kv values on some of the layers) and the cause-effect relationship of why the changes worked could not be given. It appears that there are properties of the aquifer that affect water availability which are not adequately represented in the model. Is this fixable or are we going to be required to use this model for our next plan knowing it has problems?
   Vertical hydraulic conductivity (Kv) is not measurable on a model grid scale and is, therefore, a calibrated parameter. For the transient calibration, the Kv of the Reklaw was important for reproducing the observed cone of depression in the Carrizo-Wilcox aquifer. In the Nacogdoches County area, the simulated drawdown was actually greater than the observed drawdown and Kv of the Reklaw was increased to limit the simulated head decline in the area. On the other hand, in the Smith County area, Kv of the Reklaw was reduced to achieve the observed drawdown. The cones of depression are produced by groundwater withdrawals; consequently, accurate pumpage data are required to constrain the calibrated hydraulic parameters, particularly those parameters for which no measurements exist and have to be inferred from model calibrations.

   Second, one of the problems with the early model is that it showed a lot of water in the geologic layers above the Carrizo (the Queen City and Reklaw). This water is generally of low quality (high Fe, I think) and low yield, only able to support small production wells. I don't think your new model showed this water as being available but then you used this water in the adjustment of the Kv discussed above (at least that's what I understood). What is really happening here?"
   The volume of water that the Queen City can contribute as cross-formational flow to the Carrizo-Wilcox is strongly affected by the Kv of the Reklaw, which was adjusted during calibration to reproduce observed water levels, and accounted for in the Northern Carrizo-Wilcox GAM. However, the potential impact of leakage of low-quality water from the Queen City above the Reklaw into Carrizo-Wilcox is not explicitely modeled in this GAM (e.g., no transport calculations were performed). On the other hand, the calculated flow in this GAM indicates that because of the relatively low permeability of the Reklaw the actual travel time of water from the Queen City into the Carrizo is typically greater than the historical period (ie. 1900 – 2000) and would not be noticed in the water quality data.

   (Note: TWDB will address the policy portion of this comment regarding use of the GAM for planning purposes. The entire comment are being included for the sake of completeness.)

EDITORIAL COMMENTS ON DRAFT REPORT

Table of Contents:

1. Page ix, Figure 10.2.2: Please complete the parenthesis after Queen City.
   Completed.
2. Page ix, Figure 10.2.5: Please complete the parenthesis after upper Wilcox.
   Completed.
3. Page ix, Figure 10.2.7: Please complete the parenthesis after middle Wilcox.
   Completed.

Abstract:

1. No comments.

<u>Sections 1 to 15:</u>

General Comments:

1. If there are only two authors, list both authors instead of et al. Use et al. only if more than two authors.
   Completed.
2. Use "**Northern Carrizo-Wilcox GAM**" throughout the report instead of "north" or "northeastern".
   Completed.
3. Replace TNRCC with TCEQ (Texas Commission on Environmental Quality) everywhere in the report.
   Completed.
4. Use comma separators for numbers on all figures and tables (except years, of course), and in the text.
   Completed.
5. If two or more rivers, counties or geological units are listed, keep the "rivers", "counties", etc. lowercase (e.g., Walker and Grimes counties, Sabine and Neches rivers, Wilcox and Queen City formations).
   Completed.

Section 1: Introduction

1. Section 1.0, Page 1-1, Para 4, Para Line 1: Please delete "This" at the beginning of the sentence and replace with "The".
   Completed.
2. Section 1.0, Page 1-2, Para 4, Para Line 10: Please change "development of the model grid, development of the model" to "developing a model grid and model".
   Completed.

Section 2: Study Area

1. Section 2.0, Page 2-1, Para 1, Para Line 3: Please delete “River” from “Rio Grande River”.
   Completed.
2. Section 2.0, Page 2-1, Para 3, Para Line 6: Insert “the” between “as model”.
   Completed.

Section 3: Previous Investigations

1. No comments.

Section 4: Hydrogeologic Setting

1. Section 4.2, Page 4-21, Para 6, Para Line 6: Please change the spelling of “later”. Should be “latter”.
   Completed.
2. Section 4.3.5, Page 4-40, Para 2, Para Line 7: Please correct the spelling of “Clairborne” to “Claiborne”.
   Completed.
3. Section 4.4, Page 4-41, Para 2, Para Line 6: Please change “Broom and Alexander, 1965” to “Broom et al., 1965”.
   Completed.
4. Section 4.4.3, Page 4-55: Please change subsection number to “4.4.4”.
   Completed.
5. Section 4.4.4, Page 4-64: Please change subsection number to “4.4.5”.
   Completed.

Section 5: Conceptual Model of Groundwater Flow in the Aquifer

1. Section 5.0, Page 5-1, Para 2, Para Line 9: Please replace “gulf coast” with “Gulf of Mexico”.
   Completed.
2. Section 5.0, Page 5-2, Para 5, Para Line 2: Please delete“ evapotranspiration” and the parentheses around “ET”.
   Completed.

Section 6: Model Design

1. Section 6.3.4, Page 6-7, Para 1, Para Line 8: Please replace “evapotranspiration (ET)” with “ET”. It has already been defined.
   Completed.

Section 7: Modeling Approach

1. General: Change the tense in the entire section from future tense (we will perform) to past tense (we performed).
   Completed.

Section 8: Steady-State Model

1. Section 8.1, Page 8-1: Please add a brief description of the subsections that follow.
   Completed.
2. Section 8.1.2, Page 8-3: Please change subsection number to 8.1.3.
   Completed.
3. Section 8.1.2, Page 8-3, Para 2, Para Lines 1, 5, 8: Please replace "evapotranspiration" with "ET" on all these lines.
   Completed.
4. Section 8.1.3, Page 8-3: Please change subsection number to 8.1.4.
   Completed.
5. Section 8.2.3, Page 8-14, Para 1, Para Line 4: Please correct the spelling of "decending".
   Completed.

Section 9: Transient Model

1. Section 9.2, Page 9-4: Please include a short sentence or two describing the subsections that follow.
   Completed.
2. Section 9.2.1, Page 9-5, Para 5, Para Line 5: Please change "measure" to "measured".
   Completed.
3. Section 9.2.1, Page 9-5, Para 5, Para Line 7: Please change "decrease" to "decreases".
   Completed.
4. Section 9.2.1, Page 9-6, Para 7, Para Line 7: Please change "measure" to "measured".
   Completed.
5. Section 9.2.1, Page 9-6, Para 7, Para Line 13: Please change "increase" to "increased".
   Completed.

Section 10: Model Predictive Simulations

1. Section 10.1, Page 10-1, Para 1, Para Line 3: Please change "recurrent" to "recurring".
   Completed.
2. Section 10.1, Page 10-3, Para 6, Para Line 18: Uppercase "county".
   Completed.
3. Section 10.3, Page 10-34, Para 2, Para Line 3: Uppercase "formation".
   This paragraph was removed.

Section 11: Limitations of the Model

1. Section 11.1, Page 11-2, Para 3, Para Line 2: Please delete "s" from "Formations".
   Completed.

Section 12: Future Improvements

1. Section 12.2, Page 12-2, Para 1, Para Lines 5 to 7: Sentence is unclear. Please rewrite.
   Completed.

Section 13: Conclusions

1. No comments.

Section 14: Acknowledgements

1. No comments.

Section 15: References

1. General: For consistency, please add a comma everywhere between the last author's initials and the year of publication, or remove the comma where present.
   Completed.
2. Page 15-5: Isaaks and Srivastava, 1989. Please add a space between "University" and Press".
   Completed.
3. Page 15-6: Kaiser, Johnston and Bach, 1978. Please correct typo in "Beological".
   Completed.

Figures:

1. No comments.

Tables:

1. No comments.

Appendices:

Appendix A:

1. Please change "hydraulic connected" to "hydraulically connected" everywhere it appears in the text of the appendix.
   Completed.
2. Page A-11: Limestone County, Texas, Line 2. Change "Rettman 1994" to "Rettman 1984".
   Completed.

3. The following authors (Baker, et al., 1963; Bennett, 1942; Sundstrom et al., 1948; White, 1973) in the Reviewed Reports list are not referenced in the text of the appendix. Please include in the text or remove from the list of references.
The Reviewed Reports list includes all reports reviewed for information about development of the Carrizo-Wilcox aquifer, not just those referenced in the county summaries.

Appendix B:

1. No comments.

Appendix C:

1. No comments.

Appendix D1:

1. No comments.

Appendix D2:

1. No comments.

Appendix D3:

1. No comments.

Appendix E:

1. No comments.

COMMENTS ON THE DRAFT MODEL

1. Section 8: Steady-state model as provided fails to converge in PM 5.3.0 using MODFLOW version provided by the consultants. When we used the SIP solver, output.dat file flags "failed to converge at the end of time step 1". If we used PCG2 or SSOR, the steady-state model converges but the simulated heads generated don't match those included in the report. Because of this problem, additional review comments may be provided by the TWDB once the consultants have provided a workable steady-state model.
The TWDB successfully ran the steady-state model after retrieving the files from the data model CDs a second time. We suspect that the files may have been corrupted when originally retrieved from the data model CDs.

2. Section 9.0: Transient model 1980-1999 runs and produces the general distribution of the simulated heads as reported. In the simulated heads, we observed that some active cells around the outcrop areas go dry that were not accounted for in the report. These cells are active with ibound values of 1 and simulated head values of 999 indicative of dry cells. Please include the simulated heads more representative of the simulation runs. Please provide an explanation on the occurrences of these dry cells.
Some cells around the edges of the outcrops do go dry during the simulation. This is to be expected since many of the edge cells are thin (down to a thickness of 20 ft) and the water table could be below the base of these cells. Since the rewetting option was used, cells are allowed to dewater and resaturate. Dry cells were added to Figures 9.2.1 – 9.2.5 (end of calibration period) and 9.2.12 – 9.2.15 (end of verification period).

3. Section 9.0: Transient model. Please provide the bore hole file and the observation well file for the transient model so that we can review the RMS values.
Completed.

4. Please include a detailed water budget for:
   - steady-state
     Please see Table 8.2.2.
   - beginning of calibration period
     Please see Table 9.2.3.
   - the drought of the calibration period
     Completed. Added to Table 9.2.3.
   - end of the calibration period
     Please see Table 9.2.3.
   - end of the verification period
     Please see Table 9.2.3.
   - end of 2000, 2010, 2020, 2030, 2040, and 2050.
     Please see Table 10.3.1.

COMMENTS ON DRAFT DATA STRUCTURE

Did we get all of the data files we requested? NO
Is the data organized in the way we requested? YES

Introduction:

It is imperative that we receive enough source data to completely rebuild the groundwater model from scratch and reproduce all report figures and tables should it be necessary. In other words, if a new model grid resolution and/or orientation was needed, there should be sufficient data to create a new model for the study area. Moreover, there should be enough data to regenerate any or all of the intermediate derivative data with updated information. This source and intermediate derivative data should be organized under the SRCDATA folder/directory according to the guidelines set forth in Attachments 1 & 2 of the RFP. An empty directory tree structure was provided to facilitate the organization of the project data. The empty directory tree structure is available for download in zip format at http://www.twdb.state.tx.us/gam/resources/gam_tree.zip.

It is also required that all **final** model parameter and variable/stress data be delivered in a database format that can easily be referenced to each and every model grid cell. In other words, there should be enough cell-referenced data to regenerate all or update any individual cell value of the required MODFLOW or PMWIN input files. The file format of these databases may be in Excel 97, Access 97, or in an ESRI GIS format compatible with ArcView 3.2 or ArcInfo 7.21. Each sheet, table, or coverage should be attributed with the appropriate model grid cell-reference information as set forth in Attachments 1 & 2 of the RFP. These data sets should be organized under the GRDDATA folder directory and with in the appropriate sub-folders/directories. The GRDDATA OUTPUT folder and its sub-folders/directories may be omitted or left empty.

Finally, the actual MODFLOW 96 and PMWIN 5.0 formatted files for both INPUT and OUTPUT must be organized as set forth in Attachments 1 & 2 of the RFP. Separate folders/directories must be used for 1) the calibrated steady-state model files; 2) the calibrated transient model files; 3) the verification transient model files; 4) and each of the decadal transient predictive model simulation run files.

Review Summary:

The data provided by the CZWX_n contractor is missing some required data sets as listed in sections below. Listing files are needed within each folder/directory listing all file names or groups of file names and their contents

Descriptors were added.

The contractor did follow the requirements as set forth in Attachments 1 & 2 of the RFP for the most part. However, a few of the metadata files had incorrect spatial reference information or missing altogether. Furthermore, the SWAT model and all data used within the SWAT model must be provided in a separate folder/directory tree structure if used to calculate parameters for the ET, streamflow-routing, and/or recharge packages of MODFLOW.

Metadata was examined and augmented where necessary. SWAT data added in a separate directory.

DRIVE:\CZWX_n\grddata\input\hydraul

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access database files converted to Access97.

DRIVE:\CZWX_n\grddata\input\ibnd

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\stress\ststate\drns

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

N/A.

DRIVE:\CZWX_n\grddata\input\stress\ststate\evt

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\stress\ststate\rech

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access database files converted to Access97.

DRIVE:\CZWX_n\grddata\input\stress\ststate\res

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

N/A.

DRIVE:\CZWX_n\grddata\input\stress\ststate\strm

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

N/A.

DRIVE:\CZWX_n\grddata\input\storage

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\stress\ststate\well

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\stress\trans\drns

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

N/A.

DRIVE:\CZWX_n\grddata\input\stress\trans\evt

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\stress\trans\rech

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\stress\trans\res

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\stress\trans\strm

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\stress\trans\well

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access97 tables added.

DRIVE:\CZWX_n\grddata\input\struct

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access database files converted to Access97.

DRIVE:\CZWX_n\modflow\modfl_96\input\ststate

These files are acceptable.

DRIVE:\CZWX_n\modflow\modfl_96\input\trans

These files are acceptable.

DRIVE:\CZWX_n\modflow\pmwin_50\input\ststate

These files are acceptable except for missing calibration borehole file.

Borehole and observation files added.

DRIVE:\CZWX_n\modflow\pmwin_50\input\trans

These files are acceptable except for missing calibration borehole file.

Borehole and observation files added.

DRIVE:\CZWX_n\modflow\pmwin_50\refdxf

These files are acceptable.

DRIVE:\CZWX_n\scrdata\bndy

Need a listing file listing name of each file or grouped set of files and their contents or purpose.

Completed.

Aquifers coverage has incorrect spatial reference in metadata file.

Aquifers coverage was moved to \subhyd with corrected referencing.

DRIVE:\CZWX_n\scrdata\clim

Need a listing file listing name of each file or grouped set of files and their contents or purpose.

Completed.

The evaporation coverage needs a completed metadata file.

Spatial information added.

The monthly precipitation Access database must be compatible with Access97.

Access database files converted to Access97.

Redundant metadata files for precipitation raster data.

Redundant files removed.

DRIVE:\CZWX_n\scrdata\cnsv

Need a listing file listing name of each file or grouped set of files and their contents or purpose.

Completed.

The ecological regions coverages for Arkansas and Louisiana have incorrect projection information in metadata file.

Metadata corrected.

DRIVE:\CZWX_n\scrdata\geol

Need a listing file listing name of each file or grouped set of files and their contents or purpose.

Completed.

The outcrop delineations coverages need at least one metadata file or readme document describing the metadata and purpose of the coverages.

Completed.

Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access database files converted to Access97.

No cross-sections used in study? If yes, cross-sections must be provided under this folder.

N/A.

DRIVE:\CZWX_n\scrdata\geom

Need a listing file listing name of each file or grouped set of files and their contents or purpose.

Completed.

The DEM needs a completed metadata file.

Completed.

The DEM needs a completed metadata file and must be in units of feet rather than meters.

Completed.

A physiography coverage is required by RFP.

USGS coverage added.

DRIVE:\CZWX_n\scrdata\geop

NO DATA FOUND – geophysical data should go here if used in study.

N/A.

DRIVE:\CZWX_n\scrdata\soil

Need a listing file listing name of each file or grouped set of files and their contents or purpose.

Completed.

The runoff raster data for Texas needs a metadata file as well as for remaining soil coverages.

Runoff data not used in final model and was subsequently removed. Metadata added for soil coverages.

DRIVE:\CZWX_n\scrdata\subhyd

Need a listing file listing name of each file or grouped set of files and their contents or purpose.

Completed.

Unable to evaluate data because Access file format not compatible with Access97. Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access database files converted to Access97.

The binary Surfer grid files should be converted into ESRI, Access97, or ASCII format.

Completed.

Need source and intermediate derivative coverages used to spatially distribute pumpage data here.

Pumping datasets added.

Need source and intermediate derivative coverages used to spatially distribute water level data here.

Water level data added.

Need source and intermediate derivative coverages used to spatially distribute conductivity data here.

Hydraulic conductivity data added.

Need source and intermediate derivative coverages used to spatially distribute specific yield and porosity if available.

N/A.

Need point coverage of calibration target boreholes and hydrographs.

Target location coverage added.

DRIVE:\CZWX_n\scrdata\surhyd

Need a listing file listing name of each file or grouped set of files and their contents or purpose.

Completed.

Must make Access database file compatible with Access97 as stated in Attachments 1 and 2 of RFP.

Access database files converted to Access97.

DRIVE:\CZWX_n\scrdata\tran

Need a listing file listing name of each file or grouped set of files and their contents or purpose otherwise, these files are acceptable.

Completed.