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LAS VEGAS VALLEY
1998 SUBSIDENCE REPORT

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This information should be considered preliminary. It has not been edited or checked for completeness or accuracy.

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Scope of 1998 Subsidence Study

The 1998 subsidence study was designed to provide an updated database for detecting and monitoring groundwater-related land subsidence in Las Vegas Valley. The last previous subsidence studies were conducted in 1991 for a consortium of local, city, county, and federal agencies (Bell and Price, 1991). This present study was conducted through an interlocal agreement with the Las Vegas Valley Water District and the Nevada Bureau of Mines and Geology at the University of Nevada, Reno, and it consisted of three principal elements:

- Conventional level survey of benchmark lines previously established across geologic faults.
- GPS survey of benchmark network established in 1991.
- Re-inventory and mapping of earth fissures in the valley.

A fourth element-- analysis of synthetic aperture radar (SAR) imagery -- was added as the study progressed. A primary product of this study was the development of a SAR interferogram depicting subsidence throughout the valley during the 1992-97 period (Fig. 1)

The conventional level surveys were performed by Stantec Consultants (formerly SEA Engineers) and the data were provided to J.W. Bell for synthesis and evaluation. The GPS survey was supervised by A.R. Ramelli and assisted by K. Austin, a graduate student at the University of Nevada, Reno. The fissure inventory was conducted by C.M. dePolo. The SAR study was conducted by F. Amelung at the Department of Geophysics, Stanford University.

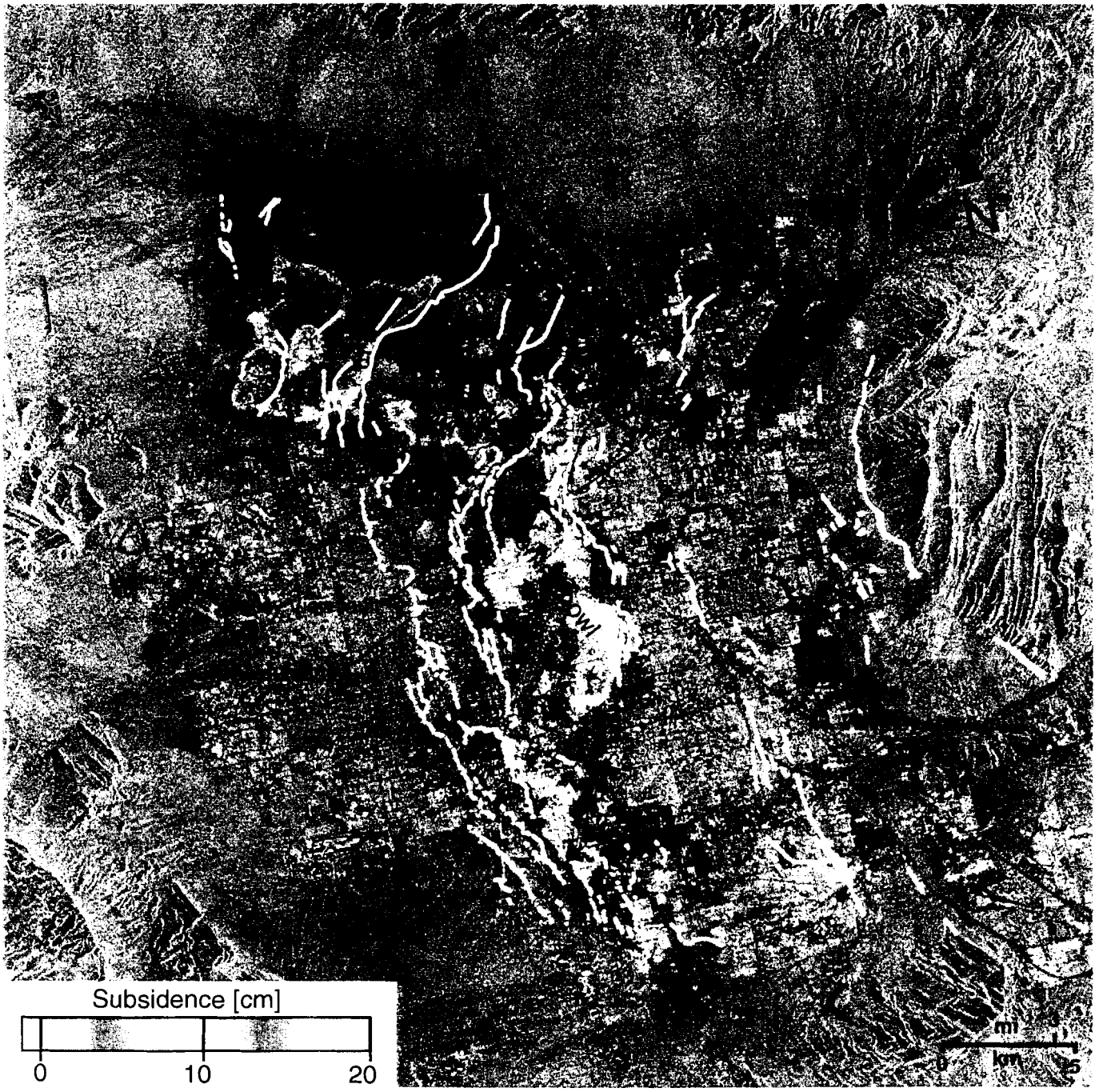


Figure 1. InSAR map showing subsidence in Las Vegas Valley between April, 1992 and December, 1997 based on three composite SAR interferograms (see Fig. 14). The base is the radar image covering the valley. Four localized subsidence bowls are delineated: the Northwest, North Las Vegas, Central, and Southern bowls. InSAR values are displayed as 10 cm color cycles; that is, each blue-red-yellow sequence represents 10 cm of subsidence. The Northwest bowl exhibits nearly 2 complete color cycles, or about 19 cm of subsidence, and a small area near Whitney Mes shows a reverse cycle indicating 1-2 cm of uplift. The subsidence bowls are bounded by the preexisting Quaternary faults (shown in white) which are acting as subsidence barriers. From Amelung et al. (1999).

Conventional Level Line Surveys

Eight second-order vertical control (level) lines were established across selected geologic faults in 1978 in order to monitor subsidence-induced differential movement across the faults. The lines were re-surveyed annually by the Nevada Department of Transportation until 1989. Beginning in 1991 the lines were surveyed by SEA Engineers (now doing business as Stantec, Inc) at which time one new line (line 11) and one line extension (east half of line 4) were added. In July, 1997 the lines were re-surveyed by Stantec as part of the present study. Line locations are shown on Figure 2, and the results for the individual level lines are shown in Figs. 3-10. Each line uses an assumed fixed station elevation to calculate elevations and to provide a measure of relative movement. The results for some lines show apparent positive movements because the lines are not fixed to surveyed orthometric heights.

Line 1

Line 1 originally crossed the Eglington fault near Ann Road and Decatur Boulevard, and was destroyed by development of the Los Prados subdivision in 1985. Results of leveling between 1978-85 (Fig. 3) indicated that this line showed the highest rate of movement of all lines in the valley (Table 1). A prominent subsidence spike of nearly 40 cm was measured across the Eglington fault during the 7 year period; this subsidence pattern was already evident in the 1979 survey, indicating that the Northwest bowl was active during the late 1970's.

Line 2

Line 2 extends across the Windsor Park fault(s) slightly east of the Windsor Park Subdivision in North Las Vegas (Fig. 2). Results of leveling for 1991-97 (Fig. 4) indicate that the pattern of movement across the faults remains similar to that found in the previous surveys, although the rate has slightly decreased. This line continues to show the greatest vertical differential between two adjacent benchmarks than any of the lines-- more than 25 cm differential movement between stations about 100 m apart. These movements are consistent with the results of independent level surveys conducted by the City of North Las Vegas Surveyors Office in the Windsor Park subdivision (discussed below).

Line 3

Line 3 extends across the Cashman Field fault at Lake Mead Boulevard. The 1991-97 leveling results indicate that the fault continued to move down to the west but at a significantly slower rate than previous years (Fig. 5). The total displacement of the west end of the line was more than 30 cm for the eleven year 1978-89 period, whereas the line subsided only 3 cm for the 1991-97 period.

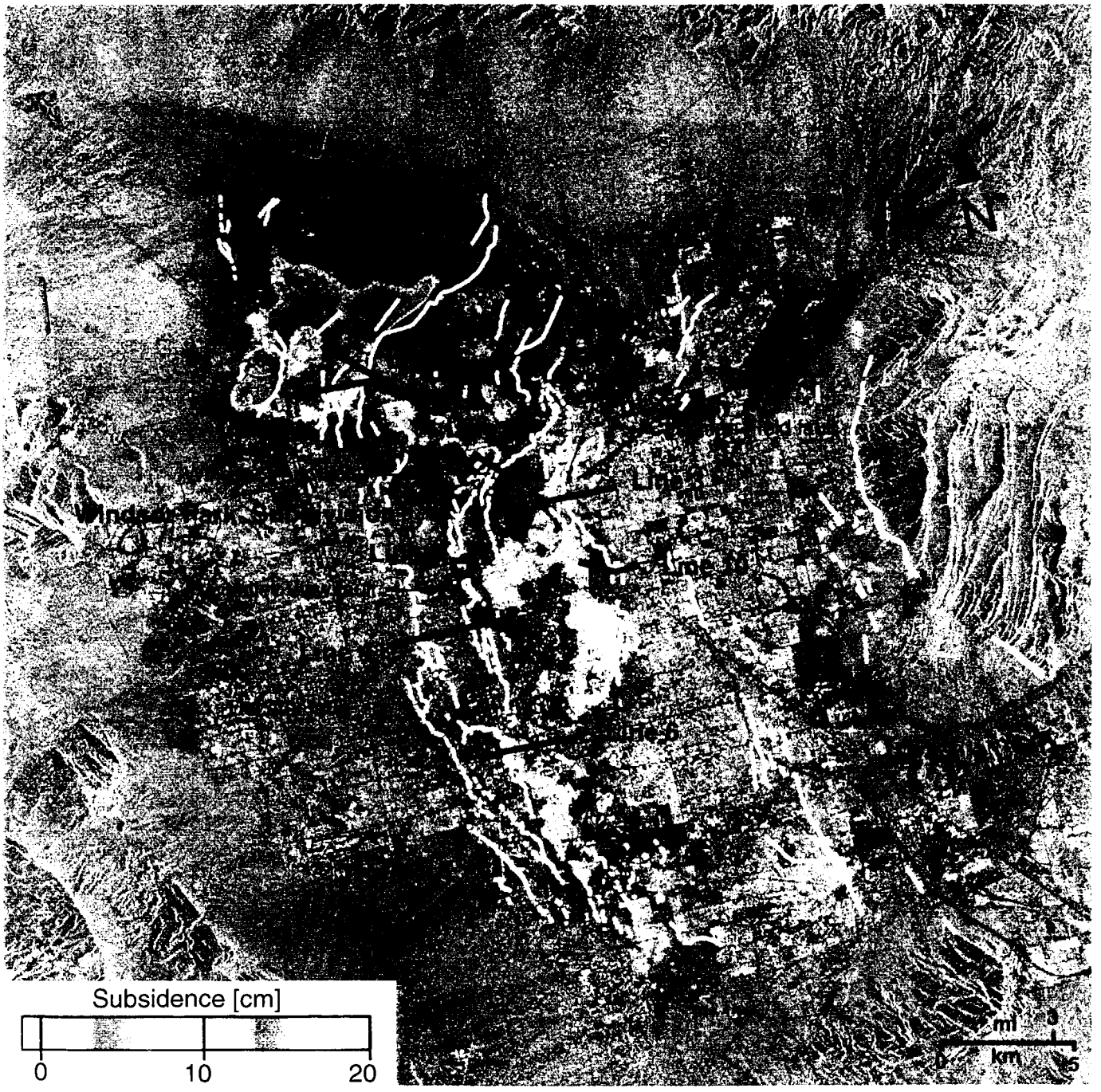


Figure 2. Location of conventional, second-order level lines across geologic faults, shown on 1992-97 InSAR base map. See Figs. 3-10 for results of leveling between 1978-1997.

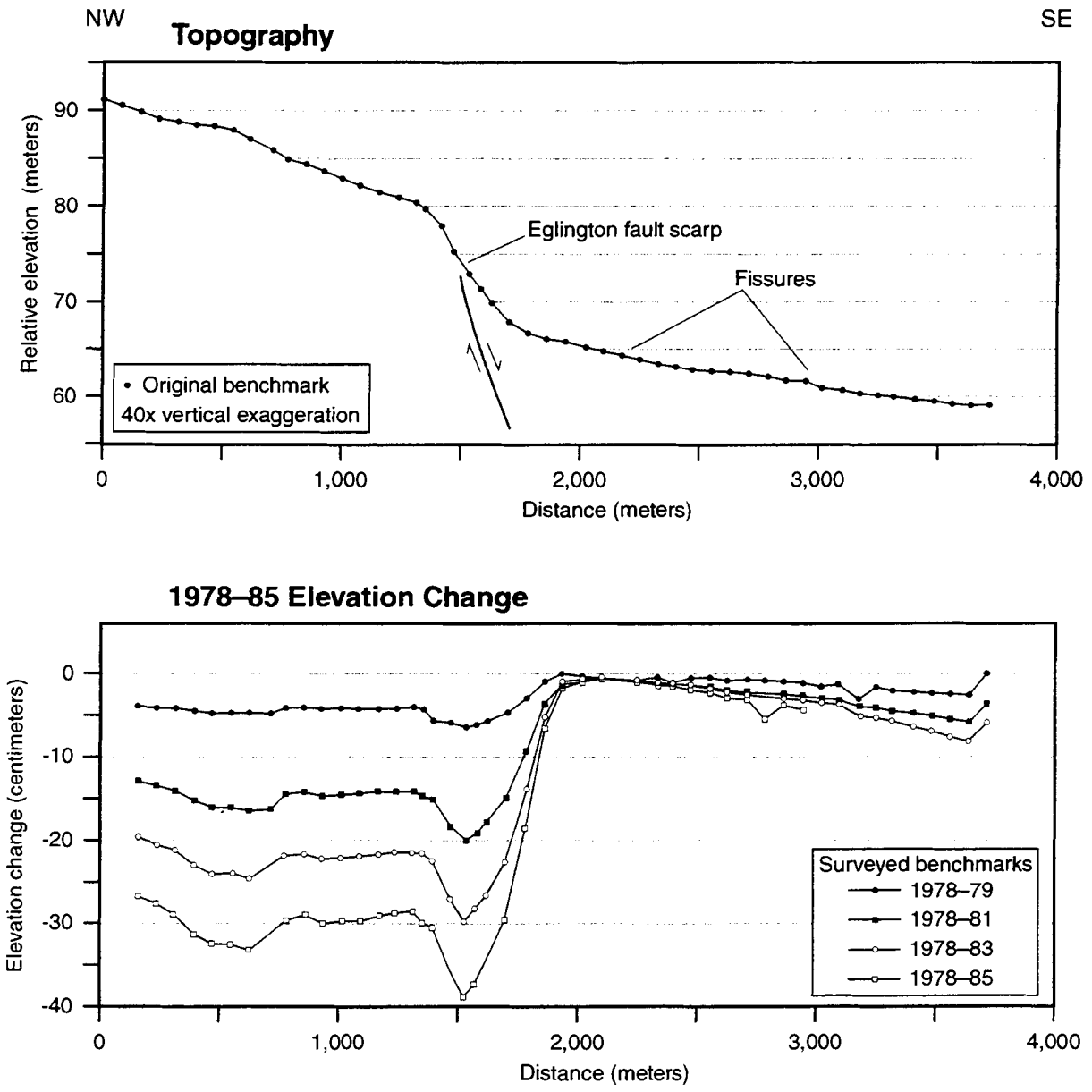


Figure 3. Results of leveling along line 1 for the period 1978–85 (line was destroyed in 1985).

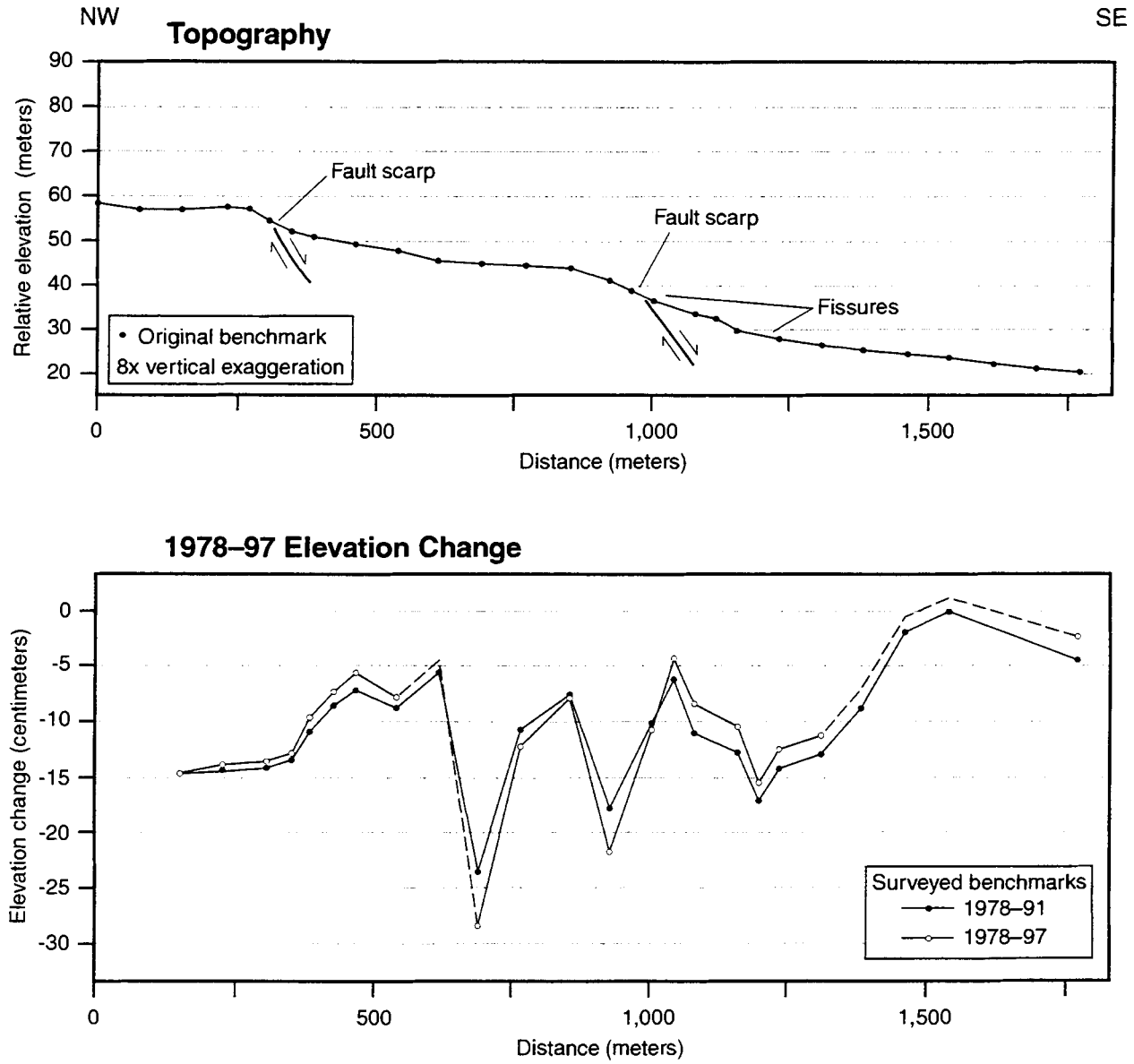


Figure 4. Results of leveling along line 2 for the period 1978–97.

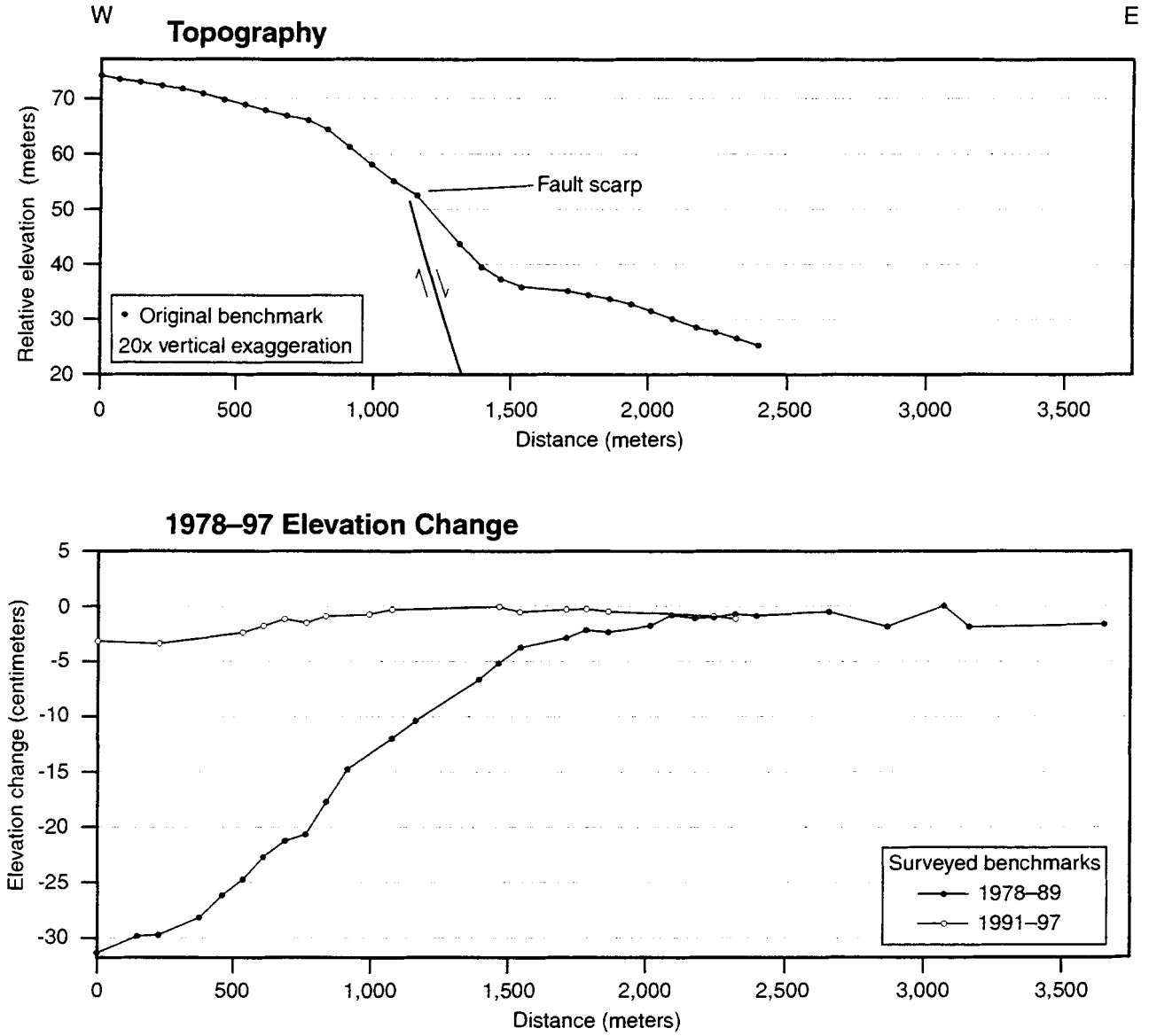


Figure 5. Results of leveling along line 3 for the period 1978–97.

Line 4

Line 4 extends along Charleston Boulevard and crosses the Decatur Boulevard and Valley View faults; the east half of the line which passes immediately south of the LVVWD main well field was added in 1991. The results of leveling the west half of the line between 1978-1991 indicated that little measurable movement was occurring across the Decatur fault. Results of leveling for 1991-97 confirmed that that no significant movement was evident on the Decatur Boulevard fault, but that 6 cm of movement down to the east has occurred across the Valley View fault (Fig. 6). This indicates an average annual subsidence rate of about 1 cm/yr (Table 1).

Line 6

Line 6 crosses the southern extensions of the Decatur Boulevard and Valley View faults. The results of 1991-97 leveling (Fig. 7) indicate that movement has continued in the same pattern seen in previous years. Although the number of benchmarks covering the entire leveling period are limited due to urban development, the long-term pattern and rate remain relatively consistent. The pattern of movement during the 1991-97 period indicates that subsidence is located principally on the faults with little relative movement occurring between the fault traces.

Line 8B

Line 8 is a level line crossing the Valley View fault immediately north of the LVVWD north well field. The entire line is rectangular consisting of 2 north-south (8A and 8C) and 2 east-west (8B and 8D) lines. Line 8B is the only line presented because it lies closest to the well field and displays the largest movements for the 1978-97 period. As illustrated on Fig. 8, more than 5 cm of movement occurred across the fault between 1978-87. Leveling in 1989 indicated that less than 1 cm of additional had occurred since 1987, and measurements in 1991 indicated that the line remained approximately unchanged between 1989-91, possibly rebounding slightly. The 1991-97 level results (indicated by the difference between the 1978-91 and 1978-97 lines) show that about 2 cm of subsidence occurred across the fault, an average annual rate slightly lower than the pre-1991 rate (Table 1).

Line 10

Line 10 crosses the Cashman Field fault along Stewart Street and is located a few miles south of line 3. Similar to line 3, results of leveling along line 10 for 1991-97 (Fig. 9) indicate that while the pattern of displacement has remained unchanged (fault movement down to the west), the rate of movement has significantly decreased; only a few centimeters of subsidence occurred between 1991-97 and some stations along the line remained unchanged.

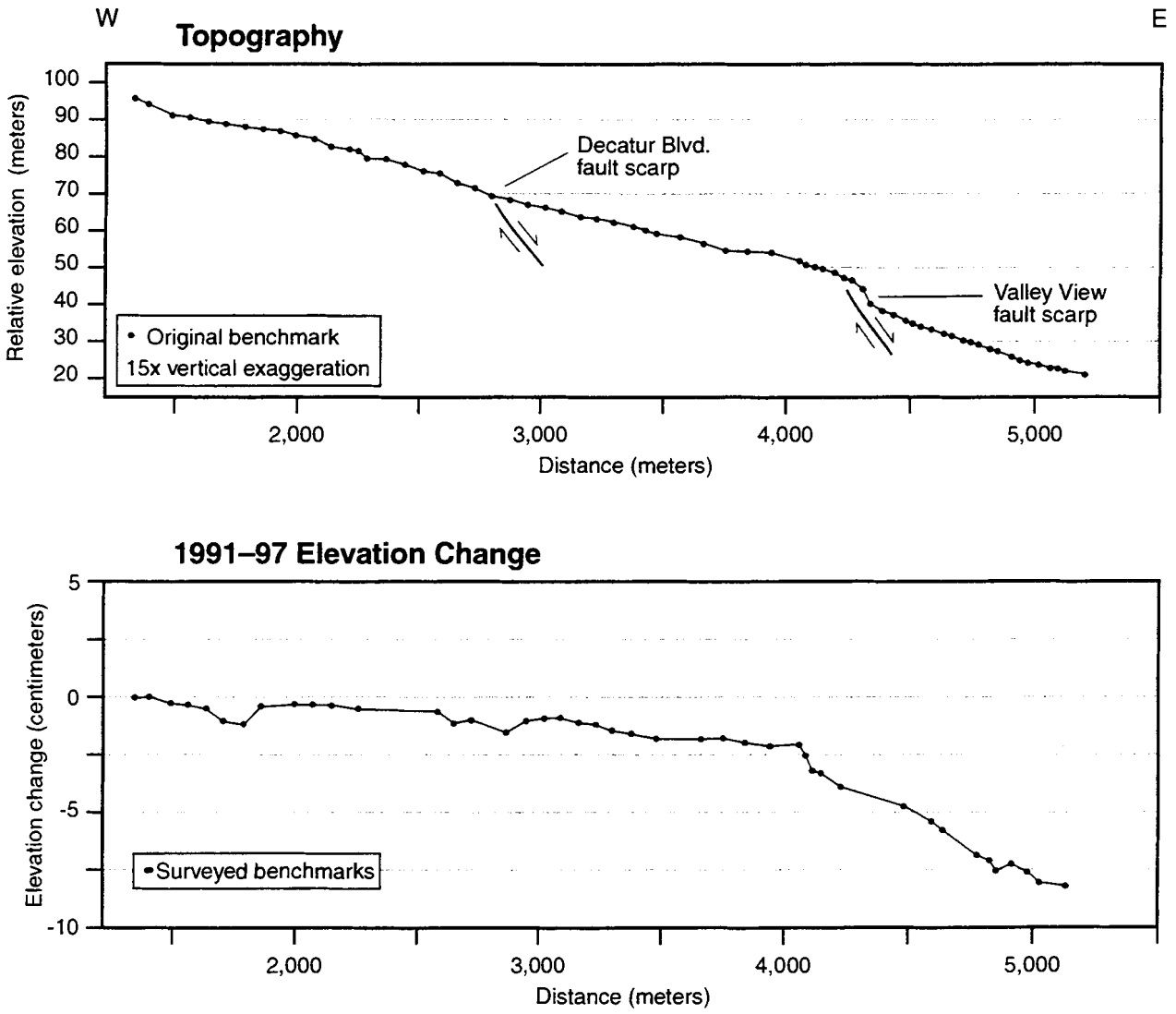


Figure 6. Results of leveling along line 4 for the period 1991–97 (line was established in 1991).

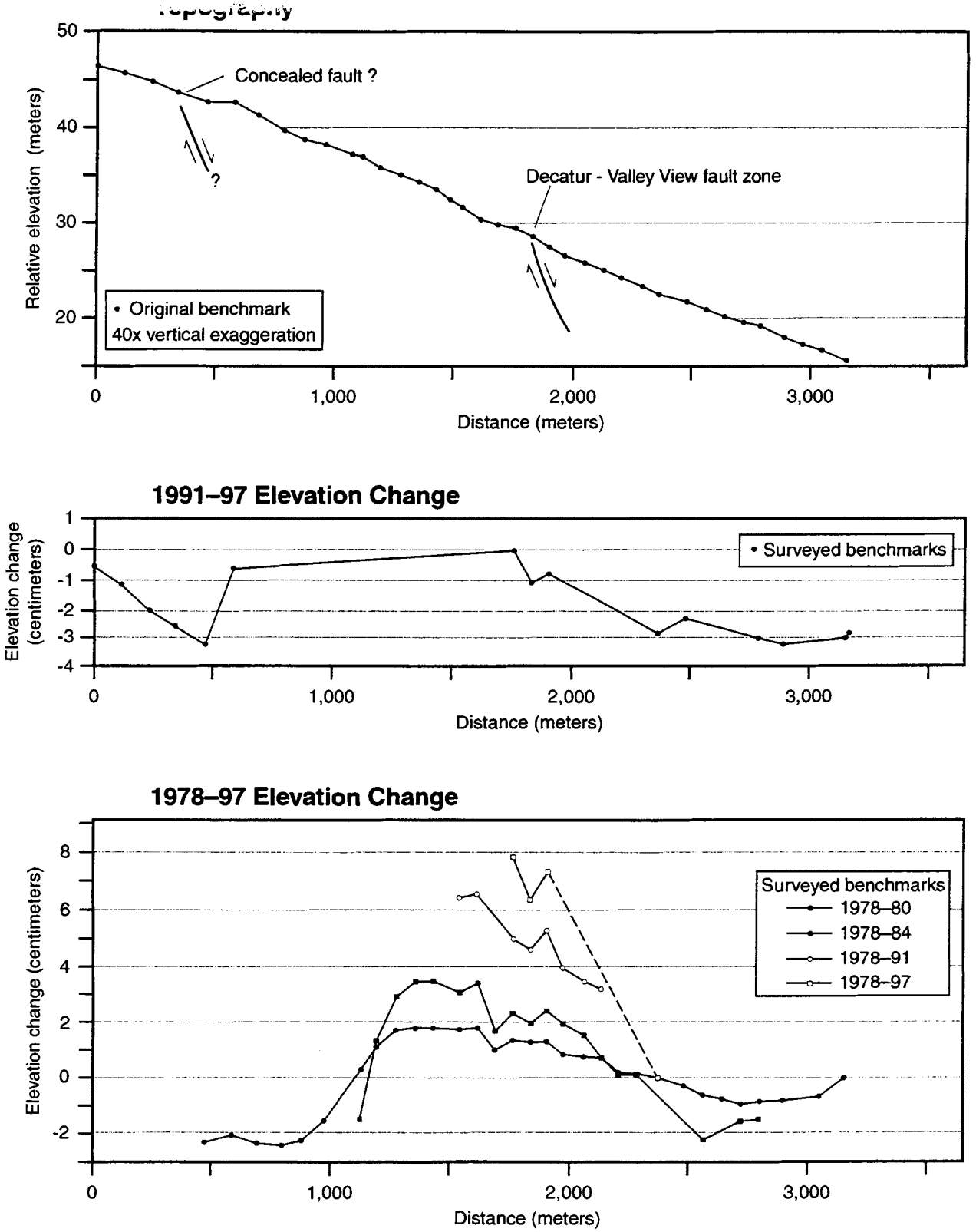


Figure 7. Results of leveling along line 6 for the period 1978–97.

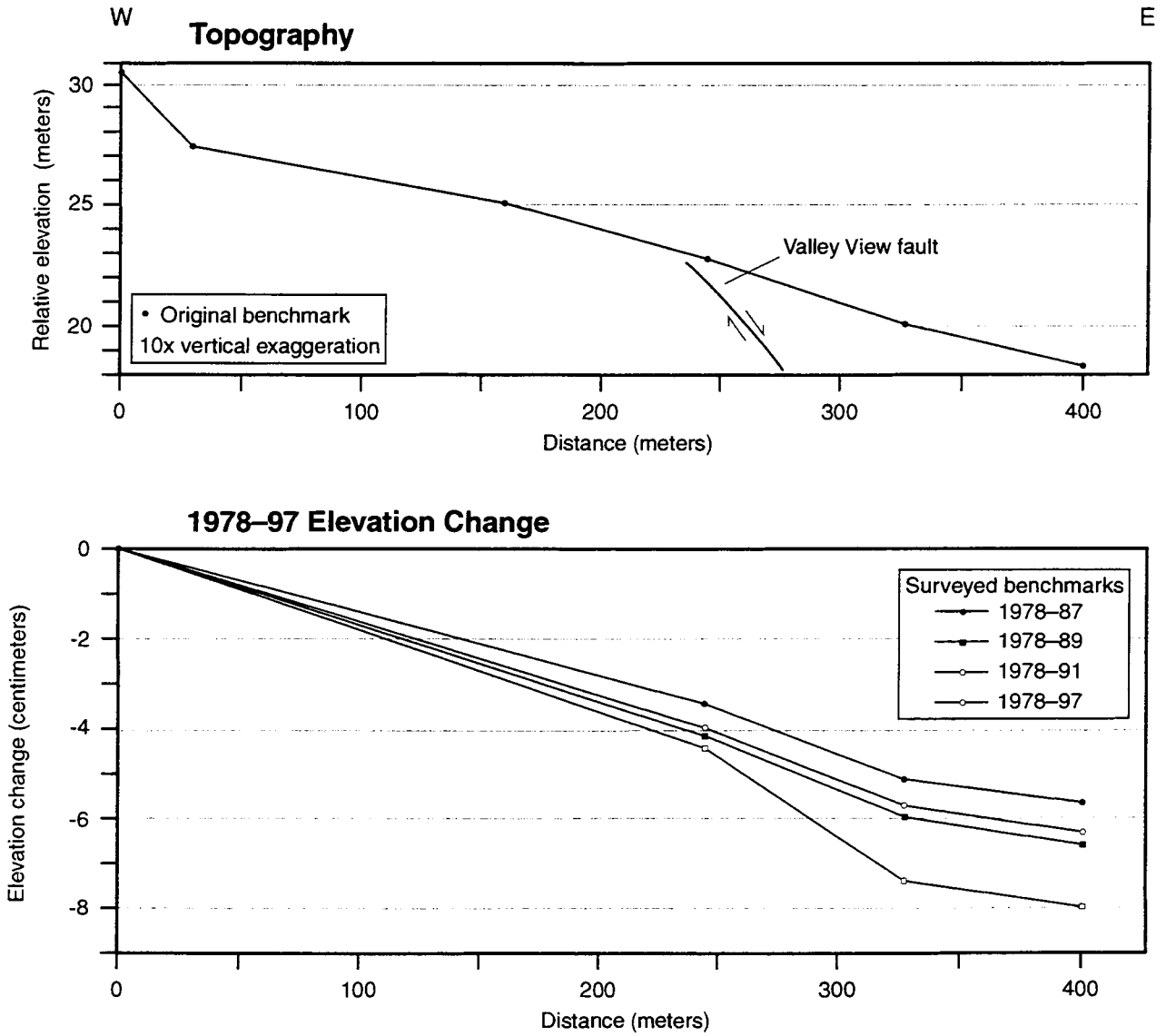


Figure 8. Results of leveling along line 8B for the period 1978–97.

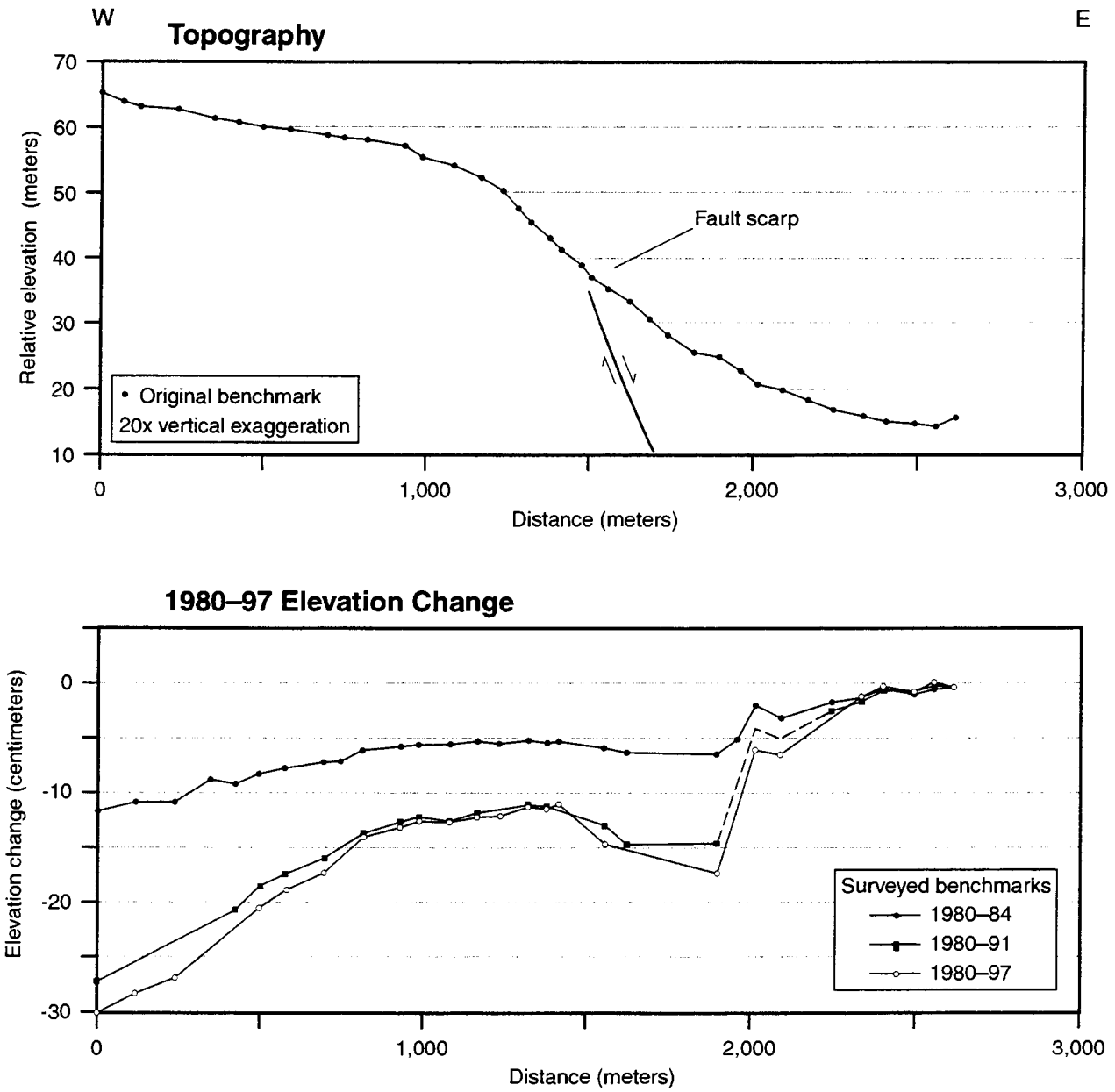


Figure 9. Results of leveling along line 10 for the period 1980–97.

Line 11

Line 11 was established in 1991 to replace line 1 across the Eglington fault. The line extends east along Lone Mountain Road from the US 95 overpass and crosses several north-south traces of the Eglington fault zone; only the largest scarp of the set is visible on the topographic profile (Fig. 10). Results of leveling for 1991-97 are similar to, but less striking than, those seen in the line 1 data (Fig. 3). The pattern of movement is similar (down-to-the-west subsidence into the Northwest bowl beginning at the fault), but the displacements are smaller and distributed across a broader area. These differences may be related to the fact that line 1 was oriented directly into the center of the Northwest subsidence bowl, whereas line 11 lies tangential to the southern margin of the bowl. The level data show that although about 5 cm of movement occurred east of the fault, 2 stations coincident with the fault scarp remained nearly unchanged during the 6 year period with more than 12 cm of subsidence occurring to the west.

Comparison of subsidence rates across faults

A comparison of subsidence rates for the 1991-97 surveys to the previous surveys indicates that the rates have measurably decreased on all lines (Table 1). This is particularly apparent on lines 3 and 10 in the Central bowl where the rate has dropped from about 2.5 cm/year to 0.5 cm/ year, a rate decline of 75-80%. Similar but smaller decreases in the 1991-97 rates are also evident on other lines. The rate of movement along line 11 (2 cm/yr) in the Northwest bowl is significantly less than that on the previous line 1 (5.2 cm/yr), but this is in part due to the different line locations and orientations. However, the InSAR data indicate that the maximum subsidence of 18 cm in the center of the Northwest bowl is equivalent to a rate of about 3.3 cm/year; InSAR values extracted from along the line 11 transect agree with the level line rate of about 2 cm/yr.

Windsor Park Level Surveys

The City of North Las Vegas Surveyors Office conducted repeat level surveys along streets in the Windsor Park subdivision (Fig. 2) in order to compare existing street elevations with the original as-built design elevation. Resurveys of street elevations were conducted in 1986 and 1995 and compared to the as-built street profiles believed to have been constructed in 1965 (Bart Dalton, North Las Vegas Surveyors Office, personal communication, 1998). Comparisons of the 1986 and 1995 elevations with the 1965 design elevations for selected streets (Fig. 11) indicate that large elevation changes have occurred in some parts of the subdivision. As much as 3-4 ft of relative elevation change has occurred since 1965 along some east-west street profiles which cross the Windsor Park fault, confirming the results of leveling along line 2 and providing evidence for the origin of the extensive structural damage occurring in the subdivision.

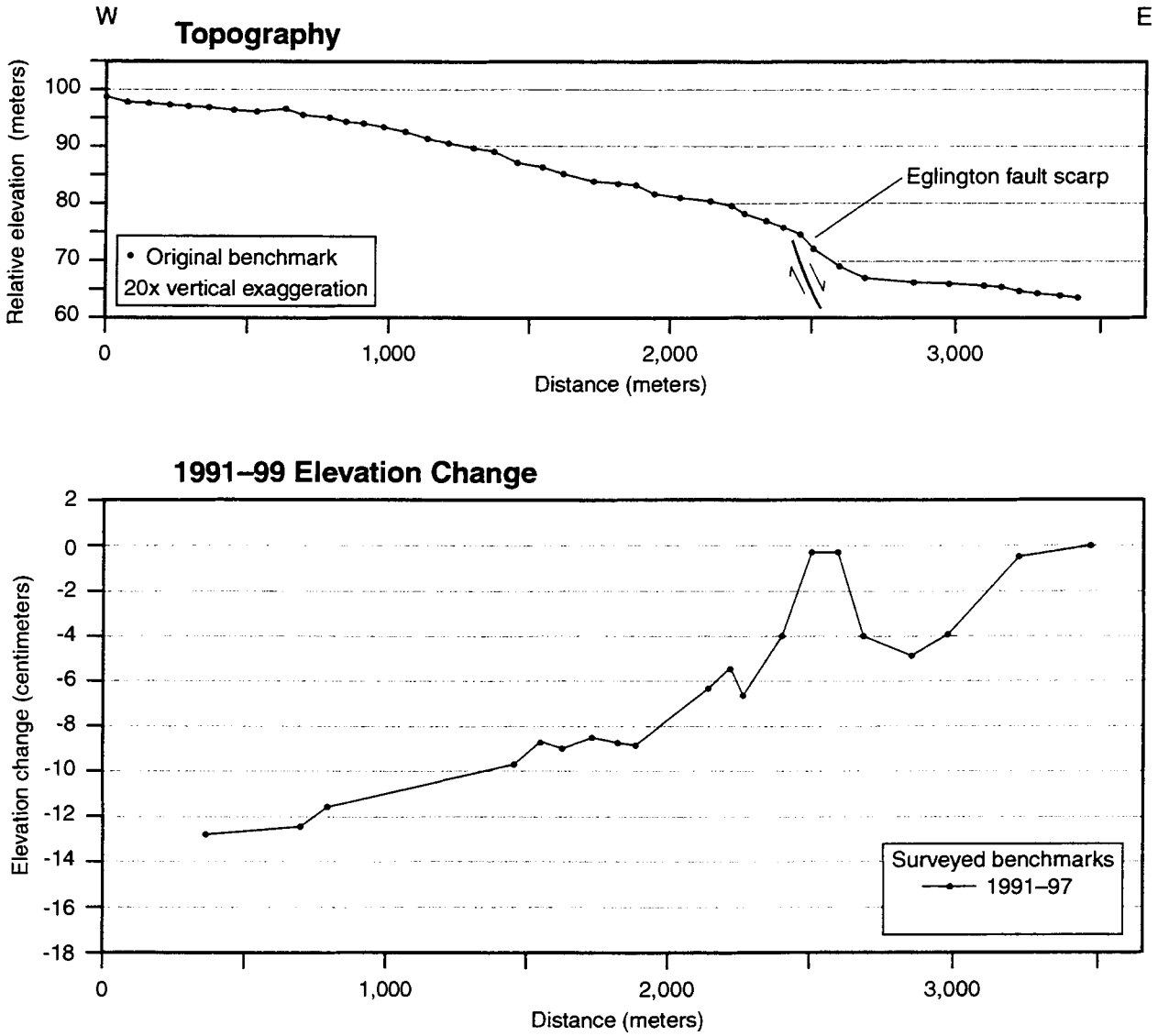
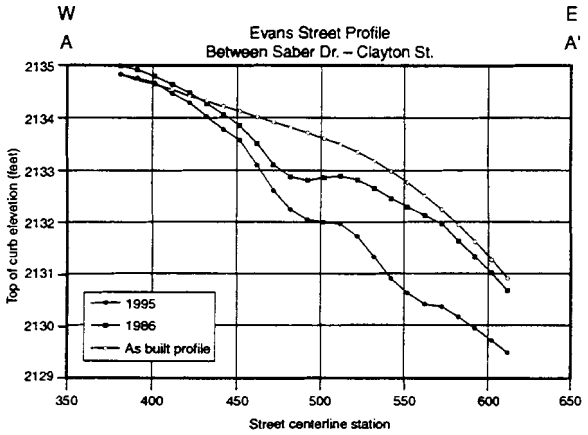


Figure 10. Results of leveling along line 11 for the period 1991–97 (line was established in 1991).

Table 1. Comparison of maximum subsidence rates (centimeters/year) measured along conventional level lines for periods between 1978-1997 and the maximum InSAR subsidence values for the corresponding lines between 1992-97. A comparison of the 1991-97 level data with the 1992-97 InSAR data indicate a relatively close agreement of average annual subsidence rates.

Line	1978-85	1978-89	1978-91	1980-91	1991-97	InSAR 1992-97
1	5.2 cm/yr					3.3 cm/yr
2			1.4 cm/yr		1.1 cm/yr	1.5 cm/yr
3		2.7 cm/yr			0.5 cm/yr	0.8 cm/yr
4					1.0 cm/yr	0.7 cm/yr
6			0.6 cm/yr		0.5 cm/yr	0.4 cm/yr
8b			0.5 cm/yr		0.3 cm/yr	0.5 cm/yr
10				2.5 cm/yr	0.5 cm/yr	0.9 cm/yr
11					2.0 cm/yr	2.1 cm/yr



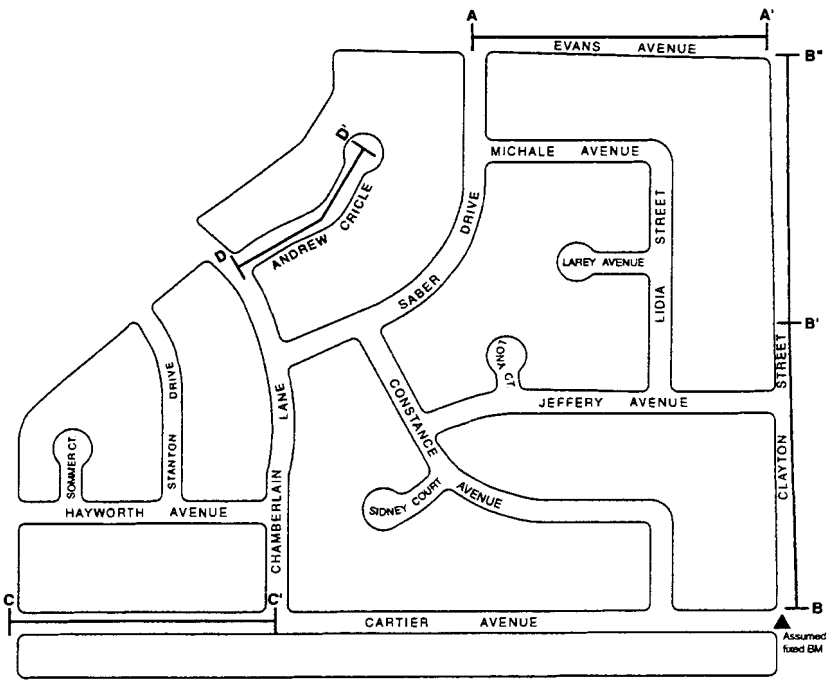
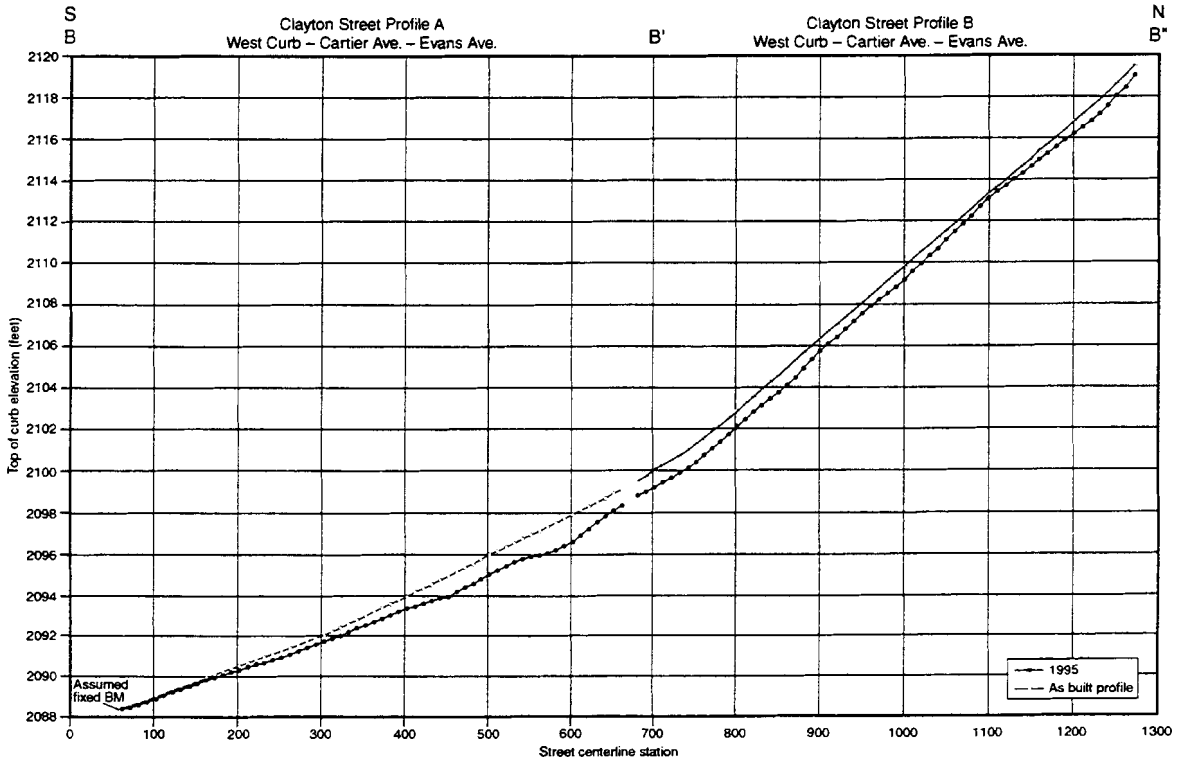
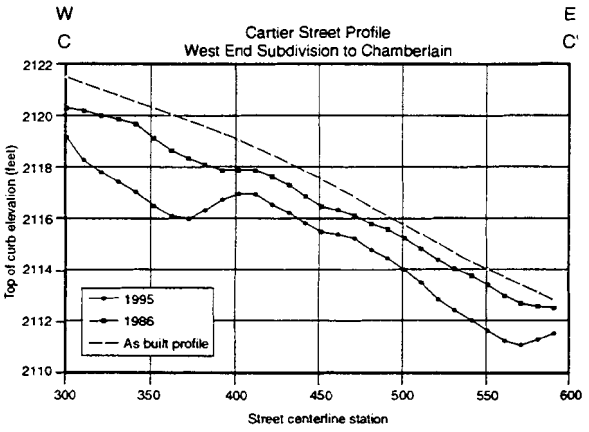
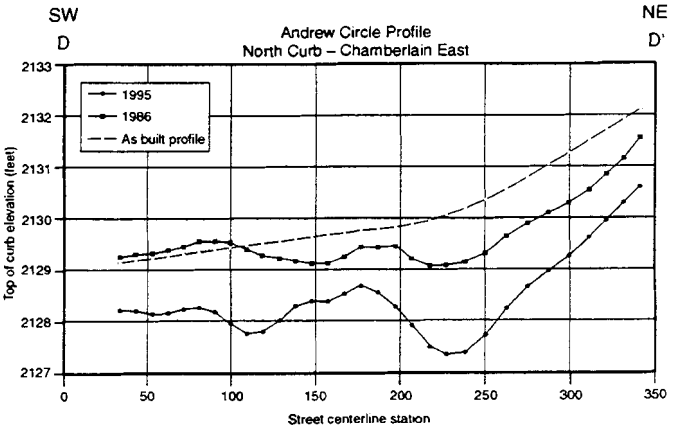


Figure 11. Results of conventional leveling conducted by the City of North Las Vegas along selected streets in the Windsor Park Subdivision. Surveys conducted in 1986 and 1995 are compared with the original (as-built) design elevations (1965).







Global Positioning System (GPS) Surveys

Approach

A network consisting of various survey marks throughout Las Vegas Valley was initially surveyed using GPS in mid-1990 and mid-1991 to provide better spatial constraints on subsidence than the existing National Geodetic Survey (NGS) level lines, which were limited to principal roadways and were being destroyed by urban development. The GPS network was laid out with a nominal grid spacing of 1 to 2 km, and to the extent possible the network incorporated points included in the NGS level lines. In mid-1994, more points were added to the network in the northwest part of the valley to better cover key areas of concern, and these points were reobserved in mid-1995. In early 1998, the entire valley-wide network was reobserved. The location of all GPS stations is shown on Figure 12, and the status of recovered stations is listed in Table 2. Station descriptions and all coordinate adjustment data are contained in Appendix 1.

1990-91

The valley-wide network, consisting of about 115 points, was initially surveyed in 1990-91. Refer to the prior project report (Bell and Price, 1991) for details of these activities. This work was done with a mix of static and kinematic observations and employed the now outdated Trimble 4000 SST receivers, early models of the geodetic-grade receivers.

1994-95

Activities in 1994 and 1995 were focused on the northwest part of the valley, with 35 points observed along US 95, Corn Creek Springs Road, Kyle Canyon Road, the high-voltage power line, and Craig Road. These surveys were conducted primarily with static observations, but were augmented by a few kinematic observations. Refer to the prior project reports (Ramelli, 1994; 1995) for details of these surveys.

1998

The valley-wide survey conducted between February and April, 1998 included points initially observed in 1990-91, as well as those observed in 1994 and 1995. The 1998 survey marked the first reobservation of the entire valley-wide network since 1991, providing the first opportunity to evaluate subsidence over an interval of approximately seven years.

Of the original 115 stations established in the 1990-91 surveys, more than 30 benchmarks could not be recovered or had to be abandoned because of adverse site conditions or obstructions. (Table 2). The vast majority of the lost stations were destroyed during urban construction

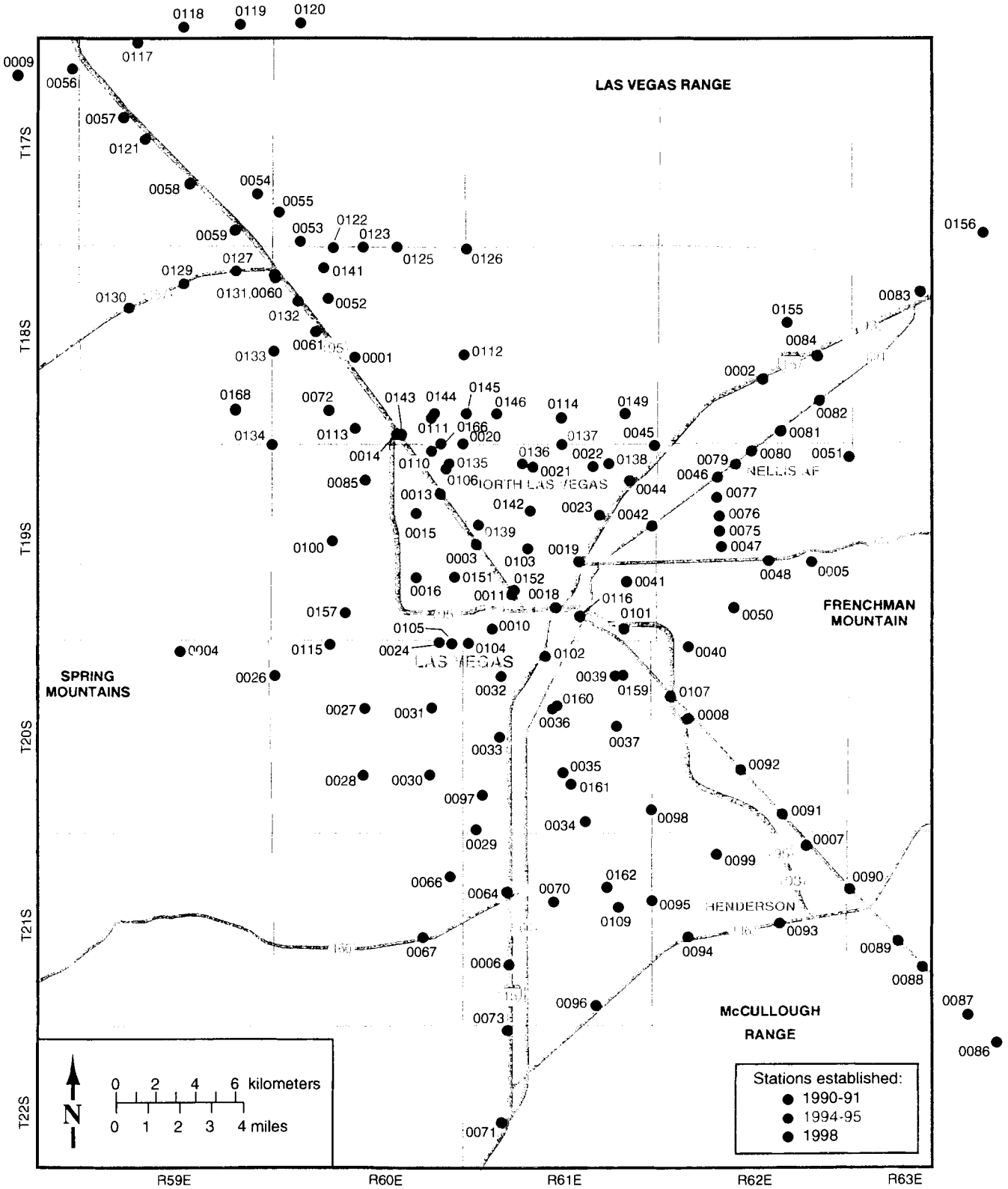


Figure 12. Location and identification number for GPS stations used in the 1990-91, 1994-95, and 1998 surveys in Las Vegas Valley. See Appendix 1 for station descriptions and data.

Table 2: Status of Points within the Las Vegas Valley GPS network

ID#	Name	Agency	Latitude			Longitude			1990- 91	1994	1995	1998
			Deg	Min	Sec	Deg	Min	Sec				
1	113USGS	USGS	36	17	14.81	115	16	3.98	x	x	x	n
2	C141	NGS	36	16	39.57	115	2	14.48	x			x
3	P169	NGS	36	12	17.58	115	12	2.23	x	n		
4	D368	NGS	36	9	16.90	115	21	47.19	x			x
5	U368	NGS	36	11	53.55	115	0	37.31	x			x
6	EA963+67.37	NVHD	36	0	22.74	115	10	48.29	x			x
7	W51	NGS	36	4	4.41	115	0	51.82	x			x
8	L399	NGS	36	7	37.04	115	4	47.51	a			
9	D371	NGS	36	24	53.32	115	27	5.65	x	x	x	x
10	WELL8	LVVWD	36	9	55.80	115	11	25.41	x			n
11	X398	NGS	36	10	52.38	115	10	43.34	x			n
13	T398	NGS	36	13	36.52	115	13	15.44	x	n		
14	R169	NGS	36	15	4.99	115	14	32.48	x	x	x	n
15	7C00-14N4	CLKCO	36	13	2.33	115	14	2.84	x			x
16	7C00-23S4	CLKCO	36	11	19.08	115	13	55.99	x			n
17	UN1	NBMG	36	11	44.20	115	10	7.40	a			
18	UN2	NBMG	36	10	37.38	115	9	13.50	x			n
19	P399	NGS	36	11	45.83	115	8	26.54	x			x
20	T19-20S/R60-61E	GLO	36	14	50.00	115	12	23.00	a	n		
21	E369	NGS	36	14	22.39	115	10	2.91	a	n		
22	2-2-92	UNK	36	14	23.89	115	8	3.12	a	n		
23	7C01-11S4	CLKCO	36	13	5.16	115	7	36.12	x			x
24	7C00-36SSW6	CLKCO	36	9	33.42	115	13	9.10	x			x
26	X367	NGS	36	8	41.65	115	19	3.99	x			n
27	7C10-15NWS	CLKCO	36	7	44.51	115	15	38.99	x			n
28	7C10-22SWS	CLKCO	36	5	58.99	115	15	38.90	x			x
29	D170	NGS	36	4	35.51	115	11	57.78	x			n
30	7C10-24SWS	CLKCO	36	6	0.05	115	13	29.21	x			x
31	7C10-13NNW6	CLKCO	36	7	44.97	115	13	12.29	x			x
32	7C11-5SSW6	CLKCO	36	8	40.34	115	11	6.97	x			x
33	N366	NGS	36	6	55.91	115	11	4.81	p			x
34	MI40	UNK	36	4	41.39	115	8	12.24	x			n
35	6C11-22SSW6	CLKCO	36	6	4.53	115	8	58.59	p			n
36	6C11-15NWS	CLKCO	36	7	46.06	115	9	16.88	x			n
37	6C11-13SWW6	CLKCO	36	7	6.97	115	7	7.98	o			o
39	C55+60	NVHD	36	8	40.04	115	7	8.46	x			n
40	6C02-32SWS	CLKCO	36	9	32.64	115	4	47.79	x			n
41	NLV5	NLV	36	11	18.18	115	6	57.22	x			n
42	7C02-18NWW6	CLKCO	36	12	52.30	115	5	54.18	x			x
44	M365	NGS	36	14	1.01	115	6	47.33	x	n		
45	T19-20S/R61-62E	GLO	36	14	49.02	115	5	55.60	x	n		
46	6C02-4SWW6	CLKCO	36	14	11.74	115	3	43.16	x			x
47	6C02-16SWS	CLKCO	36	12	13.81	115	3	43.24	x			x
48	R368	NGS	36	11	48.00	115	2	5.00	a			
50	7C02-28S4	CLKCO	36	10	27.19	115	3	10.07	p			x
51	T19-20S/R62-63E	USGLO	36	14	49.26	114	59	19.90	x			x
52	V365	NGS	36	18	50.63	115	16	48.29	x	x	x	x
53	112USGS	USGS	36	20	25.58	115	17	45.33	x	x	x	x
54	W314	NGS	36	21	45.27	115	19	11.06	x	n		

55	X314	NGS	36	21	11.77	115	18	31.12	x			x
56	Y370	NGS	36	25	5.70	115	25	13.20	p			x
57	W370	NGS	36	23	47.32	115	23	38.92	x	x		x
58	T370	NGS	36	21	57.16	115	21	25.92	x	x	x	x
59	0C89-36W6	CLKCO	36	20	35.83	115	19	44.30	x	x	x	
61	0C90-17C4	CLKCO	36	17	55.80	115	17	12.10	x	x	x	x
63	WELLS20/E6118BCCD	LVVWD	36	12	38.00	115	12	45.00	a			
64	HAPPY	NGS	36	2	50.33	115	10	53.19	x			x
66	JERK	NGS	36	3	8.13	115	12	42.43	x			x
67	F170	NGS	36	1	28.57	115	13	37.45	x			n
69	WELL22CCC	LVVWD	36	6	6.77	115	9	16.78	a			
70	RLS8547 19863,22.61	CLKCO	36	2	31.89	115	9	14.46	x			n
71	SLOAN	NGS	35	56	23.99	115	10	59.30	p			x
72	1C90-29SES	CLV	36	15	47.12	115	16	43.81	x			n
73	D146	UNK	35	58	58.35	115	10	49.75	a			
75	6C02-16W4	CLKCO	36	12	40.12	115	3	43.40	x			
76	6C02-9SWS	CLKCO	36	13	6.70	115	3	43.25	x			
77	6C02-9W4	CLKCO	36	13	33.23	115	3	43.12	x			
79	0474+92.33	NVHD	36	14	30.76	115	3	7.32	x			
80	229-44	USE	36	14	48.63	115	2	35.18	x			n
81	LVAFB B	USE	36	15	17.66	115	1	45.50	x			x
82	229-98	USE	36	15	56.60	115	0	38.29	x			n
83	UNDER	NGS	36	19	2.10	114	56	54.43	x			x
84	B141	NGS	36	17	17.48	115	0	19.96	x			n
85	1LV00-4SES	CLV	36	13	59.80	115	15	39.11	x			x
86	P364	NGS	35	58	30.47	114	54	49.47	x			x
87	J166	NGS	35	59	24.56	114	55	37.32	x			n
88	H166	NGS	36	0	39.99	114	57	2.63	x			x
89	M364	NGS	36	1	25.99	114	57	54.60	o			o
90	K364	NGS	36	2	54.26	114	59	28.95	x			n
91	D365	NGS	36	4	52.69	115	1	42.56	x			n
92	J399	NGS	36	6	8.28	115	3	7.58	o			o
93	0503+20.08	NVHD	36	1	54.27	115	1	49.51	x			x
94	0351+10.47	NVHD	36	1	30.00	115	4	53.00	a			
95	RLS8547 9522261	CLKCO	36	2	33.33	115	6	1.17	x			n
96	H169+87.05	NDOT	35	59	45.50	115	7	47.85	x			x
97	C170	NGS	36	5	28.11	115	11	45.65	x			o
98	RLS5835 73.27	CLKCO	36	4	50.66	115	6	2.83	x			n
99	6C22-5E6	CLKCO	36	3	55.83	115	3	56.22	x			n
100	0LV00-17SEE6	CLV	36	12	22.47	115	16	44.84	x			x
101	CLV35	CLV	36	9	59.90	115	7	5.46	p			a
102	K366	NGS	36	9	9.40	115	9	37.28	p			o
103	817-20-61	CLKCO	36	12	9.71	115	10	11.27	x			x
104	CLV23	CLV	36	9	33.02	115	12	5.35	o			o
105	K367	NGS	36	9	33.40	115	13	6.16	a			
106	7C00-1C4	CLKCO	36	14	19.41	115	13	0.96	x	n		
107	6C12-7SE6	CLKCO	36	8	4.76	115	5	18.94	x			x
109	8C21-11SES	CLKCO	36	2	32.88	115	7	6.22	x			n
110	1LV00-2EE6A	CLV	36	14	39.63	115	13	32.55	a	a	a	a
111	1LV90-26SES	CLV	36	15	40.36	115	13	32.62	x	n		
112	5-18-117	UNK	36	17	29.04	115	12	24.55	x	x	x	x
113	1LV90-33E6	CLV	36	15	19.89	115	15	54.50	x	x	x	x
114	PLS2050 74.75	ADAMS	36	15	41.02	115	9	23.61	x			x
115	0LV00-32SES	CLV	36	9	33.08	115	16	48.33	x			n

116	WD15+07.95	NVHD	36	10	24.50	115	8	32.59	p			x
117	110USGS	USGS	36	25	46.27	115	23	19.89		x	x	x
118	169GWM	USGS	36	26	12.97	115	21	46.59		x	x	x
119	170GWM	USGS	36	26	12.50	115	19	55.62		x	x	x
120	171GWM	USGS	36	26	15.22	115	17	48.71		x	x	x
121	Z398	NGS	36	23	9.97	115	22	53.82		x	x	x
122	32-33-5-4	GLO	36	20	9.58	115	16	43.08		x	x	x
123	802	CLKCO	36	20	9.68	115	15	38.98		x	x	x
125	34-35-3-2	GLO	36	20	8.36	115	14	34.11		x	x	x
126	803	CLKCO	36	20	7.73	115	12	25.40		x	x	x
127	2GWM	USGS	36	19	31.61	115	20	3.81		x	x	x
129	3GWM	USGS	36	19	6.91	115	21	47.60		x	x	x
130	4GWM	USGS	36	18	30.60	115	23	44.44		x	x	x
131	2C90-6SWW6	CLKCO	36	19	31.00	115	18	38.74		x	x	x
132	0C90-7SE6	CLKCO	36	18	43.45	115	17	55.31		x	x	x
133	806	CLKCO	36	17	32.17	115	18	53.20		x	x	x
134	807	CLKCO	36	14	53.54	115	12	49.65		x	x	n
135	CLV plate1	CLV	36	14	19.27	115	12	49.65		x	x	x
136	80.19	UNK	36	14	21.43	115	10	28.73		x	x	x
137	874	CLKCO	36	14	52.28	115	9	12.88		x	x	x
138	7C01-2C4	CLKCO	36	14	22.51	115	7	30.40		x	x	x
139	NVGT		36	12	36.75	115	11	54.42		x	x	x
140	LORENZI		36	14	9.27	115	14	28.67		o		o
141	V169	NGS	36	19	41.01	115	17	14.51		x	x	x
142	PLS7635 78.46	UNK	36	13	3.12	115	10	12.34				x
143	PLS6902 56.57	UNK	36	15	4.24	115	14	33.40				x
144	PLS5088 77.76	UNK	36	15	39.31	115	13	30.91				x
145	1LV90-36NES	CLV	36	15	41.10	115	12	26.58				x
146	PLS8895 29 30 31 32	UNK	36	15	41.41	115	11	20.34				x
147	CLV plate2	CLV	36	16	23.17	115	13	28.98				x
148	PLS3340 78.95	UNK	36	17	26.79	115	15	12.30				x
149	RLS4841 25 26 35 36	UNK	36	15	41.58	115	7	1.39				x
151	2LV00-25N4	CLV	36	11	17.22	115	12	53.69				x
152	7C01-29C4	CLKCO	36	10	52.43	115	10	44.88				x
154	PLS9399 10 11 14 15	UNK	36	18	20.85	115	8	3.76				x
155	D171	NGS	36	17	59.52	115	1	14.84				x
156	J171	NGS	36	20	28.05	114	55	4.38				x
157	923	CLKCO	36	9	33.09	115	16	27.13				x
158	1LV10-8S4	CLV	36	7	47.33	115	17	19.55				x
159	PLS5094 145.27	UNK	36	8	38.50	115	7	6.89				x
160	NHD 32675009	NVHD	36	7	49.62	115	9	17.87				x
161	PLS9388 76.99	UNK	36	5	34.15	115	8	50.16				x
162	RLS7190 63.44	UNK	36	2	58.67	115	7	38.09				x
163	888	CLKCO	36	2	10.70	115	5	0.34				x
166	1LV90-36SSW6	CLV	36	14	47.54	115	13	15.43				x
167	F170 RESET	NGS	36	1	28.447	115	13	37.336				x
x	successfully recovered											
n	unable to locate; apparently destroyed											
a	abandoned; severe multipathing problems and/or unable to process data											
p	poor, inconsistent, or no solution(s) for 1990-91 survey											
o	significant obstruction/multipathing problems, but repeatable results obtained											

activities, and the abandoned stations were largely lost due to the recent emplacement of new obstructions which blocked satellite reception. These lost stations constituted a fairly high percentage (>25%) of the original benchmarks. The loss rate was particularly high in key areas of concern in the central part of the valley, and some of the lost stations were important to baseline and network coordinate adjustments on other remaining points. In some locations, new points were added during the 1998 survey to replace lost points. The network was also densified in those parts of the valley having the greatest subsidence during the mid-1990s based on the InSAR data (Fig. 1; discussed below).

For the 1998 survey, improvements in equipment included an upgrade to the Trimble 4000SSi receivers with choke ring antennae and P-code capabilities. Together with upgraded post-processing software, the equipment allowed precise measurements to be made with shorter static observation times (rapid static methodology). All sites were observed statically during sessions lasting a minimum of 20 minutes. The 1998 survey was carried out in three phases that covered overlapping parts of Las Vegas Valley: the northeast, southern, and northwest parts of the valley. The first phase (northeast) was conducted in cooperation with surveyors from the City of North Las Vegas, and the second phase (southern) was done with the cooperation of Tim Wolfe at the Las Vegas Valley Water District.

Network adjustment procedures

The principal objective of these GPS surveys was to determine relative changes in benchmark ellipsoid heights over time. The results were not intended to provide land survey control although many of the stations were already used for that purpose by the local city and county survey agencies. Therefore, in our network adjustments, coordinates for several points around the margins of the valley were held fixed in order to best evaluate change in the central part of the valley. Where available, reported coordinates and ellipsoid heights from the NGS High Accuracy Reference Network (HARN) were used, including "key-entered" elevations; in other cases, coordinates obtained from this project were used. The coordinates and heights which were held fixed likely have variable accuracies with respect to existing survey control, and caution should be exercised with regard to use of the coordinates listed here. Refer to the coordinate adjustment summaries in Appendix 1 for a list of fixed stations in the individual surveys. All network adjustments were done using the Trimble software GPSurvey.

Discussion of results

Adjusted GPS ellipsoid heights for those stations recovered from the 1990-91, 1994, 1995, and 1998 surveys which provided height change data are listed in Table 3. Results of the vertical height comparison between the 1990 and 1998 surveys are plotted on Fig. 13.

As can be seen on Fig. 13, few recovered stations were located within the principal subsidence

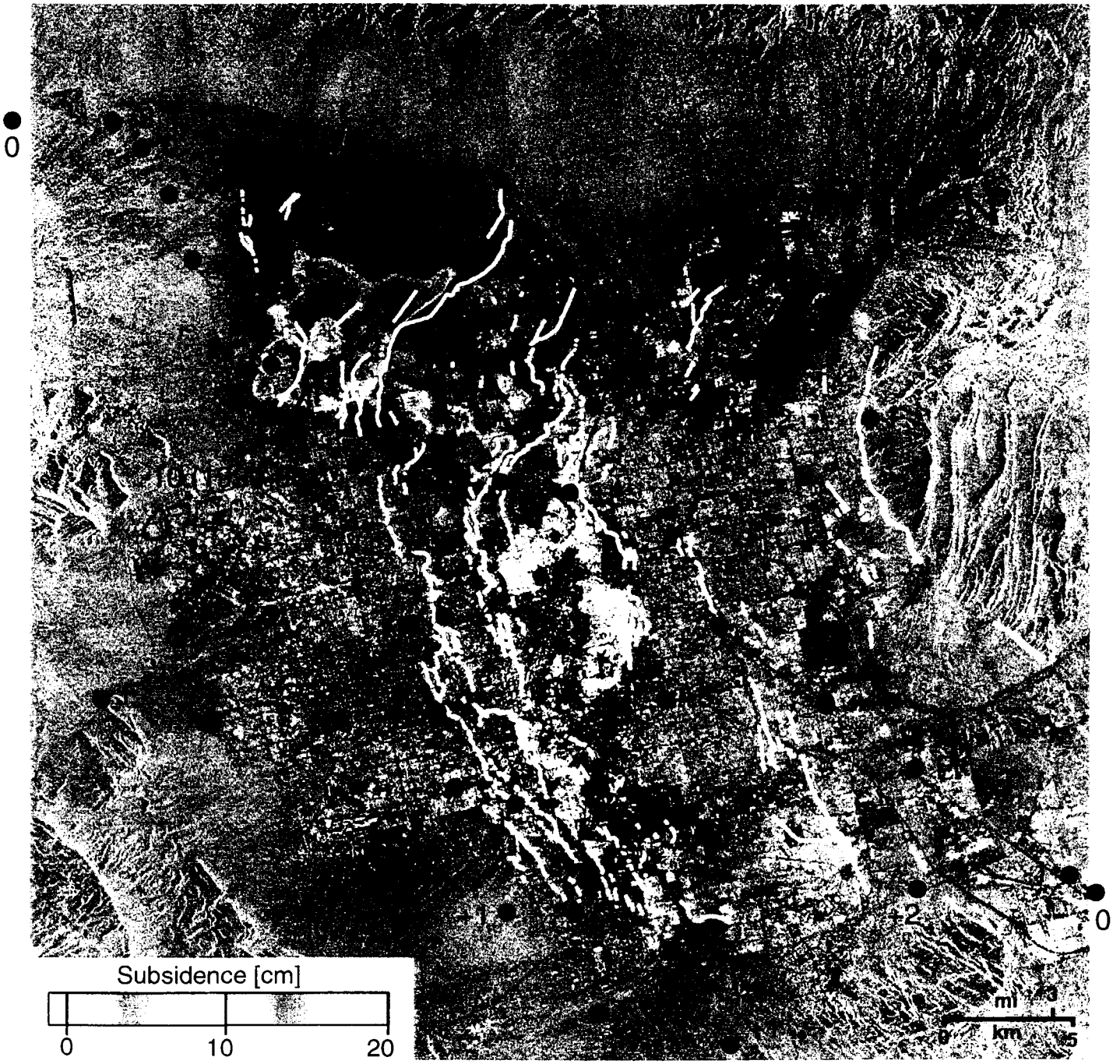


Figure 13. Vertical change (in cm) measured on recovered GPS stations for the period 1990-98, shown on the 1992-97 InSAR base map. The values are based on adjusted GPS ellipsoid heights using selected assumed fixed stations around the perimeter of the valley, indicated by "F". Only a few of the preserved stations lie within the subsidence bowls, and the results for the remainder of the valley are approaching the resolution of detection. Based on the limitations of the kinematic methodologies used in the 1990 survey, the values are estimated to be accurate only to within 2-3 cm and even greater uncertainties may be associated with the values depending on the stability and assigned values of the fixed stations. While most of the stations in the northwest part of the valley agree with InSAR results (see Table 3), the positive values in the southern portion of the valley may be related to a systematic network adjustment error.

Table 3: Comparison of GPS heights (meters) determined for Las Vegas Subsidence GPS network and InSAR heights for same stations

ID	Station	1990-91	1994	1995	1998	1990-94	1990-95	1990-98	1994-98	1995-98	INSAR 1992-97
93	0503+20.08	554.998			555.018			0.020			-0.004
59	0C8936W6	856.061	856.089	856.078		0.028	0.017				
61	0C9017C4	766.096	766.045	766.085	766.068	-0.051	-0.011	-0.028	0.023	-0.017	-0.003
132	0C907SE6		793.450	793.488	793.481				0.030	-0.008	
117	110USGS		850.400	850.430	850.414				0.015	-0.015	
53	112USGS	779.574	779.588	779.581	779.574	0.014	0.006	-0.001	-0.014	-0.007	
1	113USGS	720.778	720.685	720.770		-0.093	-0.008				
118	169GWM		855.114	855.153	855.154				0.039	0.000	
119	170GWM		942.944	942.942	942.961				0.017	0.019	
120	171GWM		1068.892	1068.892	1068.892				F	F	
85	1LV004SE				686.214						
113	1LV9033E6	696.439	696.354	696.425	696.358	-0.086	-0.015	-0.081			-0.068
131	2C906SW		824.960	824.994	824.985				0.025	-0.010	
127	2GWM		895.114	895.153	895.144				0.030	-0.010	
122	32-33-5-4		745.225	745.201	745.208				-0.016	0.007	-0.0004
125	34-35-3-2		712.855	712.832	712.850				-0.005	0.018	
129	3GWM		992.579	992.560	992.566					0.006	
130	4GWM		1111.965	1111.965	1111.965				F	F	
112	5-18-117	676.828	676.766	676.820	676.800	-0.062	-0.009	-0.028	0.034	-0.020	-0.024
47	6C0216SW	520.714			520.737			0.024			-0.0002
46	6C024SW	540.003			539.969			-0.033			+0.002
37	6C1113SW	560.983			561.036			0.053			-0.012
107	6C127SE6	522.822			522.847			0.025			-0.006
15	7C0014N4	669.295			669.296			0.001			-0.015
24	7C0036SS	664.412			664.425			0.013			-0.012
23	7C0111S4	560.061			560.106			0.045			-0.012
138	7C012C4		565.836	565.869	565.845				0.009	-0.024	
42	7C0218NW	536.415			536.458			0.043			-0.017
31	7C1013NN	667.735			667.754			0.019			-0.019
28	7C1022SW	712.526			712.633			0.107			
30	7C1024SW	674.486			674.526			0.040			-0.013
32	7C115SSW	621.821			621.828			0.007			
136	80.19		624.001	624.060	623.991				-0.010	-0.068	
123	802		726.704	726.697	726.693				-0.011	-0.004	
126	803		708.957	708.957	708.957				F	F	
133	806		841.167	841.223	841.199				0.032	-0.023	
103	817-20-61	604.792			604.816			0.024			-0.032
134	874		600.054	600.137	600.108				0.054	-0.029	
2	C141	585.573			585.573			F			-0.005
97	C170	652.529			652.515			-0.014			-0.022
135	CLV plate1		647.496	647.576	647.536				0.040	-0.040	

ID	Station	1990-91	1994	1995	1998	1990-94	1990-95	1990-98	1994-98	1995-98	INSAR 1992-97
	CLV23	637.348			637.404			0.056			-0.018
4	D368	962.508			962.508			F			-0.004
9	D371	1040.380	1040.380	1040.380	1040.380	F	F	F	F	F	
6	EA963+67.	667.238			667.238			F			-0.005
88	H168	617.987			617.973			-0.013			+0.048
96	H169+87.0	677.779			677.789			0.010			
64	HAPPY	665.964			665.972			0.008			-0.009
92	J399	483.265			483.300			0.035			-0.004
66	JERK	699.696			699.710			0.014			-0.011
140	LORENZI		676.978		676.996						
81	LVAFB B	550.311			550.298			-0.013			-0.002
89	M364	591.769			591.766			-0.003			-0.009
33	N366	625.282			625.574			0.292			
41	NVGT		639.765	639.855	639.816				0.051	-0.040	
86	P364	681.100			681.100			F			
19	P399	567.926			567.968			0.042			-0.022
114	PLS2050	612.254			612.214			-0.039			-0.009
14	R169	679.692	679.577	679.588		-0.116	-0.104				-0.051
51	T19-20SR6	553.494			553.467			-0.026			+0.004
58	T370	877.459	877.402	877.466	877.459	-0.057	0.007	0.000	0.056	-0.007	
5	U368	629.619			629.619			F			-0.005
83	UNDER	734.795			734.795			F			
141	V169		764.066	764.064	764.054				-0.013	-0.011	
52	V365	748.324	748.296	748.311	748.302	-0.029	-0.013	-0.022	0.007	-0.009	-0.006
57	W370	855.357	855.356	855.372	855.356	-0.002	0.015	-0.002	0.000	-0.017	
7	W51	476.621			476.621			F			-0.010
55	X314	796.190			796.170			-0.020			-0.0007
121	Z398		868.883	868.935	868.913				0.029	-0.022	

"F" indicates assumed fixed elevation point

zones, because, as previously noted, many of the original stations surveyed in 1990-91 were destroyed by urban development. In addition, recovered stations which lie outside the subsidence bowls may be influenced by one or more of the uncertainties discussed below, and the 1990-98 results in these areas may be approaching the resolution of detection. The results plotted on Fig. 13 should therefore be used with caution.

Repeated observations of the same station-to-station baselines indicate that measured ellipsoid heights are generally accurate to within 2-3 cm. For the 1990 and 1991 surveys, which are combined for comparative purposes in this report, 2 to 3 cm repeatability was generally achieved, but ranged up to several centimeters in some cases (Bell and Price, 1991). In performing network adjustments where redundant observations are averaged, the relative positions determined for proximal stations should in most cases be improved, but positions with respect to the network as a whole may vary by more than the general 2-3 cm accuracy of a given baseline. Based on consistency between surveys conducted in different years and comparison with the independently determined values from InSAR images (Table 3), we believe the heights reported here are accurate to within 2-3 cm in most cases, and within a maximum of 5 cm in nearly all cases.

Differences between the 1990-91 and 1998 surveys are very sensitive to the accuracy of the older equipment and kinematic observations used in the 1990-91 surveys. For several reasons, including numerous urban-environment obstructions, potential multipathing problems, and short observation times, the quality of the kinematic observations are highly variable and the residual 1-sigma errors are large (see 1σ values in the coordinate adjustment summaries in Appendix 1). Due to numerous in-transit cycle slips, several sites could not be successfully recovered or results were in some cases inconsistent with subsequent, better constrained observations. In a few cases, highly suspect, single-observation solutions from 1990-91 were subsequently shown to be off by tens of centimeters or more, and these results are not included here.

In the 1990-91 survey, ties to some bedrock sites surrounding the valley included relatively long baselines that proved to have larger errors than subsequent observations. Therefore, in order to better evaluate relative changes, coordinates for several sites around the margins of the basin were held fixed (Table 3; Appendix 1). Some of these sites may have experienced small changes between surveys (e.g., benchmark W51), but the actual amount of height change is probably less than the GPS measurement error.

The results for stations in the northwest part of the valley correlate relatively well with the subsidence occurring around the Northwest bowl. Two stations lie within the bowl and indicate 8-10 cm of subsidence during this period. Most stations in the south-central part of the valley show higher (positive) values for the 1998 survey than in 1990-91 (Table 3; Fig. 13). The majority of these sites show a consistent difference of a few centimeters, likely indicating that results for the central part of the valley are internally consistent, but that the baseline ties to fixed benchmarks contain systematic errors, most likely from the 1990-91 kinematic surveys. Alternatively, this apparent uplift in height of a few centimeters may be real; the 1990-91 surveys were conducted during mid- to late summer months of heavy groundwater withdrawal, whereas the 1998 survey

was conducted during late winter/early spring months, during a period of ground-water recharge. The results of the InSAR analysis for the period 1992-97 by Amelung et al. (1999) showed that numerous areas of small (cm-scale) localized uplift were related to an extensive artificial recharge program (discussed further below).

With few exceptions, adjusted coordinates for the different surveys agree within a few centimeters and agree closely with subsidence interpreted from InSAR images (Table 3), indicating a lower rate of subsidence than occurred between 1963 and 1987 (Bell and Price, 1991). Some of the larger differences between surveys are likely due to multipathing reception problems caused by obstructions at certain sites. Sites with the most significant potential multipathing problems are noted in Table 2, and these sites should be discarded in future surveys.

Future GPS surveys

Results from the GPS surveys conducted from 1990 to 1998 are considered satisfactory and within the range of uncertainty anticipated when the network was constructed in 1990 (Bell and Price, 1991). As noted, the acquisition of upgraded receivers and antennae and the use of rapid static methodologies for the 1998 campaign significantly improved the accuracy of the survey. However, results could be further improved in future surveys. The 1995 and 1998 surveys involved more redundancy and relied more heavily on static observations, and thus are judged to be more accurate than the 1990-91 and 1994 surveys. The 1995 and 1998 surveys should therefore provide a better baseline for future GPS observations. Accuracy could be further improved by substituting points for those located at the more obstructed sites, and by incorporating more station redundancy (multiple observations) into the surveys. Many of the GPS stations that could be included in future subsidence networks are city and county benchmarks that are separately surveyed by these GPS groups. The observational data from these stations could be used to enhance our existing network, particularly in the active subsidence zones. Lastly, because InSAR provides much better spatial coverage, the highest priority for future GPS efforts would logically be to conduct more frequent observations of selected points in key locations that can be used to ground-truth InSAR studies.

Synthetic Aperture Radar Interferometry (InSAR) Study

Approach

European Space Agency ERS-1 and -2 satellites have been acquiring 56-mm wavelength synthetic aperture radar (SAR) images of the earth's surface since 1992. Each image shows millimeter-scale radar reflections from the ground surface in a 4 x 20 meter pixel format with ground reflection coherence dependent upon vegetation, topography, disturbance, water vapor and other atmospheric conditions. By comparing SAR images flown over the same area, small changes in the position of undisturbed ground surface reflectors may be detected by identification of radar wave phase changes in successive images. Two or more images are precisely compared and analyzed for phase changes by computer processing, and small ground displacements are shown as phase change maps, or interferograms. SAR interferogram (InSAR) studies have been previously applied to a wide range of crustal displacement studies (e.g., Massonnet and others, 1993), but the Las Vegas study is one of the first studies to successfully utilize InSAR analyses in groundwater subsidence areas of the US. The results of this study are contained in the journal paper by Amelung et al. (1999) and are summarized here.

An interferogram map showing subsidence in Las Vegas Valley for the period 1992-97 (Fig. 1) was produced by Dr. Falk Amelung, Department of Geophysics, Stanford University using ERS images purchased by the Las Vegas Office, Water Resources Division, U.S. Geological Survey. Differential interferograms for four shorter time periods were produced (Fig. 14). The Fig. 1 interferogram used here as a base map for several figures is a composite (phase unwrapped) map obtained by summing three separate interferograms for the periods April 1992 to November 1993; November 1993 to February 1996; and January 1996 to December 1997. The topographic phase was removed using the "four-pass" method. One cycle of phase change (one color fringe on Fig.14) represents 28 mm in radar line-of-sight (range) displacement between observations. A typical accuracy for detecting surface deformation using interferometry is on the order 5-10 mm for changes in radar range. However, as discussed in Amelung et al. (1999) and below, a comparison of InSAR results with conventional level line data indicates that accuracies of a few millimeters are possible in arid environments such as Las Vegas.

The interferogram map contains approximately 1.6 million pixel values. The Fig. 1 composite interferogram translates the 28 mm color fringe cycles from the original Fig. 14 interferograms into a simplified color cycle where each blue-red-yellow cycle on the map is equal to 10 cm of vertical displacement. Two successive blue-red-yellow cycles indicate 20 cm of vertical movement, such as seen in the Northwest bowl, and a blue-yellow-red reversal of the cycle indicates positive height change, or uplift, such as near Whitney Mesa. The x, y, and z values determined for each of the InSAR pixels were used to construct a 3-D oblique view of subsidence (Fig. 15) in which the interferogram values have been grouped into 25 mm categories.

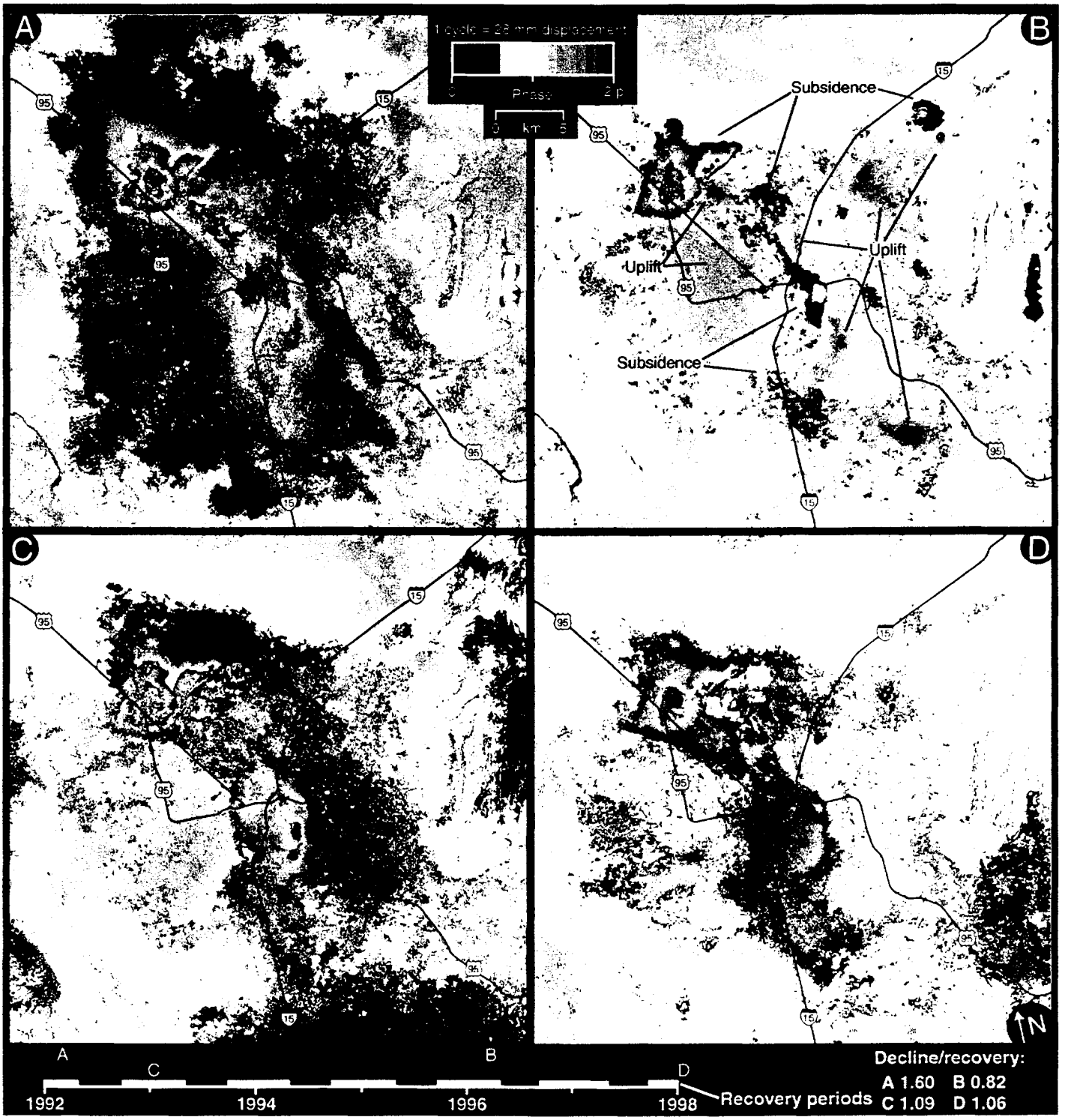


Figure 14. Four differential interferograms covering the same area shown on the composite map (Fig. 1) for separate time periods: A. 21 April 1992 to 2 November 1993; B. 2 November 1993 to 9 February 1996; C. 2 March 1993 to 4 January 1996; D. 4 January 1996 to 5 December 1997. One cycle of phase represents 28 mm of change in radar line-of-sight distance or 31 mm of subsidence or uplift. Yellow represents zero range displacement. Yellow-red-blue is in the direction of increasing range displacement (subsidence), yellow-blue-red is in the direction of decreasing range displacement (uplift). Decline/recovery is ratio between periods of water-level decline and recovery for each interferogram. From Amelung et al. (1999).

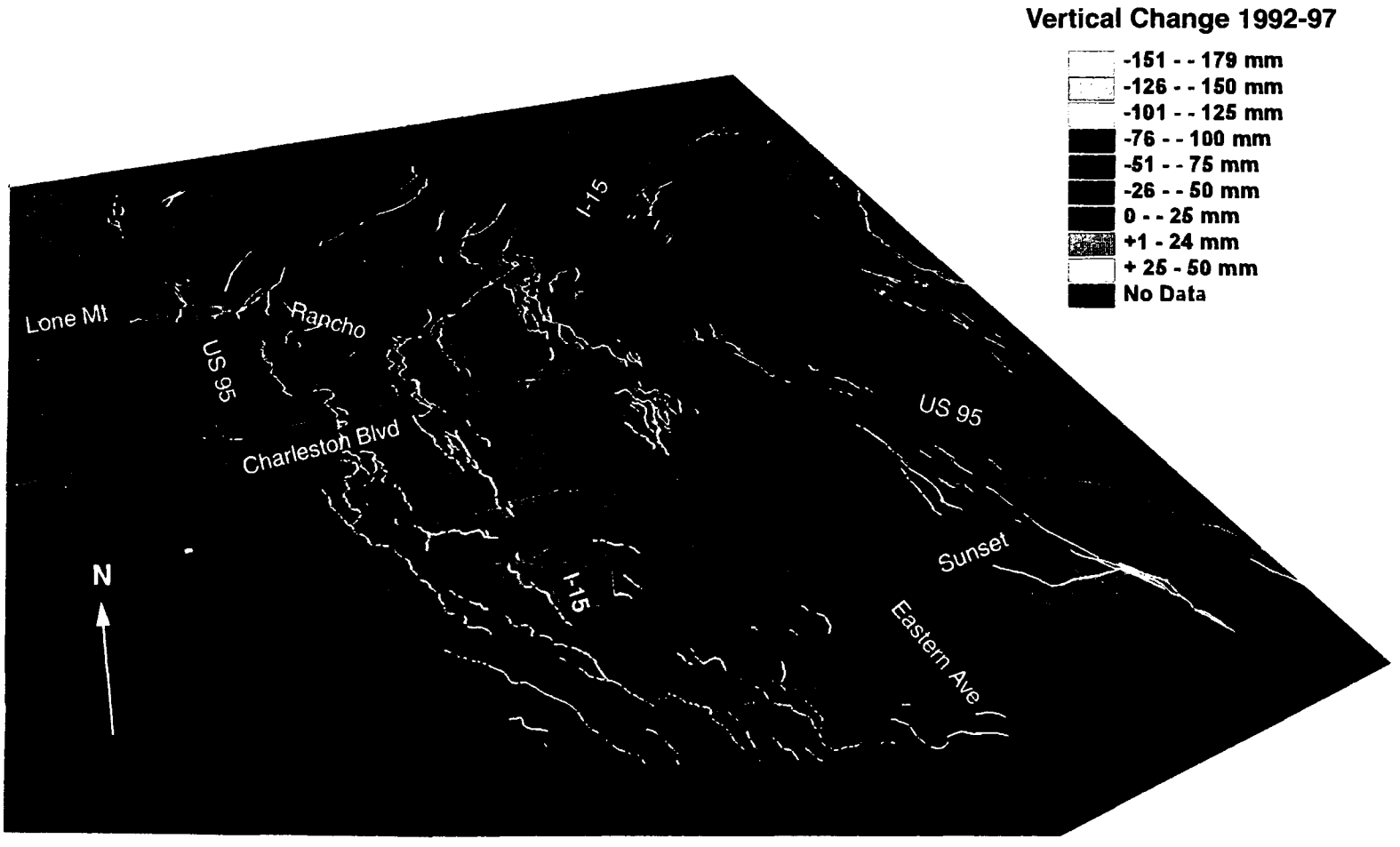


Figure 15. Oblique 3-D view of 1992-97 InSAR subsidence looking northeast across Las Vegas Valley. InSAR x, y, and z values were converted in ArcView to 25 mm (approximately 1 inch) color-coded categories and vertically exaggerated to produce relief.

Interpretation of InSAR Results

The 1992-97 interferogram map (Fig. 1) shows that subsidence is occurring in a series of localized bowls that are coalescing to form a 5- to 10-km wide, north-northwest trending, curvilinear depression along the axis of the valley. The greatest subsidence is concentrated in the localized subsidence zone in the northwest part of the valley, where a maximum vertical displacement of 19 cm (19 cm) was measured during the 5.75 yr period; this is equivalent to a subsidence rate of 3.3 cm/yr (Table 1). The Northwest bowl is roughly triangular in shape, bounded on the southeast by the Eglington fault which forms an abrupt, linear margin. The North Las Vegas bowl displays a maximum subsidence of 9-10 cm, and lesser amounts of maximum subsidence (6-9 cm) are seen in the Central and Southern localized bowls. Some areas in the southeast (Whitney Mesa) and northeast (Nellis AFB) parts of the valley show apparent uplift of ≤2.5 cm.

Additional interferometric analysis for the shorter time intervals shown on Fig. 14 indicated that seasonal fluctuations could be discriminated in the subsidence and uplift patterns in apparent response to pumping and artificial recharge. Refer to Amelung et al. (1999) for a detailed discussion of the seasonal data.

Comparison of InSAR Results with Conventional and GPS Vertical Height Data

The results of the second-order level line surveys were compared with the InSAR data for three areas (Fig. 16): 1) the southern margin of the Northwest subsidence bowl along level lines 1 and 11; 2) the western margin of the Central subsidence bowl along level line 4; and 3) the eastern margin of the Central subsidence bowl along line 10. Line 11 was established along Lone Mountain Road across the Eglington fault in 1991 as a replacement for line 1 which was destroyed by development in 1985 (Fig. 2). A comparison of the interferogram profile with line 11 vertical displacement indicates a close correlation, with the exception of a sharp upward spike of unchanged vertical height recorded on the level line data. The failure of the InSAR profile to detect this spike may be due to the close spacing of the benchmark data which the InSAR analysis was unable to resolve (F. Amelung, personal commun.). Level lines 4 (along Charleston Boulevard) and 10 (along Stewart Street) show similar correlations with the InSAR subsidence profiles, but the level line displacements are somewhat greater possibly owing to movement occurring in 1991-92. A comparison of subsidence rates determined from the 1992-97 interferogram with rates determined along level lines 1 (1980-82) and 10 (1980-91) indicates that although the pattern of displacement remained unchanged, the rate of vertical movement has decreased substantially.

A comparison of 1992-97 InSAR height values determined for each GPS station location and 1990-98 GPS data (Fig. 13; Table 3) indicates a good correlation within the range of uncertainties for the two methodologies (a few millimeters to 1 cm for InSAR and 3-5 cm for the GPS). However, many of the recovered GPS benchmark points fall outside of the principal areas showing subsidence on the interferogram map and therefore comparison of large measurable vertical changes are limited to a few sites. In the Northwest subsidence bowl two benchmarks showing large displacements agree well with

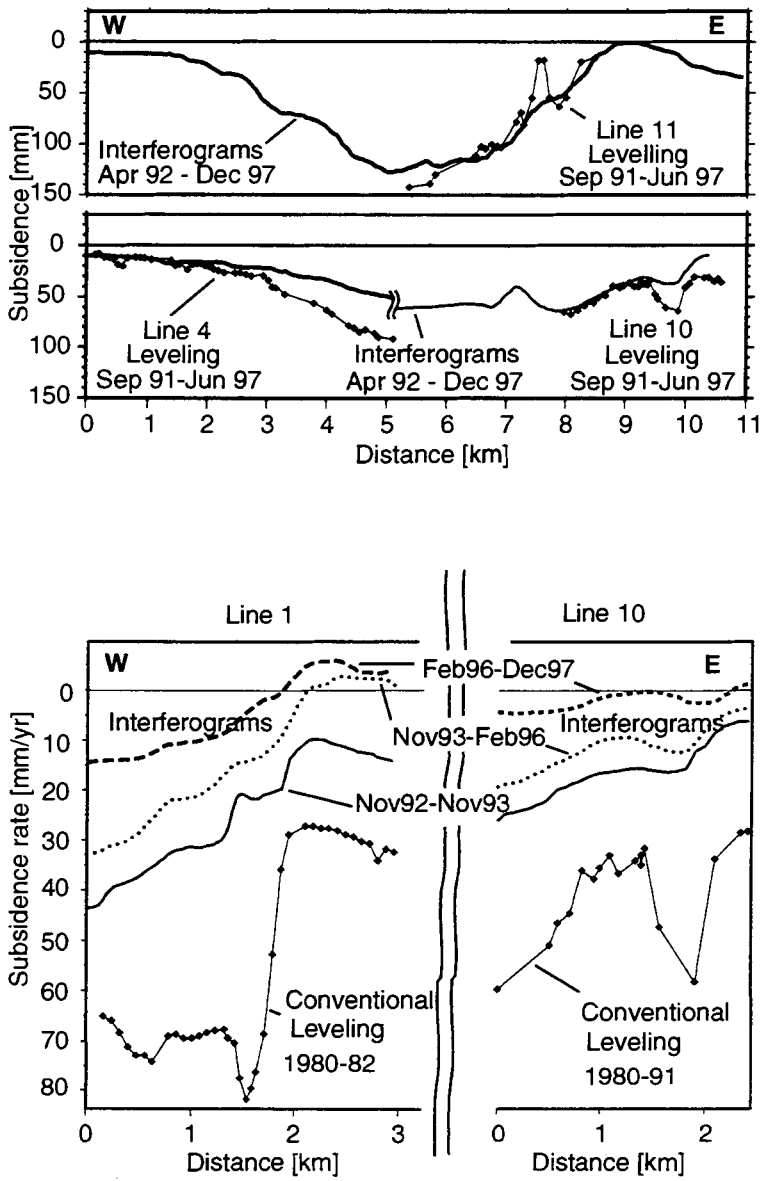


Figure 16. (Top) Comparison of 1992-97 interferogram profiles with conventional leveling results from lines 4, 10, and 11 for the period 1991-97. Interferogram data are taken from pixel values along the level line transects. (Bottom) Comparison of subsidence rates from interferograms and pre-1991 conventional level data for lines 1 and 10. From Amelung et al. (1999).

InSAR-determined displacements: Benchmark R169 had 10 cm of subsidence measured by GPS for the period 1990-95 (when the benchmark was destroyed) and this site recorded 15 cm of subsidence as determined from InSAR point values for 1992-97. The elevation change of benchmark 1LV9033E6 for 1990-98 (-8 cm) shows a good correlation with the InSAR height change for 1992-97 (-6.8 cm).

A comparison of GPS and InSAR values outside of the principal subsidence bowls shows a range of correlation, with most values agreeing within a few centimeters. All of the GPS stations set as assumed fixed benchmarks for processing are within a few millimeters of the InSAR values. The only exception is the assumed fixed benchmark W51 which showed an InSAR value of -1 cm. The larger positive GPS values, particularly in the southern part of the valley, are attributed to possible systematic GPS uncertainties discussed earlier in this report. The InSAR data suggest, however, that some areas of the valley have experienced measurable uplift some of which may be partially recorded in the GPS data.

Pattern of Subsidence Determined from InSAR

The composite interferogram map for 1992-97 (Fig. 1) provides new insights on the pattern of subsidence in Las Vegas Valley, and, in particular, illustrates the degree to which the preexisting geologic structure is controlling the spatial distribution of subsidence. In contrast to previous subsidence maps showing relatively uniform subsidence bowls (e.g., Bell, 1981; Bell and Price, 1991), InSAR data clearly indicate that subsidence is largely confined to a series of irregular, coalescing localized bowls bounded by the principal faults which cut the alluvial valley fill. Four principal localized subsidence bowls are now recognized: 1) Northwest, 2) North Las Vegas, 3) Central , and 4) Southern.

The largest and deepest localized bowl, the Northwest bowl, is bounded on the southeast by the Eglington fault which appears to form a hydraulic and/or subsidence barrier. Similarly, the North Las Vegas bowl is bounded on the southeast by the Windsor Park fault which also acts as a barrier. A smaller, secondary bowl which appears to be a continuation of the North Las Vegas bowl lies slightly to the east. The deformation in both the Northwest and North Las Vegas bowls is occurring on the footwall side of the faults, a relation that may be related to the nature of the fault barriers. The Central bowl is bounded on the west by the Valley View fault and on the east by the Cashman Field fault; the southern extensions of the Valley View and Decatur fault zone form the western margin of the Southern bowl. These faults collectively control the distribution of subsidence in the axis of the valley, forming an elongated north-south-trending graben.

Reinterpretation of 1963-87 Subsidence Map

Previous maps outlining subsidence in Las Vegas Valley have relied on conventional vertical leveling data. The most recent map showing subsidence for the period 1963-87 (Fig. 17) was based upon first-

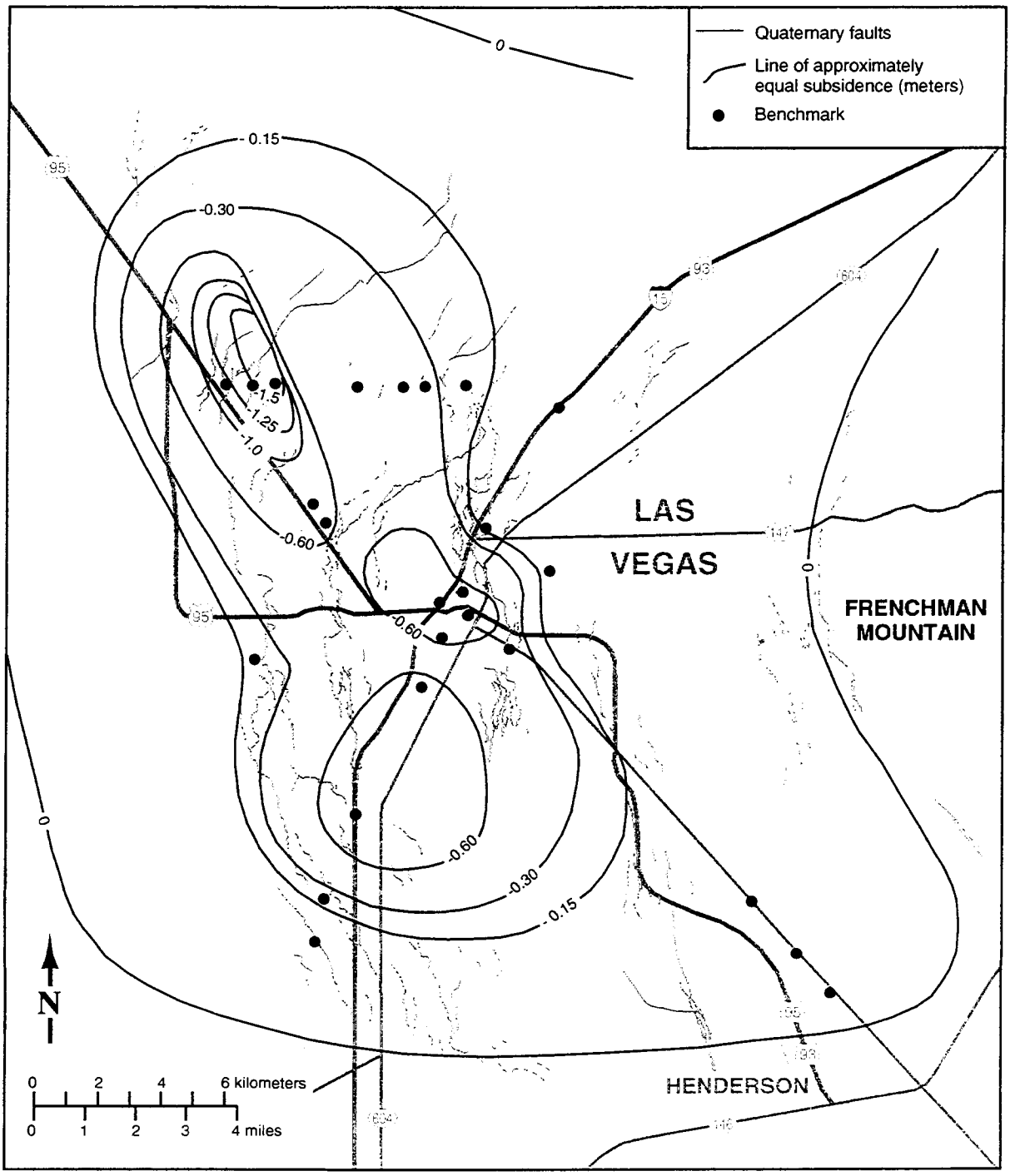


Figure 17. Subsidence map for the period 1963-1987 from Bell and Price (1991). Contours were mapped based on conventional equidistant interpolation of values between the benchmark data points without consideration of the influence of geologic structure.

and third-order leveling results for 27 established benchmarks in the valley (Bell and Price, 1991). This contour map was produced using proportional interpolation scaling between the benchmarks and did not reflect the (now apparent) strong influence of geologic structure. Three principal localized bowls were delineated at that time: Northwest, Central, and Southern. Although the general location of these bowls appears to have been relatively well defined by the conventional leveling data, the InSAR map now provides additional detail and resolution to the subsidence contour maps.

A revised map showing subsidence for the period 1963-87 is shown in Figure 18 based upon the subsidence pattern interpreted from the SAR interferogram map (Fig. 1) while remaining consistent with the original data set of 27 benchmark elevations. There are several principal differences that can be noted. Based on interpolation between benchmarks, the previous 1963-87 contour map grouped the elevation changes in the Northwest bowl with those to the southeast near the North Las Vegas Airport to form an elongated northwest-trending bowl. The Northwest bowl is now interpreted to be more elongated in a northeast-southwest direction reflecting the strong structural influence of the Eglington fault, and the subsidence near the airport is differentiated as a separate new bowl (North Las Vegas). The position of the Central and Southern bowls remain relatively unchanged, although their orientations are more elongated to the south, and the southern extent of the Southern bowl is somewhat greater than previously recognized.

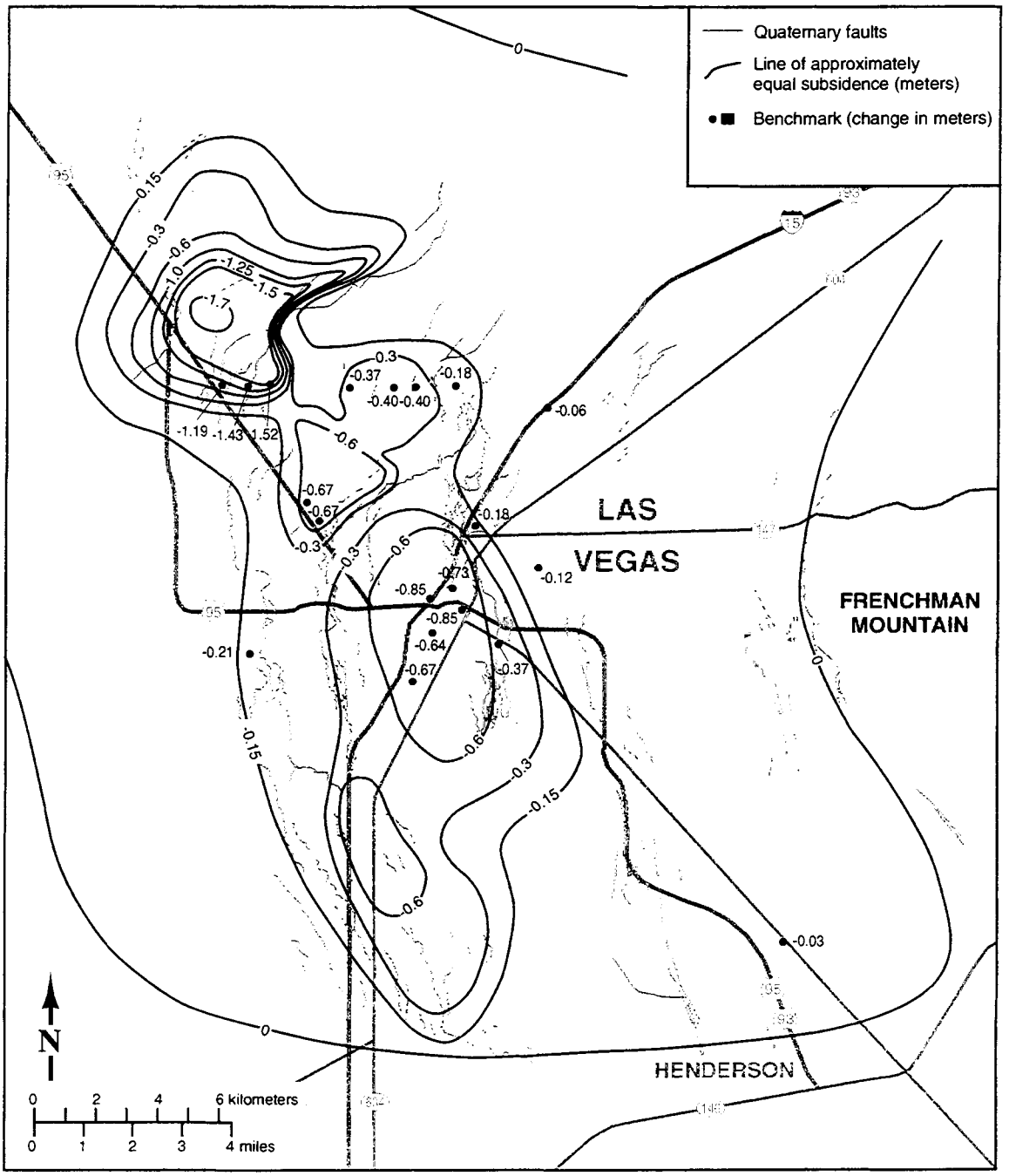


Figure 18. Revised subsidence map for the period 1963-87 based on the spatial pattern revealed by the InSAR map (Fig. 1). Contours have been redrawn to conform to a pattern of localized subsidence bowls delineated by the bounding geologic faults. The revised contour map is consistent with the original 27 benchmark data points used to contruct the Bell and Price (1991) map as well as with the results of the1978-97 conventional level line surveys.

Inventory of Earth Fissures

In March and April of 1998 a field reconnaissance was conducted to observe the condition of previously identified fissures and sinkholes in Las Vegas Valley, noting changes in fissures and any new fissure development. This was a particularly optimum time to observe fissures because of heavy rains that occurred in January of that year. These rains tended to enhance the existing fissures, more easily revealing their state of activity.

The reconnaissance was conducted by visiting the areas identified by Mifflin et al. (1991) and contacting local geotechnical consultants who are familiar with earth fissures in the Las Vegas region. The maps which were updated were those of Mifflin et al. (1991), and unpublished 1:24,000 maps showing fissures zones compiled by John Bell of the Nevada Bureau of Mines and Geology. The major areas of fissuring were easily found as were the larger fissures that had not been urbanized. But most of the smaller fissures were difficult to specifically locate, due to high rates of surface change (grading, eolian deposition, urban deposition (trash), changes to surface-water flow, and some difficulties in locating fissures using Mifflin et al. (1991) small-scale maps. Nevertheless, a general comparison of the fissure area as previously mapped and as it existed in early 1998 can be made. These areas are given letter designations following Patt and Maxey (1978), and Mifflin et al. (1991).

New fissures were mapped using a Garmin hand-held GPS unit, which may have inherent uncertainties that are as high as ● 50 m, and by using conventional pace and compass techniques. Thus, many of the mapped locations of fissures may be limited in precision and somewhat schematic in nature, and the fissure data are best utilized in delineating zones.

In this report the term *fracture* refers to a crack or opening related to tension in the earth. If movement of the sides relative to each other has occurred beyond tension it is referred to as a *fault*. *Earth fissure* or *fissure* is used for fractures that have been enlarged commonly by erosion or piping from water. *Sinkholes* are collapse features where the surface is falling into a subsurface cavity, and *down-hole* is a place along a fissure where a major part of the water and its load flowing along the fissure flow downwards into in the subsurface. *Active* fissures are those that have had water flowing down them within the last few years, and in particular, the January 1998 storms. These fissures show relatively fresh evidence of erosion and local deposition. The term active is not used in the same sense as that used for earthquake faults; *inactive* fissures are those that have not had water flowing down them recently. The sides of these fissures have sloughed and bottoms are usually present because the fissure is filling up with sediment. In many cases these are expressed as shallow swales in the ground surface. These later two terms are subjective and are not meant to be used in a definitive sense. They are an attempt to define fissures that are flowing and enlarging versus those that are not (for example, a fissure that was flowing during the Mifflin and others (1991) survey but ceased thereafter would be an inactive fissure).

The results of this inventory are shown on Plate 1, Map of Earth Fissures in the Las Vegas Area, and are shown schematically on Figure 19. A detailed report on the 1998 fissure study is contained in Appendix 2.

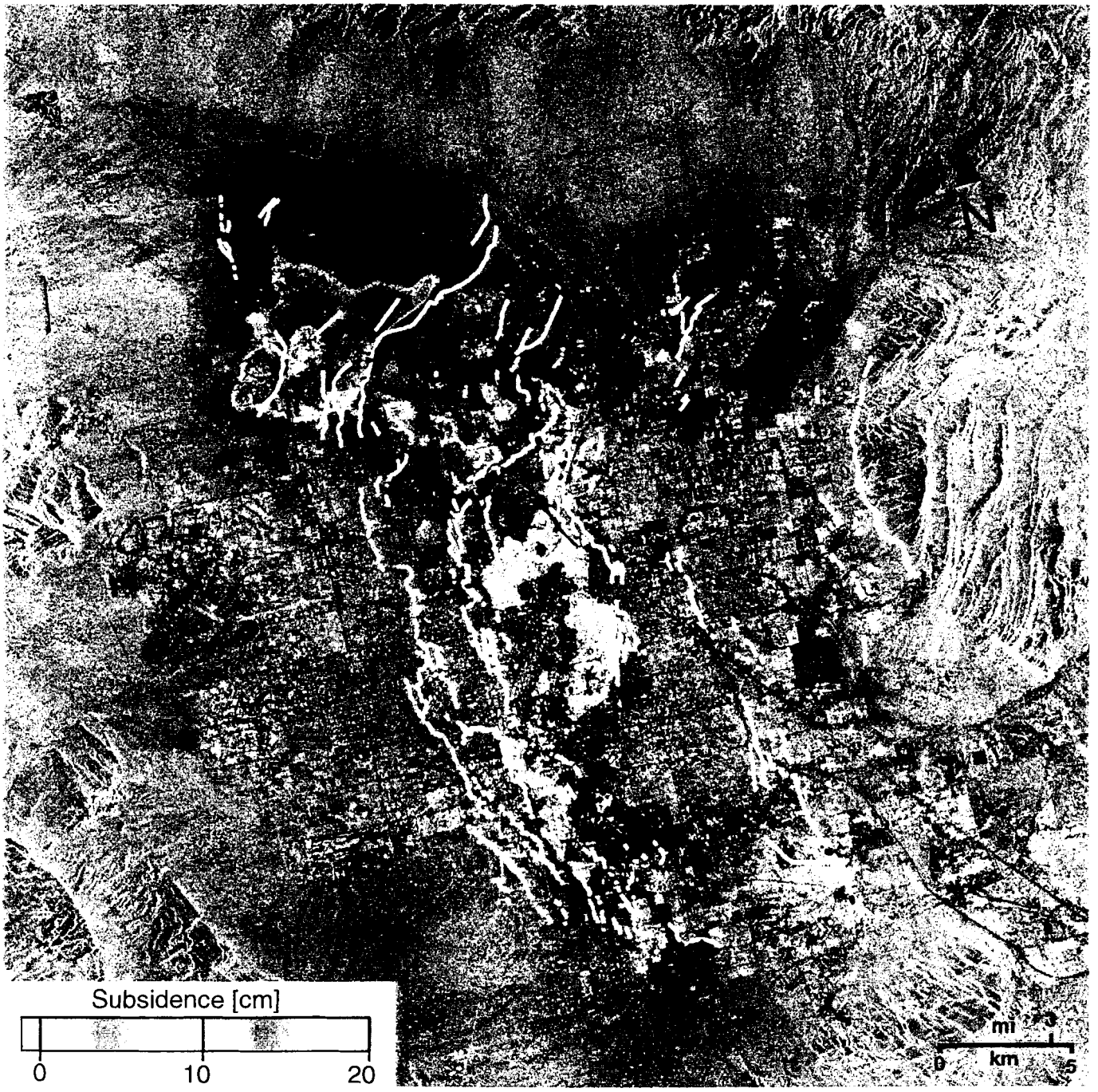


Figure 19. Generalized distribution of earth fissure zones (in black) in Las Vegas Valley shown on 1992-97 InSAR map to illustrate the close spatial relation between fissuring, faults, and localized subsidence bowls. See Appendix 2 and Plate 1 for a detailed location and description of each zone.

The principal conclusions of this survey are:

- Small (<0.3 m wide) preexisting fissures in undisturbed settings were commonly not active (enlarging), and many were difficult to discern.

- Larger preexisting fissures (>1 m wide) in undisturbed settings are usually still visible if not developed over and are commonly, but not always, still actively enlarging.

- Many of the fissures that were identified in the Mifflin (1991) study have been graded or developed over.

- New fissures could usually be clearly related to a water runoff source. This underscores the importance of controlling water runoff in the mitigation of the earth fissure hazard.

- New fissures were generally parallel to preexisting fissure patterns. This indicates that the orientations of future fissures are likely predictable.

- The formation of new fissures appears to be accelerating with time in undisturbed areas, and is presumably stopped or delayed in areas where fissures have been developed over.

- A new area of earth fissures in southern Las Vegas Valley is added to the inventory, and is named Area I.

- Evidence of recent, new primary ground fracturing (in contrast to fissure enlargement) was noted along the northern portion of the Decatur Boulevard fissure zone and in some portions of the Craig Road fissure zones.

- Most new fissures were within the existing fissure-zone areas identified by Bell and Price (1991). Minor enlargements of a few of these areas were made to include some new fissures.

- In Areas D and E1 horizontal extension directions could be measured. These extension directions are N48°-60°W and ~N44°W, respectively. These directions will be of use to future modelers, and are curiously subparallel to the presumed regional stress regime, but this may be coincidence. The measurements are along the Windsor Park fault of the Las Vegas Valley fault system.

- Detailed mapping should be conducted in Areas C1, C2, C3, D, and E1 to precisely record the locations of earth fissures for use in future research.

- Sinkholes and subsurface pipes constitute significant hazards when flowing with water and debris.

Existing areas of fissures should be mapped in detail for future research on earth fissures before they are developed over and lost. This research will likely be important because of the large amount of development over earth fissures. Fissures may continue to be developed in the subsurface in preexisting fissure areas, and with the new potential runoff sources that accompany urbanization, new fissure areas may develop. Additional detailed data should be collected to provide the understanding and reasoning for predicting the potential extent of fissures, fissure networks, and subsurface cavities.

Conclusions

- Conventional level line, GPS, and InSAR results for 1990-98 collectively indicate that the rate of subsidence has decreased in most areas.

  The Northwest subsidence bowl continues to be the most active subsidence area in the valley, moving at a maximum rate of 3.3 cm /yr based on InSAR data. This rate, however, is about 40% lower than rates measured during the early and mid-1980's, and rates during late 1990's appear to be even lower (Amelung et al., 1999). This area experienced more than 1.7 m of subsidence between 1963-87, and the continued movement between 1990-98 may reflect either the effects of residual compaction and/or the continuing influence of groundwater pumping in the area. Line 11 established along Lone Mountain Road in 1991 on the southern margin of the bowl displayed subsidence as much as 2 cm/yr through 1997.

  The North Las Vegas bowl is a newly recognized localized subsidence zone based on the spatial pattern delineated by the InSAR map; the area was included within the Northwest bowl by Bell and Price (1991). Conventional leveling data collected since 1978 along line 2 near the Windsor Park subdivision indicate that the rate of subsidence has decreased from 1.4 cm/yr to 1.1 cm/yr.

  The Central subsidence bowl shows the most significant decline in subsidence rates, as measured along level lines 3 and 10. Both lines showed rates on the order of 2.5 cm/yr during the 1978-91 period; the 1997 surveys indicate that this rate has declined to about 5 mm/yr, a reduction of 75%. This reduction is attributed to the effects of the artificial recharge program which has produced rising water levels in this part of the valley.

  InSAR mapping indicates that the highest subsidence rates appear to have occurred during the 1992-93 period, and that beginning in late 1993 or early 1994 the rate diminished apparently in response to the effects of the artificial recharge program.

- More than 25% of the 115 GPS benchmarks established in 1990-91 were not recoverable, due primarily to destruction by urban development. Recovered GPS stations yielded results for the 1990-98 period which are generally accurate to within 2-3 cm, but most recovered stations were situated in areas outside of the principal subsidence zones and thus provided limited new information on large-scale vertical movement.

- The InSAR map showing subsidence between 1992-97 provides important new insights into the pattern and rate of subsidence. In contrast to previous subsidence maps which outlined relatively uniform subsidence patterns (Bell, 1981; Bell and Price, 1991), InSAR data indicate that subsidence is strongly controlled by the preexisting geologic faults. The InSAR map shows four principal subsidence zones in the valley: the Northwest, North Las Vegas, Central,

and Southern localized bowls. It further indicates that the Eglington and Windsor Park faults appear to act as hydraulic or subsidence barriers with most deformation occurring on the footwall (northwest) side of the faults. The other principal faults in the valley (such as the Valley View and Cashman Field faults) are seen to bound the subsidence zone along the axis of the valley and serve as preferred sites of differential movement.

- An inventory of fissure zones mapped in 1991 indicates that, where not covered by subsequent construction, fissures are continuing to enlarge by surface erosion, and that some renewed primary ground cracking may have occurred in the Decatur Boulevard and Craig Road fissure zones. A new, previously unmapped fissure zone was also identified in the south part of the valley.

Recommendations for Future Work

Based on the results of the 1998 surveys, we recommend that the following areas be considered for future work:

- Continue to geodetically monitor the deformation in the northwest part of the valley where residual compaction and/or additional water level declines will continue to produce movement. The Northwest and North Las Vegas subsidence bowls continue to exhibit the highest rates of vertical movement, and it is recommended that the monitoring network be densified and re-surveyed more frequently in order to ensure a more continuous record. Successful and more accurate extension of the GPS network can be accomplished through the use of newly developed methodologies and upgraded equipment obtained in 1998. Network densification designed to replace the stations lost to urban development can be accomplished with more extensive utilization of GPS benchmarks jointly used by local survey agencies.

- Establish a new conventional level line (line #12) through the deepest part of the Northwest bowl as indicated by InSAR data. This line would extend east-west along Ann Road, which lies across the center of the bowl, and it would be designed to verify the maximum measured amounts and rates of relative subsidence through the bowl.

- Densify and re-survey GPS stations in targeted portions of the Northwest and North Las Vegas subsidence bowl areas in order to provide regional vertical control for the level lines. It is recommended that selected benchmarks on lines 2, 11, and 12 be re-surveyed by static and rapid static GPS methods concurrent with the conventional level line surveys.

- Re-survey lines 2, 4, 11, and 12 by conventional second-order leveling on an annual or biennial basis in order to provide a continuous and spatially detailed record of subsidence and/or uplift in key areas of the valley and to document localized movement across the

Eglington, Windsor Park, and Valley View faults.

- Continue InSAR analysis of subsidence in the northern part of the valley in order to verify the spatial pattern and magnitude of vertical movement. The conventional level line and GPS surveys will provide selected sites for verifying InSAR results.

- Conduct annual ground surveys of the Decatur Boulevard and Craig Road fissure zones to monitor the possible development of new primary ground cracks.

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Appendix 1

GPS Station and Coordinate Adjustment Data

Alan R. Ramelli
Ken Austin

STATION DESCRIPTIONS - LAS VEGAS SUBSIDENCE GPS NETWORK

ID#	Name	Latitude	Longitude
~~0001~~	~~113USGS~~	~~36 17 14.814~~	~~115 16 03.980~~

UNABLE TO LOCATE (apparently destroyed); 0.5 mi N of Durango along old RR grade

0002	C141	36 16 39.574	115 02 14.479

SE side of I-15 at Mile 52.95; 4.5 mi NE of Craig Rd.; 0.1 mi NE of first Exit 54 sign; about 150 ft from road; 3 ft metal witness post.

~~0003~~	~~P169~~	~~36 12 17.577~~	~~115 12 2.228~~

UNABLE TO LOCATE (apparently destroyed); replaced with NVGT (0139)

0004	D368	36 09 16.900	115 21 47.189

W on Charleston Blvd. 6.65 mi from Rainbow Blvd. to a bridge after highway curves left; continue for 0.1 mi to a bedrock ridge on the left; station is on NE side of ridge, 188 ft SE and 23 ft higher than highway centerline.

0005	U368	36 11 53.553	115 00 37.313

E on Lake Mead Blvd. 2.94 mi from Nellis Blvd.; station is approx. 200 ft S of centerline of Lake Mead Blvd., set in bedrock on north-facing hillslope.

0006	EA963+67.37	36 00 22.743	115 10 48.294

E side of I-15 @ mile 30.85; adjacent to W end of E. Pyle Ave.; 2.65 mi S of Blue Diamond Rd. overpass; 3.05 mi N of Lake Mead Dr. overpass; 0.25 mi N of power lines.

0007	W51	36 04 04.408	115 00 51.816

SW side Boulder Hwy.; 35 ft W of edge of Boulder Hwy.; 280 ft N of centerline of Elliott Rd.

~~0008~~	~~L399~~	36 7 37.04	115 04 47.51

ABANDONED (severe multipathing problems; not recovered from 1990 data)

0009	D371	36 24 53.323	115 27 05.652

Lucky Strike Canyon; about 1.8 mi west of US 95. Go NW on US 95 9.4 mi from Mt. Charleston turnoff, turn left onto dirt road opposite Corn Creek Springs Rd., follow dirt road for 1.64 mi to a fork, take left fork and go 0.16 mi to N side of ridge; station is in saddle of ridge.

~~0010 WELL8 36 09 55.798 115 11 25.409~~

UNABLE TO LOCATE (apparently destroyed); LVVWD yard off of Valley View

---

~~0011 X398 36 10 52.376 115 10 43.344~~

UNABLE TO LOCATE (apparently destroyed); 18 ft N of N curb of Washington Ave.; 120 ft E of E curb of Rancho Dr.; replaced with 2C01/29C4 (0152)

~~0012 P169 (same point as 0003)~~

~~0013 T398 36 13 36.52 115 13 15.44~~

UNABLE TO LOCATE (apparently destroyed);

~~0014 R169 36 15 04.987 115 14 32.478~~

UNABLE TO LOCATE (apparently destroyed); replaced with PLS6902 56.57 (0143)

0015 7C00-14N4 36 13 02.332 115 14 02.835

SW corner of Torrey Pines Dr. and Cheyenne Ave.

~~0016 7C00-23S4 36 11 19.079 115 13 55.993~~

UNABLE TO LOCATE (apparently destroyed); NW corner of Vegas Dr. and Barrel Cactus Ct.

~~0017 UN1~~ 36 11 44.19 115 10 07.41

ABANDONED (unable to recover from 1990 data)

~~0018 UN2 36 10 37.379 115 09 13.497~~

UNABLE TO LOCATE; 835 Bonanza Rd.; unmarked shiner set in parking lot near curb; offset from Q365, which is located in side of loading dock

---

0019 P399 36 11 45.827 115 08 26.541

RR bridge over Lake Mead Blvd.; W side RR tracks; N side Lake Mead Blvd.; top of concrete wall.

~~0020 T19-20S/R60-61E~~ 36 14 50 115 12 23

UNABLE TO LOCATE (apparently destroyed)

~~0021 E369 36 14 22.391 115 10 02.907~~

UNABLE TO LOCATE (apparently destroyed); replaced with 80.19 (0136)

~~0022 2-2-92 36 14 23.888 115 08 03.116~~

UNABLE TO LOCATE (apparently destroyed); replaced with 7C01-2C4 (0138)

0023 7C01-11S4 36 13 05.161 115 07 36.124

NE corner of Losee Rd. and Cheyenne Ave.

0024 7C00-36SSW6 36 09 33.423 115 13 09.100

NE corner of Charleston Blvd. and Upland Blvd.

~~0026 X367 36 08 41.648 115 19 03.988~~

UNABLE TO LOCATE (apparently buried and soon to be destroyed by construction); 125 ft N of Sahara Ave.; 500 ft W of Hualapai Way; set in calcrete about 2 ft above the ground

---

~~0027 7C10-15NWS 36 07 44.511 115 15 38.991~~

UNABLE TO LOCATE (apparently destroyed); SE corner of Buffalo Dr. and Desert Inn Rd.

0028 7C10-22SWS 36 05 58.990 115 15 38.902

NE corner of Tropicana Ave. and Buffalo Dr.

~~0029 D170 36 04 35.509 115 11 57.778~~

UNABLE TO LOCATE (found witness post and broken-off concrete post); E side RR

tracks; 0.35 mi N of Sunset Rd.

0030 7C10-24SWS 36 06 00.053 115 13 29.210

NE corner of Tropicana Ave. and Jones Blvd.

0031 7C10-13NNW6 36 07 44.969 115 13 12.292

SE corner of Desert Inn Rd. and cul-de-sac, 200 ft E of Duneville St.

0032 7C11-5SSW6 36 08 40.337 115 11 06.974

NE corner of Sahara Ave. and Rye St.-Spanish Oaks Dr.

0033 N366 36 06 55.914 115 11 04.806

SE headwall of RR bridge; 325 ft N of Flamingo Rd. overpass at tracks.

~~0034 MI40 36 04 41.388 115 08 12.235~~

UNABLE TO LOCATE (apparently destroyed by airport expansion); N side of airport fence, due S of junction of Maryland Pkwy at Patrick Rd.

~~0035 6C11-22SSW6 36 06 04.533 115 08 58.588~~

UNABLE TO LOCATE (apparently destroyed); NE corner of Tropicana Ave. and Paradise Rd.

~~0036 6C11-15NWS 36 07 46.064 115 09 16.882~~

UNABLE TO LOCATE (apparently destroyed); SE corner of Desert Inn Rd. and Paradise Rd.

0037 6C11-13SWW6 36 07 06.97 115 07 07.98

NE corner of Eastern Ave. and Viking Rd.

~~0038 RLS 1788 56.82~~

ABANDONED (located on same corner as 0039)

~~0039 C55+60 36 08 40.04 115 07 08.46~~

UNABLE TO LOCATE (apparently destroyed); NW corner of Sahara Ave. and Eastern Ave.; also 6C11-2SES; stamped STA C 55+60, DIST. 60.29.

~~0040 6C02-32SWS 36 09 32.642 115 04 47.794~~

UNABLE TO LOCATE (apparently destroyed); NE corner of Charleston Blvd. and Lamb Blvd.

~~0041 NLV5 36 11 18.178 115 06 57.218~~

UNABLE TO LOCATE (apparently destroyed after single 1998 observation); SE corner of Owens Ave. and Civic Center Dr.-Eastern Ave.; stamped North Las Vegas #5, 1947.

0042 7C02-18NWW6 36 12 52.305 115 05 54.175

SE corner of Pecos Rd. and Las Vegas Blvd.

~~0043 7C01-11S4 (same point as 0023)~~

~~0044 M365 36 14 01.006 115 06 47.330~~

UNABLE TO LOCATE (apparently destroyed)

~~0045 T19-20S R61-62E 36 14 49.021 115 05 55.602~~

UNABLE TO LOCATE (apparently destroyed); replaced with RLS4841 (0149)

0046 6C02-4SWW6 36 14 11.740 115 03 43.155

NE corner of Nellis Blvd. and Las Vegas Blvd.

0047 6C02-16SWS 36 12 13.808 115 03 43.244

NE corner of Nellis Blvd. and Carey Ave.

~~0048 R368~~ 36 11 48 115 02 05

ABANDONED (unable to recover from 1990 data); NW corner of Lake Mead Blvd. and Mt. Hood; 2 ft. N of hydrant; tenuous, extended setup due to proximity to tree

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~~0049 U368 (same point as 0005)~~

0050 7C02-28S4 36 10 27.19 115 3 10.07

NE corner of Bonanza Rd. and Christy Ln.

0051 T19-20S/R62-63E 36 14 49.258 114 59 19.897

From Craig Rd., 3.0 mi NE along Las Vegas Blvd.; right 1.3 mi to gate; section corner is 0.5 mi to SSE; E of pond; access must be obtained from Nellis Air Force Base.

0052 V365 36 18 50.633 115 16 48.291

NE side of old RR grade (dirt road across Durango from Tule Springs State Park turnoff)

0053 112USGS 36 20 25.584 115 17 45.331

NE side of old RR grade; SW 1/4, Sec. 32, T18S, R60E; ~0.35 mi north of high-voltage transmission line; 50 ft NE of RR grade; on top of 1.6-ft-high iron pipe.

~~0054 W314 36 21 45.271 115 19 11.064~~

UNABLE TO LOCATE (apparently destroyed)

0055 X314 36 21 11.774 115 18 31.115

1.45 mi N of high-voltage power line; 40 ft NE of old RR grade

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0056 Y370 36 25 05.927 115 25 13.355

SW side of Hwy. 95; just N of Mile 101 marker; about 350 ft W of Hwy. 95.

0057 W370 36 23 47.324 115 23 38.922

SW side of Hwy. 95; about 300 ft S of Mile 99 marker; about 200 ft W of Hwy. 95.

0058 T370 36 21 57.156 115 21 25.923

SW side of Hwy 95; just S of Mile 96 marker; about 200 ft W of Hwy. 95.

~~0059 0C89-36W6 36 20 35.829 115 19 44.302~~

SW side of Hwy. 95; just S of Mile 94 marker; in culvert headwall; replaced in 1997

0061 0C90-17C4 36 17 55.805 115 17 12.095

SW side of Hwy. 95; just N of State Park turnoff; in culvert headwall

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~~0062 R169 (same point as 0014)~~

~~0063 WELL S20/E61 18BCCD~~ 36 12 38 115 12 45

ABANDONED; well head at entrance to North Las Vegas Airport

0064 HAPPY 36 02 50.330 115 10 53.189

W side I-15 at Blue Diamond Rd. Exit; 0.2 mi N of Blue Diamond overpass

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~~0065 D170 (same point as 0029)~~

0066 JERK 36 03 08.126 115 12 42.429

E side of RR tracks; 0.35 mi S of Warm Springs Rd.

~~0067 F170 36 01 28.568 115 13 37.454~~

UNABLE TO LOCATE (apparently destroyed); E side of RR tracks; about 300 ft S of Blue Diamond Rd.; replaced by F170 RESET 1990 [0167]

~~0068 6C11-22SSW6 (same point as 0035)~~

~~0069 WELL S21/E61 22CCC 36 06 06.77 115 09 16.78~~

~~0070 RLS8547 19863,22.61 36 02 31.892 115 09 14.465~~

UNABLE TO LOCATE (apparently destroyed); Windmill Ln. and Bermuda Rd.

0071 SLOAN 35 56 23.988 115 10 59.297

0.15 mi SE of I-15; 2.4 mi S of Lake Mead Dr.

~~0072 1C90-29SES 36 15 47.123 115 16 43.812~~

UNABLE TO LOCATE (apparently destroyed); Ann Rd. and Durango

~~0073 D146~~ 35 58 58.35 115 10 49.75

ABANDONED (not recovered from 1990 data); E side of I-15; 4 to 5 mi S of Blue Diamond Rd.

0075 6C02-16W4 36 12 40.119 115 03 43.396

NE corner of Nellis Blvd. and Alto Ave.

0076 6C02-9SWS 36 13 06.698 115 03 43.250

NE corner of Nellis Blvd. and Cheyenne Ave.

0077 6C02-9W4 36 13 33.226 115 03 43.123

NE corner of Nellis Blvd. and Gowan Rd.

0079 0474+92.33 36 14 30.758 115 03 07.315

On median of Las Vegas Blvd., 0.15 mi NE of Craig Rd.; adjacent to NAFB Visitor's Center and Main Gate.

~~0080 229-44 36 14 48.632 115 02 35.179~~

UNABLE TO LOCATE (apparently destroyed); SE side of Las Vegas Blvd.; 0.1 mi NE of Range Rd.; 50 ft SE of Las Vegas Blvd.

0081 LVAFB B 36 15 17.664 115 01 45.503

SE side of Las Vegas Blvd.; 1.1 mi NE of Range Rd.; 30 ft SW of end of chainlink fence, 50 ft SE of Las Vegas Blvd.

~~0082 229-98 36 15 56.602 115 00 38.292~~

UNABLE TO LOCATE (apparently destroyed); SE side of Las Vegas Blvd.; 2.4 mi NE of Range Rd.; 100 ft SW of entrance to Area II; 75 ft SE of Las Vegas Blvd.

0083 UNDER 36 19 02.097 114 56 54.433

From Apex exit off I-15, go 0.4 mi N and pass underneath RR tracks; 100 yd N of RR tracks, turn right onto dirt road; go 0.1 mi along RR tracks; turn left and go 0.1 mi on graded dirt road to station at top of large gravel knoll; brass cap set in concrete to the right of road; UNDER 1957

~~0084 B141 36 17 17.479 115 00 19.963~~

UNABLE TO LOCATE (apparently destroyed); SE side of I-15; 1.9 mi NE of station

C141 (0002); 600 ft SE of I-15.

0085 1LV00-4SES 36 13 59.798 115 15 39.107

NW corner of Buffalo Dr. and Alexander Rd.

0086 P364 35 58 30.468 114 54 49.470

E side of Hwy. 93; 0.3 mi NW of the Railroad Pass Casino; 78 ft NE of Hwy. 93; 43 ft SE of culvert headwall; set in NW side of prominent bedrock outcrop.

~~0087 J166 35 59 24.556 114 55 37.322~~

UNABLE TO LOCATE (apparently destroyed); SW side of Hwy. 93; 0.4 mi S of Wagon Wheel Dr.; 50 ft W of Hwy. 93.

0088 H166 36 00 39.995 114 57 02.633

SW side of Hwy. 93; 0.25 mi SE of Race Track Rd.-Horizon Dr.; 250 ft NW of Equestrian Dr.; 100 ft SW of Hwy. 93.

0089 M364 36 01 25.987 114 57 54.600

SW side of Hwy. 93; S corner of Hwy. 93 and Greenway Rd.-Palo Verde Dr.; 120 ft SW of Hwy. 93; on top of east side of concrete footing for east steel leg of tower 12 N 4.

~~0090 K364 36 02 54.255 114 59 28.954~~

UNABLE TO LOCATE (apparently destroyed); NE side of Hwy. 93; 0.2 mi NW of Water St.

~~0091 D365 36 04 52.691 115 01 42.564~~

UNABLE TO LOCATE (apparently destroyed); NE side of Hwy. 93; 0.3 mi SE of Russell Rd.

0092 J399 36 06 08.284 115 03 07.585

NE side of Hwy. 93; 610 ft N of Tropicana Ave.; 1.8 ft S of power pole #14179NP; 2 ft N of witness post.

0093 0503+20.08 36 01 54.272 115 01 49.513

N side of Lake Mead Dr.; 250 ft W of Gibson Rd.; stamped STAT 0503+20.08, DIST.

97.00.

~~0094 0351+10.47~~

ABANDONED (not recovered from 1990 data); N side of Lake Mead Dr.; 0.2 mi E of Green Valley Pkwy.; NHD station 0351+10.47, DIST. 50.00; clear site in 1998, but replaced with GIS point 888 (0163)

~~0095 RLS8547 9522261 36 02 33.333 115 06 01.170~~

UNABLE TO LOCATE (apparently destroyed); Pecos Rd. and Windmill Ln.

0096 H169+87.05 35 59 45.503 115 07 47.850

N side of Lake Mead Dr.; 1.1 mi SW of Eastern Ave.; 0.25 mi SW of Seven Hills Dr.; 0.5 mi NE of Maryland Pkwy.; also 0C21/35N6 (plate on 4X4 witness post)

0097 C170 36 05 28.106 115 11 45.651

E side of RR tracks; between Mesa Vista Ave. and Diablo Dr.; behind warehouse (5475 Wynn Rd.)

~~0098 RLS5835 73.27 36 04 50.66 115 06 02.83~~

UNABLE TO LOCATE (apparently destroyed); SE corner of Pecos Rd. and Callahan Ave.

~~0099 6C22-5E6 36 03 55.827 115 03 56.219~~

UNABLE TO LOCATE (apparently destroyed); S side of Sunset Rd.; E side of Pepper Tree Ln.-Scimitar Dr.; S entrance to Ridgeview Village; replaced with 7C22-5E4 in 1997.

0100 0LV00-17SEE6 36 12 22.474 115 16 44.841

W side of Rampart Blvd. at Point Conception Dr.

~~0101 CLV35 36 09 59.905 115 07 05.459~~

ABANDONED (obstruction/multipathing problems and confusion over point); NE corner of Stewart Ave. and 23rd St.; observed 56135A10 in 1998

0102 K366 36 09 09.401 115 09 37.279

NE corner of Oakey Blvd.-Wyoming Ave. and RR tracks; top of W end of retaining wall;

8 ft N of curb; 15 E of RR tracks

0103 817-20-61 36 12 09.706 115 10 11.268

S of Carey Ave. and Clayton St. intersection

0104 CLV23 36 09 33.023 115 12 05.349

NW corner of Charleston Blvd. and Essex Dr.; multipathing problem from adjacent light pole

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~~0105 K367 36 09 33.399 115 13 06.159~~

ABANDONED (obstruction/multipathing); On curb, N side Charleston Blvd.; 300 ft E of Upland Blvd.

0107 6C12-7SE6 36 08 04.755 115 05 18.945

NE side of Hwy. 93; on curb at U.S. 93-95 North on ramp

~~0109 8C21-11SES 36 02 32.878 115 07 06.215~~

UNABLE TO LOCATE (apparently destroyed); NW corner Eastern Ave. and Windmill Ln.; replaced with 7C21-12SWS

~~0110 1LV00-2NEE6A 36 14 39.626 115 13 32.554~~

ABANDONED (multipathing problems); SW corner of Jones Blvd. and Sadler Dr. (0.15 mi S of Lone Mt. Rd.)

~~0111 1LV90-26SES 36 15 40.360 115 13 32.619~~

UNABLE TO LOCATE (apparently destroyed); NW corner of Jones Blvd. and Ann Rd.

0112 5-18-117 36 17 29.045 115 12 24.552

NW of intersection of Elkhorn Rd. and Decatur Blvd.; also 1LV91-19NWS; SE of C.C. GIS and BLM benchmarks

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0113 1LV90-33E6 36 15 19.891 115 15 54.497

N side of W Washburn Rd.; opposite E edge of N Conough Ln.; 9 ft E of light pole

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0114 PLS2050 74.75 36 15 41.019 115 09 23.608

NE corner of Ann Rd. and Camino Eldorado

~~0115 0LV00-32SES 36 09 33.084 115 16 48.329~~

UNABLE TO LOCATE (apparently destroyed); NE corner of Charleston Blvd. and Durango

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0116 WD15+07.95 36 10 24.498 115 08 32.587

On curb, W side of Casino Center Blvd.; 120 ft N of Stewart Ave.; offset from K169

0117 110USGS 36 25 46.269 115 23 19.890

E side of old RR grade; ~1.9 mi E on Corn Creek Rd. from US 95; ~0.13 mi S on old RR grade from Corn Creek Rd.

0118 169GWM 36 26 12.969 115 21 46.589

Corn Creek Springs; in cement pad W of Corn Creek Field Station

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0119 170GWM 36 26 12.499 115 19 55.624

S side of Mormon Well Road; about 1.5 mi E of Corn Creek Field Station

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0120 171GWM 36 26 15.218 115 17 48.706

S side of Mormon Well Road; about 3.5 mi E of Corn Creek Field Station

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0121 Z398 36 23 09.967 115 22 53.820

SW side of Hwy 95; about 200 ft S of Mile 98 marker; about 200 ft W of US 95.

0122 32-33-5-4 36 20 09.578 115 16 43.079

Section corner along high-voltage power line; 3 ft N of 1-ft-high steel witness post

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0123 802 36 20 09.682 115 15 38.976

Clark County GIS control point along high-voltage power line. From Elkhorn, go 2.5 mi N on Jones; as road turns to right, turn left (NW) onto jeep trail and go 1.0 mi to a jeep trail running parallel to a channel; go 1.7 mi W to end of channel, turn right and go 0.2 mi,

turn right again on dirt road and go 0.6 mi, then left 200 ft to station.

~~0124 33-34-4-3~~ 36 20 08.966 115 15 38.565

ABANDON (same location as 0123)

0125 34-35-3-2 36 20 08.360 115 14 34.106

Section corner along high-voltage power line; disk on pipe 1" above ground; also 1LV90-3NES; 1 ft E of section corner marker on leaning concrete post

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0126 803 36 20 07.727 115 12 25.403

Clark County GIS control point along high-voltage power line. From Craig Rd., go 3 mi N on Jones, turn right and go 1 mi E on Elkhorn, then left and go 3 mi N on Decatur to angle point of power line; station is 135 ft NE of corner power pole and 63 ft NW of Township corner marker.

0127 2GWM 36 19 31.609 115 20 03.807

S side of Kyle Canyon Rd.; about 1.3 mi W of Hwy. 95; 0.4 mi W of Mile 20 marker; 0.25 mi W of Rimrock St.; in culvert headwall.

0129 3GWM 36 19 06.911 115 21 47.596

S side of Kyle Canyon Rd.; ; 300 ft W of Mile 18 marker; 0.1 mi E of Lucky Star Rd.; in culvert headwall.

0130 4GWM 36 18 30.595 115 23 44.436

S side of Kyle Canyon Rd. at Mile 16 marker; 0.15 mi W of Buena Vida; in culvert headwall.

0131 2C90-6SWW6 36 19 31.000 115 18 38.738

SW side of Hwy. 95; just S of Kyle Canyon Rd.; in culvert headwall

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0132 0C90-7SE6 36 18 43.447 115 17 55.313

SW side of Hwy. 95; just N of Adopt-A-Highway Clark County 4-H sign; in culvert headwall

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0133 806 36 17 32.169 115 18 53.199

Clark County GIS control point; corner of Secs.13-18-19-24, T19S, R59-60E; about 1.5 mi SW of Hwy. 95; about 2.3 mi S of Kyle Canyon Rd.

~~0134 807 36 14 53.542 115 18 54.024~~

UNABLE TO LOCATE (apparently destroyed by road grading); GIS control point; corner of Secs.36-31-6-1, T19-20S, R59-60E; N of Lone Mountain.

0135 CLV plate1 36 14 19.268 115 12 49.649

SW corner of Craig Rd. and Lake Tahoe St.

0136 80.19 36 14 21.430 115 10 28.732

SW corner of Craig Rd. and Laurel Hill

0137 874 36 14 52.276 115 09 12.882

Clark County GIS control point; E side of Camino Al Norte at Scoundrels Pub II; N of Lone Mountain Rd.; ~10 ft north of transformer; top of curb

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0138 7C01-2C4 36 14 22.510 115 07 30.400

SE corner of Craig Rd. and Arcata; ~6 ft NW of light pole; top of curb

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0139 NVGT 36 12 36.747 115 11 54.425

North Las Vegas airport; HARN station FAA VGT A

0140 LORENZI 36 14 09.273 115 14 28.672

Wellhead in SE corner of substation off Rainbow Blvd., S of Craig Rd.

0141 V169 36 19 41.008 115 17 14.506

E side of old RR grade; 0.2 mi W of Homestead Rd.; 130 ft S of Log Cabin Way; 25 ft E of power line.

0142 PLS7635 78.46 36 13 03.118 115 10 12.338

SE corner of Cheyenne Ave. and Clayton St.

0143 PLS6902 56.57 36 15 04.240 115 14 33.395

NE corner of Rancho and Rainbow; across Rancho from Santa Fe Hotel; 50 ft E of Rancho in the NW curb of Rainbow; above center of culvert.

0144 PLS5088 77.76 36 15 39.314 115 13 30.911

SE corner of Ann Rd. and Jones Blvd.

0145 1LV90-36NES 36 15 41.097 115 12 26.580

SW corner of Ann Rd. and Decatur Blvd.

0146 PLS8895 29 30 31 32 36 15 41.411 115 11 20.344

N side of Ann Rd. at Allen Ln.; 25 ft N of centerline of Ann Rd.; 15 ft E of centerline of Allen Ln.; well monument w/"SURVEY" cap

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0147 CLV plate2 36 16 23.168 115 13 28.983

E side of Jones Blvd. in curb; 0.1 mi S of Centennial; 120 ft S of S entrance to Lamb of God Lutheran Church; 12 ft N of cinder block wall; 12 ft S of transformer

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0148 PLS3340 78.95 36 17 26.791 115 15 12.298

NE corner of Elkhorn Rd. and Monte Cristo Way; in curb on E side of Monte Cristo Way; 25 ft N of Elkhorn Rd.

0149 RLS4841 25 26 35 36 36 15 41.581 115 07 01.394

Well monument; W edge of Losee Rd. at Ann Rd.

~~0150 1LV00-4SES (same point as 0085)~~

0151 2LV00-25N4 36 11 17.219 115 12 53.688

SE corner of W Vegas Dr. and N Michael Way

0152 7C01-29C4 36 10 52.430 115 10 44.884

NE corner of Rancho Dr. and Washington Ave.

0154 PLS9399 10 11 14 15 36 18 20.855 115 08 03.757

Grand Teton and N 5th St.; brass cap in concrete marked "North Las Vegas Survey Monument T19S R61E S10 S11 S15 S14 PLS 9399"

0155 D171 36 17 59.524 115 01 14.843

From Exit 54 off of I-15 (Speedway Blvd./Hollywood Blvd.), go 1.0 mi NW along RR spur to Union Pacific RR tracks; turn right and go 1.1 mi NE along SE side of RR tracks; station is on N side of road; brass cap set in concrete, next to wood witness post

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0156 J171 36 20 28.054 114 55 04.376

From Apex exit off of I-15, go NE 3.05 mi to a dirt road; turn right and go about 200 ft to station; 51 ft NW of center of RR tracks; HARN station

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0157 923 36 09 33.092 115 16 27.132

CC GIS control point; N side of Charleston Blvd.; 0.34 mi E of Durango Dr.; opposite entrance to Silver Shadow Apts.

0158 1LV10-8S4 36 07 47.328 115 17 19.553

NW corner of Desert Inn Rd. and Crystal Water Way

0159 PLS5094 145.27 36 08 38.502 115 07 06.889

SE corner of Eastern Ave. and Sahara Ave.

0160 NHD 32675009 36 07 49.623 115 09 17.868

W side of Paradise Rd. in curb; 250 ft N of Desert Inn Rd.; 80 ft S of Marriot entrance

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0161 PLS9388 76.99 36 05 34.153 115 08 50.163

NE corner of Paradise Rd. and Kitty Hawk Way

0162 RLS7190 63.44 36 02 58.666 115 07 38.087

SE corner of Robindale Rd. and Spencer St.

0163 888 36 02 10.700 115 05 00.335

Clark County GIS control point; E side of Green Valley Pkwy., N of Wigwam Pkwy., just S of golf-cart tunnel running under Green Valley Pkwy.

~~0164 PLS9388~~

ABANDONED; aluminum cap on island at Paradise Rd. and Kitty Hawk

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~~0165 34-35-3-2A~~

ABANDONED (same location as 0125); Section corner along high-voltage power line; section corner marker on leaning concrete post; 1 ft W of point 0125 (disk on pipe 1" above ground)

0166 1LV90-36SSW6 36 14 47.536 115 13 15.428

NE corner of Lone Mountain Rd. and Leon Ave.

0167 F170 RESET 36 01 28.447 115 13 37.336

E side of RR tracks on top of culvert headwall; about 300 ft S of Blue Diamond Rd.; stamped F170 RESET 1990; replaced F170 [0067]

COORDINATE ADJUSTMENT SUMMARY
1990 Survey

Datum = WGS-84
Coordinate System = Geographic
Zone = Global

Network Adjustment Constraints:
8 fixed coordinates in y
8 fixed coordinates in x
8 fixed coordinates in H

POINT	NAME	OLD COORDS	ADJUST	NEW COORDS	1.00σ
1	0503+20.08				
	LAT=	36° 01' 54.272532"	+0.011195"	36° 01' 54.283727"	0.021876m
	LON=	115° 01' 49.512240"	-0.009507"	115° 01' 49.521748"	0.028293m
	ELL HT=	553.6281m	+1.3698m	554.9980m	0.041013m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
2	0C89/36W6				
	LAT=	36° 20' 35.829331"	+0.011359"	36° 20' 35.840690"	0.034058m
	LON=	115° 19' 44.299203"	-0.011121"	115° 19' 44.310324"	0.034503m
	ELL HT=	854.8504m	+1.2105m	856.0609m	0.091925m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
3	0C90/17C4				
	LAT=	36° 17' 55.806085"	+0.011422"	36° 17' 55.817507"	0.032403m
	LON=	115° 17' 12.094198"	-0.010629"	115° 17' 12.104827"	0.039066m
	ELL HT=	764.8044m	+1.2917m	766.0960m	0.082403m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
4	0C90/6SWW6				
	LAT=	36° 19' 30.990104"	+0.011276"	36° 19' 31.001379"	0.076891m
	LON=	115° 18' 38.728548"	-0.011077"	115° 18' 38.739625"	0.051788m
	ELL HT=	823.6953m	+1.2780m	824.9734m	0.131982m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
5	0LV00/32SES				
	LAT=	36° 09' 33.087489"	+0.009163"	36° 09' 33.096652"	0.069238m
	LON=	115° 16' 48.325379"	-0.013026"	115° 16' 48.338405"	0.056471m
	ELL HT=	782.8728m	+1.2609m	784.1337m	0.182272m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
6	112USGS				
	LAT=	36° 20' 25.585945"	+0.011187"	36° 20' 25.597132"	0.068686m
	LON=	115° 17' 45.329953"	-0.010441"	115° 17' 45.340394"	0.056807m
	ELL HT=	778.3430m	+1.2312m	779.5742m	0.150184m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN

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 7 113USGS
       LAT=  36° 17' 14.815958" +0.011249"  36° 17' 14.827207"    0.001919m
       LON= 115° 16' 03.978147" -0.010975" 115° 16' 03.989122"    0.002103m
    ELL HT=            719.4937m   +1.2840m            720.7777m    0.004694m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

 8 1LV90/26SES
       LAT=  36° 15' 40.359881" +0.011237"  36° 15' 40.371119"    0.060956m
       LON= 115° 13' 32.617839" -0.010885" 115° 13' 32.628724"    0.049177m
    ELL HT=            672.1027m   +1.2866m            673.3893m    0.159666m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

 9 1LV90/33E6
       LAT=  36° 15' 19.891305" +0.009955"  36° 15' 19.901260"    0.096492m
       LON= 115° 15' 54.495758" -0.011746" 115° 15' 54.507505"    0.074908m
    ELL HT=            695.1786m   +1.2606m            696.4391m    0.201883m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

10 229-44
       LAT=  36° 14' 48.635812" +0.007766"  36° 14' 48.643579"    0.069913m
       LON= 115° 02' 35.175038" -0.013596" 115° 02' 35.188634"    0.058616m
    ELL HT=            547.0034m   +1.2363m            548.2397m    0.132438m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

11 229-98
       LAT=  36° 15' 56.605961" +0.007813"  36° 15' 56.613773"    0.042448m
       LON= 115° 00' 38.288294" -0.013564" 115° 00' 38.301858"    0.042820m
    ELL HT=            560.9685m   +1.2288m            562.1973m    0.110627m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

12 5-18-117
       LAT=  36° 17' 29.045997" +0.011280"  36° 17' 29.057277"    0.068675m
       LON= 115° 12' 24.550524" -0.010613" 115° 12' 24.561137"    0.043739m
    ELL HT=            675.5446m   +1.2837m            676.8284m    0.113844m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

13 6C02/16SWS
       LAT=  36° 12' 13.811656" +0.007649"  36° 12' 13.819305"    0.082468m
       LON= 115° 03' 43.240465" -0.012960" 115° 03' 43.253424"    0.058239m
    ELL HT=            519.4845m   +1.2290m            520.7135m    0.154517m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

14 6C02/16W4
       LAT=  36° 12' 40.122994" +0.007705"  36° 12' 40.130699"    0.116690m
       LON= 115° 03' 43.391856" -0.013591" 115° 03' 43.405448"    0.072143m
    ELL HT=            524.6481m   +1.2469m            525.8950m    0.193687m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

15 6C02/4SWW6
       LAT=  36° 14' 11.743931" +0.008128"  36° 14' 11.752059"    0.044608m
       LON= 115° 03' 43.150922" -0.012961" 115° 03' 43.163883"    0.054496m
    ELL HT=            538.7560m   +1.2468m            540.0028m    0.088419m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN
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16 6C02/9SWS
       LAT=  36° 13' 06.701703" +0.007715"  36° 13' 06.709418"    0.110791m
       LON= 115° 03' 43.245791" -0.013598" 115° 03' 43.259389"    0.069241m
    ELL HT=            528.2711m   +1.2450m           529.5161m    0.175960m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

17 6C02/9W4
       LAT=  36° 13' 33.229204" +0.007726"  36° 13' 33.236930"    0.106169m
       LON= 115° 03' 43.118734" -0.013605" 115° 03' 43.132339"    0.068828m
    ELL HT=            531.7168m   +1.2432m           532.9600m    0.162790m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

18 6C11/13SWW6
       LAT=  36° 07' 06.973228" +0.009293"  36° 07' 06.982521"    0.063686m
       LON= 115° 07' 07.978847" -0.011906" 115° 07' 07.990753"    0.053858m
    ELL HT=            559.7618m   +1.2209m           560.9827m    0.134726m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

19 6C11/15NWS
       LAT=  36° 07' 46.067153" +0.008962"  36° 07' 46.076115"    0.029400m
       LON= 115° 09' 16.878835" -0.011912" 115° 09' 16.890747"    0.025671m
    ELL HT=            593.8600m   +1.2131m           595.0731m    0.063278m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

20 6C11/22SSW6
       LAT=  36° 06' 04.535982" +0.009345"  36° 06' 04.545327"    0.055542m
       LON= 115° 08' 58.582326" -0.013726" 115° 08' 58.596052"    0.052767m
    ELL HT=            598.3373m   +1.2111m           599.5485m    0.128497m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

21 6C12/7SE6
       LAT=  36° 08' 04.755605" +0.011777"  36° 08' 04.767383"    0.069606m
       LON= 115° 05' 18.944000" -0.009834" 115° 05' 18.953834"    0.041393m
    ELL HT=            521.4653m   +1.3571m           522.8224m    0.101868m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

22 6C22/5E6
       LAT=  36° 03' 55.826838" +0.011950"  36° 03' 55.838787"    0.047446m
       LON= 115° 03' 56.217774" -0.009671" 115° 03' 56.227446"    0.039298m
    ELL HT=            535.5127m   +1.3634m           536.8761m    0.101774m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

23 7C00/14N4
       LAT=  36° 13' 02.335570" +0.009061"  36° 13' 02.344631"    0.112105m
       LON= 115° 14' 02.831767" -0.012361" 115° 14' 02.844128"    0.166634m
    ELL HT=            668.0812m   +1.2138m           669.2950m    0.326334m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

24 7C00/23S4
       LAT=  36° 11' 19.082044" +0.009044"  36° 11' 19.091088"    0.034739m
       LON= 115° 13' 55.988655" -0.012780" 115° 13' 56.001435"    0.023201m
    ELL HT=            676.8047m   +1.2439m           678.0487m    0.060889m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN
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25 7C00/36SSW6
       LAT=  36° 09' 33.425037" +0.009687"  36° 09' 33.434724"    0.016542m
       LON= 115° 13' 09.097284" -0.011439" 115° 13' 09.108724"    0.019199m
    ELL HT=            663.1942m   +1.2175m            664.4117m    0.039306m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

26 7C01/11S4
       LAT=  36° 13' 05.164522" +0.008985"  36° 13' 05.173507"    0.070939m
       LON= 115° 07' 36.120784" -0.012179" 115° 07' 36.132963"    0.030383m
    ELL HT=            558.8574m   +1.2039m            560.0613m    0.076109m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

27 7C02/18NWW6
       LAT=  36° 12' 52.307900" +0.009095"  36° 12' 52.316995"    0.086946m
       LON= 115° 05' 54.171005" -0.012087" 115° 05' 54.183092"    0.070892m
    ELL HT=            535.2162m   +1.1989m            536.4151m    0.235966m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

28 7C10/13NNW6
       LAT=  36° 07' 44.973044" +0.008812"  36° 07' 44.981855"    0.026121m
       LON= 115° 13' 12.288018" -0.012928" 115° 13' 12.300946"    0.025123m
    ELL HT=            666.5341m   +1.2011m            667.7352m    0.053628m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

29 7C10/15NWS
       LAT=  36° 07' 44.514324" +0.008920"  36° 07' 44.523244"    0.097603m
       LON= 115° 15' 38.987562" -0.012320" 115° 15' 38.999882"    0.099569m
    ELL HT=            731.6611m   +1.2380m            732.8991m    0.353065m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

30 7C10/22SWS
       LAT=  36° 05' 58.992990" +0.008879"  36° 05' 59.001870"    0.129645m
       LON= 115° 15' 38.898230" -0.012293" 115° 15' 38.910523"    0.102171m
    ELL HT=            711.2808m   +1.2453m            712.5261m    0.476931m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

31 7C10/24SWS
       LAT=  36° 06' 00.056078" +0.008901"  36° 06' 00.064979"    0.106263m
       LON= 115° 13' 29.206741" -0.012239" 115° 13' 29.218979"    0.102956m
    ELL HT=            673.2437m   +1.2421m            674.4858m    0.350225m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

32 7C11/5SSW6
       LAT=  36° 08' 40.339881" +0.008912"  36° 08' 40.348793"    0.017023m
       LON= 115° 11' 06.969975" -0.012153" 115° 11' 06.982128"    0.013609m
    ELL HT=            620.6060m   +1.2151m            621.8211m    0.029434m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

33 817-20-61
       LAT=  36° 12' 09.710066" +0.009596"  36° 12' 09.719662"    0.096607m
       LON= 115° 10' 11.263279" -0.012334" 115° 10' 11.275613"    0.065147m
    ELL HT=            603.6280m   +1.1638m            604.7918m    0.168413m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN
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34 8C21/11SES
       LAT=  36° 02' 32.879021" +0.011742"  36° 02' 32.890763"    0.072230m
       LON= 115° 07' 06.214581" -0.009839" 115° 07' 06.224420"    0.064833m
    ELL HT=            609.4067m   +1.3656m           610.7723m    0.206604m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

35 B141
       LAT=  36° 17' 17.482677" +0.007847"  36° 17' 17.490524"    0.047918m
       LON= 115° 00' 19.958627" -0.013577" 115° 00' 19.972204"    0.065739m
    ELL HT=            608.6890m   +1.2227m           609.9118m    0.177623m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

36 C141
       LAT=  36° 16' 39.587066" +0.000000"  36° 16' 39.587066"        FIXED
       LON= 115° 02' 14.488410" +0.000000" 115° 02' 14.488410"        FIXED
    ELL HT=            585.5727m   +0.0000m           585.5727m        FIXED
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

37 C170
       LAT=  36° 05' 28.106212" +0.011846"  36° 05' 28.118058"    0.116995m
       LON= 115° 11' 45.649237" -0.009961" 115° 11' 45.659197"    0.147975m
    ELL HT=            651.1588m   +1.3698m           652.5286m    0.480951m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

38 CLV23
       LAT=  36° 09' 33.041016" +0.009541"  36° 09' 33.050557"    0.023451m
       LON= 115° 12' 05.346306" -0.012549" 115° 12' 05.358855"    0.017777m
    ELL HT=            636.0767m   +1.2715m           637.3482m    0.048087m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

39 D170
       LAT=  36° 04' 35.512263" +0.008666"  36° 04' 35.520929"    0.055729m
       LON= 115° 11' 57.773378" -0.013357" 115° 11' 57.786735"    0.062802m
    ELL HT=            668.4505m   +1.2372m           669.6876m    0.172434m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

40 D365
       LAT=  36° 04' 52.691302" +0.012113"  36° 04' 52.703415"    0.016776m
       LON= 115° 01' 42.562663" -0.009823" 115° 01' 42.572486"    0.014949m
    ELL HT=            471.3975m   +1.3631m           472.7606m    0.029655m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

41 D368
       LAT=  36° 09' 16.912620" +0.000000"  36° 09' 16.912620"        FIXED
       LON= 115° 21' 47.198540" +0.000000" 115° 21' 47.198540"        FIXED
    ELL HT=            962.5080m   +0.0000m           962.5080m        FIXED
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

42 D371
       LAT=  36° 24' 53.335680" +0.000000"  36° 24' 53.335680"        FIXED
       LON= 115° 27' 05.663360" +0.000000" 115° 27' 05.663360"        FIXED
    ELL HT=           1040.3800m   +0.0000m          1040.3800m        FIXED
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN
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43 EA963+67.37
       LAT=  36° 00' 22.753961" +0.000000"  36° 00' 22.753961"        FIXED
       LON= 115° 10' 48.302966" +0.000000" 115° 10' 48.302966"        FIXED
    ELL HT=            667.2375m   +0.0000m           667.2375m        FIXED
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

44 F170
       LAT=  36° 01' 28.570967" +0.008605"  36° 01' 28.579572"    0.077062m
       LON= 115° 13' 37.449655" -0.013532" 115° 13' 37.463186"    0.052225m
    ELL HT=            725.5860m   +1.2702m           726.8562m    0.161102m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

45 H166
       LAT=  36° 00' 39.995593" +0.011882"  36° 00' 40.007475"    0.079359m
       LON= 114° 57' 02.631974" -0.009504" 114° 57' 02.641478"    0.070949m
    ELL HT=            616.6184m   +1.3683m           617.9867m    0.172979m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

46 H169+87.05
       LAT=  35° 59' 45.503698" +0.011215"  35° 59' 45.514913"    0.088274m
       LON= 115° 07' 47.849024" -0.010124" 115° 07' 47.859148"    0.075767m
    ELL HT=            676.3911m   +1.3877m           677.7788m    0.234110m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

47 HAPPY
       LAT=  36° 02' 50.333222" +0.008665"  36° 02' 50.341887"    0.055513m
       LON= 115° 10' 53.183765" -0.013483" 115° 10' 53.197248"    0.052171m
    ELL HT=            664.7034m   +1.2606m           665.9639m    0.120767m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

48 J166
       LAT=  35° 59' 24.556443" +0.011867"  35° 59' 24.568310"    0.079383m
       LON= 114° 55' 37.321606" -0.009448" 114° 55' 37.331054"    0.101834m
    ELL HT=            663.3006m   +1.3714m           664.6719m    0.232410m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

49 J399
       LAT=  36° 06' 08.284864" +0.010988"  36° 06' 08.295852"    0.025385m
       LON= 115° 03' 07.583184" -0.009621" 115° 03' 07.592805"    0.020019m
    ELL HT=            481.8902m   +1.3746m           483.2648m    0.043128m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

50 JERK
       LAT=  36° 03' 08.128928" +0.008654"  36° 03' 08.137582"    0.059498m
       LON= 115° 12' 42.424219" -0.013534" 115° 12' 42.437753"    0.051410m
    ELL HT=            698.4341m   +1.2620m           699.6960m    0.130624m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

51 K364
       LAT=  36° 02' 54.255784" +0.011910"  36° 02' 54.267694"    0.041692m
       LON= 114° 59' 28.952680" -0.009602" 114° 59' 28.962283"    0.051297m
    ELL HT=            508.7515m   +1.3626m           510.1141m    0.086208m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN
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52 LVAFB B
       LAT=  36° 15' 17.668108" +0.007786"  36° 15' 17.675895"    0.054749m
       LON= 115° 01' 45.499143" -0.013582" 115° 01' 45.512726"    0.050524m
    ELL HT=            549.0779m   +1.2331m           550.3110m    0.123035m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

53 M364
       LAT=  36° 01' 25.987644" +0.011891"  36° 01' 25.999535"    0.072347m
       LON= 114° 57' 54.599406" -0.009539" 114° 57' 54.608945"    0.051798m
    ELL HT=            590.4024m   +1.3664m           591.7688m    0.135150m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

54 MI40
       LAT=  36° 04' 41.379350" +0.008924"  36° 04' 41.388274"    0.003054m
       LON= 115° 08' 12.223395" -0.012084" 115° 08' 12.235479"    0.002767m
    ELL HT=            599.7397m   +1.2399m           600.9796m    0.007446m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

55 N366
       LAT=  36° 06' 55.917046" +0.008948"  36° 06' 55.925994"    0.070318m
       LON= 115° 11' 04.802710" -0.012192" 115° 11' 04.814901"    0.096384m
    ELL HT=            624.0473m   +1.2347m           625.2821m    0.193180m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

56 P169
       LAT=  36° 12' 17.579037" +0.009922"  36° 12' 17.588959"    0.002996m
       LON= 115° 12' 02.226008" -0.011601" 115° 12' 02.237609"    0.003380m
    ELL HT=            639.0638m   +1.2678m           640.3315m    0.007816m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

57 P364
       LAT=  35° 58' 30.480663" +0.000000"  35° 58' 30.480663"        FIXED
       LON= 114° 54' 49.478251" +0.000000" 114° 54' 49.478251"        FIXED
    ELL HT=            681.0997m   +0.0000m           681.0997m        FIXED
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

58 P399
       LAT=  36° 11' 45.830451" +0.009341"  36° 11' 45.839792"    0.052516m
       LON= 115° 08' 26.536837" -0.012131" 115° 08' 26.548969"    0.030092m
    ELL HT=            566.7329m   +1.1929m           567.9258m    0.075465m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

59 PLS2050/74.75
       LAT=  36° 15' 41.020800" +0.011029"  36° 15' 41.031829"    0.081864m
       LON= 115° 09' 23.604908" -0.011207" 115° 09' 23.616115"    0.057876m
    ELL HT=            610.9759m   +1.2778m           612.2537m    0.131479m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN

60 R169
       LAT=  36° 15' 04.990939" +0.008442"  36° 15' 04.999381"    0.079520m
       LON= 115° 14' 32.474524" -0.013890" 115° 14' 32.488414"    0.068594m
    ELL HT=            678.5133m   +1.1791m           679.6924m    0.150713m
  ORTHO HT=              0.0000m   +0.0000m             0.0000m    NOT KNOWN
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61 T19-20S/R61-62E
       LAT=  36° 14' 49.024330" +0.009434"  36° 14' 49.033764"    0.065579m
       LON= 115° 05' 55.598029" -0.011991" 115° 05' 55.610020"    0.048772m
    ELL HT=           559.0164m   +1.1533m           560.1696m    0.126349m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

62 T19-20S/R62-63E
       LAT=  36° 14' 49.261273" +0.007799"  36° 14' 49.269072"    0.002135m
       LON= 114° 59' 19.893511" -0.013514" 114° 59' 19.907025"    0.002004m
    ELL HT=           552.2619m   +1.2317m           553.4936m    0.004638m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

63 T370
       LAT=  36° 21' 57.148293" +0.011154"  36° 21' 57.159447"    0.025718m
       LON= 115° 21' 25.903831" -0.010603" 115° 21' 25.914434"    0.033239m
    ELL HT=           876.2323m   +1.2266m           877.4589m    0.093341m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

64 U368
       LAT=  36° 11' 53.565090" +0.000000"  36° 11' 53.565090"        FIXED
       LON= 115° 00' 37.322430" +0.000000" 115° 00' 37.322430"        FIXED
    ELL HT=           629.6190m   +0.0000m           629.6190m        FIXED
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

65 UNDER
       LAT=  36° 19' 02.109074" +0.000000"  36° 19' 02.109074"        FIXED
       LON= 114° 56' 54.441695" +0.000000" 114° 56' 54.441695"        FIXED
    ELL HT=           734.7953m   +0.0000m           734.7953m        FIXED
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

66 V365
       LAT=  36° 18' 50.634920" +0.011160"  36° 18' 50.646080"    0.077411m
       LON= 115° 16' 48.290018" -0.010392" 115° 16' 48.300409"    0.053495m
    ELL HT=           747.0877m   +1.2364m           748.3241m    0.165852m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

67 W314
       LAT=  36° 21' 45.272294" +0.011204"  36° 21' 45.283498"    0.002757m
       LON= 115° 19' 11.063191" -0.010498" 115° 19' 11.073689"    0.002915m
    ELL HT=           805.5494m   +1.2281m           806.7775m    0.006637m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

68 W370
       LAT=  36° 23' 47.318713" +0.011206"  36° 23' 47.329919"    0.067784m
       LON= 115° 23' 38.904959" -0.010645" 115° 23' 38.915604"    0.079240m
    ELL HT=           854.1314m   +1.2259m           855.3572m    0.218757m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

69 W51
       LAT=  36° 04' 04.420570" +0.000000"  36° 04' 04.420570"        FIXED
       LON= 115° 00' 51.824610" +0.000000" 115° 00' 51.824610"        FIXED
    ELL HT=           476.6208m   +0.0000m           476.6208m        FIXED
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN
```

```
70 WELL8
       LAT=  36° 09' 55.801678" +0.009014"  36° 09' 55.810692"    0.002756m
       LON= 115° 11' 25.405185" -0.012247" 115° 11' 25.417432"    0.002532m
    ELL HT=           619.7493m   +1.2231m           620.9724m    0.007136m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

71 X314
       LAT=  36° 21' 11.775789" +0.011198"  36° 21' 11.786986"    0.065268m
       LON= 115° 18' 31.114393" -0.010473" 115° 18' 31.124866"    0.082446m
    ELL HT=           794.9608m   +1.2292m           796.1900m    0.115052m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

72 X367
       LAT=  36° 08' 41.651025" +0.008948"  36° 08' 41.659973"    0.089882m
       LON= 115° 19' 03.984037" -0.012736" 115° 19' 03.996773"    0.073085m
    ELL HT=           862.5637m   +1.2559m           863.8196m    0.246528m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN

73 X398
       LAT=  36° 10' 52.379022" +0.009114"  36° 10' 52.388135"    0.018903m
       LON= 115° 10' 43.340592" -0.012200" 115° 10' 43.352791"    0.016759m
    ELL HT=           609.8472m   +1.2046m           611.0518m    0.042285m
  ORTHO HT=             0.0000m   +0.0000m             0.0000m    NOT KNOWN
```

COORDINATE ADJUSTMENT SUMMARY
1994 Survey

Datum = WGS-84
Coordinate System = Geographic
Zone = Global

Network Adjustment Constraints:
4 fixed coordinates in y
4 fixed coordinates in x
4 fixed coordinates in H

POINT	NAME	OLD COORDS	ADJUST	NEW COORDS	1.00σ
1	0C8936W6				
	LAT=	36° 20' 35.840307"	+0.000000"	36° 20' 35.840307"	0.160649m
	LON=	115° 19' 44.310900"	+0.000000"	115° 19' 44.310900"	0.106395m
	ELL HT=	856.0887m	+0.0000m	856.0887m	0.447325m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
2	0C9017C4				
	LAT=	36° 17' 55.817138"	+0.000000"	36° 17' 55.817138"	0.159677m
	LON=	115° 17' 12.105090"	+0.000000"	115° 17' 12.105090"	0.109063m
	ELL HT=	766.0449m	+0.0000m	766.0449m	0.310442m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
3	0C907SE6				
	LAT=	36° 18' 43.447074"	+0.000000"	36° 18' 43.447074"	0.178999m
	LON=	115° 17' 55.312800"	+0.000000"	115° 17' 55.312800"	0.128000m
	ELL HT=	793.4503m	+0.0000m	793.4503m	0.373500m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
4	110USGS				
	LAT=	36° 25' 46.269899"	+0.000000"	36° 25' 46.269899"	0.236386m
	LON=	115° 23' 19.889255"	+0.000000"	115° 23' 19.889255"	0.167443m
	ELL HT=	850.3998m	+0.0000m	850.3998m	0.411598m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
5	112USGS				
	LAT=	36° 20' 25.596436"	+0.000000"	36° 20' 25.596436"	0.132853m
	LON=	115° 17' 45.340523"	+0.000000"	115° 17' 45.340523"	0.168240m
	ELL HT=	779.5877m	+0.0000m	779.5877m	0.304206m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
6	113USGS				
	LAT=	36° 17' 14.827038"	+0.000000"	36° 17' 14.827038"	0.010164m
	LON=	115° 16' 03.989866"	+0.000000"	115° 16' 03.989866"	0.009348m
	ELL HT=	720.6849m	+0.0000m	720.6849m	0.030417m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
7	169GWM				
	LAT=	36° 26' 12.968835"	+0.000000"	36° 26' 12.968835"	0.004028m
	LON=	115° 21' 46.588471"	+0.000000"	115° 21' 46.588471"	0.003262m

```
    ELL HT=            855.1142m   +0.0000m            855.1142m    0.008698m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

 8 170GWM
       LAT=  36° 26' 12.500337" +0.000000"  36° 26' 12.500337"    0.305085m
       LON= 115° 19' 55.624485" +0.000000" 115° 19' 55.624485"    0.211957m
    ELL HT=            942.9438m   +0.0000m            942.9438m    0.509764m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

 9 171GWM
       LAT=  36° 26' 15.219015" +0.000000"  36° 26' 15.219015"        FIXED
       LON= 115° 17' 48.705988" +0.000000" 115° 17' 48.705988"        FIXED
    ELL HT=           1068.8915m   +0.0000m           1068.8915m        FIXED
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

11 1LV9033E6
       LAT=  36° 15' 19.902602" +0.000000"  36° 15' 19.902602"    0.013436m
       LON= 115° 15' 54.507733" +0.000000" 115° 15' 54.507733"    0.011720m
    ELL HT=            696.3535m   +0.0000m            696.3535m    0.040868m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

12 2C906SWW6
       LAT=  36° 19' 31.000070" +0.000000"  36° 19' 31.000070"    0.167778m
       LON= 115° 18' 38.738175" +0.000000" 115° 18' 38.738175"    0.126993m
    ELL HT=            824.9599m   +0.0000m            824.9599m    0.400947m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

13 2GWM
       LAT=  36° 19' 31.608921" +0.000000"  36° 19' 31.608921"    0.006717m
       LON= 115° 20' 03.806857" +0.000000" 115° 20' 03.806857"    0.006825m
    ELL HT=            895.1142m   +0.0000m            895.1142m    0.020765m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

14 32-33-5-4
       LAT=  36° 20' 09.578338" +0.000000"  36° 20' 09.578338"    0.127612m
       LON= 115° 16' 43.078751" +0.000000" 115° 16' 43.078751"    0.129842m
    ELL HT=            745.2245m   +0.0000m            745.2245m    0.262983m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

15 33-34-4-3
       LAT=  36° 20' 08.965950" +0.000000"  36° 20' 08.965950"    0.136615m
       LON= 115° 15' 38.564615" +0.000000" 115° 15' 38.564615"    0.121169m
    ELL HT=            726.8893m   +0.0000m            726.8893m    0.282076m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

16 34-35-3-2
       LAT=  36° 20' 08.359061" +0.000000"  36° 20' 08.359061"    0.141936m
       LON= 115° 14' 34.105279" +0.000000" 115° 14' 34.105279"    0.132436m
    ELL HT=            712.8553m   +0.0000m            712.8553m    0.341334m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

17 3GWM
       LAT=  36° 19' 06.911274" +0.000000"  36° 19' 06.911274"    0.223866m
       LON= 115° 21' 47.595208" +0.000000" 115° 21' 47.595208"    0.212878m
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    ELL HT=          992.5788m   +0.0000m          992.5788m    0.459086m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

18 4GWM
       LAT=  36° 18' 30.596019" +0.000000"  36° 18' 30.596019"        FIXED
       LON= 115° 23' 44.436123" +0.000000" 115° 23' 44.436123"        FIXED
    ELL HT=         1111.9650m   +0.0000m         1111.9650m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

19 5-18-117
       LAT=  36° 17' 29.057176" +0.000000"  36° 17' 29.057176"    0.014662m
       LON= 115° 12' 24.561964" +0.000000" 115° 12' 24.561964"    0.012716m
    ELL HT=          676.7660m   +0.0000m          676.7660m    0.033861m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

20 7C012C4
       LAT=  36° 14' 22.509850" +0.000000"  36° 14' 22.509850"    0.019066m
       LON= 115° 07' 30.398708" +0.000000" 115° 07' 30.398708"    0.017797m
    ELL HT=          565.8356m   +0.0000m          565.8356m    0.055819m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

21 80.19
       LAT=  36° 14' 21.430197" +0.000000"  36° 14' 21.430197"    0.173522m
       LON= 115° 10' 28.732165" +0.000000" 115° 10' 28.732165"    0.147585m
    ELL HT=          624.0014m   +0.0000m          624.0014m    0.450179m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

22 802
       LAT=  36° 20' 09.682019" +0.000000"  36° 20' 09.682019"    0.006854m
       LON= 115° 15' 38.975546" +0.000000" 115° 15' 38.975546"    0.006133m
    ELL HT=          726.7039m   +0.0000m          726.7039m    0.014279m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

23 803
       LAT=  36° 20' 07.727714" +0.000000"  36° 20' 07.727714"        FIXED
       LON= 115° 12' 25.403243" +0.000000" 115° 12' 25.403243"        FIXED
    ELL HT=          708.9566m   +0.0000m          708.9566m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

24 806
       LAT=  36° 17' 32.169484" +0.000000"  36° 17' 32.169484"    0.009989m
       LON= 115° 18' 53.199307" +0.000000" 115° 18' 53.199307"    0.008899m
    ELL HT=          841.1670m   +0.0000m          841.1670m    0.028400m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

25 807
       LAT=  36° 14' 53.542026" +0.000000"  36° 14' 53.542026"    0.012180m
       LON= 115° 18' 54.023733" +0.000000" 115° 18' 54.023733"    0.010653m
    ELL HT=          798.2081m   +0.0000m          798.2081m    0.039305m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

26 874
       LAT=  36° 14' 52.276812" +0.000000"  36° 14' 52.276812"    0.014033m
       LON= 115° 09' 12.881424" +0.000000" 115° 09' 12.881424"    0.013039m
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    ELL HT=            600.0535m   +0.0000m            600.0535m    0.041660m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

28 CLV plate1
       LAT=  36° 14' 19.267770" +0.000000"  36° 14' 19.267770"    0.306972m
       LON= 115° 12' 49.648935" +0.000000" 115° 12' 49.648935"    0.296046m
    ELL HT=            647.4958m   +0.0000m            647.4958m    0.787292m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

29 D371
       LAT=  36° 24' 53.335680" +0.000000"  36° 24' 53.335680"        FIXED
       LON= 115° 27' 05.663360" +0.000000" 115° 27' 05.663360"        FIXED
    ELL HT=           1040.3800m   +0.0000m           1040.3800m        FIXED
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

30 LORENZISUB
       LAT=  36° 14' 09.272237" +0.000000"  36° 14' 09.272237"    0.011912m
       LON= 115° 14' 28.671806" +0.000000" 115° 14' 28.671806"    0.010955m
    ELL HT=            676.9784m   +0.0000m            676.9784m    0.039080m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

31 NVGT
       LAT=  36° 12' 36.747614" +0.000000"  36° 12' 36.747614"    0.013492m
       LON= 115° 11' 54.424366" +0.000000" 115° 11' 54.424366"    0.012686m
    ELL HT=            639.7648m   +0.0000m            639.7648m    0.047747m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

33 T370
       LAT=  36° 21' 57.159339" +0.000000"  36° 21' 57.159339"    0.005280m
       LON= 115° 21' 25.915118" +0.000000" 115° 21' 25.915118"    0.005166m
    ELL HT=            877.4024m   +0.0000m            877.4024m    0.018447m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

34 V169
       LAT=  36° 19' 41.007033" +0.000000"  36° 19' 41.007033"    0.130408m
       LON= 115° 17' 14.505475" +0.000000" 115° 17' 14.505475"    0.135407m
    ELL HT=            764.0664m   +0.0000m            764.0664m    0.294087m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

35 V365
       LAT=  36° 18' 50.645528" +0.000000"  36° 18' 50.645528"    0.008724m
       LON= 115° 16' 48.300646" +0.000000" 115° 16' 48.300646"    0.007793m
    ELL HT=            748.2955m   +0.0000m            748.2955m    0.019835m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

36 W370
       LAT=  36° 23' 47.330011" +0.000000"  36° 23' 47.330011"    0.004698m
       LON= 115° 23' 38.916775" +0.000000" 115° 23' 38.916775"    0.004104m
    ELL HT=            855.3556m   +0.0000m            855.3556m    0.010583m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

37 Z398
       LAT=  36° 23' 09.968796" +0.000000"  36° 23' 09.968796"    0.334784m
       LON= 115° 22' 53.819487" +0.000000" 115° 22' 53.819487"    0.263417m
```

ELL HT=	868.8833m	+0.0000m	868.8833m	0.596070m
ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN

COORDINATE ADJUSTMENT SUMMARY
1995 Survey

Datum = WGS-84
Coordinate System = Geographic
Zone = Global

Network Adjustment Constraints:
4 fixed coordinates in y
4 fixed coordinates in x
4 fixed coordinates in H

POINT	NAME		OLD COORDS	ADJUST	NEW COORDS	1.00σ
1	0C8936W6					
		LAT=	36° 20' 35.840851"	+0.000000"	36° 20' 35.840851"	0.109228m
		LON=	115° 19' 44.310593"	+0.000000"	115° 19' 44.310593"	0.097119m
		ELL HT=	856.0780m	+0.0000m	856.0780m	0.243327m
		ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
2	0C9017C4					
		LAT=	36° 17' 55.817190"	+0.000000"	36° 17' 55.817190"	0.107739m
		LON=	115° 17' 12.105216"	+0.000000"	115° 17' 12.105216"	0.085586m
		ELL HT=	766.0848m	+0.0000m	766.0848m	0.279627m
		ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
3	0C907SE6					
		LAT=	36° 18' 43.446729"	+0.000000"	36° 18' 43.446729"	0.109179m
		LON=	115° 17' 55.312882"	+0.000000"	115° 17' 55.312882"	0.088442m
		ELL HT=	793.4881m	+0.0000m	793.4881m	0.222382m
		ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
4	110USGS					
		LAT=	36° 25' 46.269777"	+0.000000"	36° 25' 46.269777"	0.096056m
		LON=	115° 23' 19.889903"	+0.000000"	115° 23' 19.889903"	0.119952m
		ELL HT=	850.4295m	+0.0000m	850.4295m	0.224106m
		ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
5	112USGS					
		LAT=	36° 20' 25.596834"	+0.000000"	36° 20' 25.596834"	0.003067m
		LON=	115° 17' 45.340950"	+0.000000"	115° 17' 45.340950"	0.002916m
		ELL HT=	779.5806m	+0.0000m	779.5806m	0.007108m
		ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
6	113USGS					
		LAT=	36° 17' 14.827132"	+0.000000"	36° 17' 14.827132"	0.003018m
		LON=	115° 16' 03.989317"	+0.000000"	115° 16' 03.989317"	0.002732m
		ELL HT=	720.7698m	+0.0000m	720.7698m	0.008156m
		ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
7	169GWM					
		LAT=	36° 26' 12.968724"	+0.000000"	36° 26' 12.968724"	0.002406m
		LON=	115° 21' 46.588786"	+0.000000"	115° 21' 46.588786"	0.002290m

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    ELL HT=            855.1532m   +0.0000m            855.1532m    0.006492m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

 8 170GWM
       LAT=  36° 26' 12.500450" +0.000000"  36° 26' 12.500450"    0.140041m
       LON= 115° 19' 55.625026" +0.000000" 115° 19' 55.625026"    0.162178m
    ELL HT=            942.9421m   +0.0000m            942.9421m    0.337537m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

 9 171GWM
       LAT=  36° 26' 15.219015" +0.000000"  36° 26' 15.219015"        FIXED
       LON= 115° 17' 48.705988" +0.000000" 115° 17' 48.705988"        FIXED
    ELL HT=           1068.8915m   +0.0000m           1068.8915m        FIXED
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

10 1LV002NEE6
       LAT=  36° 14' 39.638828" +0.000000"  36° 14' 39.638828"    0.004531m
       LON= 115° 13' 32.563828" +0.000000" 115° 13' 32.563828"    0.004447m
    ELL HT=            664.5153m   +0.0000m            664.5153m    0.013382m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

11 1LV9033E6
       LAT=  36° 15' 19.902507" +0.000000"  36° 15' 19.902507"    0.003595m
       LON= 115° 15' 54.507268" +0.000000" 115° 15' 54.507268"    0.003325m
    ELL HT=            696.4245m   +0.0000m            696.4245m    0.010728m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

12 2C906SWW6
       LAT=  36° 19' 31.000094" +0.000000"  36° 19' 31.000094"    0.117212m
       LON= 115° 18' 38.738137" +0.000000" 115° 18' 38.738137"    0.101952m
    ELL HT=            824.9944m   +0.0000m            824.9944m    0.247516m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

13 2GWM
       LAT=  36° 19' 31.608863" +0.000000"  36° 19' 31.608863"    0.002945m
       LON= 115° 20' 03.806874" +0.000000" 115° 20' 03.806874"    0.002622m
    ELL HT=            895.1533m   +0.0000m            895.1533m    0.006911m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

14 32-33-5-4
       LAT=  36° 20' 09.578600" +0.000000"  36° 20' 09.578600"    0.149812m
       LON= 115° 16' 43.078859" +0.000000" 115° 16' 43.078859"    0.146619m
    ELL HT=            745.2014m   +0.0000m            745.2014m    0.407752m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

15 34-35-3-2
       LAT=  36° 20' 08.359037" +0.000000"  36° 20' 08.359037"    0.151314m
       LON= 115° 14' 34.106164" +0.000000" 115° 14' 34.106164"    0.191389m
    ELL HT=            712.8321m   +0.0000m            712.8321m    0.340191m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

16 3GWM
       LAT=  36° 19' 06.910750" +0.000000"  36° 19' 06.910750"    0.169158m
       LON= 115° 21' 47.595298" +0.000000" 115° 21' 47.595298"    0.136182m
```

```
    ELL HT=          992.5597m   +0.0000m          992.5597m    0.379054m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

17 4GWM
       LAT=  36° 18' 30.596019" +0.000000"  36° 18' 30.596019"        FIXED
       LON= 115° 23' 44.436123" +0.000000" 115° 23' 44.436123"        FIXED
    ELL HT=         1111.9650m   +0.0000m         1111.9650m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

18 5-18-117
       LAT=  36° 17' 29.057527" +0.000000"  36° 17' 29.057527"    0.002809m
       LON= 115° 12' 24.561594" +0.000000" 115° 12' 24.561594"    0.002472m
    ELL HT=          676.8199m   +0.0000m          676.8199m    0.007519m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

19 7C012C4
       LAT=  36° 14' 22.510187" +0.000000"  36° 14' 22.510187"    0.005375m
       LON= 115° 07' 30.398814" +0.000000" 115° 07' 30.398814"    0.005064m
    ELL HT=          565.8687m   +0.0000m          565.8687m    0.015056m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

20 80.19
       LAT=  36° 14' 21.430520" +0.000000"  36° 14' 21.430520"    0.005005m
       LON= 115° 10' 28.731014" +0.000000" 115° 10' 28.731014"    0.004579m
    ELL HT=          624.0597m   +0.0000m          624.0597m    0.014043m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

21 802
       LAT=  36° 20' 09.682204" +0.000000"  36° 20' 09.682204"    0.003243m
       LON= 115° 15' 38.975570" +0.000000" 115° 15' 38.975570"    0.002886m
    ELL HT=          726.6972m   +0.0000m          726.6972m    0.007648m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

22 803
       LAT=  36° 20' 07.727714" +0.000000"  36° 20' 07.727714"        FIXED
       LON= 115° 12' 25.403243" +0.000000" 115° 12' 25.403243"        FIXED
    ELL HT=          708.9566m   +0.0000m          708.9566m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

23 806
       LAT=  36° 17' 32.169518" +0.000000"  36° 17' 32.169518"    0.003561m
       LON= 115° 18' 53.199114" +0.000000" 115° 18' 53.199114"    0.003346m
    ELL HT=          841.2226m   +0.0000m          841.2226m    0.009203m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

24 807
       LAT=  36° 14' 53.541845" +0.000000"  36° 14' 53.541845"    0.005369m
       LON= 115° 18' 54.023610" +0.000000" 115° 18' 54.023610"    0.004794m
    ELL HT=          798.2913m   +0.0000m          798.2913m    0.014763m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

25 874
       LAT=  36° 14' 52.276904" +0.000000"  36° 14' 52.276904"    0.004428m
       LON= 115° 09' 12.880871" +0.000000" 115° 09' 12.880871"    0.004219m
```

```
    ELL HT=          600.1373m   +0.0000m          600.1373m    0.012622m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

27 CLV plate1
       LAT=  36° 14' 19.268090" +0.000000"  36° 14' 19.268090"    0.004672m
       LON= 115° 12' 49.648599" +0.000000" 115° 12' 49.648599"    0.004336m
    ELL HT=          647.5758m   +0.0000m          647.5758m    0.013608m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

28 D371
       LAT=  36° 24' 53.335680" +0.000000"  36° 24' 53.335680"        FIXED
       LON= 115° 27' 05.663360" +0.000000" 115° 27' 05.663360"        FIXED
    ELL HT=         1040.3800m   +0.0000m         1040.3800m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

29 NVGT
       LAT=  36° 12' 36.747582" +0.000000"  36° 12' 36.747582"    0.004486m
       LON= 115° 11' 54.424014" +0.000000" 115° 11' 54.424014"    0.004363m
    ELL HT=          639.8553m   +0.0000m          639.8553m    0.014578m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

30 R169
       LAT=  36° 15' 05.000166" +0.000000"  36° 15' 05.000166"    0.003486m
       LON= 115° 14' 32.487193" +0.000000" 115° 14' 32.487193"    0.003273m
    ELL HT=          679.5881m   +0.0000m          679.5881m    0.010659m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

31 T370
       LAT=  36° 21' 57.159124" +0.000000"  36° 21' 57.159124"    0.002380m
       LON= 115° 21' 25.915257" +0.000000" 115° 21' 25.915257"    0.002008m
    ELL HT=          877.4655m   +0.0000m          877.4655m    0.005501m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

32 V169
       LAT=  36° 19' 41.007059" +0.000000"  36° 19' 41.007059"    0.004148m
       LON= 115° 17' 14.505633" +0.000000" 115° 17' 14.505633"    0.003886m
    ELL HT=          764.0644m   +0.0000m          764.0644m    0.009680m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

33 V365
       LAT=  36° 18' 50.645466" +0.000000"  36° 18' 50.645466"    0.002579m
       LON= 115° 16' 48.300875" +0.000000" 115° 16' 48.300875"    0.002381m
    ELL HT=          748.3113m   +0.0000m          748.3113m    0.006376m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

34 W370
       LAT=  36° 23' 47.329928" +0.000000"  36° 23' 47.329928"    0.001862m
       LON= 115° 23' 38.916592" +0.000000" 115° 23' 38.916592"    0.001779m
    ELL HT=          855.3723m   +0.0000m          855.3723m    0.004384m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

35 Z398
       LAT=  36° 23' 09.968020" +0.000000"  36° 23' 09.968020"    0.005359m
       LON= 115° 22' 53.819757" +0.000000" 115° 22' 53.819757"    0.028893m
```

ELL HT=	868.9349m	+0.0000m	868.9349m	0.010679m
ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN

COORDINATE ADJUSTMENT SUMMARY
1998 Survey

Datum = WGS-84
Coordinate System = Geographic
Zone = Global

Network Adjustment Constraints:
6 fixed coordinates in y
6 fixed coordinates in x
6 fixed coordinates in H

POINT	NAME	OLD COORDS	ADJUST	NEW COORDS	1.00σ
1	0503+20.08				
	LAT=	36° 01' 54.283416"	+0.000237"	36° 01' 54.283653"	0.002909m
	LON=	115° 01' 49.522018"	-0.000172"	115° 01' 49.522190"	0.002672m
	ELL HT=	555.0605m	-0.0429m	555.0177m	0.006073m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
2	06135A17				
	LAT=	36° 09' 59.916354"	+0.000044"	36° 09' 59.916398"	0.005476m
	LON=	115° 07' 05.469442"	-0.000058"	115° 07' 05.469500"	0.004037m
	ELL HT=	536.5098m	-0.0110m	536.4987m	0.010633m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
3	0C90-17C4				
	LAT=	36° 17' 55.817027"	+0.000002"	36° 17' 55.817029"	0.004174m
	LON=	115° 17' 12.104759"	-0.000033"	115° 17' 12.104791"	0.003584m
	ELL HT=	766.0708m	-0.0026m	766.0681m	0.008946m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
4	0C90-7SE6				
	LAT=	36° 18' 43.446595"	-0.000002"	36° 18' 43.446593"	0.004389m
	LON=	115° 17' 55.313088"	-0.000032"	115° 17' 55.313120"	0.003766m
	ELL HT=	793.4827m	-0.0021m	793.4806m	0.009378m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
5	0LV00-17SEE6				
	LAT=	36° 12' 22.487277"	+0.000021"	36° 12' 22.487298"	0.006771m
	LON=	115° 16' 44.850640"	-0.000020"	115° 16' 44.850660"	0.005754m
	ELL HT=	738.4521m	-0.0045m	738.4475m	0.014748m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
6	110USGS				
	LAT=	36° 25' 46.269785"	-0.000005"	36° 25' 46.269780"	0.004322m
	LON=	115° 23' 19.889593"	-0.000019"	115° 23' 19.889612"	0.003682m
	ELL HT=	850.4154m	-0.0010m	850.4144m	0.008906m
	ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN
7	112USGS				
	LAT=	36° 20' 25.596773"	-0.000009"	36° 20' 25.596764"	0.004596m
	LON=	115° 17' 45.341168"	-0.000037"	115° 17' 45.341205"	0.003985m

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    ELL HT=            779.5752m   -0.0016m            779.5736m    0.009919m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

 8 169GWM
       LAT=  36° 26' 12.968989" -0.000005"  36° 26' 12.968984"    0.004442m
       LON= 115° 21' 46.588888" -0.000028" 115° 21' 46.588916"    0.003865m
    ELL HT=            855.1553m   -0.0017m            855.1536m    0.009478m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

 9 170GWM
       LAT=  36° 26' 12.500319" -0.000003"  36° 26' 12.500315"    0.004142m
       LON= 115° 19' 55.624491" -0.000038" 115° 19' 55.624530"    0.003612m
    ELL HT=            942.9638m   -0.0027m            942.9611m    0.008921m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

10 171GWM
       LAT=  36° 26' 15.219015" +0.000001"  36° 26' 15.219016"    0.004093m
       LON= 115° 17' 48.705988" -0.000049" 115° 17' 48.706037"    0.003580m
    ELL HT=           1068.8957m   -0.0041m           1068.8915m    0.009115m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

11 1LV00-4SES
       LAT=  36° 13' 59.810541" +0.000017"  36° 13' 59.810559"    0.004848m
       LON= 115° 15' 39.116133" -0.000029" 115° 15' 39.116162"    0.004273m
    ELL HT=            686.2188m   -0.0047m            686.2141m    0.010985m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

12 1LV10-8S4
       LAT=  36° 07' 47.328088" +0.000037"  36° 07' 47.328125"    0.006079m
       LON= 115° 17' 19.553398" -0.000010" 115° 17' 19.553409"    0.004656m
    ELL HT=            789.3087m   -0.0059m            789.3027m    0.012239m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

13 1LV90-33E6
       LAT=  36° 15' 19.902680" +0.000011"  36° 15' 19.902691"    0.004140m
       LON= 115° 15' 54.507300" -0.000032" 115° 15' 54.507333"    0.003562m
    ELL HT=            696.3626m   -0.0041m            696.3584m    0.009058m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

14 1LV90-36NES
       LAT=  36° 15' 41.096719" +0.000015"  36° 15' 41.096734"    0.004860m
       LON= 115° 12' 26.579553" -0.000047" 115° 12' 26.579600"    0.004145m
    ELL HT=            653.4683m   -0.0058m            653.4624m    0.010375m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

15 1LV90-36SSW6
       LAT=  36° 14' 47.535711" +0.000019"  36° 14' 47.535730"    0.004376m
       LON= 115° 13' 15.428117" -0.000043" 115° 13' 15.428160"    0.003885m
    ELL HT=            660.7438m   -0.0061m            660.7377m    0.009634m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

16 2C90-6SWW6
       LAT=  36° 19' 30.999687" -0.000007"  36° 19' 30.999680"    0.004602m
       LON= 115° 18' 38.738356" -0.000034" 115° 18' 38.738390"    0.003887m
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    ELL HT=            824.9864m   -0.0016m            824.9848m    0.009759m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

17 2GWM
       LAT=  36° 19' 31.609050" -0.000001"  36° 19' 31.609048"    0.005290m
       LON= 115° 20' 03.806822" -0.000026" 115° 20' 03.806848"    0.004716m
    ELL HT=            895.1451m   -0.0013m            895.1437m    0.011090m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

18 2LV00-25N4
       LAT=  36° 11' 17.219041" +0.000034"  36° 11' 17.219075"    0.004567m
       LON= 115° 12' 53.687658" -0.000035" 115° 12' 53.687693"    0.003892m
    ELL HT=            655.5589m   -0.0077m            655.5512m    0.009361m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

19 32-33-5-4
       LAT=  36° 20' 09.578372" -0.000007"  36° 20' 09.578365"    0.004868m
       LON= 115° 16' 43.079316" -0.000040" 115° 16' 43.079356"    0.004198m
    ELL HT=            745.2105m   -0.0021m            745.2084m    0.010556m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

20 34-35-3-2
       LAT=  36° 20' 08.359101" -0.000004"  36° 20' 08.359097"    0.005272m
       LON= 115° 14' 34.105668" -0.000050" 115° 14' 34.105718"    0.004537m
    ELL HT=            712.8534m   -0.0035m            712.8499m    0.011505m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

21 3GWM
       LAT=  36° 19' 06.911083" +0.000003"  36° 19' 06.911087"    0.004708m
       LON= 115° 21' 47.595320" -0.000013" 115° 21' 47.595333"    0.003985m
    ELL HT=            992.5671m   -0.0010m            992.5662m    0.010052m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

22 4GWM
       LAT=  36° 18' 30.596019" +0.000004"  36° 18' 30.596024"    0.004933m
       LON= 115° 23' 44.436123" -0.000001" 115° 23' 44.436125"    0.004211m
    ELL HT=           1111.9650m   +0.0000m           1111.9650m    0.010685m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

23 5-18-117
       LAT=  36° 17' 29.057465" +0.000012"  36° 17' 29.057476"    0.004825m
       LON= 115° 12' 24.561655" -0.000052" 115° 12' 24.561707"    0.003721m
    ELL HT=            676.8055m   -0.0053m            676.8002m    0.009544m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

24 6C02-16SWS
       LAT=  36° 12' 13.819952" +0.000033"  36° 12' 13.819986"    0.005910m
       LON= 115° 03' 43.254585" -0.000045" 115° 03' 43.254630"    0.003951m
    ELL HT=            520.7454m   -0.0081m            520.7373m    0.010598m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

25 6C02-4SWW6
       LAT=  36° 14' 11.753062" +0.000020"  36° 14' 11.753082"    0.005393m
       LON= 115° 03' 43.164212" -0.000033" 115° 03' 43.164245"    0.003582m
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    ELL HT=          539.9744m   -0.0051m          539.9694m    0.009948m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

26 6C11-13SWW6
       LAT=  36° 07' 06.982365" +0.000062"  36° 07' 06.982427"    0.006539m
       LON= 115° 07' 07.991434" -0.000052" 115° 07' 07.991486"    0.005160m
    ELL HT=          561.0491m   -0.0134m          561.0356m    0.014656m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

27 6C12-7SE6
       LAT=  36° 08' 04.766295" +0.000056"  36° 08' 04.766351"    0.006905m
       LON= 115° 05' 18.953651" -0.000054" 115° 05' 18.953705"    0.006622m
    ELL HT=          522.8608m   -0.0135m          522.8474m    0.014827m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

28 7C00-14N4
       LAT=  36° 13' 02.344653" +0.000024"  36° 13' 02.344677"    0.004289m
       LON= 115° 14' 02.845480" -0.000034" 115° 14' 02.845514"    0.003537m
    ELL HT=          669.3024m   -0.0061m          669.2963m    0.008960m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

29 7C00-36SSW6
       LAT=  36° 09' 33.433844" +0.000041"  36° 09' 33.433885"    0.004961m
       LON= 115° 13' 09.109854" -0.000033" 115° 13' 09.109887"    0.004211m
    ELL HT=          664.4329m   -0.0085m          664.4245m    0.010398m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

30 7C01-11S4
       LAT=  36° 13' 05.173446" +0.000032"  36° 13' 05.173478"    0.004954m
       LON= 115° 07' 36.133466" -0.000056" 115° 07' 36.133523"    0.003690m
    ELL HT=          560.1152m   -0.0091m          560.1061m    0.010156m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

31 7C01-29C4
       LAT=  36° 10' 52.429857" +0.000039"  36° 10' 52.429896"    0.004311m
       LON= 115° 10' 44.884258" -0.000041" 115° 10' 44.884299"    0.003751m
    ELL HT=          611.1638m   -0.0091m          611.1546m    0.009311m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

32 7C01-2C4
       LAT=  36° 14' 22.509603" +0.000027"  36° 14' 22.509630"    0.005249m
       LON= 115° 07' 30.398764" -0.000059" 115° 07' 30.398823"    0.004560m
    ELL HT=          565.8532m   -0.0081m          565.8450m    0.012717m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

33 7C02-18NWW6
       LAT=  36° 12' 52.317271" +0.000032"  36° 12' 52.317303"    0.006143m
       LON= 115° 05' 54.184017" -0.000052" 115° 05' 54.184069"    0.004037m
    ELL HT=          536.4667m   -0.0088m          536.4580m    0.010808m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

34 7C02-28S4
       LAT=  36° 10' 27.189636" +0.000030"  36° 10' 27.189666"    0.006146m
       LON= 115° 03' 10.071263" -0.000035" 115° 03' 10.071298"    0.004555m
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    ELL HT=            506.6121m   -0.0077m            506.6044m    0.011089m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

35 7C10-13NNW6
       LAT=  36° 07' 44.981827" +0.000050"  36° 07' 44.981878"    0.005081m
       LON= 115° 13' 12.301309" -0.000028" 115° 13' 12.301337"    0.004072m
    ELL HT=            667.7639m   -0.0095m            667.7544m    0.010508m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

36 7C10-22SWS
       LAT=  36° 05' 59.001049" +0.000053"  36° 05' 59.001102"    0.006867m
       LON= 115° 15' 38.911714" -0.000013" 115° 15' 38.911727"    0.005705m
    ELL HT=            712.6414m   -0.0083m            712.6330m    0.014373m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

37 7C10-24SWS
       LAT=  36° 06' 00.064533" +0.000059"  36° 06' 00.064592"    0.005074m
       LON= 115° 13' 29.219001" -0.000023" 115° 13' 29.219023"    0.004491m
    ELL HT=            674.5360m   -0.0101m            674.5259m    0.011439m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

38 7C11-5SSW6
       LAT=  36° 08' 40.348559" +0.000050"  36° 08' 40.348609"    0.003845m
       LON= 115° 11' 06.983013" -0.000040" 115° 11' 06.983053"    0.003113m
    ELL HT=            621.8385m   -0.0104m            621.8280m    0.008407m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

39 80.19
       LAT=  36° 14' 21.430097" +0.000024"  36° 14' 21.430121"    0.004980m
       LON= 115° 10' 28.731157" -0.000051" 115° 10' 28.731208"    0.003885m
    ELL HT=            623.9987m   -0.0073m            623.9914m    0.010541m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

40 802
       LAT=  36° 20' 09.682106" -0.000008"  36° 20' 09.682098"    0.004864m
       LON= 115° 15' 38.975742" -0.000045" 115° 15' 38.975787"    0.004187m
    ELL HT=            726.6956m   -0.0025m            726.6930m    0.010737m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

41 803
       LAT=  36° 20' 07.727714" -0.000002"  36° 20' 07.727712"    0.005402m
       LON= 115° 12' 25.403243" -0.000061" 115° 12' 25.403304"    0.004411m
    ELL HT=            708.9608m   -0.0042m            708.9566m    0.011476m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

42 806
       LAT=  36° 17' 32.169556" +0.000001"  36° 17' 32.169556"    0.004295m
       LON= 115° 18' 53.199588" -0.000022" 115° 18' 53.199610"    0.003698m
    ELL HT=            841.2009m   -0.0016m            841.1993m    0.009275m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

43 817-20-61
       LAT=  36° 12' 09.718705" +0.000032"  36° 12' 09.718737"    0.003777m
       LON= 115° 10' 11.276340" -0.000044" 115° 10' 11.276384"    0.003123m
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    ELL HT=            604.8240m   -0.0082m            604.8158m    0.008800m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

44 874
       LAT=  36° 14' 52.276574" +0.000023"  36° 14' 52.276597"    0.004889m
       LON= 115° 09' 12.881053" -0.000057" 115° 09' 12.881110"    0.003875m
    ELL HT=            600.1157m   -0.0078m            600.1079m    0.010560m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

45 888
       LAT=  36° 02' 10.699867" +0.000158"  36° 02' 10.700025"    0.003926m
       LON= 115° 05' 00.334944" -0.000066" 115° 05' 00.335011"    0.003873m
    ELL HT=            592.5918m   -0.0304m            592.5614m    0.009709m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

46 923
       LAT=  36° 09' 33.092326" +0.000033"  36° 09' 33.092359"    0.005325m
       LON= 115° 16' 27.131873" -0.000018" 115° 16' 27.131891"    0.004279m
    ELL HT=            769.7157m   -0.0059m            769.7098m    0.011370m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

47 C141
       LAT=  36° 16' 39.587066" +0.000008"  36° 16' 39.587074"    0.004331m
       LON= 115° 02' 14.488410" -0.000030" 115° 02' 14.488439"    0.003271m
    ELL HT=            585.5763m   -0.0036m            585.5727m    0.008734m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

48 C170
       LAT=  36° 05' 28.117048" +0.000066"  36° 05' 28.117114"    0.004119m
       LON= 115° 11' 45.658996" -0.000030" 115° 11' 45.659026"    0.003876m
    ELL HT=            652.5268m   -0.0117m            652.5151m    0.009945m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

49 CLV plate1
       LAT=  36° 14' 19.267820" +0.000021"  36° 14' 19.267841"    0.004755m
       LON= 115° 12' 49.648747" -0.000041" 115° 12' 49.648789"    0.003763m
    ELL HT=            647.5422m   -0.0061m            647.5361m    0.009568m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

50 CLV plate2
       LAT=  36° 16' 23.167317" +0.000012"  36° 16' 23.167329"    0.004583m
       LON= 115° 13' 28.982863" -0.000045" 115° 13' 28.982908"    0.003755m
    ELL HT=            676.5513m   -0.0053m            676.5461m    0.009886m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

51 CLV23
       LAT=  36° 09' 33.050411" +0.000044"  36° 09' 33.050455"    0.005285m
       LON= 115° 12' 05.359216" -0.000036" 115° 12' 05.359252"    0.004316m
    ELL HT=            637.4135m   -0.0092m            637.4043m    0.011179m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

52 CNLV
       LAT=  36° 12' 58.895336" +0.000032"  36° 12' 58.895368"    0.003479m
       LON= 115° 07' 39.172598" -0.000056" 115° 07' 39.172655"    0.002724m
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    ELL HT=          568.0747m   -0.0093m          568.0654m    0.007046m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

53 D171
       LAT=  36° 17' 59.523851" +0.000004"  36° 17' 59.523855"    0.004461m
       LON= 115° 01' 14.843039" -0.000038" 115° 01' 14.843077"    0.003222m
    ELL HT=          637.7038m   -0.0038m          637.7000m    0.008698m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

54 D368
       LAT=  36° 09' 16.912620" +0.000000"  36° 09' 16.912620"        FIXED
       LON= 115° 21' 47.198540" +0.000000" 115° 21' 47.198540"        FIXED
    ELL HT=          962.5080m   +0.0000m          962.5080m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

55 D371
       LAT=  36° 24' 53.335680" +0.000000"  36° 24' 53.335680"        FIXED
       LON= 115° 27' 05.663360" +0.000000" 115° 27' 05.663360"        FIXED
    ELL HT=         1040.3800m   +0.0000m         1040.3800m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

56 EA963+67.37
       LAT=  36° 00' 22.753961" +0.000077"  36° 00' 22.754037"    0.003648m
       LON= 115° 10' 48.302966" -0.000006" 115° 10' 48.302972"    0.003589m
    ELL HT=          667.2502m   -0.0127m          667.2375m    0.009875m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

57 F170 RESET
       LAT=  36° 01' 28.446815" +0.000077"  36° 01' 28.446893"    0.005110m
       LON= 115° 13' 37.335812" -0.000003" 115° 13' 37.335815"    0.005153m
    ELL HT=          726.6700m   -0.0118m          726.6582m    0.012357m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

58 H166
       LAT=  36° 00' 40.007127" +0.000254"  36° 00' 40.007380"    0.009315m
       LON= 114° 57' 02.641770" -0.000192" 114° 57' 02.641962"    0.006229m
    ELL HT=          618.0202m   -0.0468m          617.9734m    0.016314m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

59 H169+87.05
       LAT=  35° 59' 45.514466" +0.000088"  35° 59' 45.514554"    0.003949m
       LON= 115° 07' 47.859714" -0.000023" 115° 07' 47.859736"    0.003868m
    ELL HT=          677.8042m   -0.0154m          677.7888m    0.010991m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

60 HAPPY
       LAT=  36° 02' 50.342125" +0.000073"  36° 02' 50.342198"    0.003778m
       LON= 115° 10' 53.197244" -0.000017" 115° 10' 53.197261"    0.003668m
    ELL HT=          665.9850m   -0.0128m          665.9722m    0.009476m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

61 J171
       LAT=  36° 20' 28.054020" +0.000000"  36° 20' 28.054020"        FIXED
       LON= 114° 55' 04.375440" +0.000000" 114° 55' 04.375440"        FIXED
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    ELL HT=          707.3310m   +0.0000m          707.3310m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

62 J399
       LAT=  36° 06' 08.295777" +0.000098"  36° 06' 08.295875"    0.010928m
       LON= 115° 03' 07.592979" -0.000214" 115° 03' 07.593193"    0.011964m
    ELL HT=          483.3232m   -0.0233m          483.2999m    0.021796m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

63 JERK
       LAT=  36° 03' 08.137743" +0.000072"  36° 03' 08.137815"    0.004638m
       LON= 115° 12' 42.437998" -0.000015" 115° 12' 42.438013"    0.004568m
    ELL HT=          699.7219m   -0.0118m          699.7101m    0.010878m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

64 K366
       LAT=  36° 09' 09.413070" +0.000049"  36° 09' 09.413119"    0.004215m
       LON= 115° 09' 37.287654" -0.000047" 115° 09' 37.287701"    0.003442m
    ELL HT=          596.0086m   -0.0110m          595.9976m    0.008858m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

65 LORENZI
       LAT=  36° 14' 09.272242" +0.000019"  36° 14' 09.272262"    0.004003m
       LON= 115° 14' 28.671839" -0.000036" 115° 14' 28.671874"    0.003396m
    ELL HT=          677.0012m   -0.0056m          676.9955m    0.008659m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

66 LVAFB B
       LAT=  36° 15' 17.676702" +0.000016"  36° 15' 17.676718"    0.004958m
       LON= 115° 01' 45.512565" -0.000039" 115° 01' 45.512604"    0.003576m
    ELL HT=          550.3030m   -0.0052m          550.2978m    0.009627m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

67 LVVWD
       LAT=  36° 09' 34.025650" +0.000045"  36° 09' 34.025695"    0.003187m
       LON= 115° 11' 28.794448" -0.000041" 115° 11' 28.794489"    0.002630m
    ELL HT=          632.5534m   -0.0099m          632.5435m    0.006735m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

68 M364
       LAT=  36° 01' 25.999779" +0.000248"  36° 01' 26.000028"    0.010487m
       LON= 114° 57' 54.609264" -0.000190" 114° 57' 54.609455"    0.007453m
    ELL HT=          591.8119m   -0.0459m          591.7660m    0.020195m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

69 N366
       LAT=  36° 06' 55.925644" +0.000059"  36° 06' 55.925702"    0.004196m
       LON= 115° 11' 04.815171" -0.000036" 115° 11' 04.815207"    0.003456m
    ELL HT=          625.5853m   -0.0113m          625.5740m    0.010658m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

70 NHD32675009
       LAT=  36° 07' 49.622554" +0.000057"  36° 07' 49.622611"    0.004830m
       LON= 115° 09' 17.867978" -0.000046" 115° 09' 17.868024"    0.003874m
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    ELL HT=          595.1513m   -0.0120m          595.1393m    0.011877m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

71 NVGT
       LAT=  36° 12' 36.747178" +0.000028"  36° 12' 36.747206"    0.004585m
       LON= 115° 11' 54.424297" -0.000042" 115° 11' 54.424339"    0.003611m
    ELL HT=          639.8231m   -0.0075m          639.8156m    0.008921m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

72 P364
       LAT=  35° 58' 30.480663" +0.000269"  35° 58' 30.480931"    0.012452m
       LON= 114° 54' 49.478251" -0.000196" 114° 54' 49.478447"    0.008856m
    ELL HT=          681.1490m   -0.0494m          681.0997m    0.026718m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

73 P399
       LAT=  36° 11' 45.839263" +0.000037"  36° 11' 45.839300"    0.003696m
       LON= 115° 08' 26.549658" -0.000052" 115° 08' 26.549710"    0.002945m
    ELL HT=          567.9772m   -0.0096m          567.9676m    0.007653m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

74 PLS2050 74.75
       LAT=  36° 15' 41.031761" +0.000023"  36° 15' 41.031784"    0.005399m
       LON= 115° 09' 23.616762" -0.000055" 115° 09' 23.616818"    0.004069m
    ELL HT=          612.2210m   -0.0068m          612.2143m    0.011038m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

75 PLS3340 78.95
       LAT=  36° 17' 26.791037" +0.000005"  36° 17' 26.791042"    0.004119m
       LON= 115° 15' 12.298351" -0.000041" 115° 15' 12.298392"    0.003486m
    ELL HT=          696.4165m   -0.0039m          696.4126m    0.008849m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

76 PLS5088 77.76
       LAT=  36° 15' 39.314116" +0.000014"  36° 15' 39.314130"    0.004396m
       LON= 115° 13' 30.910606" -0.000043" 115° 13' 30.910649"    0.003759m
    ELL HT=          672.5506m   -0.0054m          672.5452m    0.009946m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

77 PLS5094 145.27
       LAT=  36° 08' 38.501291" +0.000052"  36° 08' 38.501342"    0.005510m
       LON= 115° 07' 06.888811" -0.000055" 115° 07' 06.888866"    0.004479m
    ELL HT=          547.4137m   -0.0122m          547.4015m    0.011497m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

78 PLS6902 56.57
       LAT=  36° 15' 04.239389" +0.000015"  36° 15' 04.239405"    0.004265m
       LON= 115° 14' 33.395335" -0.000037" 115° 14' 33.395372"    0.003619m
    ELL HT=          680.1537m   -0.0051m          680.1486m    0.009484m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

79 PLS7635 78.46
       LAT=  36° 13' 03.117985" +0.000028"  36° 13' 03.118013"    0.003780m
       LON= 115° 10' 12.338419" -0.000046" 115° 10' 12.338465"    0.003101m
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    ELL HT=            633.1007m   -0.0078m            633.0930m    0.008732m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

80 PLS8895 29 30 31 32
       LAT=  36° 15' 41.410917" +0.000017"  36° 15' 41.410934"    0.004884m
       LON= 115° 11' 20.344219" -0.000050" 115° 11' 20.344269"    0.003624m
    ELL HT=            636.9622m   -0.0062m            636.9560m    0.009649m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

81 PLS9388 76.99
       LAT=  36° 05' 34.152987" +0.000073"  36° 05' 34.153060"    0.004644m
       LON= 115° 08' 50.162991" -0.000043" 115° 08' 50.163034"    0.003999m
    ELL HT=            602.2255m   -0.0143m            602.2112m    0.009759m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

82 PLS9399 10 11 14 15
       LAT=  36° 18' 20.854466" +0.000015"  36° 18' 20.854481"    0.005388m
       LON= 115° 08' 03.756347" -0.000073" 115° 08' 03.756420"    0.004715m
    ELL HT=            642.1156m   -0.0073m            642.1082m    0.011606m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

83 RLS4841 25 26 35 36
       LAT=  36° 15' 41.580333" +0.000023"  36° 15' 41.580357"    0.005127m
       LON= 115° 07' 01.393643" -0.000062" 115° 07' 01.393705"    0.004074m
    ELL HT=            579.9983m   -0.0080m            579.9903m    0.011236m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

84 RLS5835 73.27
       LAT=  36° 04' 50.662761" +0.000084"  36° 04' 50.662846"    0.008064m
       LON= 115° 06' 02.870322" -0.000092" 115° 06' 02.870414"    0.006822m
    ELL HT=            562.0504m   -0.0195m            562.0309m    0.015293m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

85 RLS7190 63.44
       LAT=  36° 02' 58.665788" +0.000093"  36° 02' 58.665881"    0.004167m
       LON= 115° 07' 38.086915" -0.000064" 115° 07' 38.086979"    0.003861m
    ELL HT=            601.8264m   -0.0182m            601.8082m    0.009999m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

86 SLOAN
       LAT=  35° 56' 23.987540" +0.000000"  35° 56' 23.987540"        FIXED
       LON= 115° 10' 59.297180" +0.000000" 115° 10' 59.297180"        FIXED
    ELL HT=            781.4280m   +0.0000m            781.4280m        FIXED
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

87 T19-20S/R62-63E
       LAT=  36° 14' 49.269830" +0.000016"  36° 14' 49.269846"    0.005269m
       LON= 114° 59' 19.906340" -0.000049" 114° 59' 19.906389"    0.003791m
    ELL HT=            553.4744m   -0.0071m            553.4674m    0.010286m
  ORTHO HT=              0.0000m   +0.0000m              0.0000m    NOT KNOWN

88 T370
       LAT=  36° 21' 57.159235" +0.000000"  36° 21' 57.159235"    0.004086m
       LON= 115° 21' 25.915423" -0.000017" 115° 21' 25.915440"    0.003417m
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    ELL HT=          877.4602m   -0.0015m          877.4587m    0.008416m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

89 U368
       LAT=  36° 11' 53.565090" +0.000000"  36° 11' 53.565090"        FIXED
       LON= 115° 00' 37.322430" +0.000000" 115° 00' 37.322430"        FIXED
    ELL HT=          629.6190m   +0.0000m          629.6190m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

90 UNDER
       LAT=  36° 19' 02.109074" +0.000002"  36° 19' 02.109075"    0.003470m
       LON= 114° 56' 54.441695" -0.000015" 114° 56' 54.441710"    0.002479m
    ELL HT=          734.7972m   -0.0019m          734.7953m    0.006533m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

91 V169
       LAT=  36° 19' 41.007107" -0.000004"  36° 19' 41.007103"    0.004725m
       LON= 115° 17' 14.505984" -0.000037" 115° 17' 14.506021"    0.004130m
    ELL HT=          764.0558m   -0.0020m          764.0537m    0.010080m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

92 V365
       LAT=  36° 18' 50.645806" +0.000000"  36° 18' 50.645806"    0.004395m
       LON= 115° 16' 48.301293" -0.000037" 115° 16' 48.301330"    0.003759m
    ELL HT=          748.3046m   -0.0026m          748.3020m    0.009407m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

93 W370
       LAT=  36° 23' 47.329936" -0.000001"  36° 23' 47.329935"    0.003377m
       LON= 115° 23' 38.916766" -0.000014" 115° 23' 38.916780"    0.002749m
    ELL HT=          855.3564m   -0.0009m          855.3555m    0.006883m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

94 W51
       LAT=  36° 04' 04.420570" +0.000000"  36° 04' 04.420570"        FIXED
       LON= 115° 00' 51.824610" +0.000000" 115° 00' 51.824610"        FIXED
    ELL HT=          476.6208m   +0.0000m          476.6208m        FIXED
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

95 WD15+07.95
       LAT=  36° 10' 24.510887" +0.000043"  36° 10' 24.510930"    0.003799m
       LON= 115° 08' 32.595596" -0.000051" 115° 08' 32.595647"    0.002992m
    ELL HT=          585.3241m   -0.0105m          585.3136m    0.007691m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

96 X314
       LAT=  36° 21' 11.786399" -0.000011"  36° 21' 11.786388"    0.004537m
       LON= 115° 18' 31.126013" -0.000039" 115° 18' 31.126051"    0.003849m
    ELL HT=          796.1717m   -0.0013m          796.1704m    0.009754m
  ORTHO HT=            0.0000m   +0.0000m            0.0000m    NOT KNOWN

97 Y370
       LAT=  36° 25' 05.927141" -0.000001"  36° 25' 05.927139"    0.002733m
       LON= 115° 25' 13.354904" -0.000009" 115° 25' 13.354913"    0.002042m
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ELL HT=	892.4590m	-0.0005m	892.4585m	0.005528m
ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN

98 Z398

LAT=	36° 23' 09.967970"	+0.000002"	36° 23' 09.967972"	0.003480m
LON=	115° 22' 53.819997"	-0.000015"	115° 22' 53.820013"	0.002843m
ELL HT=	868.9140m	-0.0014m	868.9126m	0.007092m
ORTHO HT=	0.0000m	+0.0000m	0.0000m	NOT KNOWN

Appendix 2

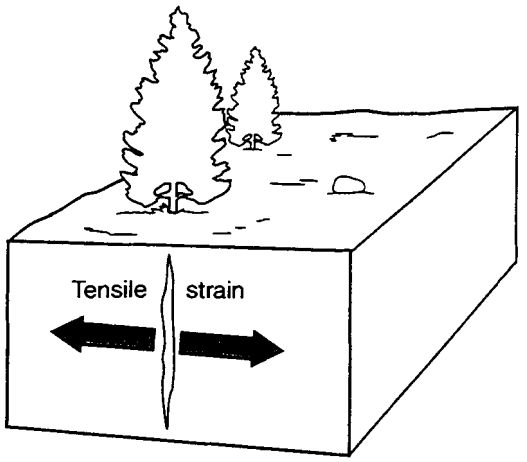
1998 Reconnaissance of Earth Fissures and Sinkholes in Las Vegas Valley

Craig M. dePolo
Nevada Bureau of Mines and Geology

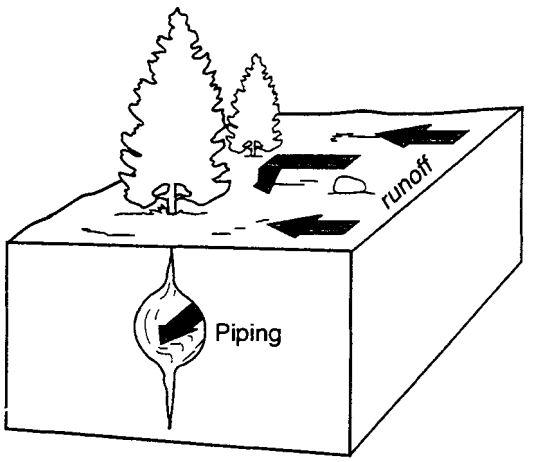
Earth Fissures in Las Vegas

Earth fissures have been identified in Las Vegas Valley at least since about 1925 (Patt and Maxey, 1978). Prehistorical fissures are also suspected (Mifflin and others, 1991; this study). Work on the earth fissures began in the 1960s following subsidence studies in the valley and studies of fault scarps in the valley, referred to as compaction scarps (e.g., Domenico and Maxey, 1964). Surveys of earth fissures continued in the 1970s with a thesis based on the features (Passmore, 1975) and an inventory of fissures (Patt and Maxey, 1978). The 1981 report on subsidence in Las Vegas (Bell, 1981) described earth fissures in the valley and their formation. In 1990, Mifflin and others (1991) inventoried earth fissures in Las Vegas Valley, compiling previous studies and mapping new fissures. Werle and others (1991) discuss earth fissures in Las Vegas Valley and describe some geotechnical mitigation techniques for building in areas with fissures. Bell and others (1992) reported the results of Mifflin and others (1991) survey and suggested some general guidelines for considering the hazard posed by earth fissures. Linnert and others (1994) discussed the results of investigations into earth fissures, including trenching studies, in the Windsor Park area of North Las Vegas. Sheng (1996) modeled the mechanics of fissuring caused by groundwater withdrawal. Sheng notes the decrease in the strength of the soil mass caused by earth fissures, broadly a conclusion of other workers as well. Sheng comments that the, "bearing capacity of soil mass may reduced even after a fissure is filled by sediments." Werle and others (1998) have developed a hazard index based on several properties, such as proximity to faults, shallow groundwater conditions, and soil conditions, to assist in defining the potential hazard of earth fissures. In addition to these studies, there are several studies by local geotechnical consultants that identify and recommend mitigation measures for the earth fissure hazard in Las Vegas Valley.

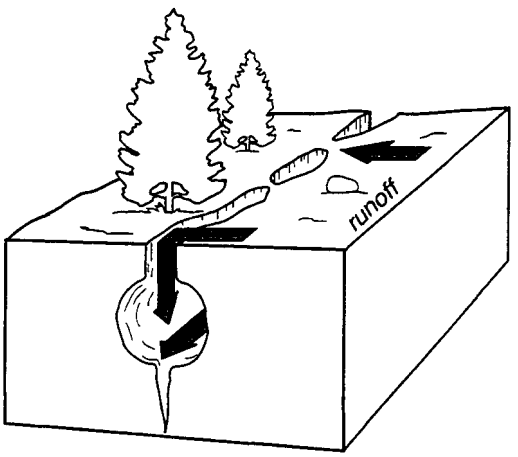
Earth fissures are formed by two fundamental processes and a series of conditions that generally dictate how large they will become. The two processes are the occurrence of stresses to create tensional forces and erosion from flowing water (Clark, 1972; Passmore, 1975; Bell, 1981; Mifflin and others, 1991; Helm, 1994). This is illustrated in Figure 1. Tensional forces are commonly generated from aquifer pumping (e.g., Helm, 1994; Sheng, 1996). Sheng concluded that, "numerical results indicate that both vertical and horizontal movements of an aquifer at depth may result in tensile failure in overlying soil masses." These tensional forces lead to small fractures in soils that are stiff enough to support a fracture. The most common occurrence of water that forms earth fissures is the runoff from large storms. When water flowing overland intersects these small fractures, it erodes them into underground pipes (that can collapse leading to surficial fissures) or into small, steep-sided gullies. The conditions that promote fissure formation are nicely laid out in a recent paper by Werle and others (1998), who use them to develop a fissure-hazard index. These conditions include the lack of a shallow groundwater table, soil conditions (including erodability, brittleness, hydrocollapsibility, expansiveness, and gypsum content),



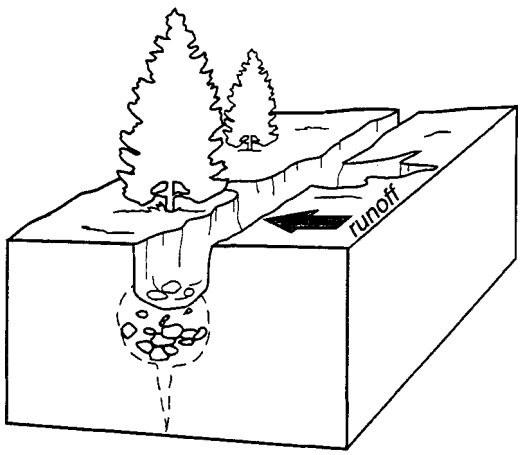
I. Lateral strain induces tension cracking.



II. Surface runoff and infiltration enlarge crack through subsurface piping.



III. As infiltration and erosion continue, fissure enlarges and completely opens to surface as tunnel roof collapses.



IV. The entire fissure is opened to the surface and enlargement continues as fissure walls are widened; extensive slumping and side-stream gullying occur.

Figure 1. Generalized stages of earth fissure development (from Bell, 1981).

distance from existing faults and/or wells, and orientation of the faults (Werle and others, 1998).

Earth fissures are clearly enhanced and caused by human activities (e.g., pumping of water creating horizontal stresses and lowering the water table, and concentration of runoff), but it seems likely that earth fissures likely proceeded 20th century urbanization. Lineaments formed by sparse desert vegetation are possible healed earth fissures in the northwestern part of the valley (Patt and Maxey, 1978). Nevertheless, Patt and Maxey (1978) and others subsequently have noted that the earth fissure process is becoming more active with time due to rapid urbanization.

Specific Observations from Areas

Area A (Gilcrease well area)

Area A is located proximal to the Gilcrease Well (originally a flowing artesian well), and near the northernmost part of the northern subsidence bowl in Las Vegas Valley. Area A is located north of the known faults in Las Vegas Valley, although some northerly-striking faults in the subsurface are projected just northwest of this location based on spring alignments and subsurface facies changes by Haynes (1967), Donovan (1996), and Bell and others (1998). The fissures are forming in active alluvium, bounded on the north by late Pleistocene muds and silts (Bell and others, 1998). These muds are fairly consolidated and likely underlie the site at an unknown depth.

Fissures in Area A were initially studied by Patt and Maxey (1978) and subsequently by Mifflin and others (1991). Mifflin and others found that the fissures differed from the descriptions of Patt and Maxey and concluded that the "fissure healing process" in this area is apparently rapid (this may be due to the lack of consolidation of the active alluvium allowing fissure walls to collapse easily). Mifflin and others observed that most of the fissures mapped in 1990 appeared to be fresh. They commented that the fissures mapped are partially filled with slope-wash material and most are overgrown with vegetation. Mifflin and others note that, "the fissures have healed by being converted to the surface drainage network." The dominate trends of fissures in this area is NNW, NW, and WNW, and that the weighted trend of all the fissures is WNW (Mifflin and others, 1991). Smith (1982) noted that these fissures are largely related to local compaction around the well.

Most of Area A has been built over or has been bulldozed. A nursery is located south of Racel Street covering much of the fissure area. Only one fissure was found in the area, to the north of the road, across the street from the nursery, although the nursery grounds were not carefully inspected. The fissure that was found is located in a wash for most of its distance and skirts the flank of the late Pleistocene mudstone along its eastern end. The fissure is arcuate shaped, concaved to the south. The fissure is oriented N70°E along its west end and east-west striking along its eastern part. This fissure is about 20 m long, has a maximum depth of 60 cm, and a maximum width of 30 cm. A fissure in this general area (FM8) is shown as covered in Mifflin and others (1991). Thus, this could be a new fissure north of the road, or because the fissure intersects a stream channel and can be easily reactivated, it could be the same fissure noted by Mifflin and others.

Several other fissures are noted to the east and south of the Gilcrease well, including one apparently

discovered in 1925 (Smith, 1982), prior to large-scale groundwater pumping in Las Vegas Valley. Most of these are now built over. None were found.

Area B (Eglington scarp area)

Area B is located in the footwall of the Eglington scarp, an 11-km long surficial warp in latest Pleistocene sediments that overlies a subsurface fault, and is near the gradient associated with the eastern edge of the northern subsidence bowl located in northwest Las Vegas Valley. Geodetic measurements suggest the footwall of the Eglington scarp is subsiding faster than the hanging wall (Bell and others, 1992).

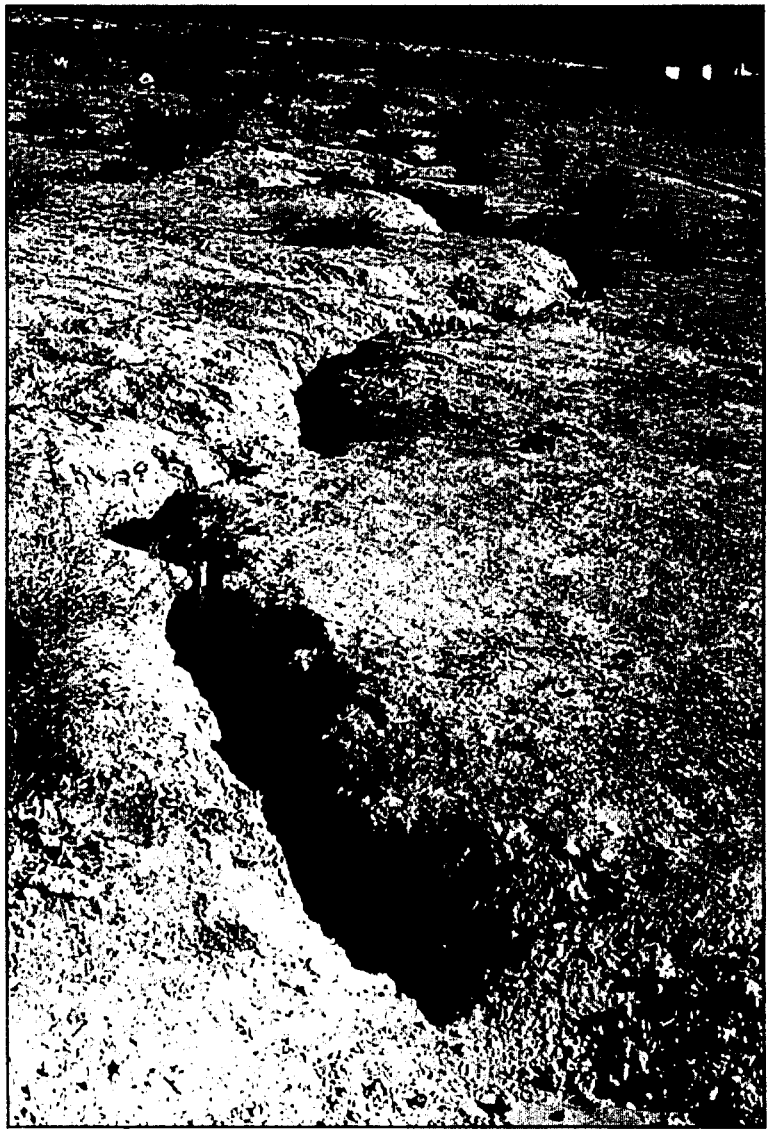
Most of these fissures are in the vicinity of Ann Road and Decatur Boulevard, where the Eglington scarp is about 15 to 20 m high and strikes northeast. The fissures are located in the downthrown side of the scarp. This is the southeast side of the scarp, on the opposite side of the fault as the subsidence basin. The fissures commonly trend northeast, generally paralleling the scarp, although a few short fissures have been mapped that are perpendicular to the scarp (Mifflin and others, 1991; Map B). The fissures are located in Holocene gravelly-sand deposits that likely overlie latest Pleistocene siltstones and paludal carbonates that are warped under the Eglington scarp. Aerial photographs taken in 1943 record vegetation lineaments that suggest fissures in this area (Smith, 1982).

Over 30 fissures have been mapped in Area B by Smith (1982). An excellent oblique aerial photograph of these fissures is shown by Bell (1981, photograph on his page 64). Nineteen of these fissures that were mapped to the west of Decatur Boulevard have been built over by a subdivision of houses. Of the remaining fissures mapped, most have apparently been naturally filled or graded. Only two fissures were found in Area B by this study.

The largest fissure in the field east of Decatur Boulevard and south of Ann Road is still clearly visible and active (fissure 1, Area B). Prior to urbanization, this fissure was 457 m long (Mifflin and others, 1991). Runoff from a golf course to the west flows into the southern end of the fissure and runoff from adjacent, undeveloped fields flows into the north end. The fissure is continuous over most of its length, but becomes discontinuous at the northern end where it is an alignment of sinkholes. This large fissure has two distinct areas where down holes exist that are where the water and its load of eroded silts and sands goes down into subsurface piping (see plate 1). Since there are no local wells in this area, the water and its load may be flowing into subsurface networks associated with groundwater flow in this area. The appearance of this fissure has not changed significantly since 1990. There are a number of new blocks collapsing into the fissure, indicating local widening (see Photograph 1). There are also a couple of small, relatively-new subparallel splay fissures that are up to 10 m to 15 m long from their intersection with the main fissure. The north end of this fissure has extended roughly 30 m since 1990. This is indicated by an alignment of small sinkholes that appear to drain a small ponded area north of the fissure. An interesting portion of the central part of this fissure is shown in Photograph 2. This portion of the fissure has a zig-zag pattern using portions of fracture sets with two dominant orientations.

The southern end of this large fissure crossed Decatur Boulevard; this road was mitigated for damage from fissures by Converse Consultants (James Werle, 1998, personal commun.). The fissure can be followed as shallow sinkholes to within about 20 m of Decatur Boulevard. Neither the pavement of

Photograph 1. Large fissure southeast of Ann Road and Decatur Boulevard (fissure 1, Area B). A small parallel fissure to the right (east) is creating a small block between the two fissures that may eventually collapse.



Photograph 2. Area along fissure 1 in Area B (southeast of Ann Road and Decatur Boulevard) where there is a distinct zigzag pattern in the fissure. This is the result of the fissure flowing along parts of different fractures with different orientations.

Decatur Boulevard nor the sidewalk along the west side showed any damage at the time of this survey, not even cracking, that might be considered related to the earth fissures.

There was evidence of renewed ground cracking noted along portions of the Decatur Boulevard fissures in Spring, 1998. Fresh ground cracking 1-2 cm in width was found by J. Bell in the northern portion of the fissure zone; the cracking was traced continuously for several hundred meters in undisturbed deposits (Photograph 3) as well as in partially healed fissures. The new cracks suggest that a ground fracturing event occurred in early 1998.

A small fissure (#2 in Area B) that may be new is located about 80 m southeast of the southern expression of Fissure 1. Fissure 2 is made up of small discontinuous sinkholes striking NNE over a distance of about 23 m. This fissure is fed at its northern end from a small overland wash. Other fissures from Mifflin and others (1991) in this area, specifically fissures FM2 through FM6, were not found.

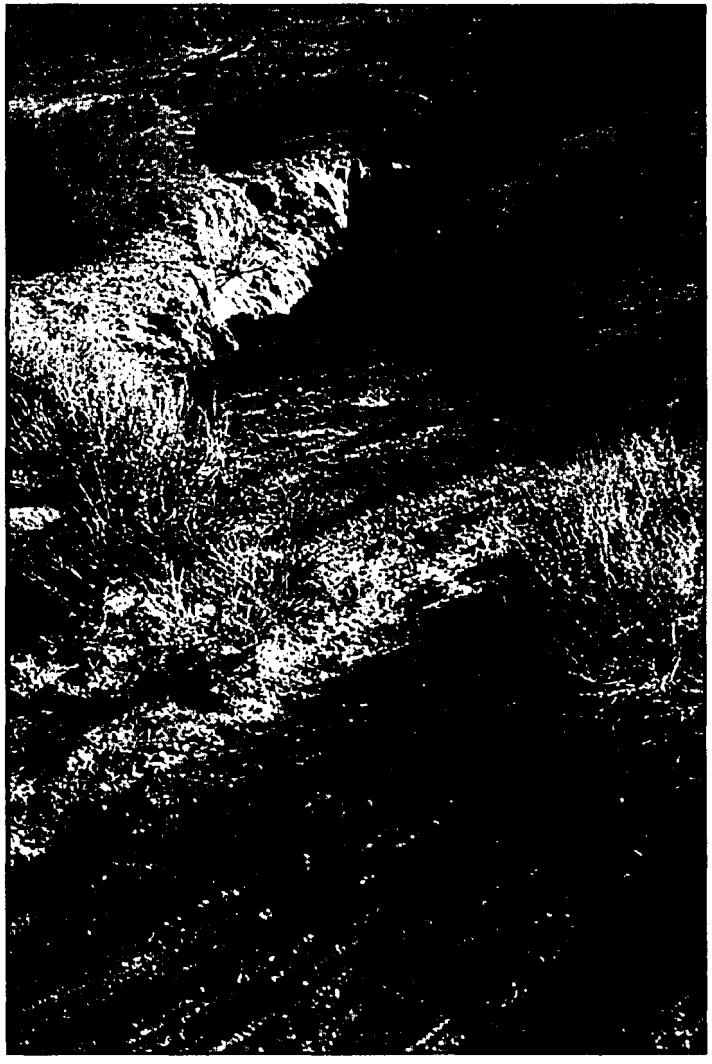
There is an account of a fissure appearing after earthquake shaking during the night in Area B. This is reported by Patt and Maxey (1978) and is given by Ted Gilcrease, a long-time rancher in the area. Ted Gilcrease reports that a 800-m long fissure appeared December 16, 1930, after an earthquake in central Nevada. Mr. Gilcrease felt the shock during the night and the next day he discovered the fissure, which was north of the Gilcrease ranch and trended northwest. There is no earthquake on record on this date in Nevada, California, Utah, or Arizona. In fact, the only earthquakes recorded during this time in the western United States was a swarm of events at Yellowstone National Park (Coffman and von Hake, 1973). Thus, this date is inaccurate. Perhaps a more likely date for a large night-time earthquake in central Nevada is December 21, 1932, the Cedar Mountain earthquake (M7.1). This event was felt distinctly and for a long duration in Las Vegas Valley. Ground motion is not considered to be an important process related to earth fissure formation in this case, merely a trigger for the failure of the land bridge over the fissure. The account does support, however, that fissures were present in the early 1930s in the valley.

Table 1 Fissures measured near Ann Road and Decatur Boulevard/ Area B

ID #	Description	Length	Width	Depth	Strike
1	large fissure	~600 m	200 cm	240 cm	~N20°E
2	discont. sinkholes	23 m	40 cm	30 cm	N15°E

Area C (Craig Road area)

Area C is part of an overall area of fissures that occur along Fault II of the Las Vegas Valley fault system (also included are Areas D and E). Several local wells apparently contributed to the horizontal stresses initially responsible for much of the fissure formation, as indicated by the proximity of these fissures to



Photograph 3. Recent (Spring, 1998) ground crack about 1 cm in width in undisturbed soil along Decatur Boulevard fissure.

Photograph 4. West end of a relatively new fissure in Area C2, fissure 3. This fissure can be seen as a small group of aligned sinkholes where it intercepts a small drainage ditch.

stresses initially responsible for much of the fissure formation, as indicated by the proximity of these fissures to the wells. Area C consists of several sets of fissures that are north of Craig Road and east of Camino Al Norte, and fissures south of Craig Road in the area of N. 5th Street. For discussion purposes, I divide these into four areas. The first area, C1, is between Camino Al Norte and the Craig Ranch Country Club, including the westernmost part of the Country Club. The second area, C2, is from the Country Club eastward to Nellis wells. The third area, C3, is the Nellis well field. The fourth area, C4, are the fissures south of the "Craig Road Speedway Site." Surficial deposits in these areas are mapped as alluvium of active washes by Matti and others (1987). The fissures observed in Area C were generally formed in Holocene silts and sands, that may be dispersive in nature. A common feature of Area 2 fissures is the confinement of the fissures to the active wash deposits (see Matti and others, 1987, where fissure areas are indicated with geology). The fissures are proximal to fault traces in a distributed portion of Fault II, and occur in both the hanging wall and the footwall. Local stresses may have contributed to fracture formation in Area C. Figure 15 of Bell (1981) shows a depression in the water table of 26 m in this area due to the pumping of groundwater. Smith (1982) notes that fissures exhibit radial and concentric patterns in the vicinity of the wells that is likely related to pumping. Severe fissuring has occurred in the Craig Ranch Country Club since at least 1965 (Patt and Maxey, 1978).

In the westernmost part of Area C1, Mifflin and others (1991) describe an "impressive set of pipes and collapse features" near the intersection of what would today be Craig Road and Martin Luther King Boulevard/Camino Al Norte. This area (the northeast corner of the intersection) is a small shopping mall and, thus these fissures have been built over. None of the small fissures shown in the western part of Mifflin and others' Map CI were found; they may have been obliterated by grading adjacent to the mall. A few small fissures were found immediately northeast of a shopping center (see plate; fissures 26-29). One of these is proximal to fissure FM13 of Mifflin and others, but it appears to be relatively new.

Immediately west of Craig Ranch Country Club, three fissures were found that may correspond to fissures presented in Mifflin and others (1991). The largest fissure they show in the area, FM11 on their Map CI, is still clearly visible and active. This fissure (fissure 34 on the plate) is almost 300 m long, up to 2 m wide, and up to 2 m deep. Mifflin and others show much of this fissure as "covered/graded." Although the westernmost portion of the fissure has been graded, the eastern half does not appear to have been and is still visible. In the central part of this fissure is a major down-hole, 2 m deep. This fissure was noted in 1965 and judged by Smith (1982) to be similar in length, but with several branches that opened up. The fissure as observed in 1998 is similar to as observed by Smith (1982). Sinkholes were found approximately where fissures FM7 and FM8 were located (sinkholes 31 and 32 on plate 1). Fissure 30 is parallel to some covered fissures noted by Mifflin and others. A through survey of the central portion of this field was not conducted and some additional fissures may exist. In Area C1 as a whole, fissures are generally in the same places as previously mapped, and one large fissure is still distinctly present. Many of the fissures that occur today appear to be relatively new, however. The zone of fissures portrayed in Bell and Price (1991) was extended slightly to the northwest to include fissure 26 (Area C1 on plate 1).

The second area, C2, lies immediately west of the Nellis well field and east of Craig Ranch Country Club. Portions of this field have dense patterns of earth fissures; much more than is indicated by Patt and Maxey (1978) or Mifflin and others (1991, Map CII). Over 50 fissures were identified in Area C2, 25 of which are listed in Table 2 and shown on the accompanying plate. The fissures listed in Table 2 were active

during the recent storms. There is also extensive evidence of older fissures that have become inactive, collapsed, and exist as degraded fissures or linear swales in the ground. At least three generations of earth fissures can be observed in this field based on the state of degradation of the sides of the fissures, and by a lichen(?) that grows on some surfaces. The area is underlain by at least a few meters of brown Holocene silts and sands, which may be dispersive in nature. There is a coincidence between 2- to 3-m high mesquite bushes and earth fissures in this field. Mesquite seems to occur in areas of active and inactive fissures, and where there is likely to be subsurface piping. There is also evidence for the existence of fissures in the adjacent field to the west, but these have been graded over.

Only the larger or longer of earth fissures in area C2 that have flowed most recently were mapped, to get a general portrayal of their layout. Mapped fissures range from 3 m to 45 m in length, from 1 mm to 2.5 m in width, and from 0.2 to 3.2 m in depth. The largest sinkhole encountered during this reconnaissance survey was found in this area, and measured 8 m to 10 m across, and 2.7 m at its maximum depth. Several areas of extensive fissures are also shown on the plate. These are areas that are riddled with fissures, too dense to map in this study. More areas like this exist but were not portrayed.

Photographs 4, 5, 6, and 7 illustrate fissure 3 and a large sinkhole (fissure 14) from Area C2. Photographs 4 and 5 show the beginning and terminus of fissure 3, respectively. Fissure 3 begins at a small drainage ditch and ends where it intersects fissure 4. The large sinkhole featured in Photographs 6 and 7 is the largest found in the survey (mentioned above).

Mifflin and others (1991) showed a number of fissures in this field. Of these, FM29 may correspond to this study's fissure 29, FM61 is probably fissure 11, FM63 is probably fissure 5 and FM64 is fissure 4. Parts of FM59 may be fissures 24 and 25. Parts of FM59 and all of FM60 appear to be inactive at the surface in 1998.

Many of the fissures appear to be part of a drainage distribution network that takes surface runoff and transfers it to the subsurface. In general, the flow across the property is from the west to the east (Figure 2). Overall, water is collected by the network in the western part and travels down fissures and pipes to about the midpoint of the property, where flow is deeper than 3 m, below which surface expression is no longer distinct. At this point, a new drainage system forms with local surface collection and transfer to the subsurface. Area C2 should be mapped in detail before this area is graded over for future research on earth fissures, since there are so few study sites left that have not been urbanized.

Area C3 is adjacent to the Nellis wells and lies on the north and south sides of Craig Road; I'll refer to these as the north and south halves. This area was mapped recently by Kleinfelder and Associates in 1994? and briefly inspected in 1998. A slightly modified version of the map produced by Kleinfelder and Associates is presented in the accompanying plate. The overall pattern shows a group of fissures in an area about 400 m wide. Wells that are pumped for water by the Nellis Air Force Base are located along the southwest side of the fissured area. In the northern part of the north half, fissures curve from east trending near the western part to northwest trending on the eastern side (see plate 1). These fissures form a crude arc around the well in the southwest corner of the north half of Area C3. Most other fissures in the north half trend northeast or northwest, with a few short ones trending east-west. Fissures in the southwest part of the southern half of Area C3 are roughly parallel to the southwest side of the fissure area (commonly northwest trending). Many of the rest of the fissures form small networks of northwest,

Photograph 5. East end of fissure 3, Area C2, where it intersects fissure 4. View is to the east. The surface is slightly overexposed, with fissure 3 in the foreground. The east wall of fissure 4 (shaded) crosses the central part of the photograph. Note that fissure 3 (cracks) crosses fissure 4 and is exposed in the east wall of fissure 4. At this location, the flow in fissure 4 has shifted subsurface to just beyond the field book, allowing fissure 3 to propagate along strike across the abandoned portion of fissure 4.

Photograph 6. Large sinkhole and collapse area 8 to 10 m in width (fissure 14, Area C2). This is the largest sinkhole found in this study (see Photograph 7).

Photograph 7. Large down hole on the east side of the sinkhole at fissure 14, Area C2. This pipe entrance is 2.7 m below the surface and is 0.5 to 0.75 m in diameter. The 2" by 6" boards, stuffed in the entrance, attest to the severe hazard that could occur if someone was caught in one of these features while it was flowing.

Photograph 8. Downward opening of fissure 14, Area D below a carbonate-rich horizon. These subsurface pipes and chambers must be common to accommodate the large volumes of water and debris that flows through fissures at times of heavy precipitation.

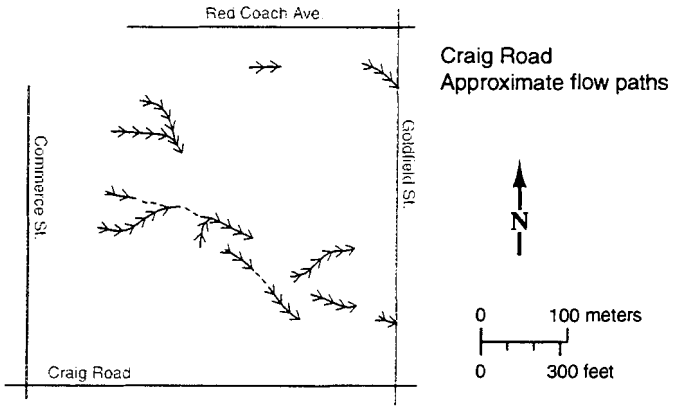


Figure 2. Schematic map of fissure area C2 showing the flow directions along earth fissures.

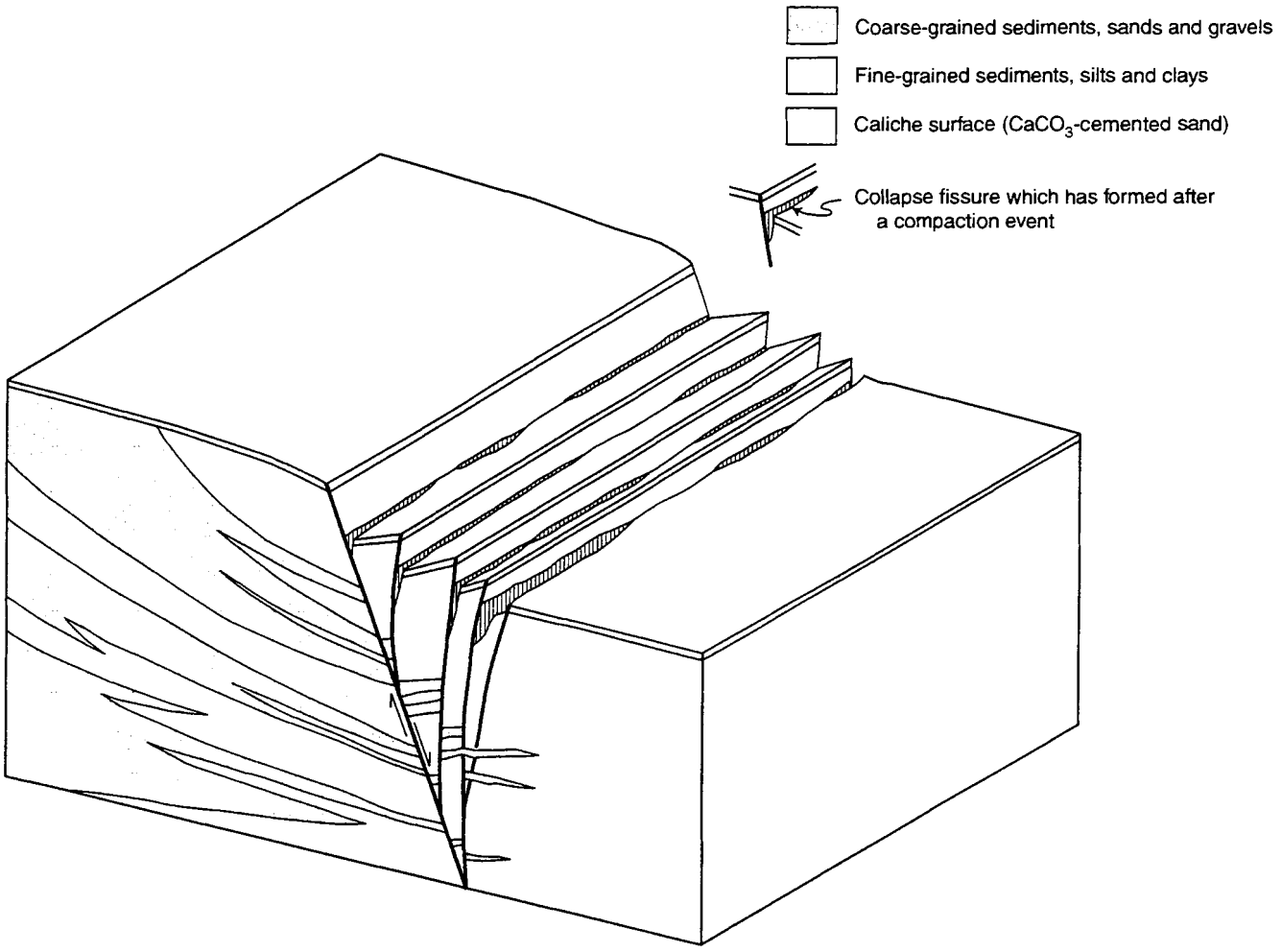


Figure 3. Near-surface fault structure in Area D with earth fissures (Passmore, 1975).

northeast, and east-west fissures. Mifflin and others (1991) mapped several fissures in this field, and several of these patterns are still present. The newest fissures that were not recorded by Mifflin and others are fissures bounding the northeast side of the fissured area.

Table 2 Fissures measured near Craig Road/ Area C

ID #	Description	Length	Width	Depth	Strike
1	sm. cont. fissure	10 m	20 cm	80 cm	≈NS
2	2 lg. aligned sinkholes	20 m	120 cm	310 cm	N65°E
3	new discont. fissure	20 m	few cm	120 cm	≈EW
4	lg. cont. fissure	15 m	200 cm	290 cm	N5°E
5	discont. fissure	~70 m	200 cm	150 cm	N80°W
6	lg. sinkhole	3 m	200 cm	~200 cm	N75°W
7	discont. fissure	~35 m	100 cm	80 cm	EW
8	aligned sinkholes	~40 m	40 cm	60 cm	N80°W
9	cont. fissure	45 m	3 cm	~20 cm	NS
10	lg fiss.. w/sinkhole	~50 m	40 cm	130 cm	N35°E
11	discont. fiss. & sinkholes	~40 m	200 cm	90 cm	≈NS
12	lg. sinkhole	5 m	250 cm	320 cm	≈EW
13	reactivated fissure	4 m	60 cm	40 cm	N75°W
14	lg. sinkhole	-	1000 cm	270 cm	~N80°W
15	sinkhole	3.5 m	140 cm	100 cm	N65°W
16	new? discont. fissure	38 m	4 cm	20 cm	N42°W
17	aligned sinkholes	14 m	60 cm	150 cm	N65°W
18	sinkhole	-	40 cm	50 cm	
19	sinkholes in road	2.3 m	60 cm	110 cm	~N5°E
20	aligned sinkholes	~45 m	40 cm	70 cm	N40°W
21	discont. fissure	44 m	200 cm	80 cm	N50°W
22	zone of fissures	~30 m	30 cm	50 cm	~N70°E
23	discont. fissure	~35 m	50 cm	50 cm	N65°E
24	reactivated fissure	~35 m	30 cm	100 cm	N80°W
25	sm. fissure	8 m	40 cm	40 cm	~N50°W
26	discont. fissure	30 m	210 cm	150 cm	N10°E
27	discont. fissure	30 m	50 cm	80 cm	N10°E
28	discont. fissure	46 m	90 cm	100 cm	N80°E
29	discont. fissure	30 m	40 cm	30 cm	N45°W
30	aligned sinkholes	61 m	30 cm	30 cm	N85°E
31	sinkhole	1 m	70 cm	80 cm	N25°W
32	sinkhole	-	40 cm	180 cm	N55°E
33	aligned sinkholes	57 m	30 cm	90 cm	N45°E
34	lg. fissure	~370 m	200 cm	200 cm	N25°E

The fourth area, C4, was identified by Patt and Maxey (1978) and Mifflin and others (1991). This speedway no longer exists and the site has been graded over. No fissures could be seen in this area. Mifflin and others comment that this area southeast of the location of the speedway is a topographic low and that sedimentation was rapidly obliterating these fissures. This topographic low and the water that used to accumulate there were likely the cause of local fissures.

Area D (Cheyenne Avenue area)

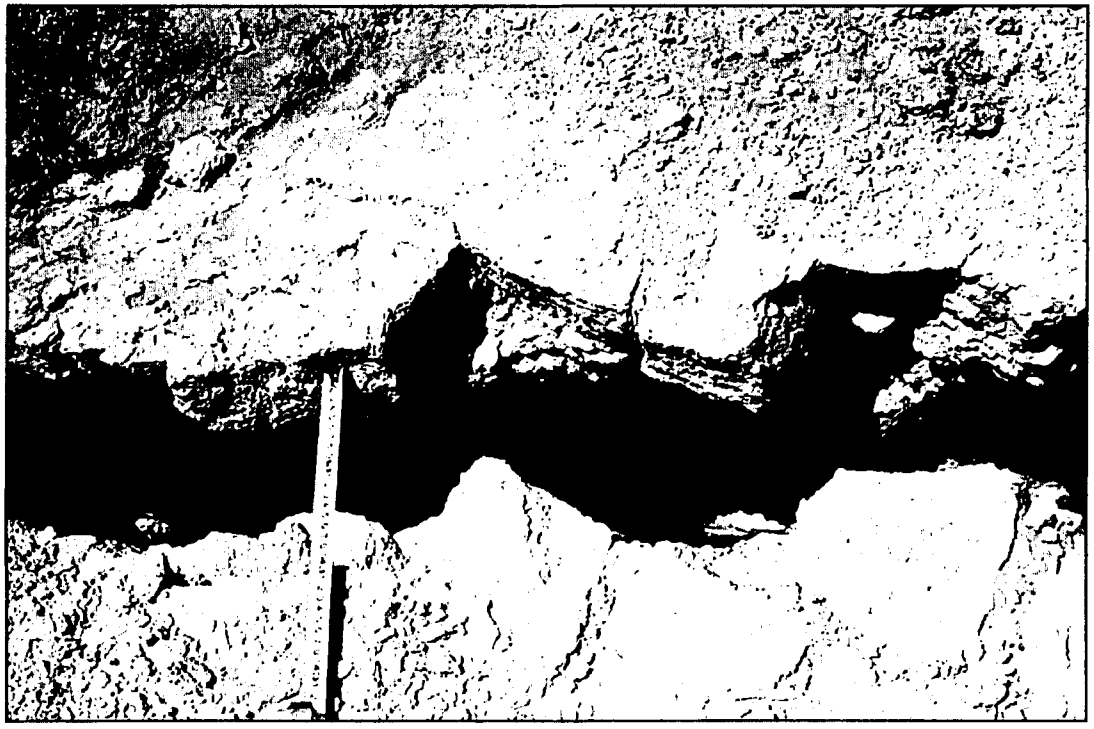
Area D is part of an overall area of fissures that occur along Fault II of the Las Vegas Valley fault system. Most of the fissures in this area occur in the hanging wall, or along the fault trace, with a few minor occurrences in the footwall. As noted by Passmore (1975), there is a strong tendency for fissures in this area to parallel Fault II. Passmore (1975) stated that these fissures show the most pronounced structural control of any of the fissures observed in Las Vegas Valley. The fissures occur in Holocene alluvium overlying consolidated sediments of undetermined Quaternary or Tertiary age (Matti and others, 1987). In a few places they are expressed at the surface in calcic horizons. Passmore examined photographs that indicate that these fissures have been present since 1958, and probably opened between 1950 and 1958.

Most of the fissures encountered were likely identified in Mifflin and others (1991), with the exception of fissure 1. Fissure 2 is probably Mifflin and others' fissure FM17, fissure 3 is their fissure FM16, and fissure 5 may be their fissure FM20. The other fissures are difficult to reckon, but were likely mapped. Fissure 1 is a 107-m long zone of aligned sinkholes, some being up to 1.5 m wide. This fissure appears to be new, and is the westernmost fissure in Area D. Fissures FM6 thru FM10, which were reported by Mifflin and others as covered, are likewise not apparent today. The short intersecting fissures around Mifflin and others' fissure FM14 are still present, but were too detailed to map in this reconnaissance survey. Figure 3 is taken from Passmore (1975) and shows the relationship of these fissures to the probable surficial structure of Fault II in this area. This figure shows the strong control of these fissures by fault traces. An example of these fissures is shown Photograph 7; illustrated in the photograph is a downward opening below a carbonate horizon.

Of the fissures shown by Mifflin and others that are south of Cheyenne Avenue only one was possibly found. Fissure 8 is a large sinkhole that may be part of their fissure FM5. The other fissures are no longer exposed or have been developed over.

Area D was mapped by Passmore (1975; his Plate 1). Carbonate horizons in this area are tilted into small questas that are progressively steeper dipping to the east (from 0 - 4° to 38°). This may be caused by an upward splaying of Fault II towards the surface (Figure 3). Thus, multiple splays of this fault are likely close to the surface. The extension direction related to fissures in Area D could be measured along a fracture in a carbonate horizon, where the two sides could be matched and an extension direction matched. This is along fissure 4, which lies at the base of a small questa (see Photograph 9). Four extension measurements were made, N55°W, N50°W, N60°W, and N48°W. The fracture was opened 18 to 20 cm.

Earth fissures have been shown in the area around the Kyle Ranch historical site by Passmore (1975; his plate II) and Patt and Maxey (1978; their Figure 5). These fissures lie along Fault III of the Las Vegas Valley fault system, near where it intersects Fault II (Matti and others, 1987). The fissures are shown



Photograph 9. Part of fissure 14, Area D that could be reconstructed for an extension measurement. The fractured surficial carbonate deposit gives an easily-determined direction of ~N50°W. The fracture is opened about 15 cm at this location.

Photograph 10. Fracture in carbonate unit that records the horizontal-extension direction (fissure 1, Area E1). Fracture is perpendicular to, and crossing, this small shallow channel, collecting water that flows through the fissure system. This fracture is proximal and parallel to a local fault trace.

as being covered or healed when inspected by Mifflin and others (1991). A brief examination of the area around Kyle Ranch historical site revealed no new or open fissures. Most of the area to the north of the historical site has been developed. A caretaker revealed that the local well that was proximal to some of these fissures was shut down in about 1991. Passmore (1975) made an interesting cross section of a trench exposure of a fault crossing immediately north of the Kyle Ranch site, along Brooks Avenue. This section shows a package of sediments abruptly downdropped by faulting. Not only does this section confirm the proximity of these earth fissures to faults, it also shows that detailed near-surface stratigraphy can be mapped to help in evaluating the origin of these faults. The cross section shows decreasing offsets of younger units and possible wedge-shaped deposits along "Fault I." Whether or not these faults undergo tectonic movement is unresolved. If they do, the potential fracturing of ground adjacent to the faults during earthquakes could contribute to preconditioning the ground for earth fissures.

Table 3 Fissures measured in the Cheyenne Avenue area/ Area D

ID #	Description	Length	Width	Depth	Strike
1	aligned sinkholes	107 m	150 cm	200 cm	N12°W
2	fissure	~60 m	30 cm	220 cm	N30°E
3	fissure	83 m	40 cm	150 cm	N20°E
4	fissure	~50 m	30 cm	180 cm	N40°E
5	aligned sinkholes	10 m	10 cm	20 cm	N70°E
6	fissure	38 m	50 cm	200 cm	N15°W
7	sm. fissure	38 m	60 cm	60 cm	N10°E
8	sinkholes	20 m	100 cm	100 cm	N70°W

Area E (Windsor Park area)

Within the Windsor Park area, extensive formation of earth fissures has damaged several homes, leading to their abandonment, demolition, and removal. This area has been investigated by Mifflin and Johnson (1988), Adenle and Mifflin (1992), and Converse Consultants Southwest (1992 and 1996). The Windsor Park area is located along Fault II of the Las Vegas Valley fault system (Matti and others, 1987). In this area, there is a large bend where Fault II changes from north-striking in the south to northeast-striking in the north. The main fault appears to be a zone of faults up to 600 m wide. Locally there are parallel overlapping fault traces and stepping traces. Additionally a major splay fault off of Fault II to the southwest occurs in the hanging wall. At Windsor Park there is an inferred fault (Converse Consultants Southwest, 1992; Linnert and others, 1994) connecting strands of the main fault and bounding the northwest side of the zone in the immediate area. At a slightly larger scale, the trace with the inferred fault is stepping to the right to a trace that becomes a more singular fault to the northeast. The Windsor Park area is where the major splay fault intersects the main fault. Within Windsor Park, there are two major, subparallel traces of the main fault and a cross-fault between the two. Activity on this set of faults may be related to activity on the splay fault as well as the main fault.

The Windsor Park area lies between two large subsidence bowls in Las Vegas Valley (Linnert and others, 1994). Subsidence indicated by satellite interferometry indicates that the Windsor Park area lies along a steep subsidence gradient along the southeastern edge of a small subsidence bowl within the central subsidence area. Fissures mapped near the North Las Vegas Airport are near the subsidence gradient along the western side of the same small subsidence bowl.

The earth fissures at Windsor Park occur in variable thicknesses (up to 1 - 2 m thick) of Holocene fine sand to pebble gravels overlying Pliocene-Pleistocene pebbly sands to gravels that have cemented carbonate horizons near the top (Matti and others, 1987). According to Converse Consultants Southwest (1992), laboratory results indicate that surficial deposits in the Windsor Park area have "low to moderate dry densities, a moderate to high potential for hydro-collapse (rapid settlement upon saturation), a low to high degree of gypsum solubility, and a moderate to critical clay swell potential." Converse Consultants Southwest (1992) also comments,

> "It should be noted that adverse soil conditions can be found throughout the Las Vegas Valley, however, the conditions encountered during our investigation at Windsor Park were such that nearly all adverse soils; expansive clays, hydro-collapsible and gypsiferous soils were found to be at nearly critical levels. It is highly unusual to find so many adverse soil types at one location."

Thus, numerous fractures likely formed from normal stresses from two subsidence bowls, localized along faults in areas with surficial deposits that are highly susceptible to forming earth fissures. This combination of factors has made the Windsor Park area one of the most spectacular areas of earth fissures in Las Vegas Valley.

The Windsor Park area is subdivided into three areas for discussion purposes (Plate 1); the area northwest of the intersection of Carey Avenue and Simons Avenue is called area E1, the area around Windsor Park and Gilbert School is area E2, and the area to the east of Windsor Park, including just east of Martin Luther King Boulevard, is called area E3. In addition, an area referred to as the North Las Vegas Airport site will be discussed in this section.

Area E1 is an open field that has two major groups of earth fissures that intersect each other. The first group is in a NNW direction parallel to the major drainage in the area. This includes fissures 2, 7, and 8. Several other fissures, including those mapped by Mifflin and others (1991) are also present but have not been active recently, or only locally have been active. The parallelism of these fissures and this drainage is remarkable, and it seems to be a reasonable hypothesis that the drainage channel itself was oriented with the influence of paleo-earth fissures. Mifflin and others (1991) suggested this possibility of some control of the drainage by fissures, and I similarly found the parallelism of the earth fissures and drainages in this area to support this notion. A secondary fault parallel to the drainage that has been preferentially eroded is also a possibility, but it would be perpendicular to the local strike of mapped fault traces. The drainage is also perpendicular to the local gradient, so no coincidence with a controlling feature is necessarily required. The new fissures mapped are on the southwest side of this major drainage. Pre-existing fissures are still evident along the northeast side of the drainage, but most are only locally active.

The other dominant trend in area E1 is northeast trending, parallel to local fault traces. These fissures are located in the footwall of a throughgoing fault trace and in the hanging wall of another trace. This includes fissures 1, 3, 5, & 6. Other fissures are present in this trend, but have not been significantly active. Fissure 6 is spectacular in that it crosses an abandoned house foundation. This foundation is a concrete slab that is perhaps analogous to the hard carbonate layers that are common in the surficial sediments of Las Vegas Valley. The slab has been cracked with a small fissure. Below the slab, however, large void spaces are developing as the underlying softer soils are laterally eroded away. Such void spaces are likely common below carbonate horizons overlying softer soils where there is extensive fissuring and helps accommodate some of the large volumes of material and water into the subsurface. Fissures of this northeast orientation were shown as short fissures by Patt and Maxey (1978). Smith (1982) added a large, northeast-trending fissure (>300 m long) that appeared after a 1978 rainstorm.

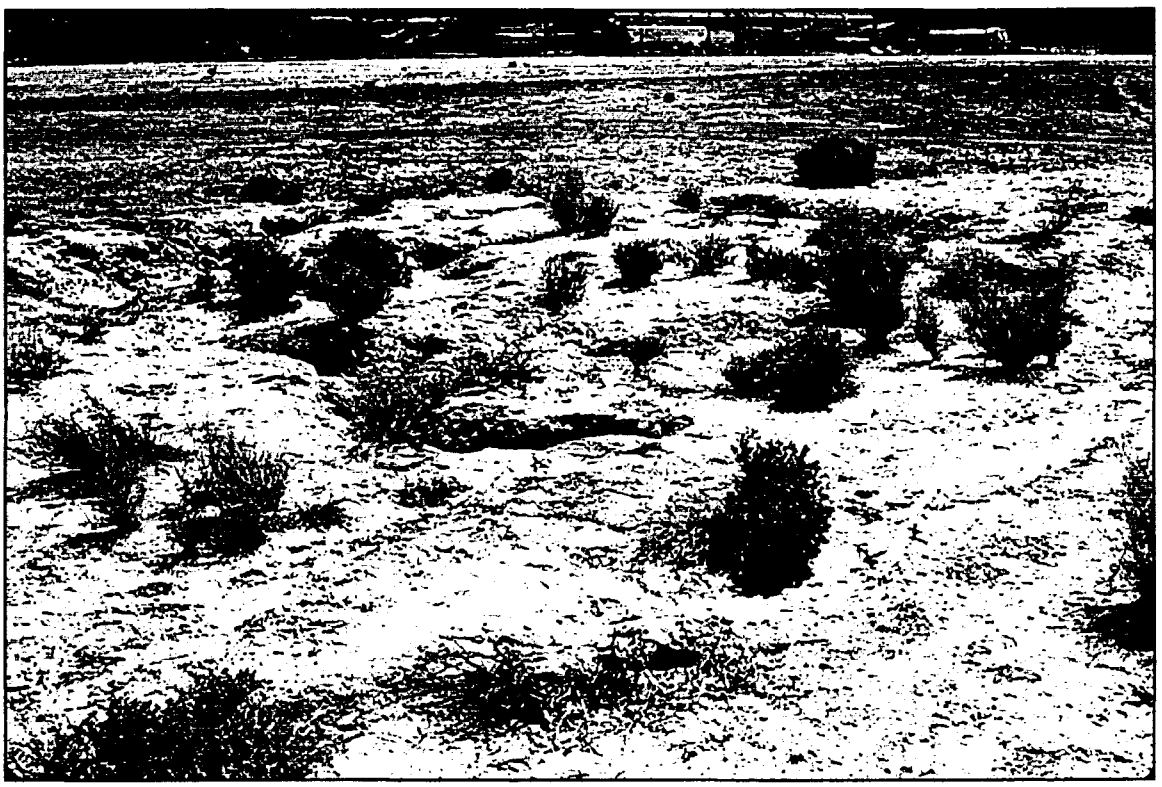
Measurements of the relative extension direction could be measured along two traces of fissure 1. Photographs 10 and 11 are also from this fissure. Fissure 1 strikes N45°E, and the extension direction indicated by the crack in carbonate is N43°W to N45°W.

Table 4 Fissures measured in the Windsor Park area/ Area E

ID #	Description	Length	Width	Depth	Strike
1	crack in calcic horiz.	21 m	3 cm	30 cm	N45°E
2	new fissures	61 m	30 cm	110 cm	N50°W
3	react. fissure	73 m	200 cm	140 cm	N40°E
4	new fissure	4 m	3 cm	60 cm	N75°W
5	react. fissure	~60 m	200 cm	160 cm	N30°E
6	react. fissure	~80 m	100 cm	80 cm	N40°E
7	new fissure	45 m	30 cm	100 cm	N55°W
8	discont. fissure	~85 m	30 cm	100 cm	N30°W
9	discont. fissure	20 m	50 cm	50 cm	~NNE
10	discont. fissure	~100 m	110 cm	100 cm	~NS

A significant amount of work studying fissures has been done in Area E2 since Mifflin and others (1991). Thus, the fissures for this area are from Mifflin International (1992), and Converse Consultants Southwest (1992 and 1996). The delineation of fissures within Windsor Park proper is difficult because of the urbanization. There is much more extensive deformation in the way of collapsing or shifting curbs, and sunken roadways and sidewalks, but it is unknown whether or not all of these are related to fissures. Fissures specifically identified are represented in the plate, and represent a minimum number that actually exist. Nearly 975 linear meters of fissures were documented in the Adenle and Mifflin (1992) study (Linnert and others, 1994). Fissures were up to 1 m wide and 1 m deep. The overall distribution of the fissures parallels and is proximal to local faults. However, the fissures trend many directions including at high angles to local fault strikes. Adenle and Mifflin (1992) and Converse Consultants Southwest (1996) also concluded that the formation of fissures in the Windsor Park area is increasing with time.

Photograph 11. Close up of fissure 1, Area E1 that shows how the extension direction could be measured by matching back the two sides of the fracture. This fracture is opened about 3 cm in a direction of about N44°W.



Photograph 12. An overview of Area I showing scattered sinkholes and fissures that make up the area.

Converse Consultants Southwest (1992) conducted an extensive trenching program in the Windsor Park area and found that most of the fissures were associated with desiccated clays and died within about 2.5 m of the surface in a desiccated clay unit (Linnert and others, 1994). This does not support a postulation by Adenle and Mifflin (1992) of an extensive subsurface network at Windsor Park (Linnert and others, 1994); nor does this necessarily support the need for horizontal stresses from local subsidence bowls.

A large fissure south of Gilbert School and north of Carey Avenue is still present, but seems to have degraded from earlier descriptions (fissure 10). This fissure lies on the projection of the major splay fault near where it would intersect Fault II, and is parallel to this splay fault. This fissure may have occurred along a fracture associated with movement along this splay fault.

Only a few minor fissures were encountered to the west of Martin Luther King Jr. Boulevard in Area E3, but these were not recorded. This area was not thoroughly examined and more fissures may exist.

Just to the northwest of Area E1 is a set of aligned earth fissures that are mapped immediately east of the major east-west runway at the North Las Vegas Airport. These fissures have been shown by Patt and Maxey (1978) and Mifflin and others (1991). No faults are shown in the immediate area of these fissures (Matti and others, 1987), although they are roughly on line with the straight portion of Fault II to the south. No fissures were found immediately east of the runway in this survey. The only fissures found are located to the west of those mapped, and would project across the east-west runway. Airport officials comment that although a short turn-around extension has been placed on the east side of the runway, the runway itself has not been modified in the last ten years. Thus, either the mapped fissures have healed or been erased and new fissures formed to the west of them, or the fissures were initially mismapped (which would perhaps be a hard thing to do given the pronounced landmark that the runway is), or the runway really was extended eastward across the fissures. In this limited survey this question was not resolved. The fissures that could be found are about 100 to 200 m west of the eastern end of the east-west runway. North of the runway there are discontinuous sinkholes over a distance of about 97 m that are up to 40 cm wide and up to 80 cm deep. South of the runway there are discontinous sinkholes over a distance of about 95 m that are up to 60 cm wide and up to 40 cm deep. All of these fissures are filled and appear degraded, but there are a few areas were there is new sluffing of the sides indicating recent subsurface flow along the fissures.

Area F (Owens Avenue area)

The fissure identified near Owens Avenue lies along Fault III of the Las Vegas Valley fault zone. This fissure lies along and parallels an eastern edge of the central subsidence bowl in Las Vegas. The parallelism between the fissure, the edge of the bowl, and local faults is remarkable. The fissure in Area F was originally identified in the early 1960s when it split a house and ruptured a cast-iron water main (Patt and Maxey, 1978). This fissure was covered when examined by Patt and Maxey (1978) and Mifflin and others (1991). Photographs of this fissure are shown in Bell (1981) on his pages 71 and 72.

The fissure mapped by Mifflin and others (1991) would traverse an area that has been built over with

houses and buildings, a freeway, a small park, or has been recently graded. No evidence of this fissure was found in this survey.

Area G (Sunset Road area)

Fissures in Area G were proximal to Fault IV of the Las Vegas Valley fault zone, and were near a spring appearing on the urbanized scarp. Patt and Maxey (1978) mapped nine fissures in this area that were perpendicular to the fault scarp. The fissures were relatively small (80 m and 30 m long, and 0.5 m and 0.8 m wide) and were formed in Pliocene-Pleistocene silty sands (Bingler, 1977). This area is near the zero contour for subsidence in the valley, and it is suggested that these fissures may be related to horizontal hydraulic forces or tectonics (Bell and Helm, 1998). The perpendicularity of these fissures to the fault scarp is interesting, and perhaps in this case indicates that subsidence forces may be the most important for creating the fissure-related fractures. However, local hydraulic effects, perhaps related to local changes in shallow groundwater table due to urbanization, cannot be ruled out.

The nine fissures were urbanized when inspected by Mifflin and others (1991), but they found two new small fissures, potentially associated with a small spring that occurs on the scarp. This area was visited in 1998 and no fissures could be found. The area where Mifflin and others (1991) found fissures is a lawn-covered slope.

Area H (Wigwam Avenue area)

The fissures in the Wigwam Avenue area are just south of the major subsidence bowls in Las Vegas Valley, and may be partly related to local wells (Bell, 1998, pers. commun.). Forty-three fissures were mapped in an east-west swath of land, 1.8 km long and about 0.5 km wide. The fissures are formed in Pliocene-Pleistocene silty sands and sandy pebbly to cobbly gravels overlain by a cemented carbonate horizon that is over 2 m thick (Bingler, 1977; Matti and Bachhuber, 1985). A photograph of one of these fissures is shown in Werle and Stilley (1991). The fractures in carbonate allowed an extension direction to be measured in this area; this is portrayed in Figure 5 of Helm (1994) and mentioned by Bell and Helm (1998). The figure shows a northwest-trending fracture that has an opening of about 2 cm. The extension direction is indicated to be north-south.

Most of these fissures have now been built over by houses and a shopping mall. The area immediately northwest of the intersection of Wigwam Avenue and Eastern Avenue is still undeveloped and an inspection of the area around the reported location of fissure FM43 (Mifflin and others, 1991) found no fissures (this fissure was not found by Mifflin and others (1991) as well).

Some fissures were found, however in the vicinity of the intersection of S. Maryland Parkway and Wigwam Avenue. Five sinkholes or fissures were found in this area (Table 5). Most of these were discontinuously expressed, minor features (<50 cm wide) formed in a cemented carbonate horizon that is about 50 cm thick. In some cases water is flowing beneath this calcic horizon. A visit to the area in July 1998 showed that the fissures mapped to the west of Maryland Parkway had already been graded over in preparation for construction.

Table 5	Fissures measured near Wigwam Avenue/ Area H				
ID #	Description	Length	Width	Depth	Strike
1	sm. discont. fissure	10 m	2 cm	30 cm	N15°E
2	sm. sinkholes	-	10 cm	20 cm	N42°E
3	aligned sinkholes	18 m	20 cm	35 cm	N5°W
4	sinkhole	-	50 cm	70 cm	N25°E
5	fissure	2 m	40 cm	100 cm	N10°E

Area I (Arroyo Grande Boulevard area)

The fissures northwest of the intersection of Arroyo Grande Boulevard and the Union Pacific Railroad tracks were reported by Ann Baxstrom of Kleinfelder and Associates in Las Vegas and are new to the inventory of fissures in Las Vegas Valley. The fissures were first identified in about 1992 to 1993 by Ann and her colleagues. They are located along Fault IV of the Las Vegas Valley fault system, near its southern end. The fissures are south of the major zones of subsidence in Las Vegas Valley, although there is a well to the southeast. The fissures in this area are within a Pliocene-Pleistocene silty sand that is considered to be in part equivalent to the Las Vegas Formation (Bingler, 1977). This deposit appears to be a well-consolidated, but erodible unit.

Area I is an area of fissuring with small equant to elongate sinkholes scattered throughout, and several fissures, commonly less than 5 m in length (Photograph 12). A fracture that is being eroded into a fissure is shown in Photograph 13. These fissures and sinkholes were too small and numerous to be individually mapped in this reconnaissance, so emphasis was placed on defining the perimeter of the fissured area (see plate 1). This perimeter is partly defined by grading on the south and west, a roadway on the east, and a stream channel on the north. A lone sinkhole also exists to the west of this area (fissure 2). Thus, a buffer zone around the mapped fissure area might be added for hazard considerations.

The fissures are generally 1 m to 2 m long, with an exception that is 10 m long. Depths are commonly 0.3 m to 1 m deep, with a couple sinkholes that have ~2-m depths. In one case a sinkhole has formed in the grading associated with Arroyo Grande Boulevard (Photograph 14). The flow in several fissures is towards the east, and a few of these discharge into the roadcut of Arroyo Grande Boulevard (Photograph 15). Several orientations of the fissures are present, including northwest-trending, northeast-trending, and east-west trending fissures. In one portion of the area runoff appears to have taken advantage of 1- to 2-m diameter columns that are part of a large-scale shrink-swell structure. There is good exposure along the drainage ditch along the north part of this field. Only one fissure intersected this ditch, and showed a pipe discharging several meters below the surface. The small cave created by the piping is being used by kids as a "party cave"; this human activity makes it difficult to determine the most recent activity of the pipe.

Photograph 13. The small fracture that is controlling the fissure in Area I is visible in the head wall of the fissure is exposed to the right of the orange field book.

Photograph 14. Sinkhole in Area I that is formed in a recently graded area along Arroyo Grande Boulevard.

Photograph 15. Discharge areas from fissures in Area I in the road cut along Arroyo Grande Boulevard.

In many regards, fissures in Area I appear youthful. Many fissures have abrupt, steep, fresh-looking sides. They are most commonly expressed as alignments of sinkholes and have bridges of dirt still covering the fissures. The uneroded fractures could still be seen in several instances in the head walls of fissures. Many fissures were flowing at shallow levels (less than 1 m). Although evidence of prior fissuring exists (e.g., small swales), much of the fissuring seems relatively recent, and is possibly more extensive than previous fissuring.

Fissure 2 is a western outlier to Area I. It is an isolated sinkhole, about 100 cm long by 30 cm wide, and 70 cm deep. A small closure that ponds water appears to be drained by a relatively new subsurface conduit with this sinkhole as a drain. This isolated sinkhole indicates that the potential for the formation for earth fissures extends beyond the zone of fissures as mapped.

Discussion

Observations of the numbers of earth fissures through the years allow some conclusions as to whether earth fissures are still forming. Of the undeveloped fissure areas, two Areas C2 (west of Nellis well) and E2 (Windsor Park area), clearly have more fissures than previously described and the rate of fissure development can be described as accelerating. This characterization is suggested by Linnert and others (1994) for Windsor Park and for Area C2 by this study. Not only do new fissures appear to be forming, but many of the larger, older fissures show evidence of renewed cracking. In most of the other areas that were not urbanized, the number of fissures was about the same as described previously, but it was uncertain that the same fissures were being encountered. The increased number of fissures in some areas may be for several reasons. First, these areas commonly have increased or focused runoff due to urbanization. Second, new fissures appear to be forming and some old fissures appear to be refracturing; more fissures available at the surface. The rate of the annealing of fissures is not clear. Some exposed in recent cuts appear to have been around for several years (infiltrated with rootlets). With new fractures being apparently added, the total number of fractures available to develop into fissures may be increasing with time.

The spacial representation of subsidence provided by satellite interferometry gives some new insights into the locations of the areas of earth fissures, and confirms several previous observations. The strong subsidence gradient through the Windsor Park area (Area E) and the coincidence of the fissures near the North Las Vegas Airport with a subsidence gradient on the edge of a bowl help to explain the location of these features. The remarkable parallelism of the fissure in Area F with the edge of a subsidence bowl and local faults is also noteworthy. The faults likely influence the edge of the subsidence bowl, leading to local concentrations of horizontal stress from subsidence, which in turn lead to fractures that can develop into earth fissures.

A limited attempt was made to find new fissures by driving across major gradients in subsidence and walking out the fringe areas around known fissure areas. No new fissures were found in this manner from this limited study. Yet the local settling and areas with horizontal stresses to create fissures is more widespread than just these identified areas and other fissures likely exist.

The addition of a new fissure area to the inventory (Area I) gives the opportunity to evaluate some of the

guidelines developed for identifying potential areas that might have an earth fissure hazard. Bell and others (1992) suggest guidelines based on a statistical analysis of the earth fissure data from the Bell and Price (1991) study. They found that 45% of the mapped fissures are within 500 feet (150 m) of mapped faults, 82% of the fissures were within 1200 feet (360 m) of faults, and 90% of the fissures were within 2000 feet (600 m). These distances from faults are proposed as possible buffer zone widths around faults to be used for identifying sites that should be examined for potential fissure hazards. Werle and others (1998) note that there is a cumulative length of about 160 km of faults mapped in Las Vegas Valley, but that only 10% of these faults are associated with earth fissures. Thus, most geotechnical studies around faults do not find fissures around the mapped faults. To improve the targeting of sites that might have potential fissures, Werle and others developed an equation that determines a index value that can be related to the potential for earth fissures. This equation is:

A*(B+C+D+E+F) = Hazard Potential Index

where **A** represents depth to shallow groundwater, **B** represents soil conditions, **C** represents the distance to the nearest faults and/or high capacity wells, **D** represents the location with respect to subsidence bowls, **E** represents the presence of intervening faults with the center of the subsidence bowl, and **F** represents the orientation of the nearest faults with the center of the subsidence bowl. For the specific guidelines on assigning values, see Werle and others (1998). Area I easily falls into all of the buffer zones defined by Bell and others (1992), and thus would have been flagged by their criteria. Applying the hazard potential index, Area I would be classified by Werle and others (1998) as having a low to moderate "risk" of having fissures (A=1, B=6, C=8, D=0 or 8, E=0, F=3 or 4, for final scores of 17 to 26). The aspects that keep this score low are that Area I is outside the major subsidence bowls, and that the mapped local fault is only about 35° from the direction towards the center of the nearest subsidence bowl. The potential for a highly fissured site to be classified as low on the hazard potential index indicates that Area I should be better understood to make sure the index is being applied properly, and the index formula itself may be tuned up to include possibilities such as Area I, if this is warranted. Nevertheless, the index proposed by Werle and others (1998) appears very insightful and useful, and it does an excellent job of directing the focus of a site investigation to the primary factors that control the formation of earth fissures.

There is a debate as to whether there is a tectonic component to faulting within the Las Vegas basin, and whether earthquakes occur along these faults (Bell, 1981; Bell and dePolo, 1996). If earthquakes have occurred and tectonics is important in the movement of these faults, then this may, 1) precondition the ground proximal to faults with fractures that could turn into fissures, 2) influence the orientations of new fissures, and 3) produce ground motion that could cause new fissures to break to the surface. Most of the fracturing observed is attributed to horizontal stresses related to local or regional groundwater pumping (e.g., Helm, 1994). Tectonic movement along faults, especially the sudden displacement that can occur during an earthquake, may produce local stresses that form fractures proximal to faults. In several cases where fault traces come close to the surface, earth fissures are parallel to them (e.g., Area D). The two extension directions measured in this study are both subparallel to the regional extension direction (c.f., Patton and Zandt, 1991). Although this is likely coincidence, if modeling of local stresses using subsidence forces cannot explain these directions, then a tectonic influence of these orientations should be explored. The third point is a small one, but it is interesting. Earth fissures usually appear during large storms or large runoff events. Passmore (1975), Patt and Maxey (1978), and Smith (1982)

all cite specific large storms that had runoff that in turn created fissures or caused them to open to the surface. Although large rain-fall storm events appear to create most of the fissures encountered, there is an account of a fairly substantial fissure appearing at the surface in Area B from earthquake ground motion. Thus, ground motion is one of the few other events that might cause fissures to manifest themselves at the surface (through collapse of surficial bridges that mask existing fissures). We might expect additional fissures to appear following a local or strong region earthquake that causes significant ground motion in Las Vegas Valley. Thus, tectonics likely does have a role in the formation of earth fissures. That role is likely largest if earthquakes rupture local faults.

During large storms, a special warning might be considered for areas with earth fissures. In several cases the sides of the fissures are unstable and land bridges over pipes can fail, potentially trapping an individual. In the larger fissures people can conceivably be jammed into a subsurface pipe entrance or carried into the subsurface and drowned. The fence around the Nellis well field is a prudent mitigation for this hazard, although homeless people still get in and are around the fissures. Scientists who study these fissures while they actively have water flowing down them should be wary.

Recommendations

A more comprehensive search for new fissure areas should be made before virtually all fissure areas are developed over. A review of most consultants files in the valley would likely turn up new areas. Another way to search for new fissures would be a helicopter survey during low-sun-angle conditions along the fault zones and proximal to high-capacity wells. Earth fissures and sinkholes should appear as shadowed areas. Detailed examination of recent aerial photography for distinct vegetation lineaments may also be a useful approach. Another clue to finding earth fissures appears to be finding small mesquite stands, especially if they have a linear aspect. Together, these kinds of surveys could target areas that can then be visited on the ground.

Detailed surveys should be made of several of the fissure areas to be used as input data in future research, particularly towards understanding the fissure potential in developed areas. If this is not done, there will be no undisturbed areas left to map in the near future and the opportunity will be lost. Specifically, Areas C1, C2, C3, D, and E1 should be mapped. Area C2 has evidence for at least three generations of fissuring, and likely more upon closer inspection. This area should be trenched to understand the history of fissuring in the area and the nature of fractures in the area. Although trenching in the Windsor Park area did not show evidence of the fissures being an integrated drainage network, it would be surprising if such a network does not exist in Area C2.

Using the new detailed satellite interferometry data, a more detailed spacial representation of subsidence can be modeled and horizontal stresses from subsidence calculated and contoured. High areas of tensile stress should strongly correlate with most areas of earth fissures and may indicate other areas that may susceptible to fissure formation. Inconsistencies of fissures with the stress models may indicate that other mechanisms should be sought.

Conclusions

All fissure areas that are undeveloped have evidence of active fissuring. In some areas, there were numerous new fissures relative to previous representations. Smaller fissures (<0.3 m wide) identified in earlier studies were difficult to confidently relocate. Most that could be relocated appeared to be inactive and filled, occurring as linear swales. Larger fissures are generally still quite distinct and most of these are still active. This indicates that there is some evolution of these fissure systems as the drainage pattern continues to erode, shift around, and integrate. Additional subsurface fractures with time may also create fissures that pirate away runoff feeding other fissures, and rendering the other fissures inactive. In some cases, local desiccation patterns appear to be activated (e.g., Area I), which could lead to the formation of new fissures in surprising places. Nearly half of the fissure areas that were mapped have been graded or built over.

Most new fissures are within areas identified on Bell and Price (1991). New fissures generally follow preexisting patterns of fissuring in an area, and could easily be related to runoff sources. A new area, Area I, is added to the inventory. This area is south of Area G, along Fault IV of the Las Vegas Valley fault system. A hazard index for identifying areas of likely fissure potential developed by Werle and others (1998) appears to work relatively well for most previously identified fissure areas, but it appears to rank Area I as having a low to moderate risk to having fissures.

The two main processes responsible for fissure formation are consistent with observations from this survey, and remain key to finding new areas of fissure formation. Small fractures are enlarged into fissures from flowing water. Tensile stresses that likely form fractures in the soil mass appear to be generated by local and/or regional subsidence. These stresses are localized around faults that both influence the locations of the edges of the subsidence bowls as well as intercept and localize horizontal stresses. Given the new detailed spacial resolution of subsidence offered by satellite interferometry, detailed maps of horizontal stresses can now be modeled. Areas of high tensile stress, especially where coincident with faults could become target areas to be examined. Essentially all new fissures found in this survey could readily be related to local runoff or water concentration. Thus, adding in local areas of water concentration or runoff in areas that coincide with high tensile stress potential will also help define the susceptibility to fissure formation. Local conditions that are conducive to fissure formation must also be factored in, such as suggested by Werle and others (1998). The new area described in this report, Area I, is removed from the subsidence bowls and likely requires another explanation for local tensile stresses, but basin-wide modeling of subsidence stresses should be done before this source is ruled out.

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